ESTIMATION OF OZONE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN NINE URBAN AREAS USING A PROBABILISTIC VERSION OF NEM

by

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In evaluating alternative National Ambient Air Quality Standards (NAAQS), the U.S. Environmental Protection Agency (EPA) assesses the risks to human health of air quality meeting each of the standards under consideration. This assessment of risk requires estimates of the number of persons exposed at various pollutant concentrations for specified periods of time. Since 1979, IT Air Quality Services (ITAQS) has assisted EPA in developing various versions of the NAAQS Exposure Model (NEM) to assist in this process. In 1993, ITAQS developed a probabilistic version of NEM applicable to ozone (pNEM/O3) and applied it to the general population residing in each of nine urban areas. In 1994, EPA directed ITAQS to develop a special version of pNEM/O3 applicable to outdoor children and to use it to estimate the ozone exposures of outdoor children residing in the nine urban areas. This report summarizes the results of this research effort.

The outdoor children project was managed by Mr. Mike McCoy of ITAQS with technical direction provided by Mr. Ted Johnson. Mr. Jim Capel of ITAQS developed the special version of pNEM/O3 and performed all computer runs of the model. He also developed the input databases listing (1) time/activity data representative or outdoor children and (2) estimates of the number of outdoor children in each of the nine study areas.

Ms. Jill Warnasch Mozier and Mr. Jim Capel were the principal authors of Section 6 and Subsection 8.4 of this report. Mr. Ted Johnson was the principal author of the remaining sections. Ms. Joan Abernethy typed the report and created many of the graphs in Section 7.

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SECTION 1

INTRODUCTION

Within the U.S. Environmental Protection Agency (EPA), the Office of Air Quality Planning and Standards (OAQPS) has responsibility for establishing and revising national ambient air quality standards (NAAQS). In evaluating alternative NAAQS proposed for a particular pollutant, OAQPS assesses the risks to human health of air quality meeting each of the standards under consideration.[1] This assessment of risk requires estimates of the number of persons exposed at various pollutant concentrations for specified periods of time. The estimates may be specific to an urbanized area such as Los Angeles or apply to the entire nation.

Several researchers[2,3] have recommended that such estimates be obtained by simulating the movements of people through zones of varying air quality so as to approximate the actual exposure patterns of people living within a defined area. OAQPS has implemented this approach through an evolving methodology referred to as the NAAQS Exposure Model (NEM). An early overview of the NEM methodology is provided in a paper by Biller et al.[4] From 1979 to 1988, IT Air Quality Services (formerly PEI Associates, Inc.) assisted OAQPS in developing and applying pollutant-specific versions of NEM to ozone,[5] particulate matter,[6] and CO.[7] These versions of NEM are referred to as "deterministic" versions in that no attempt was made to model random processes within the exposure simulation.

The deterministic versions of NEM were similar in that each was capable of simulating the movements of selected segments of an urban population through a set of environmental settings. Each environmental setting was defined by a geographic area and a microenvironment. The size and distribution of the geographic areas were determined according to the ambient characteristics of the pollutant. Ambient (outdoor) pollutant levels in each geographic area were estimated from either fixed-site monitoring data or dispersion model estimates. To better utilize fixed-site monitoring data, researchers developed special time series techniques to fill in missing values and special roll-back techniques to adjust the monitoring data to simulate conditions under attainment of a particular NAAQS.

Additional details concerning the evolution of the deterministic version of NEM are provided by Paul et al.[8] Critiques of deterministic NEM are included in surveys of exposure models by Pandian[9] and Ryan.[10] Two staff papers[11,12] prepared by EPA discuss the use of NEM in evaluating alternative NAAQS for CO and ozone.

In 1988, OAQPS began to incorporate probabilistic elements into the NEM methodology and to apply the resulting model (pNEM) to the criteria pollutants. The initial result of this work was an early version of pNEM applicable to ozone (pNEM/O3). This model used a regression-based relationship to estimate indoor ozone concentrations from outdoor concentrations. A report by Johnson et al. describes this model and its application to Houston, Texas[13].

An advanced version of pNEM applicable to carbon monoxide (pNEM/CO) was developed in 1991. This model marked the first time in the evolution of NEM that a mass balance model was used to estimate indoor pollutant concentrations. The application of pNEM/CO to Denver, Colorado, has been described by Johnson et al[14].

A new version of pNEM/O3 was developed in early 1992. Unlike the earlier version of pNEM/O3, the new model uses a mass balance model to estimate indoor ozone concentrations. A February 1993 report by Johnson et al.[15] describes the new version of pNEM/O3 and summarizes the results of an initial application of the model to 10 cities.

Subsequent to the February 1993 report, ITAQS made the following enhancements to pNEM/O3 and its input data bases.

- Use of more recent (1990-91) fixed-site monitoring data for estimating ambient ozone concentrations. The earlier analysis was based on 1981-84 monitoring data.

- An increase in the number of fixed-site monitors used to represent each urban area.
- Use of more recent (1990) census data for estimating cohort populations. The earlier analysis used 1980 census data.
- A new methodology for adjusting ambient ozone data to simulate attainment of one-hour and eight-hour NAAQS.
- Revision of the algorithm used to determine limiting values for equivalent ventilation rate.
- Development of origin/destination tables through the use of a new commuting algorithm.

A report by Johnson et al.[16] describes these enhancements and summarizes the results of applying the enhanced model to nine of the ten cities included in the previous exposure assessment. Tacoma, Washington, was excluded from the analysis because of insufficient monitoring data.

In early 1994, EPA directed ITAQS to develop a special version of pNEM/O3 applicable to outdoor workers and to use it to estimate the ozone exposures of outdoor workers residing in each of the nine areas. A summary of this work can be found in a report by Johnson et al.[17]

In a follow-up work effort for EPA, ITAQS developed a second special version of pNEM/O3 applicable to children who tend to be active outdoors (hereafter referred to as "outdoor children"). This report summarizes the results of applying this version of pNEM/O3 to outdoor children residing in the nine study areas. The report is divided into eight sections. Section 2 provides an overview of the pNEM/O3 methodology and describes in detail how the model was applied to outdoor children in a specific city (Houston). Section 3 describes the mass balance model incorporated into pNEM/O3. Section 4 describes the process by which ambient ozone data sets were selected for use in pNEM/O3. It also describes the methods used to fill in missing values in these data sets. Section 5 presents the method used to adjust ambient ozone data to simulate the attainment of proposed air quality standards. Section 6 describes the methods used to identify time/activity data representative of outdoor children and to estimate the number of outdoor children in each urban area. Section 7 provides ozone exposure estimates for each of the nine cities. The principal limitations of the model are discussed in Section 8.

SECTION 2

OVERVIEW OF THE METHODOLOGY

The general NEM methodology consists of five steps.

1. Define a study area, a population-of-interest, appropriate subdivisions of the study area, and an exposure period.

2. Divide the population-of-interest into an exhaustive set of cohorts.

3. Develop an exposure event sequence for each cohort for the exposure period.

4. Estimate the pollutant concentration, ventilation rate, and physiological indicator (if applicable) associated with each exposure event.

5. Extrapolate the cohort exposures to the population-of-interest and to individual sensitive groups.

This approach has been followed in developing a probabilistic version of NEM applicable to ozone (pNEM/03). The remainder of this section provides an overview of the pNEM/O3 methodology as applied to outdoor children. The application of pNEM/O3 to outdoor children in Houston is used as a means of demonstrating various features of the methodology.

2.1 Define Study Area, Population-of-Interest, Subdivisions of Study Area, and Exposure Period

The pNEM/O3 methodology provides estimates of the distribution of ozone exposures within a defined population (the population-of-interest) for a specified exposure period. The population-of-interest is typically defined as 1) all residents of a defined study area or 2) the residents of the study area which belong to a specific sensitive population. The study area is defined as an aggregation of exposure districts. Each exposure district is defined as a contiguous set of census tracts or block numbering areas (jointly referred to as "census units") as defined by the Bureau of Census for the 1990 U.S. census.

All census units assigned to a particular exposure district are located within a specified radius of a fixed-site ozone monitor. The pNEM/O3 methodology is based on the assumption that the ambient ozone concentration throughout each exposure district can be estimated by ozone data provided by the associated fixed-site monitor.

Table 1 lists the nine study areas defined for the exposure analyses. Each study area is associated with a major urban area. The table lists the number of exposure districts and the exposure period for each study area. In each case, the exposure period is defined as a series of months within a particular calendar year. The specified months conform to the "ozone season" specified for the urban area by EPA. The ozone season is the annual period when high ambient ozone levels are likely to occur. Three ozone seasons appear in Table 1: January through December, March through September, and April through October. The specified calendar year is either 1990 or 1991, the selected year being the higher year with respect to reported hourly ambient ozone concentrations.

In the application of pNEM/O3 to Houston, eleven fixed-site monitors were selected to represent ambient ozone concentrations (see Section 4). An exposure district was constructed around each monitor through the use of a special computer program ("DIST90"). This program identified all census units having population centroids located within 15 km of the monitor. When a census unit was paired with more than one monitor, the program assigned it to the nearest monitor.

The sum of all census units assigned to the eleven exposure districts defined the Houston study area. In 1990, the study area consisted of 532 census units and contained 2,370,512 residents[18]. A subset of this population, outdoor children, were designated as the principal population-of-interest.

The Houston ozone season spans the entire calendar year. Consequently, the Houston exposure period was defined as calendar year 1990.

TABLE 1. CHARACTERISTICS OF STUDY AREAS

Study area	Number of exposure districts	1990 population[a]	Exposure period		Number of outdoor children cohorts
			Year	Months	
Chicago	12	6,175,121	1991	Apr-Oct	360
Denver	7	1,484,798	1990	Mar-Sep	210
Houston	11	2,370,512	1990	Jan-Dec	330
Los Angeles	16	10,371,115	1991	Jan-Dec	480
Miami	6	1,941,994	1991	Jan-Dec	180
New York	12	10,657,873	1991	Apr-Oct	360
Philadelphia	10	3,785,810	1991	Apr-Oct	300
St. Louis	11	1,706,778	1990	Apr-Oct	330
Washington	11	3,085,419	1991	Apr-Oct	330

[a]Total population residing in the exposure districts which comprise the study area.

2.2 Divide the Population-of-Interest Into an Exhaustive Set of Cohorts

In a pNEM analysis, the population-of-interest is divided into a set of cohorts such that each person is assigned to one and only one cohort. Each cohort is assumed to contain persons with identical exposures during the specified exposure period.

In past pNEM/O3 analyses, cohorts were identified by 1) home district, 2) demographic group, 3) work district, and 4) residential air conditioning system.[15,16,17] Specifying the home and work districts provided a means of linking cohort exposure to ambient pollutant concentrations. Specifying the demographic group provided a means of linking cohort exposure to activity patterns that vary with age, work status, and other demographic variables.

The decision to identify cohorts with respect to the residential air conditioning system was based on the results of two supplemental analyses by ITAQS. An analysis[19] of data on window openings provided by the Cincinnati Activity Diary Study (CADS)[20] suggested that the time per day that windows are open in a residence is a function of outdoor temperature and air conditioning system, when the later is characterized as 1) no air conditioning, 2) room units, or 3) central air. An analysis[21] of data collected by Stock[22] during a study of asthmatics in Houston suggested that indoor ozone levels are significantly higher when windows are open than when windows are closed. For example, the median ratio of indoor ozone to outdoor ozone for residences in the Sunnyside section of Houston was 0.89 when windows were open and 0.09 when windows were closed. The importance of outdoor ozone concentrations in determining indoor ozone concentrations has also been reported by Weschler et al.[23]

The slightly different method was used to identify cohorts for the outdoor children assessment described in this report. Each cohort was identified by

1. Home district
2. Demographic group
3. Residential air conditioning system
4. Replicate number.

Consistent with the earlier pNEM/O3 analyses, cohorts were identified by home district, demographic group, and residential air conditioning system. Cohorts were not identified by work (or school) district, however. Analysts assumed that the members of each cohort attended schools and worked within the home district; consequently, additional cohort indices were not required for school and work locations.

Two demographic groups were specified for the outdoor children assessment:

1. Preteens -- ages 6 to 13
2. Teenagers -- ages 14 to 18.

Outdoor children were defined as children who tend to spend more time outdoors than the average child. Section 6 provides a more detailed definition of the term and describes the method used to estimate the number of children belonging to each demographic group.

A new feature was installed in the version of pNEM/O3 applicable to outdoor children. This feature permits the user to specify a "replication" value (n) such that the model will produce n cohorts for each combination of home district, demographic group, and residential air conditioning system. Because pNEM/O3 uses a Monte Carlo process to construct an activity pattern for each cohort, each of the n cohorts associated with a particular combination of district, group, and air conditioning system is associated with a distinct exposure sequence.

The replication feature permits the analyst to divide the population-of-interest into a larger number of smaller cohorts -- a process which decreases the "lumpiness" of the exposure simulation. For example, a total of 66 cohorts would be defined for the Houston area based on home district (11 possibilities), demographic group (2 possibilities), and air conditioning system (3 possibilities). The average cohort would contain 3,042 children [i.e., (200,795 children)/(66 cohorts)]. Specifying a replication value of 5 increases the number of cohorts to 330 and reduces the average size to 574 children. If all other factors are held constant, exposure estimates based on a set of 330 cohorts will display a smoother empirical distribution (with more detail in the upper percentiles) than exposure estimates based on a set of 66 cohorts.

The replication value was set equal to 5 for the analyses described in this report. Table 1 lists the number of cohorts defined for each of the nine study areas.

2.3 Develop an Exposure Event Sequence for Each Cohort for the Exposure Period

In the pNEM/03 methodology, the exposure of each cohort is determined by an exposure event sequence (EES) specific to the cohort. Each EES consists of a series of events with durations from 1 to 60 minutes. To permit the analyst to determine average exposures for specific clock hours, the exposure events are defined such that no event falls within more than one clock hour. Each exposure event assigns the cohort to a particular combination of geographic area and microenvironment. Each event also provides an indication of respiration rate. In typical applications, this indicator is a classification of slow - sleeping, slow - awake, medium, or fast.

The EESs are determined by assembling activity diary records relating to individual 24-hour periods into a series of records spanning the ozone season of the associated study area. Because each subject of a typical activity diary study provides data for only a few days, the construction of a multi-month EES requires either the repetition of data from one subject or the use of data from multiple subjects. The latter approach is used in pNEM analyses to better represent the variability of exposure that is expected to occur among the persons included in each cohort.

Previous applications of pNEM/O3 have employed activity diary data obtained from the CADS[20]. During this study over 900 subjects completed three-day activity diaries and detailed background questionnaires. Figure 1 presents a page from the Cincinnati diary. Each subject was instructed to complete a new diary page whenever he or she changed location or began a new activity.

In the outdoor children exposure analysis, analysts augmented the CADS data with diary data from six other time/activity studies (see Table 2 and Appendix A). Section 6 of this report describes how the data from all seven studies were assembled and processed to produce a unified time/activity database representative of outdoor children. The data within this special database were organized by study subject and 24-hour (midnight-to-midnight) time period. The diary records for one subject for one 24-hour period were designated a "person-day." The data base contained 792 person-days, each of which was indexed by the following factors:

1. Demographic group: preteens or teenagers
2. Season: summer or winter
3. Temperature classification: cool or warm
4. Day type: weekday or weekend.

The demographic group index was determined by the age of the child who provided the diary data. The season and day type indices were based on the calendar date of the person-day.

TIME [| | |] * AM [ ] PM [ ]

A. ACTIVITY (please specify)

____

____

____

B. LOCATION

In transit, car 01

In transit, other vehicle . . 02

Specify ________________

Indoors, your residence . . . 03

Indoors, other residence. . . 04

Indoors, office 05

Indoors, manufacturing facility. 06

Indoors, school 07

Indoors, store. 08

Indoors, other. 09

Specify ________________

Outdoors, within 10 yards of road or street. 10

Outdoors, other 11

Specify ________________

Uncertain 12

C. BREATHING RATE

Slow (e.g., sitting) 13

Medium (e.g., brisk walk). . . 14

Fast (e.g., running) 15

Breathing problem. 16

Specify ________________

D. SMOKING

I am smoking 17

Others are smoking 18

No one is smoking. 19

E. ONLY IF INDOORS

(1) Fireplace in use?

Yes. 20

No 21

(2) Woodstove in use?

Yes. 22

No 23

(3) Windows open?

Yes. 24

No 25

Uncertain. 26

*Enter MIDN for midnight and NOON for noon. Otherwise enter four-digit time (e.g., 0930 for 9:30 and 1217 for 12:17) and check a.m. or p.m.

Figure 1. Page from the activity diary used in the Cincinnati study.[20]

TABLE 2. CHARACTERISTICS OF STUDIES PROVIDING TIME/ACTIVITY DATA FOR OUTDOOR CHILDREN

Database name	Reference number(s)	Characteristics of subjects	Number of subject-days	Study calendar periods	Diary type	Diary time period	Breathing rates reported?
California - 11 and under	24	Children ages 1 to 11	1200	April 1989 - Feb. 1990	Retrospective	Midnight to midnight	No
California - 12 and over	25	Ages 12 to 94	1762	Oct. 1987 - July 1988	Retrospective	Midnight to midnight	No
Cincinnati	20	Ages 0 to 86	2800	March and August 1985	Real-time	Midnight to midnight	Yes
Los Angeles - elem. school	27,28	Elementary school students, 10 to 12 years	58	Oct. 1989	Real-time[a]	Midnight to midnight	Yes
Los Angeles - high school	27,28	High school students, 13 to 17 years	66	Sept. and Oct. 1990	Real-time[a]	Midnight to midnight	Yes
Valdez	29	Ages 10 to 72	405	Nov. 1990 - Oct. 1991	Retrospective	Retrospective	No
Washington	30	Ages 18 to 70	705	Nov. 1982 - Feb. 1983	Real-time	7 p.m. to 7 p.m. (nominal)	No

[a]Study employed the Cincinnati diary format.

The temperature classification was based on the daily maximum temperature reported for the diary study area on that date. The cool range was defined as daily maximum temperatures below 55° F in winter and temperatures below 84° F in summer.

A distinct EES was developed for each cohort in each of the nine study areas by applying a computerized sampling algorithm to the time/activity data base. The algorithm was provided with the sequence of daily maximum temperatures reported for the associated study area and exposure period (Table 1) and with the list of cohorts defined for the study area. The temperature data were used to assign each calendar day in the exposure period to one of the temperature ranges used in classifying the time/activity data. To construct the EES for a particular cohort, the algorithm selected a person-day from the time/activity data base for each calendar day in the specified exposure period according to the demographic group of the cohort and the season, day type, and temperature classification associated with the calendar day.

Each exposure event within an EES was defined by 1) district, 2) micro-environment, 3) breathing rate category, and 4) a set of supplemental variables used to predict ventilation rate. The district was the home district associated with the cohort.

Seven microenvironments were defined:

1. Indoors - residence - central air conditioning system
2. Indoors - residence - window air conditioning units
3. Indoors - residence - no air conditioning system
4. Indoors - nonresidential locations
5. Outdoors - near road
6. Outdoors - other
7. In vehicle.

Location codes appearing in the time/activity data base were used to determine the primary microenvironment location of each exposure event (indoors - residence, indoors - nonresidential locations, outdoors- near road, outdoors - other, or in vehicle). The indoors - residence location was subdivided into three microenvironments according to air conditioning (AC) system: central system, window unit(s), or none. This classification was based on the AC system specified for the cohort's residence. For example, a cohort designated as residing in a home with central AC would always be assigned to the microenvironment defined as "indoors - residence - central AC" when activity diary data indicated the cohort was inside a residence.

Four breathing rate categories were defined according to codes appearing in the time/activity data base: slow - sleeping, slow - awake, medium, and fast. Each exposure event was assigned to one of these categories.

Subsection 2.4.3 describes an algorithm which was used to estimate a value of equivalent ventilation rate for each exposure event. The algorithm determines these estimates as a function of various "predictor variables." The value of each variable for each exposure event is determined by the diary data associated with the event. Appendix B lists these variables and describes in detail how diary data are processed by the algorithm.

2.4 Estimate the Pollutant Concentration and Ventilation Rate Associated With Each Exposure Event

In the general pNEM methodology, the EES defined for each cohort is used to determine a corresponding sequence of exposures, event by event. Each exposure is defined by a pollutant concentration and a ventilation rate indicator.

2.4.1 Estimation of Pollutant Concentration

In the pNEM/03 analysis, the pollutant concentration during each exposure event was assumed to be a function of the microenvironment and district associated with the event. Consequently a continuous season or year-long sequence of hourly average ozone concentrations was developed for each combination of microenvironment and district. When an exposure event assigned a cohort to a particular combination of microenvironment and district, the cohort was assigned the ozone concentration specified for the corresponding clock hour in the appropriate microenvironment/district sequence.

Each year-long sequence of hourly average ozone values for the indoor and in-vehicle microenvironments was generated by the mass-balance algorithm described in Section 3. Briefly, this algorithm estimated the hourly average indoor ozone concentrations during hour h as a function of the indoor ozone concentration at the end of the preceding hour (i.e., hour h - 1), the ozone concentration outdoors during hour h, the air exchange rate during hour h (*v*), and an ozone decay factor (F_d). Values for the air exchange rate and the ozone decay factor were sampled from appropriate distributions on a daily basis (Subsections 3.1 and 3.3). Air exchange rate was permitted to change hourly in the three residential microenvironments depending on whether windows were assigned a status of "open" or "closed". This assignment was determined through the use of a probabilistic model (Subsection 3.4) in which the status during each clock hour was assumed to be a function of AC system, temperature range, and window status during the previous clock hour.

The outdoor ozone concentration associated with microenvironment m in district d during hour h was determined by an expression having the general form

$$C_{out}(m,d,t,s) = b(m) \times C_{mon}(d,t,s) + e(t), \tag{1}$$

where $C_{out}(m,d,t,s)$ is the outdoor (or ambient) ozone concentration in micro-environment m in district d at time t under regulatory scenario s, $C_{mon}(d,t,s)$ is the ozone concentration estimated to occur at the monitor representing district d at time t under regulatory scenario s, b(m) is a constant specific to microenvironment m, and e(t) is a random normal variable with mean = 0 and standard deviation = $\sigma(m)$. A value for e(t) was selected from a normal distribution with mean = 0 and standard deviation = $\sigma(m)$ every hour. The value of $C_{mon}(d,t,s)$ was constant over each clock hour.

In the application of pNEM/O3 described in this report, b(m) was set equal to 1.056 for all microenvironments. A value of 5.3 ppb (0.0053 ppm) was used as the value of $\sigma(m)$ for all microenvironments (Table 3). Consequently, each sequence of hourly ozone values was generated by the expression

$$C_{out}(m,d,t,s) = 1.056 \times C_{mon}(d,t,s) + e(t), \tag{2}$$

TABLE 3. PARAMETERS ASSOCIATED WITH ALGORITHMS USED TO ESTIMATE OZONE CONCENTRATIONS IN MICROENVIRONMENTS

Parameter	Equation(s) containing parameter	Microenvironment[a]	Parameter value
b(m)	1	All	1.056
σ(m)	1	All	5.3 ppb
Air exchange rate	38	1 - 4, 7	See Table 9
Ozone decay factor	38	1 - 4	Normal distribution · Arith. mean = 4.04 h^{-1} · Std. dev. = 1.35 h^{-1} · Minimum = 1.44 h^{-1} · Maximum = 8.09 h^{-1}
		7	72.0 h^{-1}

[a]Microenvironments:

1 = Indoors - residence - central air conditioning
2 = Indoors - residence - window units
3 = Indoors - residence - none
4 = Indoors - nonresidential locations
5 = Outdoors - near road
6 = Outdoors - other
7 = In vehicle

where e(t) is a random normal variate with mean = 0 and standard deviation = 5.3 ppb.

The expression is based on the results of regression analyses[13] performed by ITAQS analysts on personal exposure data collected by T. Stock during the Houston Asthmatic Study[22]. In these analyses, the dependent variable was five-minute ozone concentration measured outdoors by a personal exposure monitor (PEM). The independent variable was the simultaneous ozone concentration (hourly average value) reported by the nearest fixed-site monitor.

An initial regression analysis of 327 paired values yielded an intercept of 0.81 ppb, a slope of 1.042, and set of regression residuals with a standard deviation of 18.5 ppb. The R^2 value was 0.544. Because the regression intercept value was found to be non-significant ($p = 0.76$), a second regression analysis was performed in which the regression line was forced through the origin (i.e., intercept = 0). This analysis yielded a slope of 1.056 and a set of regression residuals with a standard deviation of 18.5 ppb. The residuals were found to be approximately normal (skewness = -0.32, kurtosis = 0.87).

Attempts were made to fit more complex regression models to the Stock data. These models included regression equations using logarithmic transformations of the variables and regression equations which included the previous PEM value as an independent variable. These alternative models were found to offer no significant improvement in performance over the model specified above. Some of the alternative models were found to be unstable.

The results of this analysis suggested that Equation 2 could be used as a means of generating five-minute values of $C_{out}(d,t,s)$, given that e(t) values were selected every five minutes from a normal distribution with mean equal to 0 and standard deviation equal to 18.5 ppb. A procedure based on this expression was used in a previous version of pNEM/O3 to generate five-minute ozone concentrations for the outdoor microenvironment[13].

As the new version of pNEM/O3 required hourly-average outdoor ozone concentrations rather than five-minute values, the procedure used in the earlier model was modified so that an hourly-average value of e(t) was selected for each hour from a normal distribution with mean equal to 0 and standard deviation equal to 5.3 ppb. The use of a smaller standard deviation (5.3 ppb versus 18.5 ppb) for the hourly-average e(t) terms was based on the statistical principle that the standard deviation of the average of n values drawn from a distribution with standard deviation equal to σ will tend to have a standard deviation equal to σ/m, where m is the square root of n. As there are 12 five-minute values in one hour, the value of n is 12. The corresponding value of m is 3.5, and 18.5 ppb/3.5 = 5.3 ppb.

The current version of pNEM/O3 provides for two outdoor microenvironments: No. 5 (outdoors - near road) and No. 6 (outdoors - other). In the pNEM/O3 analyses described in this report, these microenvironments were treated identically; that is, Equation 2 was used to determine the hourly ozone concentrations in each outdoor microenvironment. This approach is likely to over-estimate ozone concentrations in microenvironment No. 5 (outdoors - near road) because it does not account for potential ozone scavenging by nitric oxides emitted from motor vehicles. The magnitude of this bias is difficult to quantify because of the scarcity of research in this area and the inconsistency of research findings. For example, a study by Rhodes and Holland[31] of a single freeway in San Diego found that downwind ozone concentrations measured near the roadway were less than 28 percent of the ozone concentrations measured simultaneously at more distant outdoor locations judged to be unaffected by the roadway. However, an analysis[21] of outdoor personal exposure data obtained from the Stock study found that the average ratio of personal ozone concentration to fixed-site ozone concentration was approximately 1.0 in areas of both low and high traffic density.

2.4.2 The Air Quality Adjustment Model

In Equation 1, $C_{mon}(d,t,s)$ is the monitor-derived value for district d at time t under scenario s. The value for this variable was determined by adjusting monitoring data representing baseline conditions (i.e., 1990 or 1991 air quality) according to the equation

$$C_{mon}(d, t, s) = (a)\ [C_{mon}(d, t, e)]^{b} \qquad (3)$$

where $C_{mon}(d,t,e)$ is the monitor-derived value for district d under baseline conditions. The multiplicative factor (a) and the exponent (b) are specific to district and scenario. Section 5 describes the derivation of Equation 3 and provides examples of its application to Philadelphia monitoring data.

Equation 3 requires a complete (gapless) year of hourly average $C_{mon}(d,t,e)$ values for each district. These data sets were prepared by applying a special interpolation program to the hourly average ozone data reported by each fixed-site monitor. The interpolation program provided an estimate of each missing value. The resulting filled-in data sets were assumed to represent baseline conditions at each monitor.

The interpolation program provides estimates of missing values through the use of a time series model developed by Johnson and Wijnberg[32]. The time series model is based on the assumption that hourly average air quality values can be represented by a combination of cyclical, autoregressive, and noise processes. The parameter values of these processes are determined by a statistical analysis of the reported data.

2.4.3 Equivalent Ventilation Rate

In addition to ozone concentration, an equivalent ventilation rate (EVR) value was estimated for each exposure event. EVR is defined as ventilation rate divided by body surface area (BSA). Clinical research by EPA suggests that EVR exhibits less inter-person variability than ventilation rate for a given level of exertion.[33]

ITAQS analysts developed a special EVR-generator module for the version of pNEM/O3 applicable to outdoor children. The module used one of four Monte Carlo models to generate an EVR value for each exposure event associated with a given cohort. The applied model varied from event-to-event according to 1) the demographic group of the cohort (active preteens or active teenagers) and 2) the type of database (A or B) from which the associated diary data were obtained. The Type A databases were obtained from five of the studies listed in Table 2 (Cincinnati, Denver, Washington, and the two Los Angeles studies). The Type B databases included the three remaining studies listed in Table 2 (i.e., the two California studies and the Valdez study).

The Monte Carlo models were developed through an analysis of data reported by a research team directed by Dr. Jack Hackney and Mr. William Linn. The Hackney/Linn team conducted two studies in Los Angeles to obtain ventilation rate data representative of the typical daily activities of elementary school students and high school students.[27,28] The heart rate of each study subject was continuously monitored as the subject documented his or her activities in a special diary. Separate clinical trials were conducted in which the heart rate and ventilation rate of each subject were measured simultaneously. These measurements were used to develop a "calibration curve" for each subject relating heart rate to ventilation rate.

The calibration curves were used to convert the one-minute heart rate measurements obtained during each diary period into one-minute ventilation rates. The ventilation rate values were in turn divided by the subject's estimated body surface area to produce one-minute EVR values.

The Monte Carlo models were developed by applying a four-step procedure to each of the one-minute EVR databases. In Step 1, ITAQS processed each one-minute EVR database to produce a special "event EVR file." Each file provided a sequence of exposure events keyed to the activities documented by each subject. The listing for each event included the average EVR for the event and the values of 20 variables which were considered likely to influence EVR values.

In Step 2, ITAQS prepared tables of descriptive statistics for event EVR values which had been categorized by breathing rate, activity, microenvironment, time of day, and event duration.[34] These statistics provided an initial means for identifying factors to be considered in developing the EVR prediction algorithms. These factors were compiled into sets of candidate variables, each set specific to a particular database type.

In Step 3, ITAQS developed two Monte Carlo models for each database type. Each model was specific to either preteens or teenagers. The Monte Carlo models were based on the results of statistical analyses performed on EVR data obtained from the two Hackney/Linn studies discussed above; i.e., elementary school students and high school students. Models applicable to the preteens demographic group were based on analyses of data from the elementary school study; models applicable to teenagers were based on analyses of data from the high school study. To permit the use of all seven diary databases listed in Table 2, analysts developed two Monte

Carlo models for each demographic group -- one applicable to Type A databases and one applicable to Type B databases.

Each Monte Carlo model predicted EVR as a function of six or more predictor variables which constituted a "predictor set." Each predictor set was developed by first defining a candidate variable set for the database type and then performing stepwise linear regression analyses to determine which of the candidate variables were significant predictors of EVR for a particular demographic group. All regression analyses were performed on the two Hackney/Linn databases, as these were the only databases available which provided a measurement-based EVR value for each exposure event. The results of the regression analyses determined the variables to be included in the predictor set and the coefficients of various terms in the associated Monte Carlo model.

The best overall predictor variable was found to be LGM, the natural logarithm of the geometric mean of all event EVR values associated with a subject-day of diary data. Statistical analysis of the LGM values indicated that the distribution of LGM values was approximately lognormal.

In addition to LGM, the regression analyses suggested that variables associated with microenvironment, daytime activities, the exertion level of activities, day of week, and breathing rate were generally useful in predicting event EVR. Appendix B provides a listing of these variables and the associated regression coefficients.

Each regression analysis produced a set of residual values, one for each EVR value. Statistical analysis of the residuals indicated that 1) the standard deviation of the residuals varied significantly from subject to subject, and 2) the distribution of the subject-specific standard deviations was approximately lognormal.

Table 4 presents the general algorithm used to implement each Monte Carlo model. When this algorithm is applied to an appropriate database, it generates a sequence of EVR values, one for each event in the database. The EVR value generated for each individual event is determined by the values of the specified predictor variables, the regression coefficient associated with each predictor variable,

TABLE 4. ALGORITHM USED TO GENERATE EVENT-SPECIFIC VALUES OF EQUIVALENT VENTILATION RATE

1. Go to first/next person-day i.

2. Determine Monte Carlo model applicable to person-day according to demographic group of cohort and database type of diary data.

3. Model identity determines

   MEANLGM: mean of LGM values
   SDLGM: standard deviation of LGM values
   MU: mean of LSDRES values
   SIGMA: standard deviation of LSDRES values
   b_0: constant
   b_m: coefficient for variable VAR_m

   Denote the value of b_m for variable LGM as b_1.

4. Calculate LGM for person-day i:

   LGM(i) = MEANLGM + (SDLGM)[Z1(i)]

   Z1(i): randomly selected value from unit normal distribution (normal distribution with mean = 0 and standard deviation = 1).

5. If LGM(i) falls outside range indicated in Table B-7 (Appendix B), discard value and go to Step 4.

6. Calculate RESSIGMA for person-day i.

   LSDRES(i) = MU + (SIGMA)[Z2(i)]

   RESSIGMA(i) = Exp[LSDRES(i)]

   Z2(i): randomly selected value from unit normal distribution.

7. If LSDRES(i) falls outside range indicated in Table B-6 (Appendix B), discard value and go to Step 6.

8. Go to first/next event associated with person-day i.

(continued)

TABLE 4 (Continued)

9. Read values of variables VAR_2, VAR_3, ..., VAR_m for event j of person-day i from input data file.

10. Calculate residual value for event j of subject i.

$$RES(i,j) = [RESSIGMA(i)][Z(i,j)]$$

Z(i,j): randomly selected value from unit normal distribution.

11. Calculate LEVR for event j of person-day i:

$$LEVR(i,j) = b_0 + (b_1)[LGM(j)] + (b_2)[VAR_2(i,j)] + (b_3)[VAR_3(i,j)] + \ldots + (b_m)[VAR_m(i,j)] + RES(i,j)$$

12. Calculate EVR for event j of person-day i:

$$EVR(i,j) = Exp[LEVR(i,j)]$$

13. Write EVR(i,j) to output file.

14. If last event of person-day i, go to Step 1. If not, go to Step 8.

an LGM value randomly selected from a study-specific normal distribution, and a residual standard deviation selected from a subject-specific normal distribution. Because the algorithm employs Monte Carlo techniques to produce EVR estimates, each application of the algorithm to a particular time/activity database will produce a different sequence of exposure estimates. The general algorithm is described in detail in Appendix B.

In Step 4, ITAQS performed an initial check of the Monte Carlo approach by applying the EVR-generator algorithm to each of the two Los Angeles databases (see Appendix C). Each application produced a distribution of event EVR values which could be compared with the distribution of measurement-derived values. The modeled and measurement-derived distributions compared favorably with respect to mean, standard deviation, and percentiles up to the 99th or 99.5th percentiles. At higher percentiles, the algorithm tended to underestimate EVR for the elementary and high school databases.

Following these research efforts, ITAQS incorporated the newly-developed algorithm into an EVR-generator module within the larger pNEM/O3 model. This module provided an estimate of EVR for each exposure event using the Monte Carlo model appropriate to 1) the demographic group of the cohort (preteens or teenagers) and 2) the type of database (A or B) from which the associated diary data were obtained.

The EVR-generator module also contained an algorithm which established an upper limit (EVRLIM) for the EVR value assigned to each exposure event. EVRLIM varied with event duration and was set at a level estimated to be achievable by members of the cohort who 1) exercised regularly, 2) were motivated to attain high exertion levels, and 3) were not professional athletes. Joggers would be included in this group; professional basketball players would not be included.

Table 5 presents the algorithm used to determine EVRLIM. This algorithm is a variation of "Algorithm B" proposed by Johnson and Adams.[35] The algorithm accounts for the following research findings reported by Erb,[36] Astrand and Rodahl,[37] and other researchers.

1. Ventilation rate (V_E), oxygen uptake rate (VO_2), and the ratio of V_E to VO_2 increase with increasing work rate.

TABLE 5. ALGORITHM FOR DETERMINING UPPER LIMIT FOR EVR

1. Obtain values for the following quantities from Table 6.

VO_{2max}:	maximum oxygen uptake rate
MAXRATIO:	maximum ratio of ventilation rate to oxygen uptake rate
SUBRATIO:	submaximal ratio of ventilation rate to oxygen uptake rate
BSA:	body surface area

2. Determine duration of event (t).

3. If t <= 5 minutes, determine the upper limit for EVR (EVRLIM) by the expression

$$EVRLIM = (1.2)(VO_{2max})(MAXRATIO)/BSA.$$

4. If 5 minutes < t <= 162 minutes, determine the percentage of maximum oxygen uptake rate that can be maintained for duration t by the expression

$$PCTVO_{2max} = 116.19 - (10.06)[\ln(t)].$$

Next determine the ratio of ventilation rate to oxygen uptake rate by the expression

$$RATIO = SUBRATIO + (MAXRATIO-SUBRATIO)(PCTVO_{2max} - 65)/35.$$

Finally determine EVRLIM by the expression

$$EVRLIM = (1.2)(VO_{2max})(PCTVO_{2max})(RATIO)/(100)(BSA).$$

5. If t > 162 minutes, determine $PCTVO_{2max}$ by the expression presented in Step 4 and EVRLIM by the expression

$$EVRLIM = (1.2)(VO_{2max})(PCTVO_{2max})(SUBRATIO)/(100)(BSA).$$

TABLE 6. PARAMETER VALUES FOR ALGORITHM USED TO DETERMINE LIMITS FOR EQUIVALENT VENTILATION RATES FOR OUTDOOR CHILDREN

Parameter acronym	Definition	Parameter value	
		Preteens (ages 6 - 13)	Teenagers (ages 14 - 18)
BSA	Body surface area, m^2	1.23	1.70
VO_{2MAX}	Maximum oxygen uptake rate (VO_{2MAX}), liters/min	2.30	3.49
MAXRATIO	Ratio of ventilation rate (V_E) to oxygen uptake rate (VO_2) under maximum uptake conditions	34.5	32.0
SUBRATIO	Ratio of ventilation rate (V_E) to oxygen uptake rate (VO_2) under submaximal conditions	26.0	22.5

2. A person's maximum V_E is determined by his or her maximum oxygen uptake rate (VO_{2max}) and the V_E/VO_2 ratio in effect under maximum oxygen uptake conditions (MAXRATIO) such that

$$V_{Emax} = (VO_{2max})\ (MAXRATIO)\ .$$

3. VO_{2max} and MAXRATIO are functions of age, gender, and training, among other factors.

4. Individuals cannot maintain oxygen uptake rates equal to VO_{2max} for more than about five minutes.

5. For activity durations greater than five minutes (i.e., $t > 5$ min), the percentage of VO_{2max} that can be maintained continuously ($PCTVO_{2max}$) decreases as the natural logarithm of the activity duration [ln(t)] increases.

In determining the EVRLIM value for preteens (ages 6 to 13) applicable to a particular event duration, the algorithm uses estimates of VO_{2max}, MAXRATIO, SUBRATIO, and BSA specific to males aged 11 (Table 6). Estimates of EVRLIM provided by Johnson and Adams[35] suggest that children in this category are likely to experience the highest EVR values of all children included in the preteen age group. In a similar manner, the parameter values listed in Table 6 for children ages 14 to 18 are based on males aged 15.

The reader should note that each of the two sets of parameter values listed in Table 6 is based on the physiological characteristics of a subset of the specified demographic group (e.g., males aged 11), but is being applied to all members of the demographic group (e.g., preteens). Because the EVRLIM of the selected subset is likely to be higher than average EVRLIM of the demographic group, the use of these parameter values in the pNEM/O3 simulation will tend to overpredict the occurrence of high EVR values within each demographic group. This potential bias may be corrected in future versions of the model by dividing each demographic group into various subgroups according to age and gender. A separate set of EVRLIM parameters would have to be developed for each subgroup.

2.4.5 Hourly Average Exposure Sequences

Algorithms within pNEM/03 provided three estimates for each exposure event: average ozone concentration, average EVR, and the product of average ozone concentration and EVR (ozone x EVR). These estimates were processed to produce time-weighted estimates of ozone concentration, EVR, and ozone x EVR for each clock hour. The result was a year-long sequence of hourly values for each of three exposure indicators for each cohort. These sequences can be further processed to determine cohort-specific values for various multihour exposure indicators. Examples of such indicators include the largest eight-hour daily maximum ozone concentration and the number of times the hourly-average ozone concentration exceeds 0.12 ppm.

2.5 Extrapolate the Cohort Exposures to the Population-of-Interest

The cohort-specific exposure estimates developed in Step 4 of the pNEM methodology (Subsection 2.4) were extrapolated to the general outdoor children population of each study area by estimating the population size of each cohort. Cohort populations were estimated by the following four-step procedure.

In Step 1, the number of outdoor children residing in each census unit was estimated by the formula

$$POPOC(g,c) = \sum [P(g) \times POPC(g,c)] \tag{4}$$

where POPOC(g,c) is the number of outdoor children in demographic (age) group g and census unit c, POPC(g,c) is the number of children in demographic group g who reside in census unit c, and P(g) is the estimated fraction of children in demographic group g who are outdoor children. Values for POPC(g,c) were obtained directly from 1990 Bureau of Census data files[18] that list population data for age groups by census unit. Section 6 describes the method used to estimate a value of P(g) for the two demographic (age) groups used in the outdoor children analysis.

In Step 2, the fraction of homes falling into each of the three air conditioning categories was estimated by census unit. The fractions associated with each census unit were determined using 1980 census data, as the 1990 census did not collect air conditioning data. In cases where the boundaries of a 1990 census unit did not coincide with 1980 census units, analysts used the fractions associated with the 1980 census unit located nearest to the 1990 census unit.

In Step 3, the outdoor children population of each census unit was multiplied by the air conditioning fractions to provide an estimate of the number of outdoor children in each air conditioning category. The estimation equation was

$$POPOC(g,c,a) = F(c,a) \times POPOC(g,c), \tag{5}$$

where POPOC(g,c,a) is the population of outdoor children associated with census unit c and air conditioning system a. F(c,a) is the fraction of housing units in census unit c with air conditioning system a, and POPOC(g,c) is the number of outdoor children in demographic group g residing in census unit c (Equation 4). The values of POPOC(g,c,a) were summed over each exposure district to yield estimates of

POPOC(g,d,a), the number of outdoor children in demographic group g within exposure district d assigned to air conditioning category a. This summation is explained further in Section 6.3. Table 7 lists the values of POPOC (g,d,a) calculated for each study area.

As previously discussed, the replication feature was used to create five cohorts for each combination of demographic group g, exposure district d, and air conditioning system a. Each of the five cohorts associated with a particular combination of indices (g, d, and a) received one-fifth of POPOC(g,d,a); that is

$$POPCOH(g,d,a) = [POPOC(g,d,a)]/5 \tag{6}$$

where POPCOH(g,d,a) is the population assigned to each cohort.

A special tabulation program in pNEM/03 combined the cohort-specific estimates of exposure and population to produce histograms and cumulative frequency tables for various population exposure indicators and averaging times. Section 7 provides exposure estimates based on existing conditions in each study area, the attainment of the current NAAQS, and the attainment of each of seven alternative NAAQS.

TABLE 7. POPULATION ESTIMATES BY DEMOGRAPHIC GROUP AND AIR CONDITIONING STATUS

Study area	Exposure district	Population estimates by demographic group and air conditioning status					
		Preteens			Teenagers		
		Central AC[a]	Window AC	No AC	Central AC	Window AC	No AC
Chicago	1	13,260	11,240	7,410	5,245	4,450	2,980
	2	2,650	8,545	24,445	1,170	3,670	9,865
	3	6,890	13,680	9,760	2,930	5,625	3,935
	4	6,380	2,750	2,440	2,360	1,030	910
	5	9,203	29,070	47,715	3,830	11,760	19,040
	6	11,045	6,420	2,520	4,420	2,560	980
	7	4,330	5,895	6,390	1,755	2,445	2,600
	8	9,980	9,355	9,390	4,140	3,730	3,835
	9	18,525	9,290	5,160	6,780	3,425	1,885
	10	10,205	4,645	4,115	3,730	1,695	1,470
	11	9,950	3,370	2,080	3,625	1,245	755
	12	5,900	2,540	1,745	2,640	1,125	780
Denver	1	3,285	2,015	8,430	1,210	715	3,005
	2	2,215	600	7,095	860	240	2,605
	3	2,955	2,250	11,045	1,200	855	3,925
	4	675	595	3,945	305	270	1,765
	5	1,415	1,600	7,920	520	585	2,920
	6	305	1,290	7,285	305	480	2,650
	7	520	1,625	8,825	685	655	3,370
Houston	1	8,525	4,435	1,465	3,450	1,745	575
	2	7,895	650	350	2,825	235	125
	3	1,875	2,245	1,210	855	975	525
	4	25,645	2,485	945	9,505	930	405
	5	25,535	1,850	465	9,635	720	180
	6	3,705	4,175	1,035	1,405	1,610	415
	7	9,645	2,155	515	3,645	805	185
	8	10,500	2,310	515	3,925	890	205
	9	4,975	1,500	355	1,970	600	140
	10	970	2,075	1,115	385	830	460
	11	3,685	6,400	3,790	1,580	2,550	1,515

(continued)

Table 7 (Continued)

Study area	Exposure district	Population estimates by demographic group and air conditioning status					
		Preteens			Teenagers		
		Central AC[a]	Window AC	No AC	Central AC	Window AC	No AC
Los Angeles	1	5,440	7,425	5,695	2,120	2,860	2,195
	2	4,415	11,855	57,335	1,895	4,940	24,760
	3	3,170	9,145	53,895	1,215	3,500	20,160
	4	4,335	9,975	16,775	1,870	4,105	6,880
	5	10,165	16,735	18,250	4,485	6,810	7,975
	6	6,165	12,625	17,805	2,675	5,255	7,310
	7	2,585	5,130	33,220	1,055	1,920	12,160
	8	1,195	1,870	38,190	455	720	14,795
	9	8,410	9,625	17,830	3,540	4,125	7,535
	10	7,955	8,095	16,965	3,525	3,660	7,540
	11	5,780	6,215	15,030	2,540	2,585	6,320
	12	7,495	7,445	9,240	3,365	3,080	3,855
	13	19,495	4,695	6,510	6,895	1,605	2,280
	14	21,840	6,635	8,210	8,465	2,550	3,155
	15	3,300	1,125	1,255	1,155	395	440
	16	13,345	4,550	5,075	4,570	1,560	1,740
Miami	1	12,190	585	95	4,705	225	35
	2	3,610	1,715	1,010	1,415	670	390
	3	11,270	7,920	2,815	4,740	3,180	1,130
	4	8,320	1,325	120	3,150	590	55
	5	6,390	13,835	7,000	2,675	5,995	2,800
	6	11,925	3,725	1,305	4,725	1,460	515
New York	1	1,030	3,780	4,810	455	1,635	2,070
	2	3,755	21,895	20,380	1,620	9,530	8,820
	3	780	7,570	5,675	325	3,095	2,270
	4	620	2,295	3,890	265	950	1,630
	5	5,045	11,635	6,060	2,330	5,105	2,735
	6	5,805	34,070	83,060	2,540	13,750	32,460
	7	2,990	18,885	31,750	1,310	7,950	12,595
	8	2,465	30,985	59,350	985	12,565	23,785
	9	6,500	45,975	41,775	2,805	19,900	17,870
	10	5,395	13,190	13,290	2,370	5,725	5,535
	11	7,150	20,095	13,985	3,295	8,625	6,040
	12	2,805	7,605	6,170	1,215	3,215	2,715

(continued)

Table 7 (Continued)

Study area	Exposure district	Population estimates by demographic group and air conditioning status					
		Preteens			Teenagers		
		Central AC[a]	Window AC	No AC	Central AC	Window AC	No AC
Philadelphia	1	770	1,710	1,815	295	750	760
	2	8,120	12,450	13,465	3,330	4,750	5,080
	3	1,645	1,420	1,955	615	565	750
	4	1,765	2,865	2,115	685	1,105	815
	5	4,770	4,700	3,785	1,880	1,890	1,525
	6	4,410	8,740	5,880	1,770	3,430	2,365
	7	3,505	5,180	3,965	1,590	2,220	1,675
	8	4,220	16,975	15,685	1,860	7,085	6,505
	9	2,305	11,965	13,995	980	4,850	5,475
	10	11,245	17,285	7,510	4,865	6,725	2,915
St. Louis	1	3,490	3,325	2,605	1,460	1,470	1,185
	2	3,435	1,705	950	1,350	675	365
	3	8,905	1,445	750	3,210	510	260
	4	10,330	765	460	4,025	285	175
	5	3,295	2,125	710	1,265	910	285
	6	8,610	1,500	720	3,335	545	255
	7	7,255	1,820	930	2,735	665	340
	8	1,965	1,580	875	735	570	330
	9	1,500	2,315	1,510	515	800	540
	10	740	1,915	2,895	265	710	1,080
	11	3,160	4,680	4,215	1,285	1,935	1,700
Washington	1	2,505	2,795	3,335	1,435	1,555	1,630
	2	9,310	5,590	3,590	4,145	2,235	1,490
	3	17,000	2,330	1,490	6,325	850	555
	4	9,885	1,905	1,785	3,720	685	615
	5	13,575	1,770	5,195	5,120	1,865	2,090
	6	1,270	850	900	540	330	380
	7	6,755	1,315	815	2,710	525	315
	8	6,555	1,775	975	2,555	695	385
	9	6,945	800	405	3,020	345	180
	10	3,115	1,420	1,545	1,220	550	555
	11	18,105	1,475	1,185	7,940	580	455

[a]AC = air conditioning.

SECTION 3

THE MASS-BALANCE MODEL

In the pNEM/O3 simulation, the ozone concentration in a particular microenvironment during a particular clock hour is assumed to be constant. For indoor and in-vehicle microenvironments, this value is determined by using a mass balance model to calculate the average ozone concentration for the clock hour expected under the following conditions:

1. There are no indoor sources of ozone.
2. The indoor ozone concentration at the end of the preceding hour is specified.
3. The outdoor ozone concentration during the clock hour is constant at a specified value.
4. The air exchange rate during the clock hour is constant at a specified value.
5. Ozone decays at a rate that is proportional to the indoor ozone concentration. The proportionality factor is constant at a specified value.

The mass balance model employed in these calculations is based on a generalized mass balance model described by Nagda et al.,[38] hereafter referred to as the Nagda model. As originally proposed, this model assumed that pollutant concentration decays indoors at a constant rate. For use in pNEM/O3, the Nagda model was revised to incorporate the alternative assumption that the indoor decay rate is proportional to the indoor concentration. The Nagda model was further revised to incorporate ozone-specific assumptions concerning various parameter values suggested by Weschler[39] and others.

Subsection 3.1 presents the theoretical basis for the pNEM/O3 mass balance model and the principal model assumptions. Subsection 3.2 describes the algorithms which were used to generate hourly values of ozone for the indoor and in-vehicle microenvironments. Subsection 3.3 presents the procedure used to determine air exchange rate for the mass balance model. An algorithm for simulating the opening and closing of windows is described in Subsection 3.4.

3.1 Theoretical Basis and Assumptions

The Nagda model can be expressed by the differential equation

$$\frac{dC_{in}}{dt} = (1 - F_B)\ \nu C_{out} + \frac{S}{cV} - m\nu C_{in} - \frac{\lambda}{cV} - \frac{qFC_{in}}{cV} \qquad (7)$$

where C_{in} = Indoor concentration (units: mass/volume)

F_B = Fraction of outdoor concentration intercepted by the enclosure (dimensionless fraction)

ν = Air exchange rate (1/time)

C_{out} = Outdoor concentration (mass/volume)

S = Indoor generation rate (mass/time)

cV = Effective indoor volume where c is a dimensionless fraction (volume)

m = Mixing factor (dimensionless fraction)

λ = Decay rate (mass/time)

q = Flow rate through air cleaning device (volume/time)

F = Efficiency of the air cleaning device (dimensionless fraction).

In this model, the pollutant decay rate (λ) is assumed to be constant. Research by Nazaroff and Cass[40] and by Hayes[41] suggests that the decay rate for ozone should be proportional to C_{in}. Consequently, the pNEM/03 mass balance equation substitutes the term F_d C_{in} for the term Λ/cV in Equation 7. The coefficient F_d is expressed in units of 1/time.

The following notational changes were made to simplify the equation:

$$F_p = 1 - F_B, \tag{8}$$

$$V_e = cV, \tag{9}$$

F_p is the "penetration factor," and V_e is the "effective volume." The resulting equation is

$$\frac{d}{dt} C_{in} = F_p \nu \, C_{out} + \frac{S}{V_e} - m\nu \, C_{in} - F_d C_{in} - \frac{qFC_{in}}{V_e} \tag{10}$$

If the three terms that are proportional to C_{in} are collected into one term, the equation can be expressed as

$$\frac{d}{dt} C_{in} = F_p \nu \, C_{out} + \frac{S}{V_e} - \nu' C_{in}, \tag{11}$$

where

$$\nu' = m\nu + F_d + \frac{qF}{V_e}. \tag{12}$$

It can be shown that Equation 11 has the following approximate solution:

$$C_{in}(t) = k_1 C_{in}(t-\Delta t) + k_2 \underline{C}_{out} + k_3, \tag{13}$$

where

$$k_1 = e^{-v'\Delta t}, \tag{14}$$

$$k_2 = (F_p v/v')(1-k_1), \tag{15}$$

$$k_3 = (S/v'V_e)(1-k_1), \tag{16}$$

and $\underline{C}_{out}$ is the average value of the outdoor concentration over the interval t to t + Δt. If $\underline{C}_{out}$ is constant over the interval, then Equation 13 is an exact solution.

The average indoor concentration for hour h, $\underline{C}_{in}$ (h), is given by the expression

$$\underline{C}_{in}(h) = a_1 C_{in}(h-1) + a_2 \underline{C}_{out}(h) + a_3 \tag{17}$$

where C_{in}(h-1) is the instantaneous indoor concentration at the end of the preceding hour, $\underline{C}_{out}$ (h) is the average outdoor concentration for hour h,

$$a_1 = z(h), \tag{18}$$

$$a_2 = (F_p \nu / \nu') \, [1 - z(h)] \,, \tag{19}$$

$$a_3 = (\frac{S}{\nu' V_e}) \, [1 - z(h)] \,, \tag{20}$$

and

$$z(h) = (1 - e^{-\nu'}) / \nu'. \tag{21}$$

A steady-state version of the mass balance model can be developed by solving Equation 11 under the conditions that

$$\frac{d}{dt} C_{in} = 0 \tag{22}$$

and C_{out} is constant. In this case, the mass balance equation is

$$0 = F_p \nu \, C_{out} + \frac{S}{V_e} - \nu' C_{in}, \tag{23}$$

which can be rearranged as

$$C_{in} = (F_p \nu / \nu') \, C_{out} + \frac{S}{\nu' V_e} \,. \tag{24}$$

The ratio of indoor concentration to outdoor concentration is

$$C_{in}/C_{out} = (F_p \nu/\nu') + \frac{S}{\nu' V_e C_{out}} . \qquad (25)$$

Weschler[39] has developed a steady-state equation for the indoor/outdoor ratio which is expressed in his notation as

$$I/O = E_x/[E_x + k_d(A/V)] , \qquad (26)$$

where I = indoor concentration, O = outdoor concentration, E_x = air exchange rate, k_d = deposition velocity, A = surface area, and V = volume. With respect to Equation 10, Weschler's model implies that there are no indoor sources (S = zero), no air cleaning devices (F = zero), the penetration factor is unity (F_p = 1), c = 1, and m = 1. Under these conditions, Equation 10 becomes

$$\frac{d}{dt} C_{in} = \nu C_{out} - (\nu + F_d) C_{in} \qquad (27)$$

and Equation 25 becomes

$$C_{in}/C_{out} = \frac{\nu}{\nu + F_d} . \qquad (28)$$

Weschler's model (Equation 26) and Equation 28 are equivalent if the following substitutions are made:

$$C_{in} = I \qquad (29)$$

$$C_{out} = O \quad (30)$$

$$\nu = E_x \quad (31)$$

$$F_d = k_d (A/V) \; . \quad (32)$$

Equation 32 is a particularly useful relationship, as Weschler has identified a number of studies which suggest that $k_d(A/V)$ is relatively constant from building to building. He suggests that 1.0×10^{-3} sec^{-1} is a good general estimate of this quantity.

Weschler et al.[39] present 14 estimates of $k_d(A/V)$ based on data obtained from specific studies. Nine of these values are based on the observed first-order decay of ozone in isolated rooms. The remaining five values are based on reported I/O values and air exchange rates. Table 8 presents means and standard deviations for the first nine estimates, for the last five estimates, and for all 14 estimates. Two-sided 95 percent confidence intervals for the means are also provided.

The values in Table 8 can be converted to units of h^{-1} by multiplying each value by 3600. Expressed in these units, the mean and standard deviation for the 14 estimates are 4.04 h^{-1} and 1.35 h^{-1}, respectively. A normal distribution with these parameters was assumed to represent the distribution of F_d values for the non-vehicle indoor microenvironments. The value of F_d was not permitted to be less than 1.44 h^{-1} or more than 8.09 h^{-1}. The lower bound was based on the smallest value cited by Weschler[39] which was measured in a stainless steel room. The upper bound corresponds to the 99.87 percentile (i.e., z = 3) of a normal distribution with mean equal to 4.04 and standard deviation equal to 1.35. The largest value cited by Weschler et al.[39] was 7.2 h^{-1}.

The mass balance model was also used to simulate ozone concentrations for the in-vehicle microenvironment. Ideally, the in-vehicle microenvironment would have been represented by a distribution of F_d values based on ozone decay rates measured in a representative sample of motor vehicles. Because of the scarcity of research concerning ozone decay rates in motor vehicles, ITAQS analysts were not able to develop such a distribution. Instead, a point estimate of 72.0 h^{-1} was assumed for the F_d of the in-vehicle microenvironment. This value was derived by Hayes[41] from an analysis of data for one vehicle presented by Petersen and Sabersky[42]. Hayes has used this value in applications of the PAQM exposure model[41].

The use of a point estimate based on a single motor vehicle is likely to produce a bias in the ozone concentrations estimated for the in-vehicle microenvironment. The direction of this bias is uncertain.

TABLE 8. MEANS, STANDARD DEVIATIONS, AND CONFIDENCE INTERVALS FOR ESTIMATES OF $k_d(A/V)$ PROVIDED BY WESCHLER

Parameter	Source of k_d (A/V) estimate		
	Observed first-order decay	Reported I/O values	All
Sample size	9	5	14
Mean, sec^{-1}	1.133×10^{-3}	1.098×10^{-3}	1.121×10^{-3}
Standard deviation, sec^{-1}	0.447×10^{-3}	0.143×10^{-3}	0.374×10^{-3}
Two-sided 95% confidence interval, sec^{-1}	$(0.789, 1.477) \times 10^{-3}$	$(0.920, 1.276) \times 10^{-3}$	$(0.906, 1.335) \times 10^{-3}$

3.2 Simulation of Microenvironmental Ozone Concentrations

Consistent with the theoretical considerations discussed in Subsection 3.1, the following equation was used to estimate the hourly average ozone concentration in a particular indoor or in-vehicle microenvironment during hour h:

$$\underline{C}_{in}(h) = a_1 C_{in}(h-1) + a_2 \underline{C}_{out}(h) \tag{33}$$

where $\underline{C}_{in}$ (h) is the average indoor ozone concentration during hour h, C_{in} (h-1) is the instantaneous ozone concentration at the end of the preceding hour, $\underline{C}_{out}$ (h) is the outdoor ozone concentration during hour h,

$$a_1 = z(h), \tag{34}$$

$$a_2 = (\nu/\nu')\,[1 - z(h)], \tag{35}$$

$$z(h) = (1 - e^{-\nu'})/\nu', \tag{36}$$

and

$$\nu' = \nu + F_d \tag{37}$$

The instantaneous ozone concentration at the end of a particular hour, C_{in} (h), was estimated by the equation

$$C_{in}(h) = k_1 C_{in}(h-1) + k_2 \underline{C}_{out}(h), \tag{38}$$

where

$$k_1 = e^{-v'} \tag{39}$$

$$k_2 = (v/v')\,(1-k_1)\,, \tag{40}$$

and v' is determined by Equation 37.

The following algorithm was used to generate a sequence of hourly-average ozone concentrations for each combination of microenvironment and district.

1. Go to first/next day.

2. Select value of air exchange rate for day from appropriate distribution or use point estimate. If microenvironment is residential, select one air exchange value for hours when windows are open and one for hours when windows are closed. If microenvironment is a nonresidential building or vehicle, then one air exchange rate is used for all hours of the day.

3. Select value of decay rate (F_d) for day from appropriate distribution or use point estimate. If microenvironment is non-vehicular enclosure, select value of F_d from normal distribution with mean = 4.04 h^{-1} and standard deviation = 1.35 h^{-1}. Value is not permitted to be less than 1.44 h^{-1} or more than 8.09 h^{-1}. If microenvironment is "in vehicle", use point estimate of 72.0 h^{-1}.

4. Go to first/next clock hour.

5. If microenvironment is residential, use supplementary window algorithm to determine window status for current hour (open or closed). Window status determines which air exchange rate determined in Step 2 applies to current hour.

6. Use Equation 33 to determine ozone concentration for current hour based on air exchange rate specified for hour, outdoor ozone concentration during hour, and ozone concentration at end of preceding hour.

7. Use Equation 38 to determine instantaneous ozone concentration at end of current hour based on air exchange rate specified for hour, outdoor

ozone concentration during hour, and instantaneous ozone concentration at end of preceding hour. This value is saved for input into Equation 33 during the next hour.

8. If end of day, go to Step 1. Otherwise, go to Step 4.

Step 2 requires the random selection of an air exchange rate from a specified distribution. Four enclosure categories were established for this purpose.

- Residential buildings - windows open
- Residential buildings - windows closed
- Nonresidential buildings
- Vehicles.

A survey of the scientific literature determined that there were sufficient data available to define distributions for only two of the four enclosure categories: "residential building - windows closed" or "nonresidential building". In each case, a two-parameter lognormal distribution was found to provide a good fit to the data. Point (single-valued) estimates were developed for the remaining two enclosure categories.

Each of the two lognormal distributions was defined by the expression

$$AER = GM \times GSD^{Z} \tag{41}$$

where AER is the air exchange rate, GM is the geometric mean, and GSD is the geometric standard deviation. The values for GM and GSD were determined by fitting lognormal distributions to representative data sets (Subsection 3.3). A value of AER was selected at random from a particular lognormal distribution by randomly selecting a value of Z from the unit normal distribution [N(0,1)] and substituting it into Equation 41. Table 9 lists the values of GM and GSD for the two lognormal distributions and the values of the point estimates.

The distributions used to determine AER are discussed in more detail in Subsection 3.3. Subsection 3.4 provides a description of the algorithm used to determine window status in the residential microenvironments (Step 4).

TABLE 9. DISTRIBUTIONS OF AIR EXCHANGE RATE VALUES USED IN THE pNEM/03 MASS BALANCE MODEL

Enclosure category	Air exchange rate distribution
Residential building-windows closed	Lognormal distribution ° Geometric mean = 0.53 ° Geometric standard deviation = 1.704 ° Lower bound = 0.063 ° Upper bound = 4.47
Residential building-windows open	Point estimate: 6.4
Nonresidential building	Lognormal distribution ° Geometric mean = 1.285 ° Geometric standard deviation = 1.891 ° Lower bound = 0.19 ° Upper bound = 8.69
Vehicle	Point estimate: 36

3.3 Air Exchange Rate Distributions

A review of the scientific literature relating to air exchange rates identified 31 relevant references (list available on request). Of these, only a few were found to contain sufficient data to construct a distribution of air exchange rates relating to a particular building type such as residence or office. The two most useful studies were conducted by Grimsrud et al.[43] and by Turk et al.[44]

Residential Locations

Grimsrud et al.[43] measured AER's in 312 residences. Reported AER values ranged from 0.08 to 3.24. ITAQS analyzed these data to determine which of two distributions (normal versus lognormal) better characterized the data. The lognormal distribution was found to yield a better fit, as the data were highly skewed. The fitted lognormal parameters were geometric mean = 0.53 and geometric standard deviation = 1.704. This distribution was used in pNEM/03 to represent the distribution of AER's in residences with windows closed. Upper and lower limits of 4.47 and 0.063 air changes per hour were established to prevent the selection of unusually extreme values of AER. These limits corresponded to the substitution of Z = 4 and Z = -4 in Equation 41 when GM = 0.53 and GSD = 1.704. The upper bound was 38 percent larger than the largest reported AER (3.24). The lower bound was 21 percent smaller than the smallest reported AER (0.08).

No comparable data bases were identified which were considered representative of residences where windows are open. Hayes has used 6.4 h^{-1} as the AER value for open windows in applications of the PAQM model.[41] This value was based on an analysis by Hayes[45] of a hypothetical building plan with an assumed "orifice coefficient." Orifice coefficient is defined as the ratio of the equivalent area of all openings in a building to the building's volume. In support of this approach, Hayes cites a report by Moschandreas et al.[46] which suggests that infiltration is proportional to a building's orifice coefficient.

ITAQS analysts considered Hayes's estimate to be the best available estimate of AER for residences with windows open. Consequently, the AER for residences with windows open was treated as a point estimate (6.4 h^{-1}) in the pNEM/O3 analyses described here. Note that the use of an AER estimate representing a single set of conditions is likely to produce a bias in the ozone concentrations estimated for this microenvironment. The direction of this bias is uncertain.

Nonresidential Locations

Turk et al.[44] measured AER's in 40 public buildings identified as schools (n = 7), offices (n = 25), libraries (n = 3), and multipurpose buildings (n = 5). The minimum reported AER was 0.3; the maximum was 4.1. ITAQS analysts fit normal and lognormal distributions to the data for all 40 buildings and found that the lognormal distribution produced a slightly better fit, although it had a tendency to over-predict high values. The fitted lognormal parameters were geometric mean = 1.285 and geometric standard deviation = 1.891.

The buildings can be grouped as offices (n = 25) and nonoffices (n = 15). Lognormal fits to these data sets yielded geometric means and standard deviations of 1.30 and 1.93 for offices and 1.27 and 1.87 for nonoffices. ITAQS performed a two-sample t test on the two data sets and found no significant difference in the means or standard deviations of the data. Consequently, a single lognormal distribution (geometric mean = 1.285, geometric standard deviation = 1.891) was used in pNEM/03 for all nonresidential buildings. To prevent the over-prediction of high AER values, an upper bound of 8.69 was established. This value results when Z = 3 is substituted into Equation 41 with GM = 1.285 and GSD = 1.891. This value is over twice the largest AER value (4.1) reported for the 40 buildings and corresponds to the 99.87 percentile of the specified lognormal distribution. A lower bound of 0.19 was also established. This value corresponds to a Z value of -3 and represents the 0.13 percentile of the lognormal distribution.

ITAQS analysts consider the AER data obtained from Turk et al.[44] to be generally representative of buildings with closed windows. Consequently, the lognormal AER distribution derived from these data may not be applicable to non-residential buildings which are ventilated by open windows. As comparable data were not available for non-residential buildings with open windows, analysts applied the lognormal AER distribution for closed windows to all non-residential buildings. This approach is likely to under-estimate the ozone exposures of people who frequently occupy buildings with open windows.

In Vehicle Locations

A point estimate of 36 air changes per hour was used for in-vehicle locations. This value was obtained from Hayes[47] based on his analysis of data for a single vehicle presented by Peterson and Sabersky[42]. Hayes notes that the greater AER observed in vehicles, even with the windows closed, is due to wind effects on the moving vehicle and the "leakiness" of typical automobiles.

ITAQS analysts considered Hayes's estimate to be the best available estimate of AER for the in-vehicle microenvironment. Consequently, in-vehicle AER was treated as a point estimate (36 h^{-1}) in the pNEM/O3 analyses described here. It should be noted that the use of an AER estimate representing a single set of conditions is likely to produce a bias in the ozone concentrations estimated for this microenvironment. The direction of this bias is uncertain.

3.4 Window Status Algorithm

The opening and closing of windows in the three residential microenvironments was simulated by an algorithm which specified a window status (open or closed) for each clock hour. The algorithm consisted of the following eight-step procedure.

1. Identify air conditioning system associated with cohort (central, window units, none).

2. Go to first/next day.

3. Determine average temperature for day from supplementary file. Identify temperature range which contains this value (below 32, 32 to below 63, 63 to 75, above 75).

4. Select random number between zero and 1. Compare random number with probabilities listed in Table 10 for specified air conditioning system and temperature range. Determine window status for day. If day status is "windows open all day" or "windows closed all day", set window status for all clock hours of day as indicated and go to Step 2. If day status is "windows open part of day", go to Step 5.

5. Go to first/next clock hour.

6. Determine window status of preceding clock hour.

7. Select random number between zero and 1. Compare random number with probabilities listed in Table 11, 12, or 13 for specified air conditioning system, clock hour, temperature range, and window status for preceding hour. If the random number is less than the specified probability, the window will be open during the clock hour. Otherwise, the window will be closed.

8. If end of day, go to Step 2. Otherwise, go to Step 5.

This algorithm assigns each day to one of three categories: 1) windows closed all day, 2) windows open all day, and 3) windows open part of day. These assignments are made according to the air conditioning system associated with the cohort and the average temperature of the day. If the day assignment is "windows open part of day", the algorithm assigns window status on an hourly basis for each of the 24 clock hours in the day. These hourly assignments are made according to the 1) cohort's air conditioning system, 2) clock hour, 3) average temperature for the day, and 4) window status of the preceding hour. Both the daily and hourly assignments are made probabilistically by comparing random numbers to the probabilities that the specified window status will occur under the stated conditions.

The window status probabilities listed in Tables 10, 11, 12, and 13 were developed through a statistical analysis of data on window openings obtained from the CADS.[20] This analysis indicated that air conditioning system, temperature, clock hour, and window status of preceding hour were statistically significant factors affecting window status.

TABLE 10. PROBABILITY OF WINDOW STATUS FOR DAY BY AIR CONDITIONING SYSTEM AND TEMPERATURE RANGE

Air conditioning system	Temperature range, °F	Probability of window status for day		
		Closed all day	Open all day	Open part of day
Central	Below 32	1.000	0	0
	32 to 62	0.851	0.009	0.140
	63 to 75	0.358	0.343	0.299
	Above 75	0.633	0.167	0.200
Room units	Below 32	1.000	0	0
	32 to 62	0.734	0.028	0.238
	63 to 75	0.114	0.505	0.381
	Above 75	0.160	0.380	0.460
None	Below 32	1.000	0	0
	32 to 62	0.812	0.011	0.177
	63 to 75	0.095	0.672	0.233
	Above 75	0.016	0.823	0.161

TABLE 11. PROBABILITY OF WINDOWS BEING OPEN BY CLOCK HOUR, TEMPERATURE RANGE, AND WINDOW STATUS OF PRECEDING HOUR (PH) FOR RESIDENCES WITH CENTRAL AIR CONDITIONING

Clock hour	Probability of windows being open					
	32°F to 62°F		63°F to 75°F		Above 75°F	
	PH=open	PH=closed	PH=open	PH=closed	PH=open	PH=closed
1-3	1.000	0.000	0.978	0.011	0.986	0.020
4-6	1.000	0.005	0.989	0.000	1.000	0.017
7-9	0.837	0.038	0.932	0.074	0.961	0.094
10-12	0.679	0.126	0.865	0.235	0.860	0.174
13-15	0.857	0.149	0.912	0.240	0.923	0.263
16-18	0.932	0.131	0.935	0.161	0.912	0.000
19-21	0.646	0.043	0.892	0.136	0.893	0.047
22-24	0.811	0.036	0.913	0.101	0.909	0.066

TABLE 12. PROBABILITY OF WINDOWS BEING OPEN BY CLOCK HOUR, TEMPERATURE RANGE, AND WINDOW STATUS OF PRECEDING HOUR (PH) FOR RESIDENCES WITH WINDOW AIR CONDITIONING UNITS

Clock hour	Probability of windows being open					
	32°F to 62°F		63°F to 75°F		Above 75°F	
	PH=open	PH=closed	PH=open	PH=closed	PH=open	PH=closed
1-3	0.970	0.006	0.947	0.007	0.974	0.010
4-6	0.975	0.000	0.994	0.016	0.989	0.017
7-9	0.864	0.040	0.934	0.101	0.989	0.092
10-12	0.929	0.121	0.917	0.303	0.849	0.351
13-15	0.860	0.244	0.969	0.400	0.819	0.152
16-18	0.859	0.103	0.956	0.125	0.930	0.043
19-21	0.684	0.063	0.925	0.176	0.902	0.056
22-24	0.919	0.042	0.851	0.064	0.865	0.121

TABLE 13. PROBABILITY OF WINDOWS BEING OPEN BY CLOCK HOUR, TEMPERATURE RANGE, AND WINDOW STATUS OF PRECEDING HOUR (PH) FOR RESIDENCES WITH NO AIR CONDITIONING SYSTEM

Clock hour	Probability of windows being open					
	32°F to 62°F		63°F to 75°F		Above 75°F	
	PH=open	PH=closed	PH=open	PH=closed	PH=open	PH=closed
1-3	1.000	0.015	0.974	0.031	1.000	0.000
4-6	1.000	0.000	1.000	0.000	1.000	0.000
7-9	0.950	0.000	0.868	0.057	1.000	0.000
10-12	0.889	0.200	0.933	0.400	0.875	0.500
13-15	0.923	0.130	1.000	0.286	0.917	0.000
16-18	0.848	0.200	0.964	0.000	0.818	0.667
19-21	0.609	0.067	0.909	0.500	1.000	0.200
22-24	0.684	0.043	0.800	0.167	0.769	0.500

SECTION 4

PREPARATION OF AIR QUALITY DATA

The pNEM/03 mass balance model requires representative ambient air quality data for each exposure district in the form of a time series containing one value for each hour in the specified ozone season. This section describes the procedures used to select appropriate data sets for the nine study areas. It also describes the procedure used for filling in missing values in these data sets.

4.1 Selection of Representative Data Sets

To simplify the computer simulation, the ambient ozone concentration throughout an exposure district was assumed to be a function of the ozone concentration measured at a single, representative monitoring site located within the district. Based on guidance from EPA, analysts defined the shape of each exposure district by first drawing a circle of radius = 15 km with the monitoring site at the center. If the centroid of a census unit (census tract or block numbering area) was located within this circle, the census unit was assigned to the exposure district. If a centroid was located within more than one circle, the census unit was assigned to the nearest monitor. Note that the monitoring sites selected to represent a city directly determined the location and shape of the city's exposure districts.

With one exception, the monitoring sites selected for the pNEM/O3 analysis of outdoor workers were identical to those used in an earlier pNEM/O3 analysis of the ozone exposure within the general population of the nine study areas. Section 4 of the report by Johnson et al.[16] describes the selection process employed in the earlier analysis. The exception concerns one of the 12 monitoring sites selected to represent ambient ozone conditions in the New York study area. This site (identified by EPA as Site No. 36-061-0063) was selected to represent an exposure district centered on the southern end of Manhattan Island. Site No. 36-061-0063 was later judged to be unrepresentative of ground-level ozone concentrations in this area of New York due to the site's high elevation. Consistent with guidance from EPA, researchers selected the next nearest ozone monitor (No. 36-061-0010) to represent the Manhattan exposure district in the pNEM/O3 analysis of outdoor children. Monitor No. 36-061-0010 also represents another exposure district which is centered on the northern end of Manhattan Island, the actual location of this monitor.

Table 14 lists the number of ozone monitoring sites selected for each study area. The table also indicates the largest value for the second highest daily maximum hourly ozone concentration reported by the selected monitors for the indicated ozone season. It should be noted that the omission of Monitor No. 36-061-0063 from the New York study area does not affect the value of this air quality indicator (175 ppb).

4.2 Treatment of Missing Values and Descriptive Statistics

Hourly average ozone data reported by each site were used to estimate the ambient ozone levels within the associated exposure district. Gaps in the hourly average ozone data sets were filled in by using a time series model developed by Johnson and Wijnberg[32]. The model contains cyclical, autoregressive, and noise components whose parameters were determined from a statistical analysis of the reported data.

Tables 15 through 23 provide descriptive statistics for each hourly-average data set before and after application of the fill-in program. In general, the fill-in program has little or no effect on the listed percentiles or high values. Whenever there is a difference in the values for a particular percentile, the filled-in value is usually lower.

It should be noted that the data sets differ in terms of concentration resolution. The reported ozone concentration values for all 11 Houston sites and for 15 of the 16 Los Angeles sites are rounded to the nearest 10 ppb. The data for the other seven cities are rounded to the nearest 1 ppb. All other factors being equal, the algorithm used to fill in missing values generally performs better when applied to air quality data of high resolution.

TABLE 14. CHARACTERISTICS OF OZONE STUDY AREAS AND MONITORING SITES

Study area	Designated exposure period		Number of counties[a] in area	Number of monitoring sites selected	Largest reported second high daily maximum ozone concentration, ppb
	Ozone season	Year			
Chicago	Apr - Oct	1991	7	12	129
Denver	Mar - Sep	1990	6	7	110
Houston	Jan - Dec	1990	5	11	220
Los Angeles	Jan - Dec	1991	4	16	310
Miami	Jan - Dec	1991	2	6	123
New York City	Apr - Oct	1991	18	11[b]	175
Philadelphia	Apr - Oct	1991	13	10	156
St. Louis	Apr - Oct	1990	7	11	125
Washington, D.C.	Apr - Oct	1991	13	11	144

[a]Counties are geographic areas assigned a county code by the Bureau of Census in Summary Tape File 3 (STF3). A county is counted if any portion is within the study area.
[b]Monitor No. 36-061-0010 represents two exposure districts.

ITAQS analysts also constructed a data set for each monitor listing eight-hour running average ozone concentrations based on the filled-in data sets. These data were used to determine each site's status with respect to various eight-hour NAAQS under consideration by EPA. Tables 24 through 32 provide eight-hour descriptive statistics for the monitors selected to represent each city.

TABLE 15. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE CHICAGO STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
17-031-0001	Alsip	1	No	4903	19	51	61	77	83	104	108
			Yes	5136	19	50	61	77	83	104	108
17-031-0032	Chicago	2	No	4985	28	58	69	87	92	116	120
			Yes	5136	28	59	69	87	92	116	120
17-031-1003	Chicago	3	No	4895	19	51	63	81	88	129	134
			Yes	5136	19	50	61	81	87	129	134
17-031-1601	Lemont	4	No	4799	28	61	71	89	98	126	152
			Yes	5136	28	60	71	89	97	126	152
17-031-4002	Cicero	5	No	5033	18	49	60	78	86	120	125
			Yes	5136	18	49	59	78	86	120	125
17-031-4003	Des Plaines	6	No	4936	23	53	63	80	85	105	119
			Yes	5136	23	52	63	80	86	105	119
17-031-7002	Evanston	7	No	4876	30	59	69	90	97	115	123
			Yes	5136	30	58	69	90	96	115	123

(continued)

TABLE 15 (Continued)

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
17-031-8003	Calumet City	8	No	4856	23	54	64	81	86	97	109
			Yes	5136	24	54	64	81	86	97	109
17-043-6001	Lisle	9	No	5100	19	49	59	78	87	116	118
			Yes	5136	20	50	59	78	87	116	118
17-089-0005	Elgin	10	No	5041	26	54	63	82	91	126	128
			Yes	5136	26	54	63	82	90	126	128
17-097-0001	Deerfield	11	No	5011	26	56	67	85	90	116	124
			Yes	5136	26	56	67	85	90	116	124
17-097-1002	Waukegan	12	No	5038	30	61	71	92	102	119	126
			Yes	5136	30	61	71	92	102	119	126

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 16. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE DENVER STUDY AREA

Monitor ID	Monitor location	Dis-trict code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
08-001-3001	Adams Co.	1	No	4322	26	54	59	69	72	87	99
			Yes	5136	26	53	58	68	72	87	99
08-005-0002	Arapaho Co.	2	No	4047	40	63	70	88	93	109	111
			Yes	5136	39	60	67	86	91	109	110
08-005-0003	Englewood	3	No	5036	23	53	62	76	83	110	111
			Yes	5136	23	54	62	76	83	110	111
08-013-1001	Boulder Co.	4	No	4458	33	55	64	78	83	102	106
			Yes	5136	32	54	63	77	80	102	106
08-031-0002	Denver	5	No	5063	17	40	47	59	64	104	120
			Yes	5136	17	40	46	59	64	104	120
08-031-0014	Denver	6	No	4453	22	54	62	77	83	107	120
			Yes	5136	22	53	61	75	81	107	120
08-059-0002	Arvada	7	No	4908	26	56	64	79	83	115	115
			Yes	5136	26	55	64	79	83	115	115

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 17. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE HOUSTON STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
48-201-0024	Harris Co.	1	No	6865	20	60	80	110	130	220	220
			Yes	8760	20	60	70	110	120	220	220
48-201-0029	Harris Co.	2	No	7689	20	50	70	100	120	160	180
			Yes	8760	20	50	70	100	110	160	180
48-201-0046	Houston	3	No	8138	10	50	60	100	120	200	230
			Yes	8760	10	50	60	100	120	200	230
48-201-0047	Houston	4	No	7970	10	50	60	100	120	210	240
			Yes	8760	10	50	60	100	120	210	240
48-201-0051	Houston	5	No	7999	20	50	70	110	130	200	220
			Yes	8760	20	50	70	110	130	200	220
48-201-0059	Houston	6	No	6941	10	40	50	80	90	140	190
			Yes	8760	10	40	50	70	90	140	190
48-201-0062	Houston	7	No	8072	20	50	60	100	110	180	230
			Yes	8760	20	46	60	90	110	180	230

(continued)

TABLE 17 (Continued)

Monitor ID	Monitor location	Dis-trict code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
48-201-1003	Deer Park	8	No	7685	20	50	60	100	110	230	230
			Yes	8760	20	50	60	100	110	230	230
48-201-1034	Houston	9	No	8098	10	50	60	90	120	200	210
			Yes	8760	10	45	60	90	110	200	210
48-201-1035	Houston	10	No	8300	10	50	60	100	120	230	230
			Yes	8760	10	50	60	100	120	230	230
48-201-1037	Houston	11	No	8086	10	40	60	100	120	220	220
			Yes	8760	10	40	60	100	120	220	220

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 18. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE LOS ANGELES STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
06-037-0016	Glendora	1	No	8416	20	80	110	180	200	310	320
			Yes	8760	20	80	110	180	200	310	320
06-037-1103	Los Angeles	2	No	8356	10	50	70	120	130	170	190
			Yes	8760	10	50	70	110	130	170	190
06-037-1301	Lynwood	3	No	8478	10	40	50	80	90	130	160
			Yes	8760	10	40	50	80	90	130	160
06-037-1601	Pico Rivera	4	No	8523	10	60	80	130	160	250	260
			Yes	8760	10	60	80	130	160	250	260
06-037-1902	Santa Monica	5	No	8179	26	65	80	114	131	191	191
			Yes	8760	25	64	79	112	128	191	191
06-037-2005	Pasadena	6	No	8344	10	70	100	160	170	220	230
			Yes	8760	10	70	100	160	170	220	230
06-037-4002	Long Beach	7	No	8377	20	40	50	70	80	100	110
			Yes	8760	20	40	50	70	80	100	110
06-037-5001	Hawthorne	8	No	8465	20	50	60	80	90	110	110
			Yes	8760	20	50	60	80	90	110	115

(continued)

TABLE 18 (Continued)

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
06-059-0001	Anaheim	9	No	8473	10	50	60	100	110	200	250
			Yes	8760	10	50	60	100	110	200	250
06-059-1003	Costa Mesa	10	No	8358	30	50	60	80	90	140	170
			Yes	8760	30	50	60	80	90	140	170
06-059-3002	Los Alamitos	11	No	8442	20	50	60	90	100	150	170
			Yes	8760	20	50	60	90	100	150	170
06-059-5001	La Habra	12	No	8492	20	60	70	110	130	190	210
			Yes	8760	15	53	70	110	130	190	210
06-065-8001	Rubidoux	13	No	8521	20	90	110	160	180	240	240
			Yes	8760	20	80	110	160	180	240	240
06-071-1004	Upland	14	No	8408	10	70	100	160	180	240	270
			Yes	8760	10	70	90	160	180	240	270
06-071-4003	Redlands	15	No	8374	30	90	120	180	190	250	250
			Yes	8760	30	90	120	180	190	250	250
06-071-9004	San Bernardino	16	No	8514	20	80	110	160	170	240	250
			Yes	8760	13	80	110	160	170	240	250

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 19. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE MIAMI STUDY AREA

Monitor ID	Monitor location	Dis-trict code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
12-011-0003	Broward Co.	1	No	8624	22	42	48	59	63	93	94
			Yes	8760	22	42	48	59	63	93	94
12-011-2003	Pompano Beach	2	No	8664	23	41	46	58	64	91	96
			Yes	8760	23	41	46	58	63	91	96
12-011-8002	Dania	3	No	8732	26	43	49	61	64	95	100
			Yes	8760	26	43	49	61	64	95	100
12-025-0021	Dade Co.	4	No	8470	21	41	46	57	64	123	124
			Yes	8760	21	41	46	57	63	123	124
12-025-0027	Dade Co.	5	No	8486	28	44	49	58	65	90	95
			Yes	8760	28	44	49	57	64	90	95
12-025-0029	Dade Co.	6	No	8576	21	39	45	54	58	85	90
			Yes	8760	21	39	44	54	58	85	90

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 20. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE NEW YORK STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
09-001-0017	Greenwich	1	No	4882	29	61	75	110	120	147	161
			Yes	5136	29	60	74	110	118	147	161
34-013-0011	Newark	2	No	5033	18	52	67	92	97	123	132
			Yes	5136	18	52	67	92	97	123	132
34-017-0006	Bayonne	3	No	4968	24	64	81	109	116	166	167
			Yes	5136	24	64	80	108	116	166	167
34-027-3001	Morris Co.	4	No	4691	39	75	88	111	118	137	139
			Yes	5136	39	73	86	111	118	137	139
34-039-5001	Plainfield	5	No	4986	19	55	69	90	97	115	120
			Yes	5136	20	55	68	90	96	115	120
36-001-0080	Bronx Co.	6	No	4422	12	36	47	68	72	92	94
			Yes	5136	13	36	45	67	72	92	94
36-061-0010	New York City	7, 8	No	4893	14	43	58	87	95	151	155
			Yes	5136	14	42	57	87	95	151	155

(continued)

TABLE 20 (Continued)

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
36-061-0063	New York City	[b]	No	4912	41	82	96	122	130	175	177
			Yes	5136	41	82	95	122	130	175	177
36-081-0004	Queens Co.	9	No	4912	20	57	72	105	115	162	174
			Yes	5136	20	57	72	105	115	162	174
36-085-0067	Richmond Co.	10	No	4086	28	67	81	106	116	169	178
			Yes	5136	29	62	77	103	111	169	178
36-103-0002	Babylon	11	No	4884	30	67	81	111	121	175	217
			Yes	5136	30	67	80	110	120	175	217
36-119-2004	White Plains	12	No	4975	27	62	78	107	116	145	152
			Yes	5136	27	61	78	107	116	145	152

[a]Number of hourly-average ozone concentrations during designated ozone season.
[b]Originally assigned to District 8. Replaced by Monitor No. 36-061-0010.

TABLE 21. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE PHILADELPHIA STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
34-005-3001	McGuire AFB	1	No	4939	35	72	88	117	126	156	156
			Yes	5136	34	72	88	117	124	156	156
34-007-0003	Camden	2	No	4998	28	70	84	115	120	143	148
			Yes	5136	28	70	84	114	120	143	148
34-007-1001	Camden	3	No	4989	36	76	89	112	117	146	149
			Yes	5136	36	76	89	112	117	146	149
34-015-0002	Gloucester	4	No	5001	33	74	87	115	125	151	151
			Yes	5136	33	73	87	115	125	151	151
42-017-0012	Bristol	5	No	4986	28	70	84	111	119	139	144
			Yes	5136	28	70	84	110	118	139	144
42-045-0002	Chester	6	No	5085	30	67	78	103	108	125	135
			Yes	5136	30	67	78	103	108	125	135
42-091-0013	Norristown	7	No	4907	26	67	78	99	106	125	127
			Yes	5136	26	66	77	98	105	125	127

(continued)

TABLE 21 (Continued)

Monitor ID	Monitor location	Dis-trict code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
42-101-0014	Philadelphia	8	No	4900	30	70	80	100	110	140	140
			Yes	5136	30	70	80	100	110	140	140
42-101-0023	Philadelphia	9	No	4786	20	50	70	90	100	130	130
			Yes	5136	20	50	70	90	100	130	130
42-101-0024	Philadelphia	10	No	4984	30	70	80	110	110	130	140
			Yes	5136	30	70	80	110	110	130	140

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 22. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE ST. LOUIS STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
17-163-0010	East St. Louis	1	No	4963	19	48	57	73	83	116	124
			Yes	5136	19	48	57	73	82	116	124
29-183-1002	St. Charles	2	No	4587	23	55	66	90	102	125	125
			Yes	5136	27	55	66	90	98	125	125
29-189-0001	Affton	3	No	4218	28	62	75	93	100	120	127
			Yes	5136	29	59	72	90	99	120	127
29-189-0006	St. Louis Co.	4	No	5038	24	48	55	70	75	99	100
			Yes	5136	24	48	55	69	75	99	100
29-189-3001	Clayton	5	No	5042	24	53	65	83	93	125	127
			Yes	5136	24	54	65	83	92	125	127
29-189-5001	Ferguson	6	No	5026	18	42	48	61	64	75	80
			Yes	5136	18	42	47	61	64	75	80
29-189-7001	St. Ann	7	No	5036	29	58	70	92	96	130	135
			Yes	5136	29	58	70	92	96	130	135

(continued)

TABLE 22 (Continued)

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
29-510-0007	St. Louis	8	No	5008	18	44	52	69	74	96	96
			Yes	5136	18	44	52	69	74	96	96
29-510-0062	St. Louis	9	No	4928	24	53	63	82	89	108	111
			Yes	5136	24	53	63	82	89	108	111
29-510-0072	St. Louis	10	No	4830	18	40	48	64	72	100	110
			Yes	5136	18	40	48	64	72	100	110
29-510-0080	St. Louis	11	No	5044	24	53	64	86	94	117	129
			Yes	5136	24	53	65	86	94	117	129

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 23. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING HOURLY-AVERAGE OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE WASHINGTON STUDY AREA

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
11-001-0017	Washington	1	No	4928	19	54	64	82	91	137	147
			Yes	5136	19	54	64	82	90	137	147
11-001-0025	Washington	2	No	5031	24	61	72	90	99	144	148
			Yes	5136	24	60	71	90	99	144	148
24-031-3001	Rockville	3	No	4881	29	69	79	100	103	135	137
			Yes	5136	29	68	79	99	103	135	137
24-033-0002	Greenbelt	4	No	5034	30	74	87	110	115	148	153
			Yes	5136	30	74	87	109	114	148	153
24-033-8001	Suitland-Silver Hills	5	No	4997	31	69	81	102	108	139	144
			Yes	5136	31	68	81	102	108	139	144
51-013-0020	Arlington Co.	6	No	5034	28	68	80	102	107	142	148
			Yes	5136	28	68	79	102	107	142	148
51-059-0018	Mt. Vernon	7	No	4897	30	71	83	106	111	126	142
			Yes	5136	30	71	83	105	111	126	142

(continued)

TABLE 23 (Continued)

Monitor ID	Monitor location	District code	Filled in?	n[a]	Percentiles, ppb					High values, ppb	
					50	90	95	99	99.5	Second	First
51-059-1004	Seven Corners	8	No	4951	33	71	86	110	119	174	178
			Yes	5136	33	71	86	109	116	174	178
51-059-5001	McLean	9	No	5037	27	63	73	95	104	137	138
			Yes	5136	27	63	74	95	101	137	138
51-510-0009	Alexandria	10	No	4916	22	54	65	84	95	131	132
			Yes	5136	22	54	65	84	94	131	132
51-600-0005	Fairfax	11	No	4947	33	66	77	97	107	131	132
			Yes	5136	32	66	76	96	106	131	132

[a]Number of hourly-average ozone concentrations during designated ozone season.

TABLE 24. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE CHICAGO STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
17-031-0001	Alsip	1	20	46	54	69	75	94	95
17-031-002	Chicago	2	28	54	63	80	84	106	107
17-031-1003	Chicago	3	19	46	55	71	76	101	101
17-031-1601	Lemont	4	28	57	66	82	88	108	109
17-031-4002	Cicero	5	18	45	54	70	75	95	95
17-031-4003	Des Plaines	6	24	48	57	72	77	93	95
17-031-7002	Evanston	7	30	55	64	83	86	101	102
17-031-8003	Calumet City	8	24	49	58	74	78	90	90
17-043-6001	Lisle	9	20	45	53	70	79	98	98
17-089-0005	Elgin	10	26	50	58	74	82	106	106
17-097-0001	Deerfield	11	26	52	61	77	83	101	103
17-097-1002	Waukegan	12	31	58	66	84	88	104	106

TABLE 25. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE DENVER STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
08-001-3001	Adams Co.	1	26	47	52	60	63	72	74
08-005-0002	Arapaho Co.	2	38	56	62	76	80	87	87
08-005-0003	Englewood	3	24	48	54	65	70	83	83
08-013-1001	Boulder Co.	4	33	50	57	68	71	83	85
08-031-0002	Denver	5	18	35	41	51	54	84	85
08-031-0014	Denver	6	23	47	52	62	64	77	80
08-059-0002	Arvada	7	26	50	57	68	72	95	96

TABLE 26. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE HOUSTON STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
48-201-0024	Harris Co.	1	21	50	64	92	104	149	150
48-201-0029	Harris Co.	2	21	49	61	89	96	124	124
48-201-0046	Houston	3	14	42	53	84	95	151	152
48-201-0047	Houston	4	15	42	55	82	96	156	164
48-201-0051	Houston	5	21	48	61	92	105	167	170
48-201-0059	Houston	6	14	33	41	60	71	110	112
48-201-0062	Houston	7	17	41	52	79	90	154	155
48-201-1003	Deer Park	8	19	46	56	84	92	139	140
48-201-1034	Houston	9	16	41	54	81	90	144	146
48-201-1035	Houston	10	15	42	56	86	97	156	157
48-201-1037	Houston	11	12	39	51	81	92	160	164

TABLE 27. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE LOS ANGELES STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
06-037-0016	Glendora	1	24	70	95	135	150	181	182
06-037-1103	Los Angeles	2	14	47	60	85	92	120	120
06-037-1301	Lynwood	3	12	34	41	62	67	86	89
06-037-1601	Pico Rivera	4	12	51	67	97	111	142	146
06-037-1902	Santa Monica	5	27	58	69	93	101	155	155
06-037-2005	Pasadena	6	18	62	84	120	130	165	166
06-037-4002	Long Beach	7	17	35	42	56	61	82	83
06-037-5001	Hawthorne	8	21	46	51	67	76	96	99
06-059-0001	Anaheim	9	17	42	52	77	85	119	119
06-059-1003	Costa Mesa	10	25	47	55	71	76	101	102
06-059-3002	Los Alamitos	11	25	50	59	75	80	97	99
06-059-5001	La Habra	12	17	50	62	90	100	129	132
06-065-8001	Rubidoux	13	24	76	97	139	155	194	196
06-071-1004	Upland	14	16	61	84	124	134	164	165
06-071-4003	Redlands	15	30	86	110	152	162	197	197
06-071-9004	San Bernardino	16	19	74	96	135	146	192	192

TABLE 28. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE MIAMI STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
12-011-0003	Broward Co.	1	22	39	44	54	56	76	77
12-011-2003	Pompano Beach	2	22	39	44	52	54	71	72
12-011-8002	Dania	3	25	42	47	56	59	71	72
12-025-0021	Dade Co.	4	21	37	43	52	55	77	79
12-025-0027	Dade Co.	5	27	43	47	55	58	77	80
12-025-0029	Dade Co.	6	21	37	42	51	53	73	73

TABLE 29. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE NEW YORK STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
09-001-0017	Grenwich	1	29	57	67	95	103	125	126
34-013-0011	Newark	2	19	46	59	82	89	102	103
34-017-0006	Bayonne	3	25	58	72	95	103	112	112
34-027-3001	Morris Co.	4	39	70	82	100	109	125	125
34-039-5001	Plainfield	5	21	50	61	80	88	109	109
36-001-0080	Bronx Co.	6	14	32	41	56	59	69	71
36-061-0010	New York City	7, 8	15	39	50	73	79	102	102
36-061-0063	New York City	[a]	41	79	90	113	122	133	135
36-081-0004	Queens Co.	9	21	51	64	90	99	119	119
36-085-0067	Richmond Co.	10	29	58	71	95	101	135	136
36-103-0002	Babylon	11	30	62	73	97	104	129	129
36-119-2004	White Plains	12	27	58	70	94	105	125	127

[a]Originally assigned to District 8. Replaced by Monitor No. 36-061-0010.

TABLE 30. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE PHILADELPHIA STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
34-005-3001	McGuire AFB	1	34	67	80	107	114	138	141
34-007-0003	Camden	2	28	64	76	101	109	129	131
34-007-1001	Camden Co.	3	37	71	81	103	107	124	125
34-015-0002	Gloucester	4	33	68	80	105	113	135	135
42-017-0012	Bristol	5	28	64	76	100	104	115	116
42-045-0002	Chester	6	30	62	72	92	98	113	114
42-091-0013	Norristown	7	26	60	70	92	98	118	118
42-101-0014	Philadelphia	8	31	65	76	96	100	125	127
42-101-0023	Philadelphia	9	21	49	60	79	86	112	114
42-101-0024	Philadelphia	10	27	61	72	97	103	116	116

TABLE 31. DESCRIPTIVE STATISTICS FOR 1990 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE ST. LOUIS STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
17-163-0010	East St. Louis	1	20	43	51	66	70	98	99
29-183-1002	St. Charles	2	26	50	59	78	85	110	110
29-189-0001	Affton	3	30	54	64	80	85	100	103
29-189-0006	St. Louis Co.	4	24	44	50	62	67	85	86
29-189-3001	Clayton	5	25	49	58	76	80	93	94
29-189-5001	Ferguson	6	19	39	44	54	56	62	63
29-189-7001	St. Ann	7	29	54	64	81	84	101	104
29-510-0007	St. Louis	8	19	40	48	60	65	76	77
29-510-0062	St. Louis	9	25	48	57	73	77	89	91
29-510-0072	St. Louis	10	19	37	43	56	61	83	85
29-510-0080	St. Louis	11	25	50	60	76	83	99	100

TABLE 32. DESCRIPTIVE STATISTICS FOR 1991 DATA SETS CONTAINING EIGHT-HOUR OZONE CONCENTRATIONS OBTAINED FROM SELECTED MONITORING SITES IN THE WASHINGTON STUDY AREA

Monitor ID	Monitor location	District code	Percentiles, ppb					High values, ppb	
			50	90	95	99	99.5	Second	First
11-001-0017	Washington	1	20	48	58	73	78	120	120
11-001-0025	Washington	2	25	55	64	79	85	114	117
24-031-3001	Rockville	3	30	62	71	88	93	113	113
24-033-0002	Greenbelt	4	31	68	79	96	102	129	131
24-033-8001	Suitland S.H.	5	32	63	73	90	94	124	125
51-013-0020	Arlington Co.	6	29	61	72	91	97	127	128
51-059-0018	Mt. Vernon	7	30	65	75	92	99	110	112
51-059-1004	Seven Corners	8	33	66	77	97	102	147	147
51-059-5001	McLean	9	28	56	65	81	89	115	115
51-510-0009	Alexandria	10	23	50	59	75	82	111	111
51-600-0005	Fairfax	11	33	61	70	88	96	110	111

SECTION 5

ADJUSTMENT OF OZONE DATA TO SIMULATE COMPLIANCE WITH ALTERNATIVE AIR QUALITY STANDARDS

In applying pNEM/O3 to a particular study area, the analyst typically defines the air quality conditions within the area as representing (1) baseline conditions or (2) conditions in which the area just attains a specific NAAQS. This section describes the procedures used to develop monitor-specific ozone data sets representing baseline and attainment conditions in each of the nine study areas.

Fixed-site monitoring data for the years 1990 and 1991 were used to represent baseline conditions for each of the nine study areas. Special air quality adjustment procedures (AQAP's) were used to adjust the baseline data to simulate conditions in which each study area just attains a specific NAAQS. EPA identified the following NAAQS formulations for assessment:

1. One hour daily maximum - one expected exceedance (1H1EX): the expected number of daily maximum one-hour ozone concentrations exceeding the specified value shall not exceed one.

   Standard levels: 120 ppb (the current NAAQS for ozone), 100 ppb

2. Eight-hour daily maximum - one expected exceedance (8H1EX): the expected number of daily maximum eight-hour ozone concentrations exceeding the specified value shall not exceed one.

   Standard levels: 70 ppb, 80 ppb, 90 ppb, 100 ppb

3. Eight-hour daily maximum - five expected exceedances (8H5EX): the expected number of daily maximum eight-hour ozone concentrations exceeding the specified value shall not exceed five.

   Standard levels: 80 ppb, 90 ppb

A separate AQAP was developed for each of the three classes of NAAQS (1H1EX, 8H1EX, and 8H5EX).

Each AQAP consisted of the following four steps:

1. Specify an air quality indicator (AQI) to be used in evaluating the status of a monitoring site with respect to the NAAQS of interest.

2. Determine the value of the AQI for each site within the study area under baseline conditions.

3. Determine the value of the AQI under conditions in which the air pollution levels within the study area have been reduced or increased until the site with the highest pollution levels just attains a specified NAAQS.

4. Adjust the one-hour values of the baseline data set associated with each site to yield the AQI value determined in Step 3. The adjusted data set should retain the temporal profile of the baseline data set.

Subsection 5.1 discusses the specification of appropriate AQI's (Step 1) and the determination of baseline AQI values (Step 2). Subsection 5.2 presents the methods used to estimate AQI's under attainment conditions (Step 3). Subsection 5.3 describes the procedures used in Step 4 to adjust one-hour data to simulate significant reductions in ozone levels within a study area. More detailed descriptions of these procedures can be found in Appendices A and B of a report by Johnson et al.[16] Subsection 5.4 provides examples in which the procedures described in Subsection 5.3 were applied to Philadelphia. Subsection 5.5 presents an alternative procedure which analysts used to adjust one-hour data to simulate small changes (decreases or increases) in ozone levels within a study area. This procedure was applied to Denver, Chicago, and Miami for all NAAQS formulations.

5.1 Specification of AQI and Estimation of Baseline AQI Values

The following AQI's were selected for evaluating the 1H1EX, 8H1EX, and 8H5EX standards.

1H1EX: the characteristic largest daily maximum one-hour ozone concentration

8H1EX: the characteristic largest daily maximum eight-hour ozone concentration (except for Denver, in which the observed second highest daily maximum was used, as explained in Subsection 5.5)

8H5EX: the observed sixth largest daily maximum eight-hour ozone concentration.

Note that a statistical AQI (the characteristic largest value) was generally specified for the 1H1EX and 8H1EX standards, whereas a deterministic AQI (the observed sixth largest value) was used for the 8H5EX standards. Analysts elected to use statistical AQI's for the 1H1EX and 8H1EX standards because such indicators are less affected by anomalous high values than the corresponding deterministic AQI (the second highest observed value). A statistical indicator was not considered necessary for the 8H5EX standards, as the sixth highest observed value is relatively unaffected by anomalous high values.

The characteristic largest value (CLV) of a distribution is that value expected to be exceeded once in n observations. If F(x) is the cumulative distribution of x, then

$$F(x) = 1 - \frac{1}{n} \qquad (42)$$

when x is the CLV.

Selection of an appropriate cumulative distribution to fit data is important in determining a reasonable CLV. Two distributions that often provide close fits to ambient air quality data are the Weibull and the lognormal. The Weibull distribution is defined as

$$F(x) = 1 - \exp\,[-(\frac{x}{\delta})^{k}] \qquad (43)$$

where δ is the scale parameter and k is the shape parameter. The lognormal distribution is defined as

$$F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{w} \exp\,(-t^2/2)\;dt \qquad (44)$$

where

$$w = \frac{\ln x - \mu}{\sigma} \tag{45}$$

and ln x is distributed normally with mean μ and variance σ^2. As discussed in previous reports, the Weibull distribution generally provides a better fit to hourly average ozone data.[15]

The hourly average values reported by a single monitoring site during a specified ozone season form a time series x_t (t = 1, 2, 3, ..., n). If the hourly average time series is complete, it will contain n = (24)(N) values, where N is the number of days in the ozone season. From this time series a second time series of daily maximum 1-hour values can be constructed.

Assume that a Weibull distribution with parameters δ and k provides a good fit to the empirical distribution of hourly average values. If one disregards autocorrelation, the value expected to be exceeded once in n = (24)(N) hours can be estimated as

$$CLVOH = \delta\ [\ln(24)(N)]^{1/k}. \tag{46}$$

This is the characteristic largest one-hour value. If we again disregard autocorrelation, the daily maximum 1-hour value expected to be exceeded once in N days can be estimated as

$$CLVOHDM = \delta\{-\ln[1 - (\frac{N-1}{N})^{1/24}]\}^{1/k}. \tag{47}$$

This is the characteristic largest daily maximum one-hour value. For 7-month and 12-month ozone seasons, N is equal to 214 and 365, respectively. For these values of N, CLVOH and CLVOHDM are virtually indistinguishable in value over the range in k

values typically found in ozone data (0.6 < k < 2.5). For example, the following values were calculated using δ = 40 ppb.

N	k	CLVOH	CLVOHDM
214	0.6	1428	1428
	1.4	185	185
	2.5	94	94
365	0.6	1580	1580
	1.4	193	193
	2.5	97	97

The CLVOH and CLVOHDM values match to the nearest ppb. Consequently, the expression

$$CLVOHDM \doteq \delta \; [\ln(24)(N)]^{1/k} \qquad (48)$$

can be used as an alternative to Equation 47 for calculating CLVOHDM. The quantity calculated by Equation 48, hereafter denoted by CLV1, was selected as the AQI to be used in evaluating the status of a monitoring site with respect to a particular 1H1EX standard.

A data set containing one-hour concentration values can be processed to determine a corresponding data set containing eight-hour running average values. If a Weibull distribution is fit to the eight-hour data, one can determine a characteristic largest eight-hour value by the equation

$$CLVEH = \delta [\ln(24)N)]^{1/k}, \qquad (49)$$

where δ and k are the Weibull parameters for the eight-hour fit. Based on the argument made above for one-hour data, this value should be approximately equal to the characteristic largest daily maximum eight-hour value (CLVEHDM) of the data set. For simplicity, the term CLV8 is hereafter used to refer to the quantity calculated by Equation 49. CLV8 was selected as the AQI to be used in evaluating attainment status with respect to a particular 8H1EX standard.

Table 33 lists the data sets selected to represent baseline conditions in each of the nine cities under analysis. Table 33 also provides estimates of CLV1 and CLV8

TABLE 33. BASELINE AIR QUALITY INDICATORS FOR NINE CITIES

City	Year	District	Ozone concentration, ppb		
			CLV1	CLV8	EH6LDM
Chicago	1991	1	109	94	78
		2	124	107	86
		3	123	106	77
		4	134	114	90
		5	120	99	78
		6	111	97	79
		7	119	106	89
		8	104	92	78
		9	122	106	82
		10	127	111	83
		11	122	106	85
		12	131	111	91
Denver	1990	1	91	74	67
		2	116	94	84
		3	114	85	73
		4	103	86	74
		5	98	79	56
		6	117	78	65
		7	109	94	75
Houston	1990	1	224	162	116
		2	182	137	110
		3	241	161	110
		4	224	171	107
		5	227	179	124
		6	180	131	86
		7	208	165	104
		8	207	143	99
		9	231	154	101
		10	235	171	116
		11	232	167	107

(Continued)

Table 33 (Continued)

City	Year	District	Ozone concentration, ppb		
			CLV1	CLV8	EH6LDM
Los Angeles	1991	1	321	207	170
		2	185	133	109
		3	148	99	75
		4	271	166	129
		5	215	162	115
		6	248	172	146
		7	116	85	64
		8	136	104	84
		9	198	121	94
		10	153	101	81
		11	167	100	87
		12	216	134	110
		13	264	209	167
		14	266	184	146
		15	261	215	180
		16	249	204	165
Miami	1991	1	90	74	60
		2	97	74	60
		3	93	72	64
		4	105	82	59
		5	96	80	65
		6	87	72	57
New York	1991	1	158	135	108
		2	121	112	91
		3	153	133	113
		4	143	134	105
		5	123	113	88
		6	97	75	64
		7[a]	141	108	83
		8[a]	141	108	83
		9	162	131	104
		10	170	143	101
		11	183	140	107
		12	148	137	105

(Continued)

Table 33 (Continued)

City	Year	District	Ozone concentration, ppb		
			CLV1	CLV8	EH6LDM
Philadelphia	1991	1	167	142	116
		2	149	136	113
		3	153	128	111
		4	162	138	115
		5	145	120	107
		6	134	118	101
		7	135	123	102
		8	140	128	104
		9	131	116	90
		10	141	126	102
St. Louis	1990	1	124	100	73
		2	141	116	88
		3	131	106	87
		4	103	87	68
		5	122	97	81
		6	78	65	59
		7	124	103	87
		8	100	79	67
		9	114	91	80
		10	103	84	64
		11	119	104	86
Washington	1991	1	134	110	80
		2	135	113	88
		3	130	113	95
		4	143	128	106
		5	141	119	98
		6	143	123	100
		7	135	118	104
		8	169	143	102
		9	141	120	91
		10	134	112	85
		11	145	123	100

[a]Districts 7 and 8 in New York are represented by the same ozone monitor (Monitor No. 36-061-0010).

based on Weibull fits to the upper two percent of each data set. These values were used as estimates of CLV1 and CLV8 representing baseline conditions.

As previously indicated, the sixth largest daily maximum 8 hour value (denoted EH6LDM) was used to evaluate the status of a monitoring site with respect to a particular 8H5EX standards. Table 33 lists the baseline value of this AQI for each site in the nine cities under analysis.

5.2 Estimation of AQI's Under Attainment Conditions

Tables 34, 35, and 36 provide the step-by-step procedures followed in implementing the AQAP's developed respectively for 1H1EX, 8H1EX, and 8H5EX NAAQS. In general, analysts assumed that the i-th ranked site (ranking determined by baseline AQI) will undergo a change in its AQI value proportional to the change required for the highest ranked site to exactly attain the specified standard. The ranking assigned to a particular site under attainment conditions was determined by the site's average ranking over five years, rather than the site's ranking under baseline conditions. Consequently, the site ranked highest under baseline conditions was not necessarily the highest ranked site under attainment conditions. Evaluation of representative ozone data suggested that a site's future ranking could be better predicted from its long-term average rank than from a single year's ranking.

Steps 1 through 4 in each table comprise the procedures used to estimate the value of an attainment AQI value for each site in a particular city. Each attainment AQI was converted to a corresponding characteristic one-hour largest value under attainment (ACLV1). For 1H1EX standards (Table 34), the value of ACLV1 determined by Step 4 was used without further adjustment as the value of ACLV1 required in subsequent steps. For 8H1EX standards (Table 35), the value of ACLV8 determined in Step 4 was converted to the required ACLV1 value through the use of an equivalence relationship (Step 5). The equivalence relationship was

$$ACLV1 = (RATIO1)(ACLV8) \qquad (53)$$

where RATIO1 varied with urban area (Table 37).

TABLE 34. AIR QUALITY ADJUSTMENT PROCEDURE USED TO SIMULATE ATTAINMENT OF 1H1EX NAAQS (THE EXPECTED NUMBER OF DAILY MAXIMUM ONE-HOUR OZONE CONCENTRATIONS EXCEEDING THE SPECIFIED VALUE SHALL NOT EXCEED ONE)

1. Determine the following quantities.

   CLV1(i,j): the CLV1 of i-th ranked site in City j for the "baseline" or "start" year.

   MAXCLV1(j): the largest CLV1 of all sites in City j for the baseline year.

   AMAXCLV1(j): the largest CLV1 value permitted under the proposed 1-hr NAAQS.

2. Select five years prior to the baseline year and determine the value of CLV1 (or related air quality indicator) at each site m in City j for each year. Rank these values by city and year. Let RANK(m,j,y) indicate the rank of site m in city j in year y. Let MEANRANK(m,j) indicate the mean value of RANK(m,j,y) over the five years. Rank the MEANRANK(m,j) values and let RELRANK(m,j) indicate the relative rank of MEANRANK(m,j).

3. Calculate an adjusted CLV1 for the i-th ranked site in City j by the expression

$$ACLV1(i,j) = [CLV1(i,j)][AMAXCLV1(j)]/[MAXCLV1(j)]. \quad (50)$$

4. If RELRANK(m,j) = i, then m will be the i-th ranked site in City j under attainment. That is,

   ACLV1(m,j) = ACLV1(i,j) if RELRANK(m,j) = i.

5. The 1-hour data at Site m under attainment will be determined by adjusting the 1-hour data at Site m in the baseline year. A Weibull distribution fit to the adjusted data will have a CLV1 equal to ACLV1(i,j) where i = RELRANK(m,j). Subsection 5.3 provides a method for estimating the parameters of this distribution and for making the adjustment.

TABLE 35. AIR QUALITY ADJUSTMENT PROCEDURE USED TO SIMULATE ATTAINMENT OF 8H1EX NAAQS (THE EXPECTED NUMBER OF DAILY MAXIMUM EIGHT-HOUR OZONE CONCENTRATIONS EXCEEDING THE SPECIFIED VALUE SHALL NOT EXCEED ONE)

1. Determine the following quantities.

   CLV8(i,j): the eight-hour CLV of i-th ranked site in City j for the "baseline" or "start" year.

   MAXCLV8(j): the largest CLV8 of all sites in City j for the baseline year.

   AMAXCLV8(j): the largest CLV8 value permitted under the proposed 8-hr NAAQS.

2. Select five years prior to the baseline year and determine the value of CLV8 (or related air quality indicator) at each site m in City j for each year. Rank these values by city and year. Let RANK(m,j,y) indicate the rank of site m in city j in year y. Let MEANRANK(m,j) indicate the mean value of RANK(m,j,y) over the five years. Rank the MEANRANK(m,j) values and let RELRANK(m,j) indicate the relative rank of MEANRANK(m,j).

3. Calculate an adjusted CLV8 for the i-th ranked site in City j by the expression

$$ACLV8(i,j) = [CLV8(i,j)][AMAXCLV8(j)]/[MAXCLV8(j)]. \quad (51)$$

4. If RELRANK(m,j) = i, then m will be the i-th ranked site in City j under attainment. That is,

$$ACLV8(m,j) = ACLV8(i,j) \text{ if } RELRANK(m,j) = i.$$

5. Using Equation 53, estimate the CLV1 associated with each ACLV8(m,j) value. Denote this value as ACLV1(m,j).

6. The 1-hour data for Site m under attainment of the 8-hr NAAQS will be determined by adjusting the 1-hour data for Site m in the baseline year. A Weibull distribution fit to the adjusted data will have a CLV1 equal to ACLV1(i,j) where i = RELRANK(m,j). Subsection 5.3 provides a method for estimating the parameters of this distribution and for making the adjustment.

TABLE 36. AIR QUALITY ADJUSTMENT PROCEDURE USED TO SIMULATE ATTAINMENT OF 8H5EX NAAQS (THE EXPECTED NUMBER OF DAILY MAXIMUM EIGHT-HOUR OZONE CONCENTRATIONS EXCEEDING THE SPECIFIED VALUE SHALL NOT EXCEED FIVE)

1. Determine the following quantities.

EH6LDM(i,j):	the EH6LDM of the i-th ranked site in City j for the baseline year,
MAXEH6LDM(j):	the largest EH6LDM of all sites in City j for the baseline year.
AMAXEH6LDM(j):	the largest EH6LDM value permitted under the proposed 1-hr NAAQS.

2. Select five years prior to the baseline year and determine the value of EH6LDM (or related air quality indicator) at each site m in City j for each year. Rank these values by city and year. Let RANK(m,j,y) indicate the rank of site m in city j in year y. Let MEANRANK(m,j) indicate the mean value of RANK(m,j,y) over the n years. Rank the MEANRANK(m,j) values and let RELRANK(m,j) indicate the relative rank of MEANRANK(m,j).

3. Calculate an adjusted EH6LDM for the i-th ranked site in City j by the expression

$$AEH6LDM(i,j) = [EH6LDM(i,j)][(AMAXEH6LDM(j)/[MAXEH6LDM(j)]. \qquad (52)$$

4. If RELRANK(m,j) = i, then m will be the i-th ranked site in City j under attainment. That is,

$$AEH6LDM(m,j) = AEH6LDM(i,j) \text{ if } RELRANK(m,j) = i.$$

5. Using Equation 54, estimate the CLV1 associated with each AEH6LDM(m,j) value. Denote this value as ACLV1(m,j).

6. The 1-hour data for Site m under attainment of the 8H5EX NAAQS will be determined by adjusting the 1-hour data for Site m in the baseline year. A Weibull distribution fit to the adjusted data will have a CLV1 equal to ACLV1(i,j) where i = RELRANK(m,j). Subsection 5.3 provides a method for estimating the parameters of this distribution and for making the adjustment.

A similar method was employed for 8H5EX standards (Table 36). The value of AEH6LDM determined in Step 4 was converted to the required ACLV1 value through the use of an equivalence relationship (Step 5). In this case, the equivalence relationship was

$$ACLV1 = (RATIO2)(AEH6LDM) \tag{54}$$

where RATIO2 varied with city (Table 37).

Through these procedures, a distinct ACLV1 value was assigned to each site for each standard under evaluation. This ACLV1 value was subsequently used to construct an attainment one-hour data set using the procedures described in Subsection 5.3.

5.3 Adjustment of One-Hour Ozone Data Sets

After a site's attainment ACLV1 value was determined, the baseline one-hour data set associated with the site was adjusted hour-by-hour to create an attainment one-hour data set. A two-stage adjustment procedure was employed. In the first stage, the baseline one-hour data were adjusted to produce an initial attainment data set that had the specified ACLV1 value. In the second stage, the initial data set was "fine-tuned" to produce a final attainment data set having the exact AQI value specified for the site.

5.3.1 Initial Adjustment for All Standards

The initial adjustment equation was

$$y_t = (a)(x_t)^b \tag{55}$$

where x_t was the baseline ozone concentration for hour t and y_t was the attainment ozone concentration for hour t. The terms a and b were "adjustment coefficients" specific to the site and to the standard being attained.

The adjustment equation was based on the general assumption that Weibull distributions would provide good fits to the one-hour data sets under baseline and attainment conditions. A Weibull distribution can be completely characterized through the use of a shape parameter (k) and a scale parameter (δ). The baseline values of k and δ were determined by applying a special maximum likelihood fitting algorithm to each one-hour baseline data set. The attainment value of k (k') was estimated by the empirically-derived equation

$$1/k' = -0.2389 + (0.003367)(ACLV1) + (0.4726)(1/k) \tag{56}$$

where ACLV1 was the estimated value of CLV1 under attainment conditions and k was the baseline k value. The attainment value of δ (δ') was then determined by the identity equation

$$\delta' = (ACLV1)/[\ln(n)]^{1/k'} \tag{57}$$

where n was the number of one-hour values in the exposure period.

The unadjusted data set was treated as a time series where x_t represented the one-hour value at time t. The corresponding adjusted data set was constructed through the use of the expression

$$y_t = (\delta')(x_t/\delta)^{k/k'} \tag{58}$$

where y_t was the adjusted one-hour value at time t. This expression incorporates the assumption that the time series y_t at a site after attainment is related to the original time series x_t in such a way that 1) the rank of the one-hour value at each time t is unchanged, 2) the x_t values follow a Weibull distribution with parameters δ and k, and 3) the y_t values follow a Weibull distribution with parameters δ' and k'. These assumptions are discussed in Appendix A of the report by Johnson et al.[16] Equation 58 can be restated as Equation 55 above with the substitutions

$$a = (\delta')/(\delta)^{k/k'} \tag{59}$$

$$b = k/k'. \tag{60}$$

TABLE 37. VALUES FOR EQUIVALENCE RELATIONSHIPS

City	RATIO1[a]	RATIO2[b]
Chicago	1.155	1.441
Denver	1.234	1.453
Houston	1.374	2.091
Los Angeles	1.444	1.846
Miami	1.248	1.513
New York	1.178	1.436
Philadelphia	1.132	1.367
St. Louis	1.226	1.506
Washington	1.179	1.450

[a]RATIO1 = (ACLV1)/(ACLV8).
[b]RATIO2 = (ACLV1)/(EH6LDM).

5.3.2 Final adjustment for Eight-hour Standards

When applied to the 8H1EX standards, the initial adjustment procedure described above produced a one-hour data set with a CLV1 value that exactly matched the specified CLV1. Because the assumed relationship between CLV1 and CLV8 was only an approximation, the CLV8 value of the adjusted data set did not always match the attainment CLV8 value specified for the site. Consequently, analysts made a final "fine-tuning" adjustment to the one-hour data to obtain the exact CLV8 value specified. The following final adjustment equation was used.

$$\text{Adjusted } y_t = (y_t)(\text{Target attainment CLV8})/(\text{Initial attainment CLV8}) \qquad (61)$$

In this equation, y_t is the one-hour value for hour t after the initial adjustment procedure (Equation 55). The "initial attainment CLV8" is the CLV8 value of this data set. The "target attainment CLV8" is the attainment CLV8 value assigned to the site by the procedure summarized in Table 35.

A similar fine-tuning procedure was employed for the 8H5EX standards. The final adjustment equation was

$$\text{Adjusted } y_t = (y_t)(\text{Target attainment EH6LDM})/(\text{Initial attainment EH6LDM}) \qquad (62)$$

The "initial attainment EH6LDM" is the EH6LDM value of the site after the initial adjustment (Equation 55). The "target attainment EH6LDM" is the attainment EH6LDM value assigned to the site by the procedure summarized in Table 36.

5.4 Application of the AQAP's to Philadelphia

To test the reasonableness of the AQAP's described above, each was initially applied to Philadelphia. Three attainment scenarios were evaluated:

1H1EX-120: One-hour daily maximum, one expected exceedance of 120 ppb

8H1EX-80: Eight-hour daily maximum, one expected exceedance of 80 ppb

8H5EX-80: Eight-hour daily maximum, five expected exceedances of 80 ppb.

In each case, baseline conditions were represented by filled-in 1991 ozone data obtained from the 10 monitoring sites listed in Table 21.

5.4.1 Attainment of 1H1EX-120 Standard

The AQAP summarized in Table 34 was applied to Philadelphia for the purpose of simulating the attainment of the 1H1EX-120 ppb standard. Table 38 presents the results of each step. In this example, baseline conditions in Philadelphia were assumed to be represented by 1991 ozone data as reported by the 10 monitoring sites listed for Philadelphia in Table 21.

Analysts initiated the AQAP by fitting a Weibull distribution to the filled-in 1991 one-hour data set associated with each Philadelphia monitoring site. Each fit produced estimates of the Weibull parameters (k and δ) and the CLV1. The largest CLV1 for 1991 was associated with District 1 (167 ppb).

To exactly attain the specified NAAQS, the largest CLV1 must equal 120 ppb. Consequently, Equation 48 (Step 3, Table 34) was implemented as

TABLE 38. DETERMINATION OF ADJUSTMENT COEFFICIENTS FOR ONE-HOUR NAAQS ATTAINMENT (1H1EX-120) IN PHILADELPHIA

	Weibull fit to 1991 1-hr data			1-hr NAAQS attainment parameters[a]				Adjustment coefficients	
District	k	δ	CLV1	Adjusted CLV1	Reassigned CLV1	k′	δ'	a	b
1	1.69	46.9	167	120	107	2.494	45.27	3.336	0.678
2	2.21	56.4	149	107	110	2.896	52.44	2.417	0.763
3	1.96	51.0	153	110	116	2.546	49.95	2.420	0.770
4	1.81	49.3	162	116	120	2.346	48.09	2.377	0.772
5	2.28	56.6	145	104	104	3.139	52.51	2.800	0.726
6	2.23	51.2	134	96	101	3.194	51.60	3.305	0.698
7	1.93	44.3	135	97	94	3.101	47.06	4.447	0.622
8	2.14	51.2	140	101	101	3.106	50.62	3.361	0.689
9	1.74	38.1	131	94	96	2.809	44.74	4.694	0.619
10	2.26	54.5	141	101	97	3.369	51.31	3.511	0.671

[a]Assumes maximum CLV1 equals 120 ppb.

$$ACLV1(i,j) = [CLV1(i,j)](120/167) = [CLV1(i,j)](0.719). \quad (63)$$

Applying this expression to each 1991 CLV1 produced 10 ACLV1's representing attainment conditions. These values are listed in the column labeled "adjusted CLV1." These values were then reassigned to the Philadelphia districts according to the five-year ranking determined for each district. Thus, the largest adjusted CLV1 (120 ppb) was assigned to District 4 because District 4 had the highest five-year ranking. Similarly, the second largest adjusted CLV1 (116 ppb) was assigned to District 3 because District 3 had the second highest five-year ranking.

In this example, the five-year ranking of each site was determined by analyzing second-high daily maximum one-hour ozone concentrations reported by the site over a recent five-year period. Second-high daily maximum values were used in this step rather than CLV1's because they were easier to obtain from standard EPA reports.

Analysts next used Equations 56 and 57 to estimate site-specific values for k' and δ', the values of the Weibull parameters under attainment conditions. For District 1, the substitution of k = 1.69, ACLV1 = 107 ppb, and n = 5136 produced the estimates k' = 2.494 and δ' = 45.27 ppb. These values were substituted into Equations 59 and 60 to produce the values of the adjustment coefficients listed in Table 38 for District 1 (a = 3.336 and b = 0.678).

A one-hour ozone data set representing attainment conditions was constructed for each site by applying Equation 55 to the baseline one-hour data set for the site. Table 39 provides descriptive statistics for the baseline and attainment data sets associated with District 1.

5.4.2 Attainment of 8H1EX-80 Standard

To evaluate the AQAP for 8H1EX standards, the procedure summarized in Table 35 was applied to Philadelphia for the purpose of simulating the attainment of the 8H1EX-80 standard. The results are presented in Table 40. As in the previous example, baseline conditions for Philadelphia were represented by 1991 ozone data.

TABLE 39. DESCRIPTIVE STATISTICS FOR HOURLY-HOUR DATA (PPB) FOR SITE 34-005-3001 (DISTRICT 1, PHILADELPHIA): BASELINE AND ATTAINMENT OF THREE OZONE STANDARDS

Statistic	Baseline	Attainment of indicated standard		
		1H1EX-120	8H1EX-80	8H5EX-80
Number of values	5136	5136	5136	5136
Mean	38	37	36	34
Standard deviation	25	18	14	16
Minimum	0	0	0	0
5th percentile	4	9	12	7
10th percentile	8	14	17	13
25th percentile	19	25	27	23
50th percentile	34	36	36	34
75th percentile	51	48	45	43
90th percentile	72	61	54	54
95th percentile	87	69	60	61
99th percentile	117	84	71	74
99.5 percentile	124	88	73	77
99.8 percentile	137	94	77	82
99.9 percentile	143	97	78	84
Maximum	156	102	82	89

Analysts initiated the AQAP by fitting a Weibull distribution to the filled-in 1991 one-hour data set associated with each Philadelphia monitoring site. Each fit produced estimates of the Weibull parameters (k and δ) and the CLV1. As in the previous example, the largest CLV1 for 1991 was associated with District 1 (167 ppb).

Analysts next estimated a baseline CLV8 for each site by fitting a Weibull distribution to the running-average eight-hour data associated with each Philadelphia monitoring site. The largest CLV8 was 142 ppb (District 1).

To exactly attain the specified NAAQS, the largest CLV8 must equal 80 ppb. Consequently, Equation 49 (Step 3, Table 35) was implemented as

$$ACLV8(i,j) = [CLV8(i,j)](80/142) = [CLV8(i,j)](0.563). \quad (64)$$

TABLE 40. DETERMINATION OF ADJUSTMENT COEFFICIENTS FOR EIGHT-HOUR NAAQS ATTAINMENT (8H1EX-80) IN PHILADELPHIA

District	Weibull fits to 1991 data				8-hr NAAQS attainment parameters[a]			1-h Weibull parameters		Adjustment coefficients	
	1-h k	1-h δ	CLV1	CLV8	Adjusted CLV8	Reassigned CLV8	Equivalent CLV1	k'	δ'	a	b
1	1.69	46.9	167	142	80	72	82	3.173	41.45	5.339	0.533
2	2.21	56.4	149	136	77	77	87	3.725	49.01	4.481	0.593
3	1.96	51.0	153	128	72	78	88	3.339	46.44	4.618	0.587
4	1.81	49.3	162	138	78	80	91	3.057	44.89	4.465	0.592
5	2.28	56.6	145	120	68	72	82	4.119	48.41	5.183	0.554
6	2.23	51.2	134	118	66	69	78	4.237	47.08	5.932	0.526
7	1.93	44.3	135	123	69	65	74	3.941	42.70	6.671	0.490
8	2.14	51.2	140	128	72	71	80	3.960	46.75	5.572	0.540
9	1.74	38.1	131	116	65	66	75	3.518	40.60	6.708	0.495
10	2.26	54.5	141	126	71	68	77	4.359	47.06	5.922	0.518

[a]Assumes maximum CLV8 equals 80 ppb.

Analysts applied this expression to each 1991 CLV8 to obtain 10 ACLV8's representing attainment conditions. These values are listed in the column labeled "adjusted CLV8." These values were then reassigned to the Philadelphia districts according to the five-year ranking determined for each district. The resulting assignments are listed in Table 40 under the heading "reassigned CLV8."

Each reassigned CLV8 was then converted into an equivalent attainment CLV1 using Equation 53 with the RATIO1 value for Philadelphia (1.132). For example, the reassigned CLV8 for District 1 (72 ppb) was multiplied by 1.132 to produce an equivalent attainment CLV1 of 82 ppb.

Analysts next used Equations 56 and 57 to estimate site-specific values for k' and δ', the values of the Weibull parameters for one-hour data under attainment conditions. For District 1, the substitution of k = 1.69, ACLV1 = 82 ppb, and n = 5136 produced the estimates k' = 3.173 and δ' = 41.45 ppb. These values were substituted into Equations 59 and 60 to produce the values of the adjustment coefficients listed in Table 40 for District 1 (a = 5.339 and b = 0.533). These coefficients were then substituted into Equation 55 to produce an initial one-hour data set approximating attainment conditions.

The one-hour data were processed to produce a corresponding 8-hour running average data set. A Weibull distribution was next fit to the adjusted eight-hour data for the site to determine an initial attainment CLV8. Analysts then used Equation 61 to make the final "fine-tuning" adjustment to the one-hour data necessary to achieve the target CLV8 specified for the site (72 ppb). The resulting one-hour data set was assumed to represent attainment conditions for District 1. Table 39 provides descriptive statistics for this data set. Attainment data sets were developed in a similar manner for each of the other Philadelphia monitoring sites.

5.4.3 Attainment of 8H5EX-80 Standard

The AQAP for 8H5EX standards (Table 36) was applied to Philadelphia for the purpose of simulating the attainment of the 8H5EX-80 standard. The results are presented in Table 41.

As in the two previous examples, baseline conditions for Philadelphia were represented by 1991 ozone data. Analysts began the AQAP by fitting a Weibull distribution to the filled-in 1991 one-hour data set associated with each Philadelphia monitoring site. Each fit produced estimates of the Weibull parameters (k and δ) and the CLV1. The largest CLV1 for 1991 was associated with District 1 (167 ppb).

Analysts next determined a baseline EH6LDM value for each site by first calculating all eight-hour daily maximum concentrations in the associated one-hour data set and then identifying the sixth largest value. The largest EH6LDM was 116 ppb (District 1).

The largest EH6LDM value permitted under the 8H5EX-80 standard is 80 ppb. As the largest baseline EH6LDM was 116 ppb, Equation 52 (Table 36) was expressed as

$$AEH6LDM(i,j) = [EH6LDM(i,j)]\,(80/116) = [EH6LDM(i,j)]\,(0.563)\,. \quad (65)$$

Analysts applied this expression to each 1991 EH6LDM to obtain 10 AEH6LDM's representing attainment conditions. These values are listed in the Table 41 column labeled "adjusted EH6LDM." Analysts next reassigned the values to the Philadelphia districts according to the five-year ranking determined for each district. The resulting assignments are listed in Table 41 under the heading "reassigned EH6LDM."

Each reassigned EH6LDM was then converted into an equivalent attainment CLV1 using Equation 54 with the RATIO2 value for Philadelphia (1.367). In the case of District 1, the reassigned EH6LDM (74 ppb) was multiplied by 1.367 to produce an equivalent attainment CLV1 of 101 ppb.

Analysts next used Equations 56 and 57 to estimate site-specific values for k' and δ', the values of the Weibull parameters for one-hour data under attainment conditions. For District 1, the substitution of k = 1.69, ACLV1 = 101 ppb, and n = 5136 produced the estimates k' = 2.626 and δ' = 44.62 ppb. These values were substituted into Equations 59 and 60 to produce the values of the adjustment coefficients listed in Table 41 for District 1 (a = 3.750 and b = 0.644). These

TABLE 41. DETERMINATION OF ADJUSTMENT COEFFICIENTS FOR EIGHT-HOUR NAAQS ATTAINMENT (EH6LDM = 80 ppb) IN PHILADELPHIA

	Parameters of 1991 data				8-hour NAAQS attainment parameters				1-hour Weibull parameters		Adjustment coefficients	
District	1-h k	1-h δ	CLV1	EH6LDM	Adjusted EH6LDM	Rank	Reassigned EH6LDM	Equivalent CLV1	k'	δ'	a	b
1	1.69	46.9	167	116	80	5	74	101	2.626	44.62	3.750	0.644
2	2.21	56.4	149	113	78	2	79	108	2.954	52.24	2.556	0.748
3	1.96	51.0	153	111	77	1	80	109	2.708	49.37	2.869	0.724
4	1.81	49.3	162	115	79	3	78	107	2.615	47.10	3.171	0.692
5	2.28	56.6	145	107	74	4	77	105	3.106	52.64	2.721	0.734
6	2.23	51.2	134	101	70	6	72	98	3.300	51.16	3.581	0.676
7	1.93	44.3	135	102	70	8	70	96	3.038	47.38	4.261	0.635
8	2.14	51.2	140	104	72	9	70	96	3.277	49.88	3.817	0.653
9	1.74	38.1	131	90	62	10	62	85	3.136	42.89	5.689	0.555
10	2.26	54.5	141	102	70	7	70	96	3.408	51.15	3.608	0.663

[a]Assumes maximum EH6LDM equals 80 ppb.

coefficients were then substituted into Equation 55 to produce an initial one-hour data set approximating attainment conditions.

The one-hour data were processed to produce a corresponding 8-hour running average data set. These data were analyzed to determine an initial attainment EH6LDM. Analysts then employed Equation 62 to make the final "fine-tuning" adjustment to the one-hour data necessary to achieve the target attainment EH6LDM specified for the district (101 ppb). The resulting tuned data set was assumed to represent attainment conditions for District 1. Table 39 presents descriptive statistics for this data set. Attainment data sets were developed in a similar manner for each of the other Philadelphia monitoring sites.

5.5 Special Adjustment Procedures Applied in Selected Attainment Scenarios

The AQAP's described above were developed by comparing the ozone data reported by a site in a high ozone year with ozone data reported by the same site in a low ozone year. Consequently, the AQAP's are expected to perform best when used to simulate a significant reduction in the ozone levels at a site. The results of an analysis of AQAP performance by ITAQS suggested that the AQAP's described above may produce unrealistic data sets for Denver, Chicago, and Miami when used to simulate a small reduction in ozone levels or when used to simulate an increase in ozone levels. For this reason, ITAQS used a different set of AQAP's for all attainment scenarios in the Chicago, Denver, and Miami study areas. The Chicago scenarios generally required small decreases in ozone levels to exactly meet the specified attainment conditions. The Denver and Miami scenarios required small changes in both directions.

In the alternative AQAP's for the 1H1EX-120 and the 1H1EX-100 scenarios, the procedures summarized in Table 34 were followed to the point in Step 5 where the reader is directed to Section 5.3. The procedures in Section 5.3 were not employed to adjust the one-hour data; instead, each value of the adjusted data set was estimated by the expression

$$y_t = (c)\,(x_t) \qquad (66)$$

where x_t was the baseline ozone concentration for hour t and y_t was the attainment ozone concentration for hour t. The value of c was determined by the expression

$$c = (ACLV1) / (CLV1) \tag{67}$$

where ACLV1 is the characteristic largest one-hour value of the site before adjustment and ACLV1 is the characteristic largest one-hour value assigned to the site in Step 4 to represent attainment conditions.

In a similar manner, the alternative AQAP's for the 8H1EX-70, 8H1EX-80, 8H1EX-90, and 8H1EX-100 scenarios followed the procedures summarized in Table 35 to the point in Step 6 where the reader is directed to Section 5.3. Again, the procedures in Section 5.3 were not employed to adjust the one-hour data. Instead, an initial estimate of each value of the adjusted data set was estimated according to Equations 66 and 67. For Chicago and Miami, ACLV1 was the characteristic largest one-hour value assigned to the site in Step 5 of Table 35. For Denver, however, the observed second highest daily maximum value was assigned to the site in Step 5 of Table 35, instead of the ACLV1. The observed second highest daily maximum was used as the air quality indicator in Denver because it provided a better representation of the data than the characteristic largest one-hour value provided. The alternative adjustment procedure for all three cities was completed by applying Equation 61 to the data to make a final "fine-tuning" adjustment.

The alternative AQAP's for the 8H5EX-80 and 8H5EX-90 scenarios followed the steps listed in Table 36 to the point in Step 6 where the reader is directed to Section 5.3. The applicable procedures in Section 5.3 were again omitted; instead, Equations 66 and 67 were employed to make an initial estimate of each value of the adjusted data set. In Equation 67, ACV1 was the characteristic largest one-hour value assigned to the site in Step 5 of Table 36. The adjustment procedure was completed by using Equation 62 to make the final fine tuning adjustment.

SECTION 6

PREPARATION OF OUTDOOR CHILDREN DATA BASES

As previously described in Section 2 of this report, a special version of pNEM/O3 was used to estimate the exposures of outdoor children residing in nine study areas under various air quality scenarios. In these exposure assessments, the outdoor children in each study area were represented by a collection of cohorts. The distribution of ozone exposures across the outdoor children population of each study area was equal to the sum of the exposures of the individual cohorts.

To simulate the ozone exposures of a particular cohort, the pNEM/O3 model required an exposure event sequence for the cohort and an estimate of the number of people represented by the cohort. The exposure event sequence was constructed by sampling a special time/activity database containing activity diary data obtained from seven studies. Analysts estimated the population of each cohort by applying a percentage to the total population of children in each of the nine study areas. These percentages were determined from the activity diary data and represented that part of the total population of children which would be considered active outdoors. This section describes the procedures employed to create the time/activity database, to construct an exposure event sequence for each cohort, and to estimate the number of children in each cohort.

6.1 Selection of Time/Activity Data

Previous applications of pNEM/O3 have employed activity diary data obtained from the CADS[20]. In the outdoor children exposure analysis, analysts augmented the CADS data with diary data from six other time/activity studies (see Table 2). These seven studies are a subset of 10 studies identified by Johnson et al.[48] as generally appropriate for use in exposure assessments. The remaining three studies listed by Johnson et al. (Denver, Los Angeles - outdoor workers, and Los

Angeles - construction workers) did not provide any data representative of outdoor children. Appendix A provides a brief description of each of the 10 studies.

Under the direction of EPA, ITAQS developed a procedure for identifying outdoor children among the subjects of the seven time/activity studies listed in Table 2. First, analysts identified the codes (designated "microenvironment" codes) used in each study to indicate diary entries associated with outdoor microenvironments. A subject was designated an active child if the subject was associated with at least one person-day of diary data in which the child spent a specified amount of time outdoors.

The specified amount of time outdoors varied by season and weekend/weekday designation. A child was defined as "outdoor" if

- During a winter weekday the child had at least one diary day where he/she spent 120 minutes or more outdoors, or
- During a winter weekend the child had at least one diary day where he/she spent 180 minutes or more outdoors, or
- During a summer day (weekday or weekend) the child had at least one diary day where he/she spent 270 minutes or more outdoors.

For this analysis, summer was defined as June, July, and August, and winter as all other months. This procedure produced a pool containing 479 outdoor children with 792 person-days of activity diary data (Table 42).

6.2 Processing of Time/Activity Data

In a typical pNEM analysis, the ozone exposure of each cohort is determined by the cohort's exposure event sequence. An exposure event sequence consists of a series of person-days with each person-day further divided into a series of exposure events. Each exposure event specifies a start time, an event duration, a microenvironment, a breathing rate category, and a home district location. Exposure event sequences are constructed by sampling person-days from a prepared time/activity database according to a set of selection rules.

TABLE 42. CHARACTERISTICS OF ACTIVITY DATA FOR OUTDOOR CHILDREN

Study	Number of person-days	Number of persons
Cincinnati	384	130
Washington, D.C.	3	3
California - 12 and over	54	54
California - 11 and under	257	257
Los Angeles - Elementary School Students	38	13
Los Angeles - High School Students	47	13
Valdez	9	9
Total	792	479

In the special pNEM/O3 analysis of outdoor children described here, each exposure event sequence was constructed by sampling a time/activity database containing 792 person-days of diary data drawn from seven studies. To create this database, analysts first defined a standard data format which met the input requirements of the exposure model. The diary data obtained from each study were then converted into an equivalent data set with the specified format.

The standard format was designed to easily accommodate CADS data, as data from this study had been used in the majority of previous pNEM analyses. As three of the seven studies selected for the outdoor children analysis employed the CADS diary (Cincinnati, Los Angeles - elementary students, and Los Angeles - high school students), data from these studies required minimal processing to be included in the time/activity database. The data obtained from the remaining four studies (Washington, California - 12 and over, California - 11 and under, and Valdez) required significant processing. None of these four studies characterized diary entries according to a breathing rate category. Consequently, researchers developed a Monte Carlo technique to assign breathing rate categories to diary entries obtained from the these four studies.

The Monte Carlo technique employed assignment probabilities which varied according to four event descriptors: activity type, microenvironment, time of day, and duration. These descriptors were identified by Johnson et al.[34] as influencing exertion levels associated with diary events. To estimate assignment probabilities relative to these descriptors, each event in the CADS database was categorized according to the following indices:

Activity class

A: high probability of fast breathing rate
B: moderate probability of fast breathing rate
C: low probability of fast breathing rate
D: sleeping

Microenvironment

1: Indoors - residence
2: Indoors - other
3: Outdoors
4: In vehicle

Time of day

1: 0700 to 1659
2: 1700 to 0659

Duration

1: 0 to 20 minutes
2: Greater than 20 minutes

The microenvironment classification was determined by the location code (e.g., school) associated with the event in the CADS database. The time of day classification was determined by the start time of the event.

The activity classification consisted of three waking classes (A, B, and C) and one sleeping class (D). Activities were assigned to these classes based on the likelihood that the activity would be associated with a fast breathing rate, with Classification D being reserved for sleeping activities. Table 43 matches each CADS activity code to one of the four activity classes (A, B, C, or D). These matchups are based primarily on the results of an analysis of the CADS database performed by Johnson in 1992[14].

ITAQS created a data group for each of the 48 combinations of activity class, microenvironment, time of day, and duration which could be specified using only the three non-sleeping activity classes (A, B, and C). Each diary entry in the CADS database was assigned to one of the 48 groups. Within each data group, the diary entries were further identified by breathing rate category (slow, medium, or fast).

Table 44 lists the number of diary entries in each of the 48 groups which were placed in each of the three breathing rate categories and the corresponding cumulative fractions. For example, the group identified as Activity Class = A,

TABLE 43. BREATHING RATE CATEGORIES OF ACTIVITIES IN THE CINCINNATI STUDY

Activity Code	Description of Activity	Breathing Rate Category
1	All destination - oriented travel (including walking)	B
2	Income - related work	B
3	Day - care	C
4	Kindergarten - 12th grade	C
5	College or trade school	C
6	Adult education and special training	C
7	Homework	C
8	Meal Preparation and cleanup	C
9	Laundry	B
10	Other indoor chores	B
11	Yard work and outdoor chores	A
12	Child care and child - centered activities	C
13	Errands and shopping	C
14	Personal care outside home (doctor, hair dresser)	C
15	Eating	C
16	Sleeping	D
17	Other personal needs	C
18	Religious activities	C
19	Meetings of clubs, organizations, committees, etc.	C
20	Other collective participation	C

(continued)

Table 43 (continued)

Activity Code	Description of Activity	Breathing Rate Category
21	Spectator sports events	B
22	Movies, concerts, and other entertainment events outside home	C
23	Cafe, bar, tea room	C
24	Museums and exhibitions	B
25	Parties and receptions	B
26	Visiting friends	C
27	Recess and physical education	A
28	Active sports and games outside school, including exercises and aerobics	A
29	Hunting, fishing, hiking	A
30	Jogging or bicycling	A
31	Taking a walk	A
32	Artistic creations, music, and hobbies	C
33	Other active leisure	A
34	Reading	C
35	Television or radio	C
36	Conversation and correspondence	C
37	Relaxing, reflecting, thinking (no visible activity)	C
38	Other passive leisure	C
39	Asthma attack	C
40	Other sudden illness or injury	C

(continued)

Table 43 (continued)

Activity Code	Description of Activity	Breathing Rate Category
43	Interview	C
44	Wakeup	C
45	Baby crying	A

Microenvironment = 1, Time of Day = 1, and Duration = 1 contained 418 events (see first entry in Table 44). These 418 events were apportioned among the three breathing rate categories as follows:

Breathing Rate	Number	Fraction	Cumulative Fraction
Slow	262	0.63	0.63
Moderate	122	0.29	0.92
Fast	34	0.08	1.00

In this example, 63 percent of the events were characterized as slow, 29 percent as moderate, and 8 percent as fast.

Researchers developed a Monte Carlo algorithm to assign breathing rate categories to events obtained from the four diary studies which did not report breathing rate categories. Each event from one of these studies was indexed according to activity class (Tables 45 through 48), microenvironment, time of day, and duration. The algorithm generated a random number for each event which was compared to the cumulative fractions listed in Table 44 for the particular combination of indices.

For example, the random number generated for an event identified as Activity Class = A, Microenvironment = 1, Time of Day = 1, and Duration = 1 would be compared to the cumulative fractions listed in the first row of Table 44. If the random number was between 0 and 0.63, the algorithm would assign a slow breathing rate to the event. The algorithm would assign a moderate breathing rate to events with

TABLE 44. CUMULATIVE BREATHING RATE CATEGORY PROBABILITIES FROM THE CINCINNATI ACTIVITY-DIARY STUDY BY ACTIVITY CLASS, MICROENVIRONMENT, TIME OF DAY CATEGORY, AND EVENT DURATION CATEGORY

Activity class	Micro-environment	Time of day category	Event duration category	Cumulative probability of assigning breathing rate categories (number of events used to determine percentage)		
				Low (2)	Medium (3)	High (4)
A	1	1	1	0.63 (262)	0.92 (122)	1.00 (34)
A	1	1	2	0.78 (589)	0.97 (141)	1.00 (26)
A	1	2	1	0.60 (152)	0.89 (74)	1.00 (28)
A	1	2	2	0.66 (327)	0.93 (138)	1.00 (34)
A	2	1	1	0.20 (25)	0.63 (55)	1.00 (48)
A	2	1	2	0.25 (56)	0.64 (90)	1.00 (81)
A	2	2	1	0.20 (10)	0.80 (29)	1.00 (10)
A	2	2	2	0.24 (47)	0.79 (105)	1.00 (40)
A	3	1	1	0.33 (367)	0.86 (599)	1.00 (163)
A	3	1	2	0.29 (536)	0.88 (1,071)	1.00 (229)
A	3	2	1	0.32 (235)	0.88 (413)	1.00 (87)
A	3	2	2	0.27 (336)	0.86 (757)	1.00 (173)
A	4	1	1	1.00 (2)	NA[a] (0)	NA (0)
A	4	1	2	1.00 (3)	NA (0)	NA (0)
A	4	2	1	0.00 (0)	NA (0)	NA (0)

(continued)

TABLE 44 (Continued)

Activity class	Micro-environment	Time of day category	Event duration category	Cumulative probability of assigning breathing rate categories (number of events used to determine percentage)		
				Low (2)	Medium (3)	High (4)
A	4	2	2	1.00 (1)	NA (0)	NA (0)
B	1	1	1	0.71 (757)	0.99 (298)	1.00 (7)
B	1	1	2	0.80 (1,582)	1.00 (382)	NA (4)
B	1	2	1	0.75 (448)	1.00 (150)	NA (1)
B	1	2	2	0.86 (691)	1.00 (110)	NA (3)
B	2	1	1	0.68 (970)	0.99 (449)	1.00 (12)
B	2	1	2	0.90 (3,762)	1.00 (401)	NA (14)
B	2	2	1	0.80 (313)	0.99 (74)	1.00 (5)
B	2	2	2	0.81 (824)	0.99 (184)	1.00 (7)
B	3	1	1	0.63 (5,854)	0.99 (3,366)	1.00 (87)
B	3	1	2	0.53 (361)	0.96 (298)	1.00 (25)
B	3	2	1	0.67 (3,876)	0.99 (1,902)	1.00 (41)
B	3	2	2	0.72 (330)	0.98 (118)	1.00 (8)
B	4	1	1	1.00 (5,264)	NA (5)	NA (0)
B	4	1	2	1.00 (1,848)	NA (1)	NA (0)
B	4	2	1	1.00 (3,358)	NA (0)	NA (0)

(continued)

TABLE 44 (Continued)

Activity class	Micro-environment	Time of day category	Event duration category	Cumulative probability of assigning breathing rate categories (number of events used to determine percentage)		
				Low (2)	Medium (3)	High (4)
B	4	2	2	1.00 (1,266)	NA (2)	NA (0)
C	1	1	1	0.99 (7,807)	1.00 (87)	NA (0)
C	1	1	2	0.99 (8,024)	1.00 (48)	NA (0)
C	1	2	1	0.99 (6,644)	1.00 (75)	NA (1)
C	1	2	2	1.00 (10,861)	NA (41)	NA (1)
C	2	1	1	0.96 (2,559)	1.00 (117)	NA (2)
C	2	1	2	0.98 (4,032)	1.00 (88)	NA (0)
C	2	2	1	0.97 (894)	1.00 (32)	NA (0)
C	2	2	2	0.99 (1,236)	1.00 (17)	NA (0)
C	3	1	1	0.91 (505)	1.00 (46)	NA (2)
C	3	1	2	0.95 (419)	0.99 (17)	1.00 (3)
C	3	2	1	0.94 (331)	0.99 (18)	1.00 (2)
C	3	2	2	0.94 (480)	1.00 (30)	NA (2)
C	4	1	1	1.00 (12)	NA (0)	NA (0)
C	4	1	2	1.00 (10)	NA (0)	NA (0)
C	4	2	1	1.00 (13)	NA (0)	NA (0)

(continued)

TABLE 44 (Continued)

Activity class	Micro-environment	Time of day category	Event duration category	Cumulative probability of assigning breathing rate categories (number of events used to determine percentage)		
				Low (2)	Medium (3)	High (4)
C	4	2	2	1.00 (5)	NA (0)	NA (0)

[a]Not applicable.

TABLE 45. ACTIVITY CLASSES ASSIGNED TO ACTIVITY CODES USED IN THE CALIFORNIA DIARY STUDY

Activity code	Description of activity	Activity class
1	Work - income related at- and away-from-home	B
2	Unemployment - job search, welfare activities	B
3	Travel during work	B
5	Other paid work - second job, part-time youth job	B
6	Eating at work - lunch, coffee while working	C
7	Activities at work - before and after work day - i.e. conversations	C
8	Breaks - coffee breaks	C
9	Travel to/from work or job-search travel	B
10	Food preparation - cooking, serving, preserving	C
11	Food cleanup - cleaning table, dishes	C
12	Cleaning house - mainly indoor	B
13	Outdoor cleaning - yard work, garbage, snow, etc.	A
14	Clothes care - laundry, other clothes care	B
15	Car repair/maintenance - oil, tires, body work, etc.	B
16	General repairs: indoor, outdoor, carpentry, painting	B
17	Plant care - outdoor garden, houseplants	B
18	Pet and animal care - domestic, feeding livestock	B
19	Other household - garage sale, packing, groceries, chores	B
20	Baby care - feeding, etc. to children < 4	C
21	Child care - children between 5 and 17	C
22	Helping/teaching - children with homework, hobbies	C
23	Talking/reading - discipline (to children), conversing,	C
24	listening	C
25	Indoor playing with baby, children	B
26	Outdoor playing - playing, coaching children	C
27	Medical care - child	C
28	Other child care - coordinating non-school activities,	C
29	Babysitting	B
30	Dry cleaning activities - pick up/drop off	C
31	Travel related to child care (including walking)	C
32	Everyday shopping	C
33	Durable good/house shopping	C
34	Personal care services	C
35	Medical appointments	C
36	Government/financial services (errands too)	C
	Car repair services - buying gas, etc.	
	Other repairs - errands for: clothes, appliances	

(continued)

TABLE 45 (Continued)

Activity code	Description of activity	Activity class
37	Other services - lawyer, video pick up, etc. (errand related)	C
38	Errands	C
39	Travel related to goods and services	B
40	Washing - personal hygiene	C
41	Medical care - at home	C
42	Help and care - to relatives, i.e., moving neighbors	B
43	Meals at home	C
44	Meals out (friends' or at restaurant)	C
45	Night sleep	D
46	Naps/sleep	D
47	Dressing, grooming	C
48	Not ascertained activities	C
49	Travel related to personal care	B
50	Students' classes	C
51	Other classes - lectures, professional, tutor	C
54	Doing homework - reading, studying, research	C
55	Using library	C
56	Other education	C
59	Travel related to education	B
60	Work for professional/union organizations	C
61	Work for special interest identity organizations	C
62	Work for political party and civic participation	C
63	Work for volunteer/helping organizations	C
64	Work for religious groups	C
65	Religious practice	C
66	Work for fraternal organizations	C
67	Work for child/youth/family organizations	C
68	Work for other organizations	C
69	Travel related to organizational activity	B
70	Sports events - attending as spectator	B
71	Miscellaneous events - circus, fairs, rock concerts	B
72	Movies	C
73	Attending theater	C
74	Visiting museums	B
75	Visiting - socializing with friends	C

(continued)

TABLE 45 (Continued)

Activity code	Description of activity	Activity class
76	Parties and picnicking	B
77	Bars/lounges	C
78	Other social events	C
79	Travel related to event/social activities	B
80	Active sports	A
81	Outdoor leisure - hunting, fishing, boating, camping, etc.	B
82	Walking/biking/hiking/jogging, etc.	A
83	Hobbies - photography, scrapbooks, etc.	C
84	Domestic crafts - knitting, sewing, quilting	C
85	Art - sculpture, painting, potting drawing	C
86	Music/drama/dance/active leisure	A
87	Games - card, board, computer	C
88	Computer use	C
89	Travel related to active leisure	B
90	Radio use	C
91	TV use	C
92	Records/tapes	C
93	Read books	C
94	Reading magazines/not ascertained	C
95	Reading a newspaper	C
96	Conversations	C
97	Letters, writing, paperwork	C
98	Other passive leisure	C
99	Travel related to passive leisure	C

TABLE 46. ACTIVITY CLASSES ASSIGNED TO ACTIVITY CODES USED IN THE DENVER DIARY STUDY

Activity code	Description of activity	Activity class
1	All travel	B
2	Work (income-related) and study	C
3	Cooking	C
4	Laundry	B
5	Other indoor chores and child care	B
6	Yard work and other outdoor activities	A
7	Errands and shopping	C
8	Eating	C
9	Sleeping	D
10	Other personal needs	C
11	Social, political or religious activities	C
12	Cafe or pub	C
13	Walking, bicycling, or jogging (not in transit)	A
14	Other leisure activities	C
15	Uncertain of applicable code	C
16	No entry in diary	NA
17	Interview	C
18	Final entry	C
19	Autolog value (i.e., hourly value automatically logged by PEM)	C
20	Begin breath sample	C
21	End breath sample	C

TABLE 47. ACTIVITY CLASSES ASSIGNED TO ACTIVITY CODES USED IN THE VALDEZ DIARY STUDY

Activity code	Description of activity	Activity class
1	Cooking	C
2	Eating	C
3	Driving car, truck, bus	B
4	Driving boat	B
5	Driving plane	B
6	Driving other	B
7	Biking	A
8	Sedentary activity	C
9	Physical activity	A
10	At school	C
11	Grooming, dressing	C
12	Socializing	C
13	Shopping, errands	C
14	Going to bed	D
15	Getting out of bed	C
16	Exercising	A
17	Walking	B
18	At work	B
19	Fishing	B
20	Pumping gasoline	B
21	Not specified	C
22	Playing	B
23	At dock	B
99	Interview	C

TABLE 48. ACTIVITY CLASSES ASSIGNED TO ACTIVITY CODES USED IN THE WASHINGTON DIARY STUDY

Activity code	Description of activity	Activity class
1	Transit, travel	B
2	Work, business meeting	B
3	Cooking	C
4	Laundry	B
5	Inside house - chores	B
6	Outside house - chores	A
7	Errands, shopping, etc.	C
8	Personal activities	C
9	Leisure activities	C
11	Sleeping	D
12	School, study	C
13	Eating, drinking	C
14	Sports and exercise	A
15	Church, political meetings, etc.	C
16	Inside house - miscellaneous	C
17	In parking garage or lot	B
18	Outside, not otherwise specified	B
19	Doctor or dentist office	C
21-36	Same as activities 1 - 16 including suspected sleep	
77	Same as activity 87 including suspected sleep	
86	Dummy start diary	C
87	Start diary	C
88	End diary	C
89	Any other activity	C

random numbers between 0.63 and 0.92; similarly, fast breathing rates would be assigned to events with random numbers between 0.92 and 1.00.

The cumulative fractions listed in Table 44 were used by the Monte Carlo algorithm to process all diary events associated with waking activities. When the activity code for a diary entry indicated that the subject was sleeping during the event (i.e., activity class = D), the algorithm always assigned the fourth breathing rate category (sleeping) to the event.

As indicated above, 792 person-days of diary data representing 479 outdoor children were processed and combined into a database suitable for input into pNEM/O3. Subsection 2.3 describes the algorithm used by pNEM/O3 to sample this database and construct an exposure event sequence for each cohort.

6.3 City-Specific Outdoor Children Populations

In applying pNEM/O3 to the outdoor children in a study area, analysts employed Equation 6 in Subsection 2.5 to estimate the number of children represented by each cohort. This equation in turn required the estimation of a value for the P(g) term in Equation 4. P(g) was defined as the fraction of children in demographic group g who were "outdoor children." The demographic group was either preteens (children ages 6 to 13) or teenagers (children 14 to 18).

In the analyses described in this report, P(g) was assumed to be constant across all cohorts belonging to demographic group g, regardless of study area. P(g) was estimated by the expression

$$P(g) = [POPOC(g,ddb)] \ / \ [POPC(g,ddb)] \qquad (68)$$

where

P(g)	=	the fraction of outdoor children in demographic group g.
POPOC(g,ddb)	=	the number of children in demographic group g from the diary data bases (ddb) that were classified as "outdoor children."
POPC(g,ddb)	=	the total number of children in demographic group g from the diary data bases (ddb).

The values of POPOC(g,ddb) and POPC(g,ddb) were obtained from an analysis of time/activity databases obtained from three of the studies listed in Table 2: California - 11 and under, California - 12 and over, and Cincinnati. Each of these studies employed a random selection procedure to enroll a relatively large number of subjects.

Considered together, the three studies provided diary data for 771 preteens and 258 teenagers. Of the 771 preteens, 361 (46.8 percent) were judged to be active outdoors according to the criteria discussed in Subsection 6.1. In a similar manner, 80 of the 258 teenagers (31.0 percent) were judged to be active outdoors. Consequently, analysts set P(g) equal to 0.468 for preteens and 0.310 for teenagers. These estimates were multiplied by census-derived estimates for the total number of preteens and teenagers in each study area to produce the estimates listed in Table 49. The populations of individual cohorts were estimated using Equations 4 through 6.

TABLE 49. ESTIMATED NUMBER OF OUTDOOR CHILDREN IN EACH STUDY AREA

Study area	Demographic group	Total number of children	Multiplier [P(g)]	Estimated number of outdoor children
Chicago	Preteens	722,861	0.468	338,290
	Teenagers	433,639	0.310	134,420
	Total	1,156,500	-	472,710
Denver	Preteens	165,679	0.468	77,540
	Teenagers	93,934	0.310	29,125
	Total	259,613	-	106,665
Houston	Preteens	309,886	0.468	144,995
	Teenagers	180,013	0.310	55,800
	Total	489,899	-	200,795
Los Angeles	Preteens	1,216,936	0.468	569,515
	Teenagers	737,950	0.310	228,775
	Total	1,954,886	-	798,290
Miami	Preteens	203,346	0.468	95,155
	Teenagers	124,050	0.310	38,455
	Total	327,396	-	133,610
New York	Preteens	1,180,573	0.468	552,515
	Teenagers	742,235	0.310	230,085
	Total	1,922,808	-	782,600
Philadelphia	Preteens	419,237	0.468	196,215
	Teenagers	255,194	0.310	79,105
	Total	674,431	-	275,320
St. Louis	Preteens	197,617	0.468	92,480
	Teenagers	115,360	0.310	35,770
	Total	312,977	-	128,250
Washington, DC	Preteens	301,827	0.468	141,265
	Teenagers	185,767	0.310	57,595
	Total	487,594	-	198,860

SECTION 7

OZONE EXPOSURE ESTIMATES FOR NINE URBAN AREAS

The enhanced pNEM/O3 methodology described in this report was applied to the nine urban areas listed earlier in Table 1. The result of each application was a set of 18 exposure summary tables for each regulatory scenario under evaluation. This section describes the scenarios that were analyzed, provides a guide to the interpretation of output tables, and summarizes the principal results of each exposure assessment.

7.1 Regulatory Scenarios

The following regulatory scenarios were examined in applying pNEM/O3 to each study area.

Baseline — Ambient ozone conditions were represented by unadjusted fixed-site monitoring data as reported for the exposure period listed in Table 1. These data were assumed to represent ambient ozone levels typical of "as is" air quality conditions.

1H1EX — One hour daily maximum - one expected exceedance: the expected number of daily maximum one-hour ozone concentrations exceeding the specified value shall not exceed one.

Standard levels: 100 ppb, 120 ppb (the current NAAQS for ozone)

8H1EX — Eight-hour daily maximum - one expected exceedance: the expected number of daily maximum eight-hour ozone concentrations exceeding the specified value shall not exceed one.

Standard levels: 70 ppb, 80 ppb, 90 ppb, 100 ppb

8H5EX Eight-hour daily maximum - five expected exceedances: the expected number of daily maximum eight-hour ozone concentrations exceeding the specified value shall not exceed five.

Standard levels: 80 ppb, 90 ppb,

Section 5 describes the procedures used to adjust baseline data to simulate attainment of 1H1EX, 8H1EX, and 8H5EX standards.

7.2 Formats of the Exposure Summary Tables

Appendix D contains exposure summary tables for the outdoor children population obtained from a sample application of pNEM/O3 to Houston. The tables are organized according to the following table formats. (Note that the table numbers listed under each format refer to the tables in Appendix D.)

Number of people -- cumulative exposures (or doses) by EVR range

These tables list estimates by ozone concentration and EVR range. Each table entry lists the number of outdoor children who experienced one or more ozone exposures (or doses) during which the ozone concentration was at or above the level indicated by the row label and the average EVR was within the range indicated by the column heading. Separate tables provide estimates for one-hour exposures (Table 1 in Appendix D), one-hour daily maximum exposures (Table 1A), one-hour daily maximum doses (Table 1B), eight-hour daily maximum exposures (Table 4), and eight-hour daily maximum doses (Table 4A).

Number of people -- cumulative seasonal mean exposures

Table 7 in Appendix D lists estimates by ozone concentration only. Each entry lists the number of outdoor children who were associated with a seasonal mean exposure at or above the ozone level indicated by the row label. The seasonal mean is calculated as the average of the eight-hour daily maximum ozone exposures occurring from April to October, inclusive.

Number of occurrences -- exposures (or doses) by EVR range

These tables list estimates arranged by ozone concentration range and EVR range. Each table entry lists the number of times an outdoor child experienced an ozone exposure during which the ozone concentration was within the range indicated by the row label and the average EVR was within the range indicated by the column heading. There are separate tables for one-hour exposures (Table 2 in Appendix D), one-hour daily maximum exposures (Table 2A), one-hour daily maximum doses (Table 2B), eight-hour daily maximum exposures (Table 5), and eight-hour daily maximum doses (Table 5A).

Number of occurrences -- seasonal mean exposures

Table 8 in Appendix D presents estimates by ozone range only. Each entry lists the number of times an outdoor child experienced a seasonal mean exposure at or above the ozone level indicated by the row label. The seasonal mean is calculated as the average of the eight-hour daily maximum ozone exposures occurring from April to October, inclusive.

Number of people -- highest exposures (or doses) by EVR range

Each of these tables lists estimates arranged by ozone concentration and EVR range. Each entry indicates the number of outdoor children who experienced their maximum ozone exposure under conditions in which the ozone concentration was at or above the level indicated by the row label and the average EVR was within the range indicated by the column heading. There are separate tables for one-hour daily maximum exposures (Table 3 in Appendix D) and eight-hour daily maximum exposures (Table 6).

Number of people -- cumulative daily maximum doses by number of days

These tables provide estimates arranged by ozone concentration and number of days per year. Each entry lists the number of outdoor children who experienced a daily maximum dose at or above the indicated ozone concentration for the specified number of days. Separate tables are provided for daily maximum one-hour doses (Table 9 in Appendix D), daily maximum eight-hour doses (Table 10), daily maximum one-hour doses with EVR of 30 liters x min^{-1} x m^{-2} or greater (Table 11), and daily maximum eight-hour doses with EVR ranging from 13 liters x min^{-1} x m^{-2} to 27 liters x min^{-1} x m^{-2} (Table 12).

Regardless of format, each table in Appendix D provides footnotes identifying the study area and regulatory scenario. The footnotes also indicate the number of exposure districts in the study area, the first and last days of the ozone season, and the number of days in the ozone season.

7.3 Results of Analyses

The pNEM/O3 model incorporates a number of stochastic (random) elements which directly affect the exposure estimates produced by the model. Consequently, exposure estimates are likely to vary from run to run. To better characterize this variability, ITAQS ran the model 10 times for each combination of study area and regulatory scenario. Tables 50 through 53 provide means and ranges for selected exposure indicators based on these runs.

Table 50 illustrates the general format used in Tables 50 through 53. This table presents estimates for the number and percentage of outdoor children experiencing one or more one-hour daily maximum ozone exposures above 120 ppb at any ventilation rate. The first row in the table lists results for the Chicago study area under the baseline scenario. Of the estimated 472,710 outdoor children in the Chicago study area, 252,914 (53.50 percent) are estimated to have experienced the specified exposure conditions based on the mean of the 10 runs. The estimates associated with individual runs range from 233,862 (49.47 percent) to 288,683 (61.07 percent). Tables 51, 52, and 53 employ the same format to present estimates for the number and percentage of outdoor children who experience one or more eight-hour daily maximum ozone exposures above 60 ppb, 80 ppb, and 100 ppb, respectively, at any ventilation rate.

A review of the estimates in Tables 50 through 53 indicates that exposures are generally higher under baseline conditions than under any one of the standards. Denver and Miami show some exceptions to this generalization; exposures under the current NAAQS, the 8H1EX-100 and the 8H1EX-90 scenarios are higher than exposures under baseline conditions. St. Louis also displays this reversal under the current NAAQS and 8H1EX-100 scenarios for outdoor children experiencing one or more eight-hour daily maximum ozone exposures above 60 ppb at any ventilation rate. In each of these cases, the ambient ozone levels permitted by the regulatory scenario are higher than the ambient levels which occur under baseline conditions. Consequently, the adjustment of baseline data to exactly meet the current NAAQS, for example, produces an increase in ozone exposure.

TABLE 50. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE ONE-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 120 PPB AT ANY VENTILATION RATE

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	Baseline	252,914	53.50	233,862 - 288,683	49.47 - 61.07
		Current NAAQS	86,918	18.39	56,585 - 120,993	11.97 - 25.60
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	216,080	45.71	185,954 - 246,754	39.34 - 52.20
		8H1EX-90	47,557	10.06	18,498 - 90,111	3.91 - 19.06
		8H1EX-80	168	0.04	0 - 1,179	0.00 - 0.25
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	236,130	49.95	212,570 - 256,711	44.97 - 54.31
		8H5EX-80	64,579	13.66	45,242 - 85,735	9.57 - 18.14
Denver	106,665	Baseline	21,438	20.10	14,167 - 28,750	13.28 - 26.95
		Current NAAQS	33,358	31.27	18,235 - 42,539	17.10 - 39.88
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	71,923	67.43	64,180 - 77,056	60.17 - 72.24
		8H1EX-90	41,710	39.10	37,443 - 45,247	35.10 - 42.42
		8H1EX-80	9,907	9.29	6,139 - 13,347	5.76 - 12.51
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	45,140	42.32	34,287 - 54,906	32.14 - 51.48
		8H5EX-80	11,370	10.66	3,557 - 16,282	3.33 - 15.26

(continued)

TABLE 50 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Houston	200,795	Baseline	200,425	99.82	199,136 - 200,795	99.17 - 100.00
		Current NAAQS	35,892	17.87	20,888 - 48,332	10.40 - 24.07
		1H1EX-100	29	0.01	0 - 293	0.00 - 0.15
		8H1EX-100	112,215	55.89	96,504 - 116,943	48.06 - 58.24
		8H1EX-90	35,416	17.64	27,644 - 44,145	13.77 - 21.99
		8H1EX-80	5,875	2.93	0 - 8,510	0 - 4.24
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	143,166	71.30	132,566 - 153,049	66.02 - 76.22
		8H5EX-80	64,555	32.15	52,319 - 75,290	26.06 - 37.50
Los Angeles	798,290	Baseline	713,214	89.34	695,388 - 734,039	87.11 - 91.95
		Current NAAQS	16,198	2.03	12,235 - 20,532	1.53 - 2.57
		1H1EX-100	57	0.01	0 - 572	0.00 - 0.07
		8H1EX-100	162,639	20.37	147,820 - 172,915	18.52 - 21.66
		8H1EX-90	62,926	7.88	49,301 - 71,960	6.18 - 9.01
		8H1EX-80	14,179	1.78	8,794 - 18,974	1.10 - 2.38
		8H1EX-70	109	0.01	0 - 1,088	0.00 - 0.14
		8H5EX-90	90,405	11.32	80,115 - 106,528	10.04 - 13.34
		8H5EX-80	21,448	2.69	18,666 - 24,647	2.34 - 3.09

TABLE 50 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Miami	133,610	Baseline	4,374	3.27	2,554 - 5,754	1.91 - 4.31
		Current NAAQS	20,364	15.24	13,756 - 23,459	10.30 - 17.56
		1H1EX-100	3,141	2.35	24 - 5,778	0.02 - 4.32
		8H1EX-100	83,937	62.82	74,556 - 101,859	55.80 - 76.24
		8H1EX-90	29,808	22.31	23,390 - 36,802	17.51 - 27.54
		8H1EX-80	6,884	5.15	3,248 - 9,979	2.43 - 7.47
		8H1EX-70	927	0.69	0 - 2,318	0.00 - 1.73
		8H5EX-90	107,339	80.34	99,591 - 111,275	74.54 - 83.28
		8H5EX-80	37,518	28.08	24,651 - 50,133	18.45 - 37.52
New York	782,600	Baseline	541,114	69.14	500,315 - 567,283	63.93 - 72.49
		Current NAAQS	34,132	4.36	26,297 - 44,525	3.36 - 5.69
		1H1EX-100	76	0.01	0 - 756	0.00 - 0.10
		8H1EX-100	93,837	11.99	83,238 - 102,323	10.64 - 13.07
		8H1EX-90	19,208	2.45	7,548 - 31,145	0.96 - 3.98
		8H1EX-80	1,413	0.18	0 - 8,246	0 - 1.05
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	89,581	11.45	81,382 - 97,255	10.40 - 12.43
		8H5EX-80	10,561	1.35	5,028 - 17,657	0.64 - 2.26

TABLE 50 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Philadelphia	275,320	Baseline	269,385	97.84	265,362 - 271,485	96.38 - 98.61
		Current NAAQS	12,933	4.70	6,943 - 18,949	2.52 - 6.88
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	19,781	7.18	13,831 - 29,354	5.02 - 10.66
		8H1EX-90	112	0.04	0 - 573	0.00 - 0.21
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	15,892	5.77	4,281 - 29,174	1.55 - 10.60
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00
St. Louis	128,250	Baseline	45,807	35.72	42,107 - 51,554	32.83 - 40.20
		Current NAAQS	15,609	12.17	12,517 - 19,294	9.76 - 15.04
		1H1EX-100	322	0.25	0 - 1,451	0.00 - 1.13
		8H1EX-100	10,315	8.04	8,535 - 14,573	6.65 - 11.36
		8H1EX-90	3,000	2.34	994 - 4,496	0.78 - 3.51
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	32,638	25.45	26,123 - 39,788	20.37 - 31.02
		8H5EX-80	3,686	2.87	951 - 7,302	0.74 - 5.69

TABLE 50 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Washington D.C.	198,860	Baseline	190,259	95.67	183,960 - 192,795	92.51 - 96.95
		Current NAAQS	14,796	7.44	10,855 - 18,513	5.46 - 9.31
		1H1EX-100	38	0.02	0 - 381	0.00 - 0.19
		8H1EX-100	16,268	8.18	14,184 - 18,189	7.13 - 9.15
		8H1EX-90	4,915	2.47	901 - 10,267	0.45 - 5.16
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	43,941	22.10	40,217 - 46,946	20.22 - 23.61
		8H5EX-80	2,657	1.34	706 - 5,678	0.36 - 2.86

TABLE 51. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 60 PPB AT ANY VENTILATION RATE

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	Baseline	472,621	99.98	471,820 - 472,710	99.81 - 100.00
		Current NAAQS	464,191	98.20	458,510 - 469,167	97.00 - 99.25
		1H1EX-100	320,239	67.75	300,967 - 341,007	63.67 - 72.14
		8H1EX-100	472,710	100.00	472,710 - 472,710	100.00 - 100.00
		8H1EX-90	462,228	97.78	458,566 - 464,920	97.01 - 98.35
		8H1EX-80	362,463	76.68	340,715 - 380,222	72.08 - 80.43
		8H1EX-70	152,443	32.25	129,118 - 186,260	27.31 - 39.40
		8H5EX-90	472,492	99.95	471,354 - 472,710	99.71 - 100.00
		8H5EX-80	466,817	98.75	462,632 - 471,279	97.87 - 99.70
Denver	106,665	Baseline	99,449	93.23	97,015 - 102,785	90.95 - 96.36
		Current NAAQS	93,808	87.95	89,684 - 97,462	84.08 - 91.37
		1H1EX-100	68,166	63.91	60,492 - 77,765	56.71 - 72.91
		8H1EX-100	106,206	99.57	104,657 - 106,665	98.12 - 100.00
		8H1EX-90	101,820	95.46	99,305 - 104,465	93.10 - 97.94
		8H1EX-80	88,046	82.54	85,311 - 89,437	79.98 - 83.85
		8H1EX-70	49,132	46.06	41,986 - 52,135	39.36 - 48.88
		8H5EX-90	104,362	97.84	103,247 - 105,326	96.80 - 98.74
		8H5EX-80	91,092	85.40	85,715 - 94,992	80.36 - 89.06

(continued)

TABLE 51 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Houston	200,795	Baseline	200,795	100.00	200,795 - 200,795	100.00 - 100.00
		Current NAAQS	189,773	94.51	182,702 - 195,230	90.99 - 97.23
		1H1EX-100	122,526	61.02	114,768 - 130,997	57.16 - 65.24
		8H1EX-100	195,897	97.56	190,738 - 199,486	94.99 - 99.35
		8H1EX-90	180,552	89.92	174,556 - 184,568	86.93 - 91.92
		8H1EX-80	132,992	66.23	108,727 - 143,553	54.15 - 71.49
		8H1EX-70	58,555	29.16	40,618 - 70,084	20.23 - 34.90
		8H5EX-90	196,664	97.94	194,422 - 200,093	96.83 - 99.65
		8H5EX-80	181,226	90.25	173,936 - 185,528	86.62 - 92.40
Los Angeles	798,290	Baseline	789,497	98.90	782,143 - 794,073	97.98 - 99.47
		Current NAAQS	248,727	31.16	239,525 - 264,995	30.00 - 33.20
		1H1EX-100	156,847	19.65	149,423 - 166,488	18.72 - 20.86
		8H1EX-100	341,341	42.76	329,109 - 359,623	41.23 - 45.05
		8H1EX-90	284,248	35.61	277,015 - 296,505	34.70 - 37.14
		8H1EX-80	227,175	28.46	219,415 - 239,119	27.49 - 29.95
		8H1EX-70	115,220	14.43	100,530 - 122,490	12.59 - 15.34
		8H5EX-90	270,811	33.92	251,328 - 285,161	31.48 - 35.72
		8H5EX-80	206,669	25.89	198,978 - 215,761	24.93 - 27.03

(continued)

TABLE 51 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Miami	133,610	Baseline	73,725	55.18	59,528 - 81,301	44.55 - 60.85
		Current NAAQS	117,572	88.00	110,490 - 124,216	82.70 - 92.97
		1H1EX-100	57,107	42.74	45,695 - 69,183	34.20 - 51.78
		8H1EX-100	131,107	98.13	126,359 - 133,610	94.57 - 100.00
		8H1EX-90	119,964	89.79	115,156 - 127,540	86.19 - 95.46
		8H1EX-80	91,237	68.29	79,426 - 101,375	59.45 - 75.87
		8H1EX-70	37,762	28.26	33,108 - 42,797	24.78 - 32.03
		8H5EX-90	133,582	99.98	133,327 - 133,610	99.79 - 100.00
		8H5EX-80	128,818	96.41	123,328 - 131,309	92.30 - 98.28
New York	782,600	Baseline	741,850	94.79	721,627 - 762,270	92.21 - 97.40
		Current NAAQS	525,369	67.13	486,814 - 550,873	62.20 - 70.39
		1H1EX-100	316,317	40.42	292,975 - 346,748	37.44 - 44.31
		8H1EX-100	609,108	77.83	598,403 - 610,915	76.46 - 78.06
		8H1EX-90	572,823	73.19	554,906 - 594,127	70.91 - 75.92
		8H1EX-80	364,261	46.54	350,011 - 383,466	44.72 - 49.00
		8H1EX-70	170,627	21.80	164,012 - 178,692	20.96 - 22.83
		8H5EX-90	596,391	76.21	585,302 - 603,551	74.79 - 77.12
		8H5EX-80	437,680	55.93	386,569 - 465,269	49.40 - 59.45

(continued)

TABLE 51 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Philadelphia	275,320	Baseline	275,320	100.00	275,320 - 275,320	100.00 - 100.00
		Current NAAQS	275,320	100.00	275,320 - 275,320	100.00 - 100.00
		1H1EX-100	270,747	98.34	265,871 - 272,985	96.57 - 99.15
		8H1EX-100	275,320	100.00	275,320 - 275,320	100.00 - 100.00
		8H1EX-90	274,390	99.66	272,309 - 275,320	98.91 - 100.00
		8H1EX-80	252,092	91.56	246,303 - 260,476	89.46 - 94.61
		8H1EX-70	102,407	37.20	92,371 - 110,040	33.55 - 39.97
		8H5EX-90	274,718	99.78	272,927 - 275,320	99.13 - 100.00
		8H5EX-80	263,383	95.66	256,376 - 269,006	93.12 - 97.71
St. Louis	128,250	Baseline	112,768	87.93	110,241 - 117,523	85.96 - 91.64
		Current NAAQS	121,279	94.56	120,699 - 121,710	94.11 - 94.90
		1H1EX-100	96,669	75.38	92,319 - 101,910	71.98 - 79.46
		8H1EX-100	116,855	91.12	115,031 - 118,142	89.69 - 92.12
		8H1EX-90	103,510	80.71	100,256 - 105,577	78.17 - 82.32
		8H1EX-80	75,937	59.21	69,941 - 78,998	54.53 - 61.60
		8H1EX-70	25,087	19.56	21,772 - 28,812	16.98 - 22.47
		8H5EX-90	122,468	95.49	120,991 - 123,809	94.34 - 96.54
		8H5EX-80	105,291	82.10	100,020 - 109,146	77.99 - 85.10

(continued)

TABLE 51 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Washington D.C.	198,860	Baseline	198,860	100.00	198,860 - 198,860	100.00 - 100.00
		Current NAAQS	198,714	99.93	198,237 - 198,860	99.69 - 100.00
		1H1EX-100	181,013	91.03	171,334 - 188,581	86.16 - 94.83
		8H1EX-100	198,701	99.92	197,272 - 198,860	99.20 - 100.00
		8H1EX-90	196,054	98.59	191,130 - 198,079	96.11 - 99.61
		8H1EX-80	148,596	74.72	133,641 - 161,442	67.20 - 81.18
		8H1EX-70	41,670	20.95	38,770 - 44,329	19.50 - 22.29
		8H5EX-90	198,730	99.93	198,223 - 198,860	99.68 - 100.00
		8H5EX-80	191,006	96.05	187,596 - 194,134	94.34 - 97.62

TABLE 52. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 80 PPB AT ANY VENTILATION RATE

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	Baseline	339,451	71.81	316,734 - 357,026	67.00 - 75.53
		Current NAAQS	147,277	31.16	122,337 - 171,046	25.88 - 36.18
		1H1EX-100	3,662	0.77	0 - 5,035	0.00 - 1.07
		8H1EX-100	269,575	57.03	254,658 - 302,935	53.87 - 64.08
		8H1EX-90	116,934	24.74	103,478 - 146,028	21.89 - 30.89
		8H1EX-80	6,549	1.39	3,050 - 10,420	0.65 - 2.20
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	313,605	66.34	287,400 - 333,762	60.80 - 70.61
		8H5EX-80	118,124	24.99	88,860 - 150,054	18.80 - 31.74
Denver	106,665	Baseline	20,046	18.79	15,972 - 25,258	14.97 - 23.68
		Current NAAQS	32,176	30.17	28,246 - 36,327	26.48 - 34.06
		1H1EX-100	712	0.67	0 - 2,090	0.00 - 1.96
		8H1EX-100	68,815	64.52	64,388 - 72,155	60.36 - 67.65
		8H1EX-90	39,927	37.43	34,455 - 46,335	32.30 - 43.44
		8H1EX-80	5,669	5.31	3,114 - 8,651	2.92 - 8.11
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	33,438	31.35	25,110 - 39,257	23.54 - 36.80
		8H5EX-80	8,745	8.20	4,118 - 12,141	3.86 - 11.38

(continued)

TABLE 52 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Houston	200,795	Baseline	198,249	98.73	196,879 - 199,745	98.05 - 99.48
		Current NAAQS	41,968	20.90	23,580 - 63,386	11.74 - 31.57
		1H1EX-100	2,248	1.12	36 - 5,200	0.02 - 2.59
		8H1EX-100	98,802	49.21	84,776 - 108,945	42.22 - 54.26
		8H1EX-90	39,607	19.73	29,391 - 50,040	14.64 - 24.92
		8H1EX-80	8,125	4.05	4,177 - 17,118	2.08 - 8.53
		8H1EX-70	536	0.27	0 - 1,280	0.00 - 0.64
		8H5EX-90	116,698	58.12	103,422 - 133,271	51.51 - 66.37
		8H5EX-80	45,770	22.79	33,559 - 62,760	16.71 - 31.26
Los Angeles	798,290	Baseline	672,461	84.24	634,085 - 690,933	79.43 - 86.55
		Current NAAQS	23,164	2.90	16,961 - 29,087	2.12 - 3.64
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	164,153	20.56	154,585 - 178,854	19.36 - 22.40
		8H1EX-90	93,508	11.71	84,751 - 101,011	10.62 - 12.65
		8H1EX-80	13,222	1.66	8,270 - 19,039	1.04 - 2.38
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	105,039	13.16	96,547 - 117,422	12.09 - 14.71
		8H5EX-80	35,601	4.46	29,745 - 47,489	3.73 - 5.95

(continued)

TABLE 52 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Miami	133,610	Baseline	702	0.53	0 - 3,533	0.00 - 2.64
		Current NAAQS	17,344	12.98	11,189 - 26,615	8.37 - 19.92
		1H1EX-100	634	0.47	0 - 5,592	0.00 - 4.19
		8H1EX-100	65,918	49.34	55,549 - 73,943	41.58 - 55.34
		8H1EX-90	27,354	20.47	17,549 - 37,699	13.13 - 28.22
		8H1EX-80	3,014	2.26	265 - 7,313	0.20 - 5.47
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	85,434	63.94	77,113 - 94,261	57.71 - 70.55
		8H5EX-80	42,953	32.15	36,515 - 48,555	27.33 - 36.34
New York	782,600	Baseline	578,118	73.87	560,849 - 595,247	71.66 - 76.06
		Current NAAQS	130,169	16.63	110,739 - 146,820	14.15 - 18.76
		1H1EX-100	8,490	1.08	6,135 - 12,438	0.78 - 1.59
		8H1EX-100	244,838	31.29	227,164 - 262,501	29.03 - 33.54
		8H1EX-90	104,028	13.29	86,852 - 122,881	11.10 - 15.70
		8H1EX-80	13,339	1.70	7,926 - 18,090	1.01 - 2.31
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	174,570	22.31	161,793 - 184,845	20.67 - 23.62
		8H5EX-80	61,157	7.81	48,906 - 69,286	6.25 - 8.85

(continued)

TABLE 52 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Philadelphia	275,320	Baseline	273,481	99.33	271,175 - 275,320	98.49 - 100.00
		Current NAAQS	164,718	59.83	146,501 - 180,412	53.21 - 65.53
		1H1EX-100	28,861	10.48	20,147 - 35,055	7.32 - 12.73
		8H1EX-100	174,478	63.37	154,686 - 189,712	56.18 - 68.91
		8H1EX-90	63,313	23.00	46,707 -76,541	16.96 - 27.80
		8H1EX-80	8,464	3.07	4,641 - 14,705	1.69 - 5.34
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	137,731	50.03	126,576 - 154,987	45.97 - 56.29
		8H5EX-80	33,892	12.31	22,344 - 39,860	8.12 - 14.48
St. Louis	128,250	Baseline	57,054	44.49	51,550 - 64,321	40.19 - 50.15
		Current NAAQS	56,463	44.03	51,280 - 62,789	39.98 - 48.96
		1H1EX-100	4,889	3.81	1,501 - 7,414	1.17 - 5.78
		8H1EX-100	49,925	38.93	45,837 - 63,350	35.74 - 49.40
		8H1EX-90	13,045	10.17	8,384 - 19,013	6.54 - 14.82
		8H1EX-80	1,030	0.80	0 - 2,563	0.00 - 2.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	62,735	48.92	55,410 - 68,971	43.20 - 53.78
		8H5EX-80	20,986	16.36	16,192 - 25,192	12.63 - 19.64

TABLE 52 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Washington D.C.	198,860	Baseline	192,494	96.80	185,648 - 196,208	93.36 - 98.67
		Current NAAQS	76,159	38.30	62,438 - 83,945	31.40 - 42.21
		1H1EX-100	11,975	6.02	6,928 - 15,803	3.48 - 7.95
		8H1EX-100	86,540	43.52	79,074 - 97,301	39.76 - 48.93
		8H1EX-90	31,298	15.74	26,450 - 35,911	13.30 - 18.06
		8H1EX-80	7,428	3.74	4,875 - 12,364	2.45 - 6.22
		8H1EX-70	36	0.02	0 - 357	0.00 - 0.18
		8H5EX-90	120,335	60.51	112,787 - 132,359	56.72 - 66.56
		8H5EX-80	34,928	17.56	28,095 - 39,613	14.13 - 19.92

TABLE 53. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 100 PPB AT ANY VENTILATION RATE

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	Baseline	20,005	4.23	16,490 - 25,496	3.49 - 5.39
		Current NAAQS	107	0.02	0 - 528	0.00 - 0.11
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	7,653	1.62	4,041 - 12,019	0.85 - 2.54
		8H1EX-90	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	17,772	3.76	12,768 - 27,884	2.70 - 5.90
		8H5EX-80	29	0.01	0 - 294	0.00 - 0.06
Denver	106,665	Baseline	0	0.00	0 - 0	0.00 - 0.00
		Current NAAQS	111	0.10	0 - 789	0.00 - 0.74
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	6,760	6.34	3,325 - 10,870	3.12 - 10.19
		8H1EX-90	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	632	0.59	54 - 1,765	0.05 - 1.65
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00

TABLE 53 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Houston	200,795	Baseline	165,332	82.34	157,637 - 173,080	78.51 - 86.20
		Current NAAQS	481	0.24	0 - 3,207	0.00 - 1.60
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	13,408	6.68	5,852 - 24,394	2.91 - 12.15
		8H1EX-90	1,740	0.87	0 - 4,801	0.00 - 2.39
		8H1EX-80	74	0.04	0 - 737	0 - 0.37
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	25,945	12.92	15,942 - 40,102	7.94 - 19.97
		8H5EX-80	2,748	1.37	130 - 7,391	0.06 - 3.68
Los Angeles	798,290	Baseline	457,507	57.31	441,832 - 472,777	55.35 - 59.22
		Current NAAQS	0	0.00	0 - 0	0.00 - 0.00
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	9,642	1.21	5,577 - 17,963	0.70 - 2.25
		8H1EX-90	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	2,285	0.29	0 - 5,038	0.00 - 0.63
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00

TABLE 53 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Miami	133,610	Baseline	0	0.00	0 - 0	0.00 - 0.00
		Current NAAQS	0	0.00	0 - 0	0.00 - 0.00
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	3,715	2.78	0 - 8,585	0.00 - 6.43
		8H1EX-90	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	11,250	8.42	5,625 - 22,866	4.21 - 17.11
		8H5EX-80	1,157	0.87	0 - 4,108	0.00 - 3.07
New York	782,600	Baseline	284,741	36.38	262,297 - 315,800	33.52 - 40.35
		Current NAAQS	905	0.12	0 - 2,030	0.00 - 0.26
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	11,074	1.42	2,353 - 17,134	0.30 - 2.19
		8H1EX-90	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	13,010	1.66	4,273 - 18,656	0.55 - 2.38
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00

TABLE 53 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Philadelphia	275,320	Baseline	193,608	70.32	181,224 - 205,873	65.82 - 74.78
		Current NAAQS	3,654	1.33	1,271 - 9,757	0.46 - 3.54
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	6,763	2.46	4,255 - 10,039	1.55 - 3.65
		8H1EX-90	42	0.02	0 - 423	0.00 - 0.15
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	2,842	1.03	152 - 6,260	0.06 - 2.27
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00
St. Louis	128,250	Baseline	3,932	3.07	2,268 - 6,338	1.77 - 4.94
		Current NAAQS	1,196	0.93	0 - 3,000	0.00 - 2.34
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	741	0.58	186 - 1,815	0.15 - 1.42
		8H1EX-90	68	0.05	0 - 547	0.00 - 0.43
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	3,383	2.64	1,193 - 6,252	0.93 - 4.87
		8H5EX-80	0	0.00	0 - 0	0.00 - 0.00

(continued)

TABLE 53 (Continued)

Study Area	Number of Persons at Risk	Regulatory Scenario	Mean		Range	
			Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Washington D.C.	198,860	Baseline	98,432	49.50	88,321 - 113,524	44.41 - 57.09
		Current NAAQS	5,294	2.66	657 - 10,154	0.33 - 5.11
		1H1EX-100	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-100	6,437	3.24	2,026 - 11,735	1.02 - 5.90
		8H1EX-90	658	0.33	0 - 4,335	0.00 - 2.18
		8H1EX-80	0	0.00	0 - 0	0.00 - 0.00
		8H1EX-70	0	0.00	0 - 0	0.00 - 0.00
		8H5EX-90	9,788	4.92	7,053 - 13,301	3.55 - 6.69
		8H5EX-80	75	0.04	0 - 355	0.00 - 0.18

7.4 Estimates of Maximum Dose Exposures

Each ozone exposure estimated by pNEM/O3 includes a value for ozone concentration and a value for EVR. The product of ozone concentration and EVR provides an indication of ozone dose. The "daily maximum dose" is assumed to occur each day during the period when this product is highest. Consistent with this concept, pNEM/O3 provides dose estimates for two averaging times: the one-hour maximum daily dose and the eight-hour daily maximum dose. Analysts selected two specific exposure indicators from these model outputs for further evaluation:

- The number of outdoor children who experienced one or more one-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.12 ppm (120 ppb) and the EVR equaled or exceeded 30 liters $\cdot$ $min^{-1} \cdot m^{-2}$.

- The number of outdoor children who experienced one or more eight-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.08 ppm (80 ppb) and the EVR ranged from 13 liters $\cdot$ $min^{-1} \cdot m^{-2}$ to 27 liters $\cdot$ $min^{-1} \cdot m^{-2}$.

Tables 54a through 71b present a summary of the exposure estimates based on these two indicators. The tables are grouped in pairs by study area; for example, Tables 54a,b and 55a,b present the one-hour and eight-hour dose estimates, respectively, for Chicago. Note that the values listed in each table consist of mean values and ranges based on 10 runs of pNEM/O3. Each table provides a separate set of estimates for each of the nine air quality scenarios discussed previously.

Tables 58a and 58b illustrate the general format used in all of the one-hour tables. The statistics in the first row are the 10-run mean estimates (by scenario) for the number of outdoor children in Houston who experienced one or more one-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.12 ppm and the EVR equaled or exceeded 30 liters $\cdot$ $min^{-1} \cdot m^{-2}$. Under baseline conditions, 18,374 outdoor children are estimated to have experienced the specified exposure. According to the value listed in the second row, 18,374 children

TABLE 54a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN CHICAGO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 $LITERS \cdot MIN^{-1} \cdot M^{-2}$

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	3,651	390	0
Percent of Total Outdoor Children Population	0.77	0.08	0.00
Range in this percentage for 10 runs	0.00-2.76	0.00-0.58	-
Mean Estimate of Person-Occurrences	3,651	390	0
Percent of Total Person-Occurrences	d	d	0.00
Range in this percentage for 10 runs	0.00-0.01	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-
Percentage exposed for indicated number of days			
1 Day	100.00	100.00	-
2 Days	0.00	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of $pNEM/O^3$.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 54b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN CHICAGO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	1,526	138	0	0	1,268	456
Percent of Total Outdoor Children Population	0.32	0.03	0.00	0.00	0.27	0.10
Range in this percentage for 10 runs	0.00-1.23	0.00-0.29	-	-	0.00-1.48	0.00-0.58
Mean Estimate of Person-Occurrences	1,526	138	0	0	1,268	456
Percent of Total Person-Occurrences	d	d	0.00	0.00	d	d
Range in this percentage for 10 runs	0.00-0.01	e	-	-	0.00-0.01	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-	-	1.00	1.00
Percentage exposed for indicated number of days						
1 Day	100.00	100.00	-	-	100.00	100.00
2 Days	0.00	0.00	-	-	0.00	0.00
>2 Days	0.00	0.00	-	-	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 55a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN CHICAGO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ $MIN^{-1} \cdot M^{-2}$ TO 27 LITERS $\cdot$ $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	128,451	41,435	527
Percent of Total Outdoor Children Population	27.17	8.77	0.11
Range in this percentage for 10 runs	18.08-34.59	6.94-11.38	0.00-0.27
Mean Estimate of Person-Occurrences	157,505	45,280	527
Percent of Total Person-Occurrences	0.16	0.04	d
Range in this percentage for 10 runs	0.10-0.20	0.03-0.06	e
Mean Estimate of Occurrences/Person Exposed	1.23	1.09	1.00
Percentage exposed for indicated number of days			
1 Day	81.26	91.85	100.00
2 Days	15.65	7.33	0.00
3 Days	2.71	0.83	0.00
>3 Days	0.38	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 55b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN CHICAGO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	93,077	31,445	1,570	0	109,660	34,651
Percent of Total Outdoor Children Population	19.69	6.65	0.33	0.00	23.20	7.33
Range in this percentage for 10 runs	15.29-24.08	3.74-12.81	0.00-1.14	-	16.82-32.71	4.34-11.34
Mean Estimate of Person-Occurrences	115,045	33,033	1,570	0	134,610	36,388
Percent of Total Person-Occurrences	0.11	0.03	d	0.00	0.13	0.04
Range in this percentage for 10 runs	0.08-0.15	0.02-0.06	0.00-0.01	-	0.10-0.18	0.02-0.06
Mean Estimate of Occurrences/Person Exposed	1.24	1.05	1.00	-	1.23	1.05
Percentage exposed for indicated number of days						
1 Day	79.68	94.47	100.00	-	80.32	96.31
2 Days	17.96	5.53	0.00	-	17.02	2.63
3 Days	1.82	0.00	0.00	-	1.81	1.07
>3 Days	0.55	0.00	0.00	-	0.85	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 56a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN DENVER DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	34	12	0
Percent of Total Outdoor Children Population	0.03	0.01	0.00
Range in this percentage for 10 runs	0.00-0.32	0.00-0.11	-
Mean Estimate of Person-Occurrences	34	12	0
Percent of Total Person-Occurrences	d	d	0.00
Range in this percentage for 10 runs	e	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-
Percentage exposed for indicated number of days			
1 Day	100.00	100.00	-
2 Days	0.00	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 56b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN DENVER DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS$\cdot$MIN$^{-1}\cdot$M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	818	71	32	0	246	87
Percent of Total Outdoor Children Population	0.77	0.07	0.03	0.00	0.23	0.08
Range in this percentage for 10 runs	0.00-2.07	0.00-0.42	0.00-0.30	-	0.00-1.49	0.00-0.39
Mean Estimate of Person-Occurrences	818	71	32	0	246	87
Percent of Total Person-Occurrences	d	d	d	0.00	d	d
Range in this percentage for 10 runs	0.00-0.01	e	e	-	0.00-0.01	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	1.00	-	1.00	1.00
Percentage exposed for indicated number of days						
1 Day	100.00	100.00	100.00	-	100.00	100.00
2 Days	0.00	0.00	0.00	-	0.00	0.00
>2 Days	0.00	0.00	0.00	-	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 57a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN DENVER DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	4,877	10,961	378
Percent of Total Outdoor Children Population	4.57	10.28	0.35
Range in this percentage for 10 runs	2.07-6.86	5.46-16.38	0.00-1.65
Mean Estimate of Person-Occurrences	5,456	12,533	378
Percent of Total Person-Occurrences	0.02	0.05	d
Range in this percentage for 10 runs	0.01-0.04	0.03-0.08	0.00-0.01
Mean Estimate of Occurrences/Person Exposed	1.12	1.14	1.00
Percentage exposed for indicated number of days			
1 Day	87.44	86.64	100.00
2 Days	12.56	12.69	0.00
3 Days	0.00	0.56	0.00
>3 Days	0.00	0.11	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.

TABLE 57b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN DENVER DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	32,522	16,734	2,020	0	10,844	2,309
Percent of Total Outdoor Children Population	30.49	15.69	1.89	0.00	10.17	2.16
Range in this percentage for 10 runs	26.34-34.52	10.78-21.65	0.42-3.73	-	5.46-14.27	0.15-5.78
Mean Estimate of Person-Occurrences	55,103	20,018	2,020	0	13,575	2,437
Percent of Total Person-Occurrences	0.24	0.09	0.01	0.00	0.06	0.01
Range in this percentage for 10 runs	0.21-0.29	0.05-0.14	0.00-0.02	-	0.04-0.08	0.00-0.03
Mean Estimate of Occurrences/Person Exposed	1.69	1.20	1.00	-	1.25	1.06
Percentage exposed for indicated number of days						
1 Day	54.26	80.65	100.00	-	79.68	95.35
2 Days	26.87	19.07	0.00	-	14.53	4.65
3 Days	14.31	0.28	0.00	-	4.64	0.00
>3 Days	4.56	0.00	0.00	-	1.15	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.

TABLE 58a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN HOUSTON DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	18,374	299	0
Percent of Total Outdoor Children Population	9.15	0.15	0.00
Range in this percentage for 10 runs	6.50-11.64	0.00-1.05	-
Mean Estimate of Person-Occurrences	18,666	299	0
Percent of Total Person-Occurrences	0.03	[d]	0.00
Range in this percentage for 10 runs	0.02-0.03	[e]	-
Mean Estimate of Occurrences/Person Exposed	1.02	1.00	-
Percentage exposed for indicated number of days			
1 Day	98.71	100.00	-
2 Days	1.29	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 58b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN HOUSTON DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	1,452	358	74	0	799	452
Percent of Total Outdoor Children Population	0.72	0.18	0.04	0.00	0.40	0.23
Range in this percentage for 10 runs	0.00-2.91	0.00-0.64	0.00-0.37	-	0.00-1.05	0.00-1.41
Mean Estimate of Person-Occurrences	1,452	358	74	0	799	452
Percent of Total Person-Occurrences	d	d	d	0.00	d	d
Range in this percentage for 10 runs	0.00-0.01	e	e	-	e	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	1.00	-	1.00	1.00
Percentage exposed for indicated number of days						
1 Day	100.00	100.00	100.00	-	100.00	100.00
2 Days	0.00	0.00	0.00	-	0.00	0.00
>2 Days	0.00	0.00	0.00	-	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 59a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN HOUSTON DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · MIN^{-1} · M^{-2} TO 27 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	137,146	11,457	383
Percent of Total Outdoor Children Population	68.30	5.71	0.19
Range in this percentage for 10 runs	60.51-75.57	3.65-9.95	0.00-0.74
Mean Estimate of Person-Occurrences	345,211	11,550	383
Percent of Total Person-Occurrences	0.47	0.02	d
Range in this percentage for 10 runs	0.40-0.54	0.01-0.03	e
Mean Estimate of Occurrences/Person Exposed	2.52	1.01	1.00
Percentage exposed for indicated number of days			
1 Day	28.18	99.48	100.00
2 Days	28.11	0.52	0.00
3 Days	21.68	0.00	0.00
>3 Days	22.03	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 59b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN HOUSTON DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	38,544	13,798	2,640	204	49,320	16,331
Percent of Total Outdoor Children Population	19.20	6.87	1.31	0.10	24.56	8.13
Range in this percentage for 10 runs	12.28-25.77	4.59-11.46	0.00-3.77	0.00-0.64	15.76-30.46	4.61-12.24
Mean Estimate of Person-Occurrences	47,923	14,552	2,640	204	58,454	17,113
Percent of Total Person-Occurrences	0.07	0.02	d	d	0.08	0.02
Range in this percentage for 10 runs	0.04-0.09	0.01-0.03	0.00-0.01	e	0.05-0.10	0.01-0.04
Mean Estimate of Occurrences/Person Exposed	1.24	1.05	1.00	1.00	1.19	1.05
Percentage exposed for indicated number of days						
1 Day	79.31	95.06	100.00	100.00	82.47	95.93
2 Days	17.57	4.94	0.00	0.00	15.83	4.07
3 Days	2.66	0.00	0.00	0.00	1.65	0.00
>3 Days	0.47	0.00	0.00	0.00	0.05	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 60a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN LOS ANGELES DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	132,648	114	0
Percent of Total Outdoor Children Population	16.62	0.01	0.00
Range in this percentage for 10 runs	11.62-22.08	0.14	-
Mean Estimate of Person-Occurrences	175,884	114	0
Percent of Total Person-Occurrences	0.06	d	0.00
Range in this percentage for 10 runs	0.05-0.08	e	-
Mean Estimate of Occurrences/Person Exposed	1.33	1.00	-
Percentage exposed for indicated number of days			
1 Day	74.18	100.00	-
2 Days	19.19	0.00	-
>2 Days	6.62	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 60b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN LOS ANGELES DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	6,029	622	114	0	2,418	332
Percent of Total Outdoor Children Population	0.76	0.08	0.01	0.00	0.30	0.04
Range in this percentage for 10 runs	0.32-1.31	0.00-0.27	0.00-0.14	-	0.00-0.84	0.00-0.14
Mean Estimate of Person-Occurrences	6,029	622	114	0	2,532	332
Percent of Total Person-Occurrences	d	d	d	0.00	d	d
Range in this percentage for 10 runs	e	e	e	-	e	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	1.00	-	1.05	1.00
Percentage exposed for indicated number of days						
1 Day	100.00	100.00	100.00	-	94.87	100.00
2 Days	0.00	0.00	0.00	-	5.13	0.00
>2 Days	0.00	0.00	0.00	-	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 61a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN LOS ANGELES DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	496,472	7,584	0
Percent of Total Outdoor Children Population	62.19	0.95	0.00
Range in this percentage for 10 runs	59.20-64.60	0.30-1.55	-
Mean Estimate of Person-Occurrences	3,365,193	7,698	0
Percent of Total Person-Occurrences	1.15	d	0.00
Range in this percentage for 10 runs	1.12-1.19	e	-
Mean Estimate of Occurrences/Person Exposed	6.78	1.02	-
Percentage exposed for indicated number of days			
1 Day	24.51	98.77	-
2 Days	12.75	1.23	-
3 Days	9.00	0.00	-
>3 Days	53.73	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 61b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN LOS ANGELES DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	90,651	33,994	4,634	0	48,837	11,486
Percent of Total Outdoor Children Population	11.36	4.26	0.58	0.00	6.12	1.44
Range in this percentage for 10 runs	9.02-13.10	3.22-6.53	0.14-1.07	-	5.63-7.05	0.60-2.46
Mean Estimate of Person-Occurrences	147,532	41,661	4,634	0	70,829	13,800
Percent of Total Person-Occurrences	0.05	0.01	d	0.00	0.02	d
Range in this percentage for 10 runs	0.04-0.06	0.01-0.02	e	-	0.02-0.03	e
Mean Estimate of Occurrences/Person Exposed	1.63	1.23	1.00	-	1.45	1.20
Percentage exposed for indicated number of days						
1 Day	58.60	80.53	100.00	0.00	67.02	82.94
2 Days	26.61	16.98	0.00	0.00	23.79	12.40
3 Days	9.45	2.20	0.00	0.00	6.24	4.66
>3 Days	5.34	0.29	0.00	0.00	2.95	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 62a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN MIAMI DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	0	27	0
Percent of Total Outdoor Children Population	0.00	0.02	0.00
Range in this percentage for 10 runs	-	0.00-0.20	-
Mean Estimate of Person-Occurrences	0	27	0
Percent of Total Person-Occurrences	0.00	d	0.00
Range in this percentage for 10 runs	-	e	-
Mean Estimate of Occurrences/Person Exposed	-	1.00	-
Percentage exposed for indicated number of days			
1 Day	-	100.00	-
2 Days	-	0.00	-
>2 Days	-	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 62b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN MIAMI DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	850	140	0	0	1,306	28
Percent of Total Outdoor Children Population	0.64	0.10	0.00	0.00	0.98	0.02
Range in this percentage for 10 runs	0.00-2.10	0.00-1.05	-	-	0.00-2.07	0.00-0.20
Mean Estimate of Person-Occurrences	850	140	0	0	1,306	28
Percent of Total Person-Occurrences	d	d	0.00	0.00	d	d
Range in this percentage for 10 runs	0.00-0.01	e	-	-	0.00-0.01	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-	-	1.00	1.00
Percentage exposed for indicated number of days						
1 Day	100.00	100.00	-	-	100.00	100.00
2 Days	0.00	0.00	-	-	0.00	0.00
>2 Days	0.00	0.00	-	-	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 63a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN MIAMI DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	625	5,709	149
Percent of Total Outdoor Children Population	0.47	4.27	0.11
Range in this percentage for 10 runs	0.00-2.17	1.35-8.60	0.00-0.56
Mean Estimate of Person-Occurrences	625	5,867	149
Percent of Total Person-Occurrences	d	0.01	d
Range in this percentage for 10 runs	0.00-0.01	0.00-0.02	e
Mean Estimate of Occurrences/Person Exposed	1.00	1.03	1.00
Percentage exposed for indicated number of days			
1 Day	100.00	97.75	100.00
2 Days	0.00	2.25	0.00
3 Days	0.00	0.00	0.00
>3 Days	0.00	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 63b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN MIAMI DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	24,674	9,106	1,040	0	33,040	15,672
Percent of Total Outdoor Children Population	18.47	6.82	0.78	0.00	24.73	11.73
Range in this percentage for 10 runs	11.26-28.49	1.99-12.02	0.00-4.61	-	17.18-30.34	8.21-16.76
Mean Estimate of Person-Occurrences	30,049	10,352	1,040	0	41,357	16,042
Percent of Total Person-Occurrences	0.06	0.02	d	0.00	0.08	0.03
Range in this percentage for 10 runs	0.03-0.08	0.01-0.04	0.00-0.01	-	0.06-0.10	0.02-0.05
Mean Estimate of Occurrences/Person Exposed	1.22	1.14	1.00	-	1.25	1.02
Percentage exposed for indicated number of days						
1 Day	81.34	87.89	100.00	-	78.43	98.05
2 Days	14.44	12.11	0.00	-	18.54	1.95
3 Days	4.22	0.00	0.00	-	2.56	0.00
>3 Days	0.00	0.00	0.00	-	0.47	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.

TABLE 64a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN NEW YORK DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	9,979	164	0
Percent of Total Outdoor Children Population	1.28	0.02	0.00
Range in this percentage for 10 runs	0.60-2.26	0.18	-
Mean Estimate of Person-Occurrences	10,295	164	0
Percent of Total Person-Occurrences	0.01	d	0.00
Range in this percentage for 10 runs	0.00-0.01	e	-
Mean Estimate of Occurrences/Person Exposed	1.03	1.00	-
Percentage exposed for indicated number of days			
1 Day	96.19	100.00	-
2 Days	3.81	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 64b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN NEW YORK DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	1,612	0	0	0	172	0
Percent of Total Outdoor Children Population	0.21	0.00	0.00	0.00	0.02	0.00
Range in this percentage for 10 runs	0.00-1.05	-	-	-	0.00-0.12	-
Mean Estimate of Person-Occurrences	1,612	0	0	0	172	0
Percent of Total Person-Occurrences	d	0.00	0.00	0.00	d	0.00
Range in this percentage for 10 runs	e	-	-	-	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	-	-	-	1.00	-
Percentage exposed for indicated number of days						
1 Day	100.00	-	-	-	100.00	-
2 Days	0.00	-	-	-	0.00	-
>2 Days	0.00	-	-	-	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 65a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN NEW YORK DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	321,060	42,144	1,940
Percent of Total Outdoor Children Population	41.02	5.39	0.25
Range in this percentage for 10 runs	37.70-43.20	3.89-6.34	0.03-0.56
Mean Estimate of Person-Occurrences	722,616	52,207	1,940
Percent of Total Person-Occurrences	0.43	0.03	d
Range in this percentage for 10 runs	0.41-0.46	0.02-0.04	e
Mean Estimate of Occurrences/Person Exposed	2.25	1.24	1.00
Percentage exposed for indicated number of days			
1 Day	41.74	79.90	100.00
2 Days	24.12	16.48	0.00
3 Days	16.27	3.32	0.00
>3 Days	17.87	0.29	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 65b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN NEW YORK DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · $MIN^{-1} \cdot M^{-2}$ TO 27 LITERS · $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	108,048	29,435	1,410	0	68,244	16,372
Percent of Total Outdoor Children Population	13.81	3.76	0.18	0.00	8.72	2.09
Range in this percentage for 10 runs	11.31-18.03	2.37-5.74	0.00-0.51	-	6.76-10.30	1.00-3.12
Mean Estimate of Person-Occurrences	152,315	32,104	1,410	0	93,597	16,938
Percent of Total Person-Occurrences	0.09	0.02	d	0.00	0.06	0.01
Range in this percentage for 10 runs	0.07-0.11	0.01-0.03	e	-	0.04-0.08	0.00-0.01
Mean Estimate of Occurrences/Person Exposed	1.41	1.09	1.00	-	1.37	1.03
Percentage exposed for indicated number of days						
1 Day	68.51	91.84	100.00	-	69.33	96.47
2 Days	23.05	7.52	0.00	-	25.41	3.53
3 Days	6.52	0.64	0.00	-	4.52	0.00
>3 Days	1.92	0.00	0.00	-	0.74	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 66a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN PHILADELPHIA DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	9,676	81	0
Percent of Total Outdoor Children Population	3.51	0.03	0.00
Range in this percentage for 10 runs	1.26-5.78	0.00-0.15	-
Mean Estimate of Person-Occurrences	10,136	81	0
Percent of Total Person-Occurrences	0.02	d	0.00
Range in this percentage for 10 runs	0.01-0.03	e	-
Mean Estimate of Occurrences/Person Exposed	1.05	1.00	-
Percentage exposed for indicated number of days			
1 Day	94.74	100.00	-
2 Days	5.26	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 66b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN PHILADELPHIA DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	139	0	0	0	0	0
Percent of Total Outdoor Children Population	0.05	0.00	0.00	0.00	0.00	0.00
Range in this percentage for 10 runs	0.00-0.21	-	-	-	-	-
Mean Estimate of Person-Occurrences	139	0	0	0	0	0
Percent of Total Person-Occurrences	d	0.00	0.00	0.00	0.00	0.00
Range in this percentage for 10 runs	e	-	-	-	-	-
Mean Estimate of Occurrences/Person Exposed	1.00	-	-	-	-	-
Percentage exposed for indicated number of days						
1 Day	100.00	-	-	-	-	-
2 Days	0.00	-	-	-	-	-
>2 Days	0.00	-	-	-	-	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 67a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN PHILADELPHIA DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	186,273	58,377	7,500
Percent of Total Outdoor Children Population	67.66	21.20	2.72
Range in this percentage for 10 runs	65.59-70.18	18.67-24.29	1.11-4.44
Mean Estimate of Person-Occurrences	580,171	79,318	7,698
Percent of Total Person-Occurrences	0.98	0.13	0.01
Range in this percentage for 10 runs	0.89-1.10	0.12-0.17	0.01-0.02
Mean Estimate of Occurrences/Person Exposed	3.12	1.36	1.03
Percentage exposed for indicated number of days			
1 Day	21.59	74.07	97.07
2 Days	22.11	19.01	2.93
3 Days	20.98	4.41	0.00
>3 Days	35.32	2.51	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.

TABLE 67b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN PHILADELPHIA DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · MIN^{-1} · M^{-2} TO 27 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	68,765	17,971	1,634	0	50,283	6,182
Percent of Total Outdoor Children Population	24.98	6.53	0.59	0.00	18.26	2.25
Range in this percentage for 10 runs	20.88-30.23	4.32-10.65	0.12-2.27	-	15.05-21.82	0.91-4.83
Mean Estimate of Person-Occurrences	98,111	20,342	1,634	0	65,900	7,087
Percent of Total Person-Occurrences	0.17	0.03	d	0.00	0.11	0.01
Range in this percentage for 10 runs	0.14-0.20	0.02-0.06	0.00-0.01	-	0.08-0.14	0.00-0.02
Mean Estimate of Occurrences/Person Exposed	1.43	1.13	1.00	-	1.31	1.15
Percentage exposed for indicated number of days						
1 Day	69.98	87.77	100.00	-	75.47	85.64
2 Days	19.55	11.87	0.00	-	20.44	14.36
3 Days	8.87	0.37	0.00	-	2.45	0.00
>3 Days	1.60	0.00	0.00	-	1.64	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.

TABLE 68a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN ST. LOUIS DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	550	107	0
Percent of Total Outdoor Children Population	0.43	0.08	0.00
Range in this percentage for 10 runs	0.00-1.39	0.00-0.41	-
Mean Estimate of Person-Occurrences	550	107	0
Percent of Total Person-Occurrences	d	d	0.00
Range in this percentage for 10 runs	0.00-0.01	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-
Percentage exposed for indicated number of days			
1 Day	100.00	100.00	-
2 Days	0.00	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 68b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN ST. LOUIS DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	145	0	0	0	112	0
Percent of Total Outdoor Children Population	0.11	0.00	0.00	0.00	0.09	0.00
Range in this percentage for 10 runs	0.00-1.13	-	-	-	0.00-0.27	-
Mean Estimate of Person-Occurrences	145	0	0	0	112	0
Percent of Total Person-Occurrences	d	0.00	0.00	0.00	d	0.00
Range in this percentage for 10 runs	0.00-0.01	-	-	-	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	-	-	-	1.00	-
Percentage exposed for indicated number of days						
1 Day	100.00	-	-	-	100.00	-
2 Days	0.00	-	-	-	0.00	-
>2 Days	0.00	-	-	-	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 69a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN ST. LOUIS DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	20,607	20,205	1,264
Percent of Total Outdoor Children Population	16.07	15.75	0.99
Range in this percentage for 10 runs	12.25-19.96	12.14-18.23	0.00-2.32
Mean Estimate of Person-Occurrences	25,729	28,249	1,264
Percent of Total Person-Occurrences	0.09	0.10	d
Range in this percentage for 10 runs	0.07-0.13	0.07-0.14	0.00-0.01
Mean Estimate of Occurrences/Person Exposed	1.25	1.40	1.00
Percentage exposed for indicated number of days			
1 Day	78.96	70.78	100.00
2 Days	18.06	22.97	0.00
3 Days	2.80	3.37	0.00
>3 Days	0.19	2.89	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.
[d]Less than 0.01 percent.

TABLE 69b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN ST. LOUIS DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	19,910	3,980	19	0	28,486	6,844
Percent of Total Outdoor Children Population	15.52	3.10	0.01	0.00	22.21	5.34
Range in this percentage for 10 runs	12.67-17.48	1.74-4.62	0.00-0.15	-	18.94-30.58	2.21-8.38
Mean Estimate of Person-Occurrences	24,730	4,163	19	0	39,291	7,496
Percent of Total Person-Occurrences	0.09	0.02	d	0.00	0.14	0.03
Range in this percentage for 10 runs	0.07-0.11	0.01-0.02	e	-	0.13-0.19	0.01-0.04
Mean Estimate of Occurrences/Person Exposed	1.24	1.05	1.00	-	1.38	1.10
Percentage exposed for indicated number of days						
1 Day	81.45	94.38	100.00	-	70.26	91.59
2 Days	14.23	5.62	0.00	-	21.80	7.96
3 Days	2.99	0.00	0.00	-	7.37	0.45
>3 Days	1.32	0.00	0.00	-	0.58	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 70a. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN WASHINGTON D.C. DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	3,626	36	0
Percent of Total Outdoor Children Population	1.82	0.02	0.00
Range in this percentage for 10 runs	0.49-3.54	0.00-0.18	-
Mean Estimate of Person-Occurrences	3,626	36	0
Percent of Total Person-Occurrences	0.01	d	0.00
Range in this percentage for 10 runs	0.00-0.02	e	-
Mean Estimate of Occurrences/Person Exposed	1.00	1.00	-
Percentage exposed for indicated number of days			
1 Day	100.00	100.00	-
2 Days	0.00	0.00	-
>2 Days	0.00	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Current NAAQS.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 70b. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN WASHINGTON D.C. DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	0	0	0	0	321	0
Percent of Total Outdoor Children Population	0.00	0.00	0.00	0.00	0.16	0.00
Range in this percentage for 10 runs	-	-	-	-	0.00-0.66	-
Mean Estimate of Person-Occurrences	0	0	0	0	321	0
Percent of Total Person-Occurrences	0.00	0.00	0.00	0.00	d	0.00
Range in this percentage for 10 runs	-	-	-	-	e	-
Mean Estimate of Occurrences/Person Exposed	-	-	-	-	1.00	-
Percentage exposed for indicated number of days						
1 Day	-	-	-	-	100.00	-
2 Days	-	-	-	-	0.00	-
>2 Days	-	-	-	-	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O[3].
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

TABLE 71a. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN WASHINGTON D.C. DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2} TO 27 LITERS $\cdot$ MIN^{-1} $\cdot$ M^{-2}

Statistic[b]	Regulatory scenario		
	Baseline	1H1EX-120[c]	1H1EX-100
Mean Estimate of the Number of Outdoor Children	111,887	25,108	2,926
Percent of Total Outdoor Children Population	56.26	12.63	1.47
Range in this percentage for 10 runs	52.88-61.87	9.10-15.10	0.18-2.93
Mean Estimate of Person-Occurrences	256,997	35,069	2,998
Percent of Total Person-Occurrences	0.60	0.08	0.01
Range in this percentage for 10 runs	0.57-0.63	0.07-0.10	0.00-0.01
Mean Estimate of Occurrences/Person Exposed	2.30	1.40	1.02
Percentage exposed for indicated number of days			
1 Day	36.81	72.01	97.65
2 Days	28.12	16.14	2.35
3 Days	17.97	10.03	0.00
>3 Days	17.10	1.81	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[c]Current NAAQS.

TABLE 71b. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN IN WASHINGTON D.C. DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · MIN^{-1} · M^{-2} TO 27 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Regulatory scenario					
	8H1EX-100	8H1EX-90	8H1EX-80	8H1EX-70	8H5EX-90	8H5EX-80
Mean Estimate of the Number of Outdoor Children	31,209	10,353	2,043	36	44,110	8,284
Percent of Total Outdoor Children Population	15.69	5.21	1.03	0.02	22.18	4.17
Range in this percentage for 10 runs	13.92-17.68	2.37-7.14	0.00-2.35	0.00-0.18	18.20-27.89	0.97-8.37
Mean Estimate of Person-Occurrences	47,544	12,219	2,043	36	57,474	8,635
Percent of Total Person-Occurrences	0.11	0.03	d	d	0.14	0.02
Range in this percentage for 10 runs	0.09-0.14	0.02-0.04	0.00-0.01	e	0.11-0.18	0.00-0.04
Mean Estimate of Occurrences/Person Exposed	1.52	1.18	1.00	1.00	1.30	1.04
Percentage exposed for indicated number of days						
1 Day	66.31	83.03	100.00	100.00	75.76	95.41
2 Days	21.13	13.56	0.00	0.00	20.29	4.59
3 Days	8.00	2.65	0.00	0.00	2.43	0.00
>3 Days	4.56	0.76	0.00	0.00	1.52	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.
[d]Less than 0.01 percent.
[e]All values less than 0.01 percent.

comprise 9.15 percent of the total outdoor children population in Houston. Entries in the third row indicate that the percentage values ranged from 6.50 to 11.64 percent over the 10 runs.

The fourth row in Tables 58a and 58b lists 10-run mean estimates for the number of person-occurrences in which an outdoor child in Houston experienced a one-hour maximum daily dosage exposure during which the ozone concentration exceeded 0.12 ppm and the EVR equaled or exceeded 30 liters $\cdot$ $min^{-1} \cdot m^{-2}$. As each child can experience more than one person-occurrence during the Houston ozone season, the estimated number of person-occurrences can exceed the number of persons exposed at the specified levels. Under baseline conditions, for example, the 10-run mean for person-occurrences (18,666) is larger than the number of exposed children listed in the first row (18,374).

The total possible number of one-hour person-occurrences is equal to 73,290,175 -- the product of the number of Houston outdoor children (200,795) and the number of days in the Houston ozone season (365). According to the value listed in the fifth row of Table 58a, 18,666 person-occurrences is 0.03 percent of the total possible number of person-occurrences; that is, 18,666/73,290,175 = 0.03 percent. Entries in the sixth row of Table 58a indicate that the percentage values ranged from 0.02 to 0.03 percent over the 10 runs.

The seventh row in the table lists the ratio of person-occurrences to people exposed based on 10-run means. Under baseline conditions, the ratio is 18,666/18,374 or 1.02.

The last three rows in Table 58a provide exposure frequency statistics for outdoor children who experienced the specified exposure conditions on at least one day. Of the 18,374 outdoor children exposed under baseline conditions, 98.71 percent were exposed for one day only while 1.29 percent were exposed for exactly two days. No one was exposed for more than two days.

Tables 59a and 59b use this same general table format to present eight-hour daily maximum dosage estimates for Houston. The statistics in the first row are the 10-run mean estimates (by scenario) for the number of outdoor children in Houston who experienced one or more eight-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.08 ppm and the EVR ranged from 13 liters $\cdot$ min^{-1} $\cdot$ m^{-2} to 27 liters $\cdot$ min^{-1} $\cdot$ m^{-2}. Under baseline conditions, 137,146 outdoor children are estimated to have experienced the specified exposure. This value is equivalent to 68.30 percent of the total outdoor children population in Houston. The percentage values ranged from 60.51 to 75.57 percent over the 10 runs.

The fourth row in Tables 59a and 59b lists 10-run mean estimates for the number of person-occurrences in which an outdoor child in Houston experienced an eight-hour maximum daily dosage exposure during which the ozone concentration exceeded 0.08 ppm and the EVR ranged from 13 liters $\cdot$ min^{-1} $\cdot$ m^{-2} to 27 liters $\cdot$ min^{-1} $\cdot$ m^{-2}. The 10-run mean for person-occurrences under baseline conditions (345,211) is more than 2.5 times the number of exposed children listed in the first row (137,146).

Consistent with the one-hour analysis, the total possible number of eight-hour person-occurrences is equal to 73,290,175 -- the product of the number of Houston outdoor children (200,795) and the number of days in the Houston ozone season (365). According to the value listed in the fifth row of Table 59a, 345,211 person-occurrences is 0.47 percent of the total possible number of person-occurrences. The baseline percentage values ranged from 0.40 to 0.54 percent over the 10 runs.

The seventh row in Table 59a lists the ratio of person-occurrences to people exposed based on 10-run means. Under baseline conditions, the ratio is 345,211/137,146 or 2.52.

Table 59a concludes with four rows listing exposure frequency statistics for outdoor children who experienced the specified exposure conditions on at least one day. Of the 137,146 outdoor children exposed under baseline conditions, 28.18 percent were exposed for one day only, 28.11 percent were exposed for exactly two days, and 21.68 percent were exposed for exactly three days. The remaining 22.03 percent of the outdoor children were exposed for more than three days.

Figures 2a through 5b are graphs showing eight-hour daily maximum dose exposures for outdoor children under various air quality scenarios. Two graphs are provided for each of four study areas (Philadelphia, Houston, New York, and Washington). The graphs use two indicators to characterize ozone exposure:

- Number of children experiencing eight-hour daily maximum-dose exposures on one or more days under moderate exertion conditions,
- Number of occurrences in which a child experiences an eight-hour daily maximum dose exposure under moderate exertion conditions.

Moderate exertion conditions are defined as an EVR level between 13 and 27 liters $\cdot$ $min^{-1} \cdot m^{-2}$.

Figure 2a presents results for the first indicator (number of children) based on applications of pNEM/O3 to Philadelphia. Nine distributions are plotted on the graph: one for baseline ("as is") conditions; two for one-hour, one-exceedance standards (1112 and 1110); four for eight-hour, one-exceedance standards; and two for eight-hour, five-exceedance standards. The first digit in the code for each standard indicates the averaging time; the second digit specifies the number of exceedances. The last two digits indicate the ozone concentration of the standard expressed in pphm. For example, 8508 indicates an eight-hour five exceedance standard with ozone concentration equal to 8 pphm or 0.08 ppm.

The ordinate (y coordinate) of each point on the graph shows the number of children with one or more eight-hour daily maximum dose exposures equal to or above the ozone concentration indicated by the point's abscissa (x coordinate). In Figure 2a, the "as is" curve is associated with the highest number of children exposed when the specified ozone concentration falls between 0.05 ppm and 0.14 ppm. The nine curves tend to converge at lower and higher ozone concentrations. In a similar manner, the 8107 standard tends to be associated with lowest number of children exposed when the specified ozone concentration falls between 0.03 and 0.07 ppm.

Figures 2a through 5b provide eight-hour daily maximum dose distributions for exposures occurring under moderate exertion conditions (EVR values between

FIGURE 2a. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN PHILADELPHIA, PA

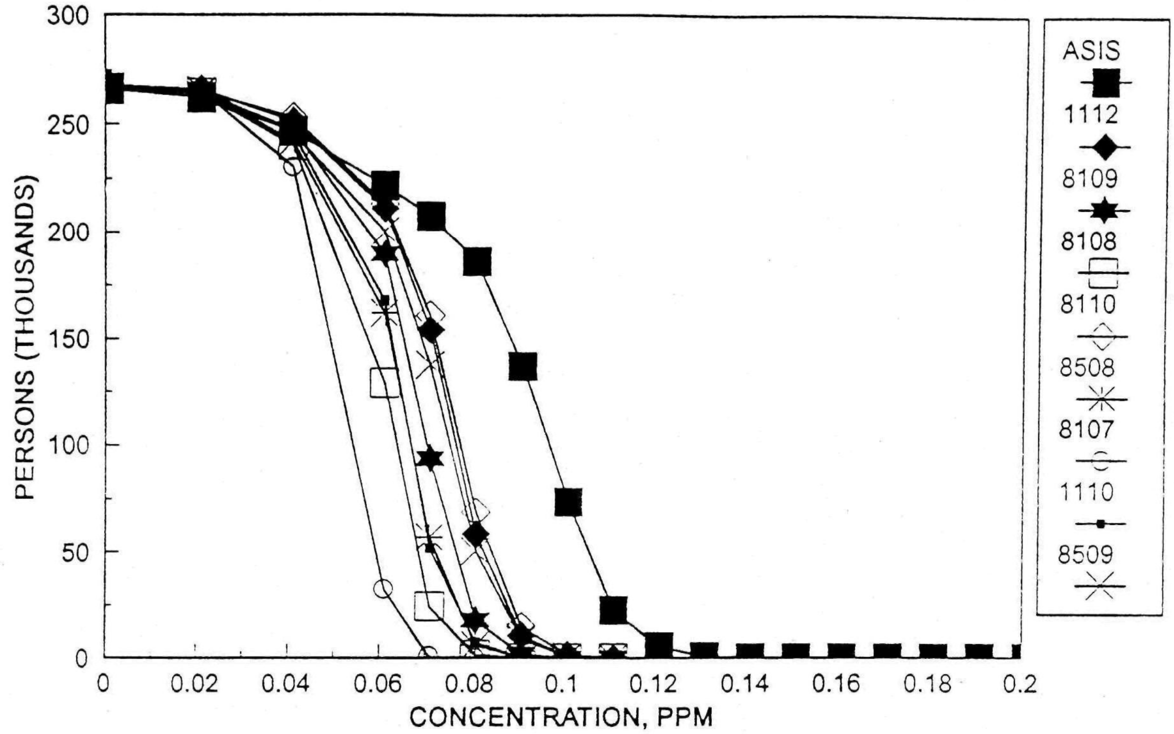


FIGURE 2b. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN PHILADELPHIA, PA

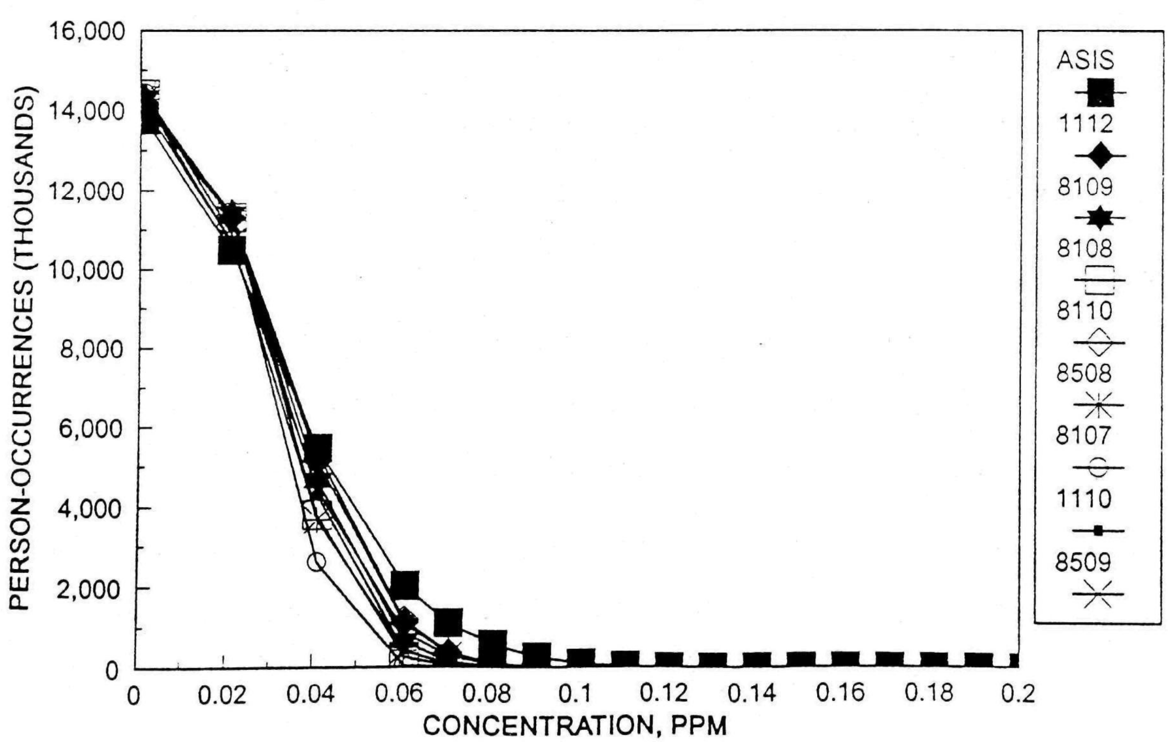


FIGURE 3a. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN HOUSTON, TX

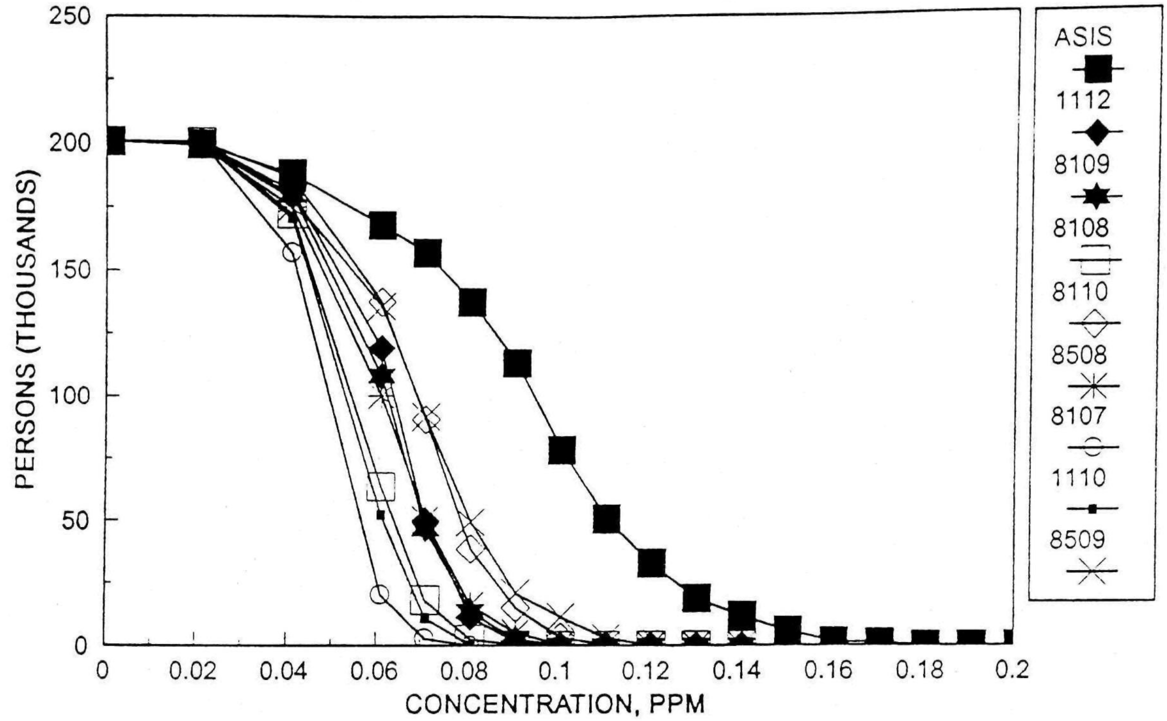


FIGURE 3b. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN HOUSTON, TX

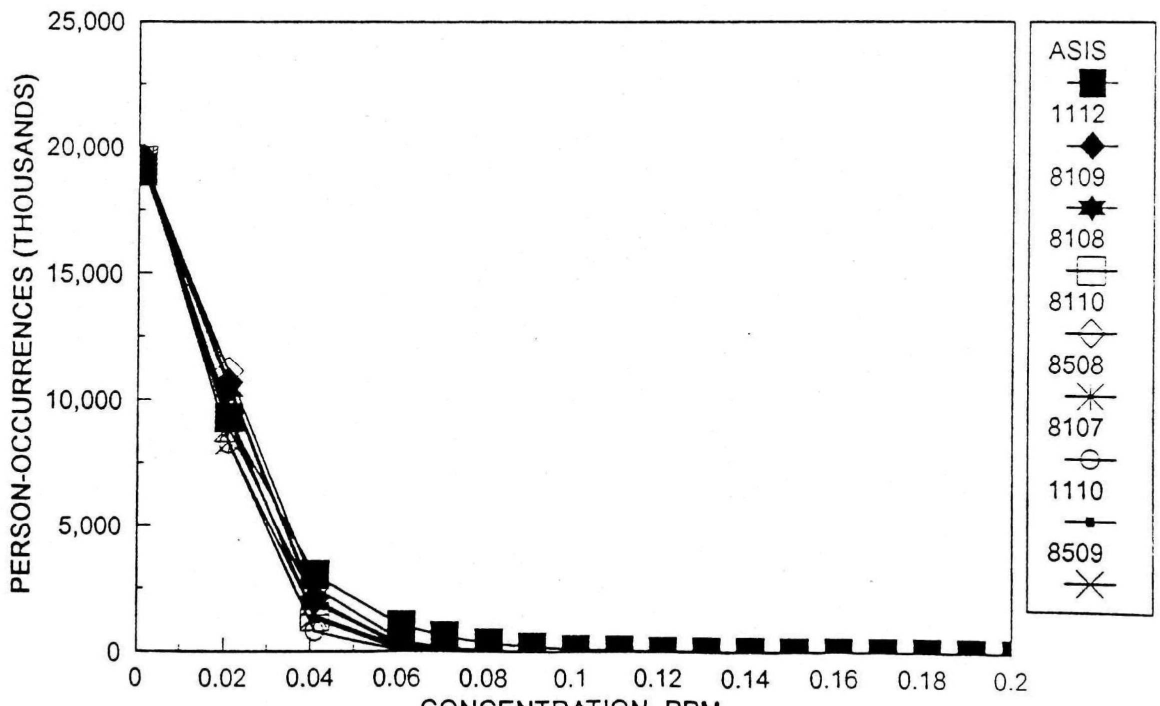


FIGURE 4a. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN NEW YORK, NY

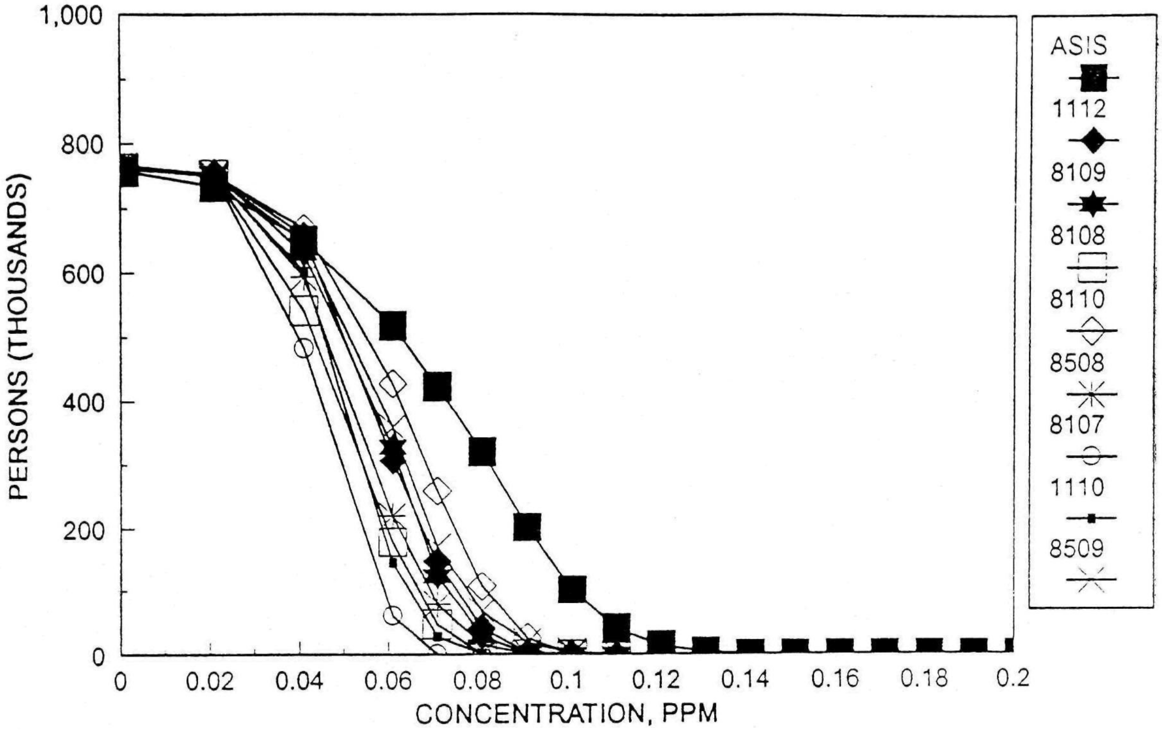


FIGURE 4b. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN NEW YORK, NY

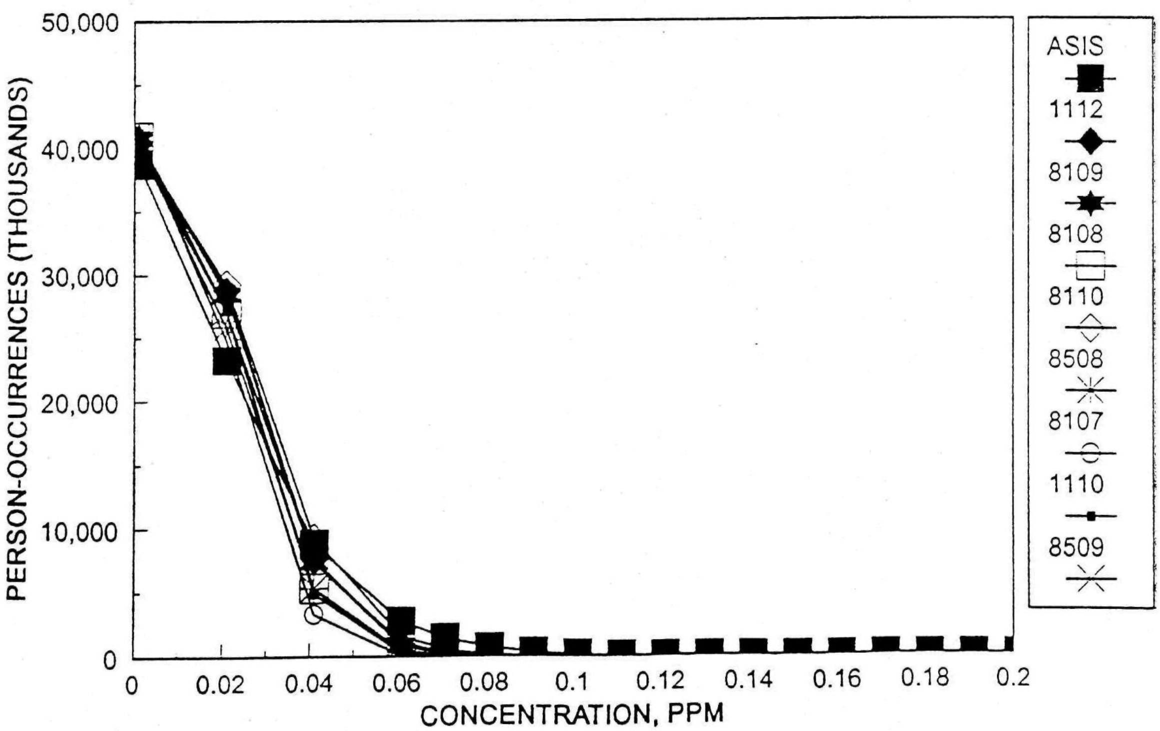


FIGURE 5a. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN WASHINGTON, D.C.

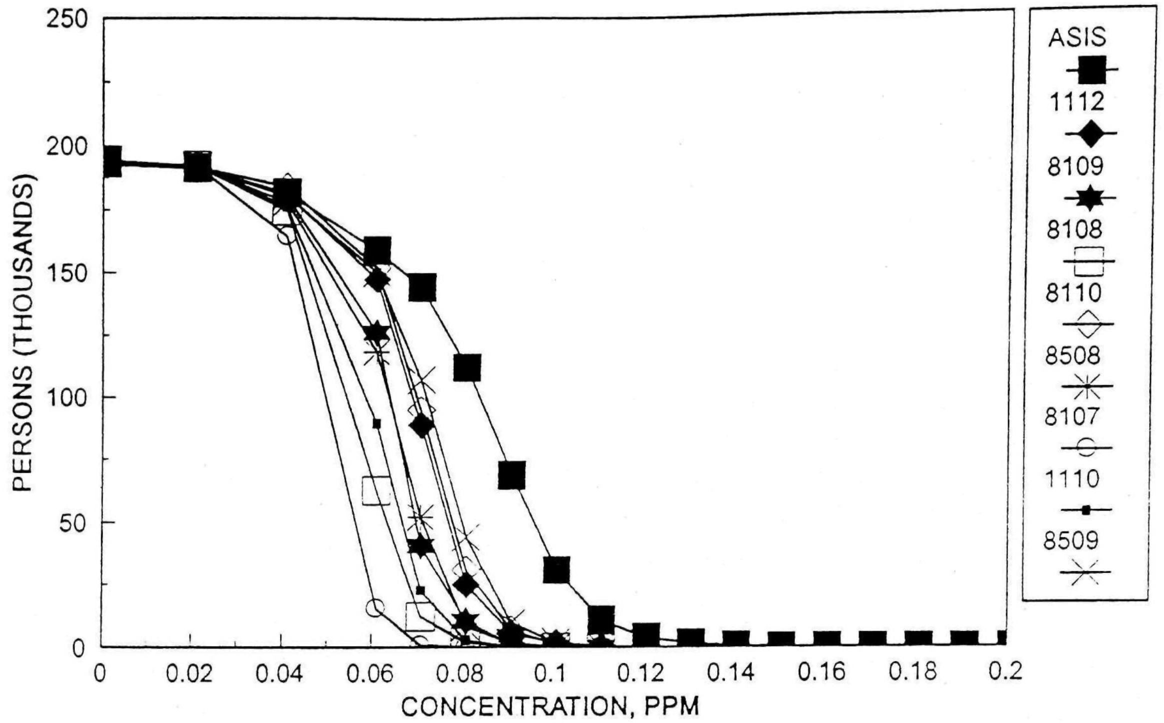
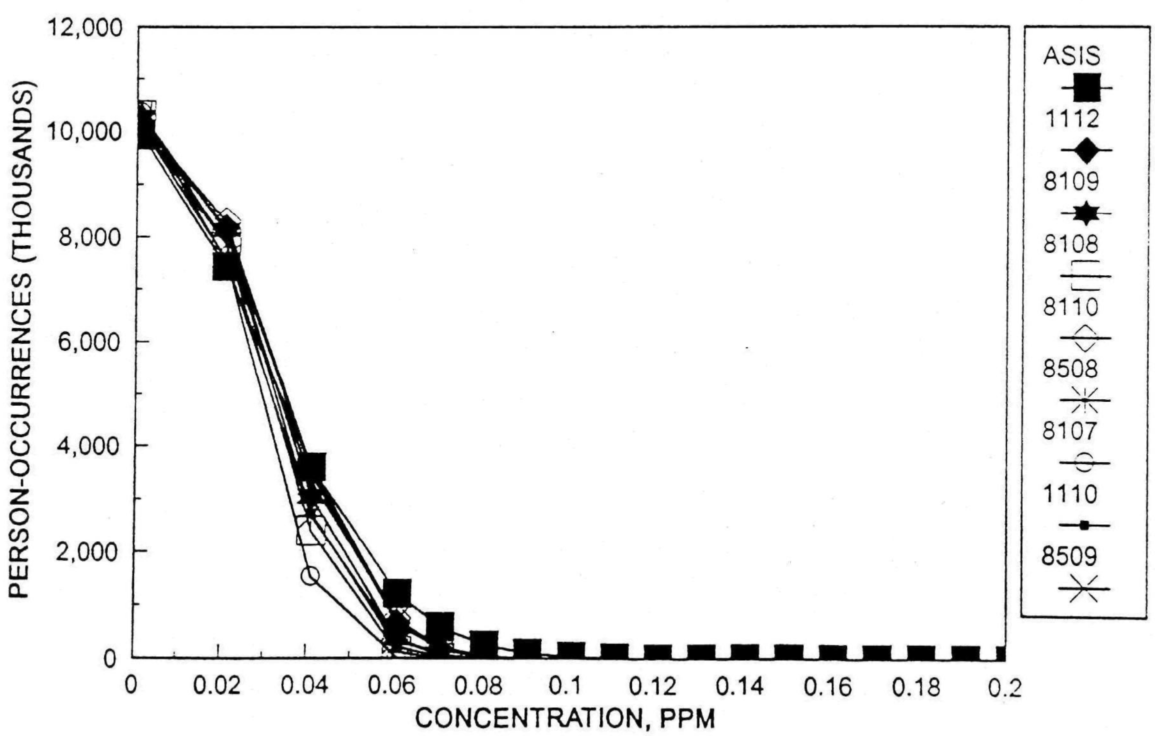


FIGURE 5b. EIGHT-HOUR DAILY MAXIMUM DOSE EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 13-27 LITERS/MIN-M2) IN WASHINGTON, D.C.



13 and 27 liters $\cdot$ min^{-1} $\cdot$ m^{-2}). Appendix E provides graphs for one-hour exposures for two other EVR ranges of interest to EPA: 16 to 30 liters $\cdot$ min^{-1} $\cdot$ m^{-2} and 30+ liters $\cdot$ min^{-1} $\cdot$ m^{-2}.

SECTION 8

PRINCIPAL LIMITATIONS OF THE pNEM/O3 METHODOLOGY

The pNEM/O3 methodology was developed specifically to meet the requirements of OAQPS for a computer-based model capable of simulating the ozone exposures of specific population groups under alternative NAAQS. In addition to meeting these needs, the designers of pNEM/O3 have attempted to create a model which is flexible in application and easy to upgrade. The model was deliberately constructed as a collection of stand-alone algorithms organized within a modular framework. For this reason, analysts can revise individual algorithms without the need to make major changes to other parts of the model.

The structure of each algorithm in pNEM/O3 is largely determined by the characteristics of the available input data. For example, the algorithm used to construct a season-long exposure event sequence for each cohort is constrained by the fact that none of the available time/activity studies provides more than three days of diary data for any one subject. To make maximum use of the available diary data, the pNEM/O3 sequencing algorithm constructs each exposure event sequence by sampling data from more than one subject. The other pNEM/O3 algorithms are similarly designed to make best use of available data bases.

In evaluating the exposure estimates presented in this report, the reader should note that the model has a number of limitations which may affect its accuracy. These limitations are usually the result of limitations in the input data bases. The available data were typically collected for purposes other than use in a population exposure model. Consequently, these data frequently represent special sets of conditions which differ from those assumed by pNEM/O3. In these situations, analysts must exercise a certain degree of judgement in adapting the data for use in pNEM/O3.

This section presents a brief discussion of the principal limitations in the pNEM/O3 methodology as applied to outdoor children. The limitations are organized according to five major components of the model: time/activity patterns, equivalent ventilation rates, air quality adjustment, the mass balance model, and the estimation of cohort populations.

Section 7 presented pNEM/O3 exposure estimates based on the assumption that a specified urban area just attained a particular standard. One of the standards under review (designated 8H5EX-80) stated that the expected exceedance rate for daily maximum 8-hour ozone concentrations above 80 ppb shall not be greater than five. To simulate this standard, the ozone data reported by the historical "high ozone" monitor for a specified year was adjusted so that the sixth highest daily maximum concentration equaled 80 ppb. Researchers assumed that this approach represented average attainment conditions when compliance was determined over a three-year period.

Subsection 8.6 presents results of alternative exposure assessments in which the data for the high ozone monitor were adjusted to permit 10 exceedances of 80 ppb. This scenario represents a reasonable upper-bound for the number of exceedances that could occur in any one year under the 8H5EX-80 standard when 16 exceedances are permitted to occur over a three-year period.

8.1 Time/Activity Patterns

In the general pNEM/O3 methodology, the exposure-related activities of each cohort are represented by a multi-day exposure event sequence which spans a specified ozone season. Each sequence is constructed by an algorithm which selects 24-hour (midnight-to-midnight) activity patterns from a specially prepared database. This database contains data from one or more time/activity studies in which subjects recorded their daily activities in diaries.

In the application of pNEM/O3 to outdoor children, the time/activity database consisted of diary data obtained from 479 subjects identified as outdoor children. The database contained 792 person-days of data, an average of slightly less than two days per subject. These data should adequately characterize the spectrum of activity patterns associated with outdoor children.

The subjects who contributed to this database may not provide a balanced representation of U.S. outdoor children. The majority of subjects (97 percent) resided in either the State of California (337 subjects) or in Cincinnati (130 subjects). Three subjects resided in Washington, DC, and nine subjects resided in Valdez, AK.

Random selection protocols were used in the selection of the 453 subjects who participated in the Cincinnati, Washington, and California studies. The remaining 26 subjects participated in the two Los Angeles studies and were solicited using non-random protocols.

Analysts used time/activity data obtained from these 479 subjects to represent the activities of outdoor children in nine study areas. Only two of these study areas (Washington and Los Angeles) were locations of diary studies which contributed time/activity data to the analysis. Although the algorithm which constructs exposure event sequences attempts to account for effects of local climate on activity, it is unlikely that this adjustment procedure corrects for all inter-city differences in children's activities. Time/activity patterns are likely to be affected by a variety of local factors, including topography, land-use, traffic patterns, mass transit systems, and recreational opportunities.

As discussed previously, the average subject provided less than two days of diary data. For this reason, the construction of each season-long exposure event sequence required either the repetition of data from one subject or the use of data from multiple subjects. The latter approach was used in the outdoor children pNEM/O3 analyses to better represent the variability of exposure expected to occur among the children included in each cohort. The principal deficiency of this approach is that it may not adequately account for the day-to-day repetition of activities common to individual children. Using activities from different subjects may underestimate multiple occurrences of high exertion and/or outdoor exposure for those segments of the population who engage in repetitive outdoor activities.

8.2 Equivalent Ventilation Rates

The application of pNEM/O3 to outdoor children marks the first use of a newly-developed algorithm for estimating EVR values. The algorithm applies one of four Monte Carlo models to each exposure event, the selected model depending on the demographic group of the cohort and on the type of database (A or B) which provided the time/activity data. The parameters of these Monte Carlo models were determined from an analysis of EVR data obtained from two diary studies conducted by J. Hackney and associates in Los Angeles. These studies are referred to as "Los Angeles - elementary school" and "Los Angeles - high school" in Table 2.

A total of 39 subjects participated in the two Los Angeles studies. Because of the small sample size, the resulting EVR database may not accurately represent the variability of EVR across the population. In addition, the database may not provide sufficient data to adequately characterize age-specific differences in EVR. For example, none of the Los Angeles subjects was below the age of 10 or above the age of 17. The two demographic groups defined for the analysis (preteens and teenagers) included children from age 6 to age 18. Consequently, the Monte Carlo models developed from the Los Angeles EVR data may not adequately characterize the younger children (6 to 9 years of age) in the preteens group and the older children (18 years of age) in the teenagers group.

As discussed in Subsection 2.4.3, EVR values were not permitted to exceed an upper bound determined by the EVR limiting algorithm for the specified demographic group and event duration. For preteens, this bound was set equal to the maximum EVR value attainable by boys aged 11 who exercise regularly and who are motivated to reach a high ventilation rate. Note that this bound is likely to be too high for other members of the preteens demographic group who differ with respect to age, gender, exercise regime, and motivation. For similar reasons, the EVR bounds set for teenagers are too high for many members of that demographic group. In general, the EVR limiting algorithm will tend to permit more high EVR values to occur in the pNEM/O3 simulation than would occur in the actual outdoor children population. This potential bias may be corrected in future versions of pNEM/O3 by distinguishing outdoor children cohorts by gender, age, and physical conditioning. The parameters of the EVR limiting algorithm would be varied according to these factors to yield a reasonable upper EVR limit for each cohort.

The algorithm used to estimate EVR requires that each exposure event be assigned to one of the four breathing rate categories. These assignments were readily available in the time/activity data obtained from the Cincinnati and Los Angeles studies, as the subjects of these studies entered this information directly into their diaries. Information on breathing rate category was not provided by the diaries used in the remaining time/activity studies. Consequently, the Monte Carlo procedure described in Subsection 6.2 was used to assign breathing rate categories to the time/activity data obtained from these studies. The Monte Carlo procedure was based on the untested assumption that the probabilistic relationships between activity type (e.g., yard work) and breathing rate category calculated from the Cincinnati time/activity data could be applied to time/activity data from other studies.

8.3 The Air Quality Adjustment Procedures

Section 5 presents a summary of the procedures used to adjust baseline ozone monitoring data to simulate conditions expected when a study area just attains a specified NAAQS. These procedures assume that 1) the Weibull distribution provides a good fit to most ozone data, and 2) the parameters of the Weibull distribution fitting data from a particular monitoring site will change over time in a predictable fashion. The adjustment procedures include equations for predicting the values of the Weibull parameters under future attainment conditions.

The prediction equations were developed through a statistical analysis of ozone data obtained from selected monitoring sites which have experienced moderate reductions in ozone levels during the 1980's. It should be noted that none of the selected monitoring sites reported ozone reductions of the magnitude required to bring Los Angeles into compliance with any one of the NAAQS under evaluation. For this reason, the prediction equations may not produce accurate estimates for the Weibull distribution parameters when applied to Los Angeles ozone data.

Researchers have recently performed a series of tests to evaluate the air quality adjustment procedures with respect to moderate reductions in ozone levels. In a technical letter, Johnson[51] describes the general test procedure and its application to six pNEM/O3 study areas (Chicago, Washington, Houston, Los Angeles, New York, and Philadelphia). Analysts first selected a year representing relatively low ozone concentrations for each city. The air quality adjustment procedure for each of the three NAAQS formulations (1H1EX, 8H1EX, and 8H5EX) was applied to the baseline ozone data for the study area with the goal of simulating the ozone levels observed during the "low ozone" year. The resulting "estimated" ozone concentrations for the low ozone year were compared with the actual ozone levels reported for the low ozone year. The comparisons were performed using selected percentiles of the cumulative ozone distributions (estimated and observed) associated with each fixed-site monitor.

The test results suggest that the air quality adjustment procedures perform adequately in the upper-tail region (90th percentile and above) of the ozone distribution, the region that determines the exposures of most concern in pNEM/O3 analyses. The results also show that the air quality adjustment procedures may significantly over-estimate ozone concentrations in the lower portions of the distribution. This problem is probably the result of using a somewhat "stiff" two-parameter distribution (the Weibull) to characterize one-hour ozone data. Researchers may achieve better results by using a more flexible three-parameter distribution, although this approach would likely require a more complicated air quality adjustment procedure.

The air quality adjustment procedure is based on an assumption that the attainment status of a particular city can be determined by a single year of monitoring data. For example, the current status of Philadelphia is determined by ozone monitoring data for 1991. This single year of monitoring data is then adjusted to exactly meet a specified NAAQS. It should be noted that the pNEM/O3 approach to determining attainment status differs somewhat from the actual method used by EPA to determine attainment status. EPA typically examines three recent years of monitoring data for a particular city and calculates a multi-year air quality indicator (e.g., the fourth highest daily maximum one-hour ozone concentration for the three-year period). The air quality indicator determined by this method is likely to differ from the air quality indicator determined in a pNEM/O3 analysis from a single year of data. As the direction of the difference is random, the degree of adjustment applied to a city by pNEM/O3 may be greater than or less than the adjustment required to bring the city into compliance based on three years of data.

8.4 Estimation of Cohort Populations

Subsection 6.3 of this report describes the procedure used to estimate cohort populations. An outdoor children cohort is defined by demographic group, home district, and air conditioning status. For the outdoor children analysis, only two demographic groups were defined: preteen (children 6 to 13) and teenager (children 14 to 18). In addition, two major assumptions were employed in order to estimate the population of each cohort. First, an outdoor child was defined as a child who spent a specified amount of time outdoors, dependent on season and weekend or weekday designation. The time criteria were determined somewhat subjectively in an effort to include a sufficient number of person-days of diary data to adequately represent the variability of activities among children, while at the same time insuring that these criteria were rigorous enough to select only data which represented children who spent noticeably more time outdoors than the "average" child. Analysts evaluated several alternative time criteria before selecting the specific criteria employed in the model (see subsection 6.1).

The second major assumption employed in the estimation of cohort populations is the assumption that the ratio of outdoor children to all children is constant across all cohorts belonging to a certain demographic (age) group, regardless of study area. In actuality, it would be expected that this ratio would vary by geographic region due to climate differences, by home district (whether rural, suburban, or urban), by finer age demarcations, and perhaps even by gender. No attempt was made to account for these factors, as applicable research and census data do not currently exist.

8.5 The Mass Balance Model

The pNEM/O3 methodology uses the mass balance model described in Section 3 to estimate ozone concentrations for the following enclosure categories:

- Residential buildings - windows closed
- Residential buildings - windows open
- Nonresidential buildings
- Vehicles.

The mass balance model provides hourly average ozone concentrations for each enclosure category as a function of outdoor ozone concentration, AER, and ozone decay rate.

In the application of pNEM/O3 to outdoor children, the outdoor ozone concentration required by the mass balance model was always derived from fixed-site monitoring data. These data were representative of local conditions and were considered to be relatively reliable.

The AER values for residential buildings with closed windows were obtained from a lognormal distribution fit to AER data from 312 residences. These data were considered to be generally representative of housing in urban areas in the U.S.

No comparable databases were identified which were considered representative of residences with open windows. Consequently, analysts represented this enclosure category with a point estimate developed by Hayes[45]. Analysts are uncertain as to the accuracy and general applicability of this estimate.

The AER values for nonresidential buildings were obtained from a lognormal distribution fit to AER data from 40 buildings provided by Turk et al.[44] This sample may be too small to adequately characterize nonresidential buildings in the U.S. It should also be noted that the Turk data are likely to represent only buildings with closed windows. Consequently, the lognormal distribution derived from the Turk data is likely to under-estimate the ozone exposures of people who frequently occupy nonresidential buildings with open windows.

A point estimate of 36 air changes per hour was used for the AER of vehicles. This value was obtained from Hayes[47] based on his analysis of data reported by Peterson and Sabersky[42] for a single vehicle. The use of a point estimate is considered unrealistic as it does not account for varying ventilation conditions within a particular motor vehicle or the variability in AER from vehicle to vehicle.

Analysts also used a point estimate for the ozone decay rate of vehicles. This value was based on data from a single automobile and may be biased.

Ozone decay rates for residential and nonresidential buildings were sampled from a normal distribution. This distribution was based on decay rate data for a relatively small number of buildings assembled by Weschler et al.[39] These data may not adequately represent the variability of ozone decay rates among urban buildings in the U.S.

8.6 Estimation of Ozone Exposures for Special Scenario Associated With Attainment of 8H5EX-80 Standard

Section 7 presents the results of a series of exposure assessments using pNEM/O3 in which the ozone levels within a specified study area have been adjusted to meet a particular formulation of the ozone NAAQS. One of the standards under review (designated 8H5EX-80) states that the expected exceedance rate for daily maximum 8-hour ozone concentrations above 80 ppb shall not be more than five. To evaluate this standard, ITAQS adjusted the ozone monitoring data representing each study area using the AQAP described in Section 5. As a result of this procedure, the ozone data reported by each monitor was adjusted so that the sixth highest daily maximum 8-hour concentration equaled a specified air quality indicator (AQI). The sixth highest value of the historical "high ozone" monitor was adjusted to equal 80 ppb.

This adjustment procedure is intended to limit the average exceedance rate of the high ozone monitor to five exceedances of 80 ppb per year, based on a single year of monitoring data. EPA has recently begun to evaluate an alternative form of this standard which limits the average value of the fifth highest daily maximum 8-

hour concentration to 80 ppb (here designated 8H5AVG-80). Under this standard, there is no explicit limit to the number of exceedances that can occur in a given year. However, a recent analysis by EPA found that very few ozone monitors report more than 10 exceedances during a single year in an area that meets the 8H5AVG-80 standard over a three-year period. As a result of this analysis, EPA directed ITAQS to develop a procedure for adjusting the monitoring data in an area to simulate conditions in which 10 exceedances occur at the historical high-ozone monitor. These data were then be used in a pNEM/O3 analysis to estimate the ozone exposures that could occur under these conditions. Subsection 8.6.1 briefly describes the AQAP developed by ITAQS. Subsection 8.6.2 provides exposure estimates for seven study areas.

8.6.1 The Air Quality Adjustment Procedure

The AQAP for the 10 exceedance scenario is similar to that used for adjusting ozone data to simulate attainment of an 8H5EX standard. In essence, the data are adjusted to meet an 8H10EX-80 standard, i.e., the expected number of daily maximum eight-hour ozone concentrations exceeding 80 ppb shall not exceed ten. The procedure is outlined in Table 1 of the letter in Appendix F. Note that supplementary material concerning Step 6 of the procedure can be found in Section 5.3 of this report.

Section 5.4 of this report describes the application of an AQAP for the 8H5EX-80 standard to Philadelphia. The new procedure described in this letter is essentially identical to the procedure in Section 5.4 when one makes the following substitutions throughout the discussion: substitute 11th highest value for sixth highest value and substitute RATIO3 for RATIO2. Table 2, in Appendix F, lists values of RATIO3 by study area.

The adjustment procedure was applied to the ozone monitoring data which have been used in previous pNEM/O3 analyses of seven study areas: Chicago, Houston, Los Angeles, New York, Philadelphia, St. Louis, and Washington, D.C. The two remaining pNEM/O3 study areas (Denver and Miami) were omitted from the analysis because the ozone levels in these cities were relatively low with respect to the levels permitted by the 8H5AVG80 standard.

8.6.2 Exposure Estimates for Selected Study Areas

The pNEM/O3 model incorporates a number of stochastic (random) elements which directly affect the exposure estimates produced by the model. Consequently, exposure estimates are likely to vary from run to run. Consistent with earlier analyses, ITAQS ran the model 10 times for each of the seven study areas. Tables 3 through 10, in Appendix F, provide means and ranges for selected exposure indicators based on these runs. In each case, the exposure estimates apply to the population group previously designated as "outdoor children" and use the adjusted ozone data described above. The exposure indicators are defined in Sections 7.2 and 7.4 of this report.

In Tables 3 through 10, of Appendix F, the attainment scenario is described in terms of a "8H10EX-80" scenario, as the ozone monitoring data were adjusted to simulate attainment of this indicator. In using this designation, it is understood that the scenario is actually intended to represent a special high-ozone situation that could occur during a single year when a 8H5AVG-80 standard is attained over a three-year period.

Appendix F provides a detailed discussion of the exposure estimates in Tables 3 through 10. The overall pattern of results indicates that ozone exposures expected under the 8H10EX-80 scenario always exceed those of the 8H5EX-80 scenario and almost always are less than those under the 8H5EX-90 scenario.

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APPENDIX A

TEN TIME/ACTIVITY DATABASES GENERALLY APPLICABLE TO AIR POLLUTION EXPOSURE ASSESSMENTS

In 1993, Johnson et al.[48] conducted a literature review to identify all time/activity databases which would be appropriate for use in pNEM exposure assessments. The survey identified ten databases with adequate data characteristics. Eight of the databases relate to five individual urban areas: Cincinnati, Ohio; Denver, Colorado; Los Angeles, California; Valdez, Alaska; and Washington, D.C. The remaining two databases relate to the entire State of California. In the discussion that follows, each database will be identified according to the associated geographical area. When a geographical area is associated with more than one database, each database will be further distinguished according to the sampled population (e.g., Los Angeles - outdoor workers).

California

The California Air Resources Board conducted two state-wide time/activity studies[24,25] to provide a large pool of activity pattern data suitable for use in estimating environmental exposures. The first study, referred to hereafter as the "California - 12 and over" study, was conducted between October 1987 and July 1988. During the study, interviewers collected one day of activity data from each of 1762 California residents over the age of 11. The second study ("California - 11 and under") was conducted from April 1989 through February 1990. The study gathered one day of activity data from each of 1200 children ages 11 and under. Both studies employed retrospective telephone interviews to obtain a record of each subject's activities during the preceding day.

Cincinnati

The Cincinnati Activity Diary Study[20] was conducted by the Electric Power Research Institute during March and August 1985 to provide an extensive database for evaluating human exposure to air pollution. The sampled population included all residents of a three-county area in and around Cincinnati, Ohio. Each subject recorded his or her activities over a three-day period in a real-time diary and completed a detailed background questionnaire. The 487 March subjects provided

1401 subject-days of diary data; the 486 August subjects provided 1399 subject-days. Activity diary data collected during the Cincinnati study have been used by the U.S. Environmental Protection Agency (EPA) in various applications of the pNEM/CO[14] and pNEM/O3[16] exposure models.

Denver and Washington

The U.S. Environmental Protection Agency conducted studies of adults (18 to 70 years) in Denver, Colorado, and Washington, D.C., during the winter of 1982 - 1983 for the purpose of collecting representative data on personal exposure to carbon monoxide. In the Denver study[26], each of 454 subjects carried a personal exposure monitor (PEM) and a real-time time/activity diary for two 24-hour periods. Each subject also provided a breath CO sample at the end of each monitored period and completed a detailed background questionnaire. The Washington study[30] employed a similar protocol to obtain data for a single 24-hour period from each of 908 subjects. Activity diary data from these two studies have been used in conjunction with data from the Cincinnati study in applications of EPA's pNEM/CO exposure model[14].

Los Angeles

Between 1989 and 1991, a research team headed by Dr. Jack Hackney conducted four activity diary studies in Los Angeles with funding provided by the American Petroleum Institute. The first of these, the "Los Angeles - outdoor worker study", was conducted during the summer of 1989.[49] Each of 20 outdoor workers wore a heart rate monitor for a three-day period during which the worker recorded his or her activities in a real-time diary identical to that used in the Cincinnati study.

In October of 1989, the outdoor worker study was expanded to include 20 healthy elementary school children. During this phase of the Los Angeles study, referred to here as the "Los Angeles - elementary school" study, each child wore a heart-rate monitor for two or three days and recorded his or her activities in the real-time Cincinnati diary. Approximately 58 subject-days of activity data were collected.[27]

A third phase of the Los Angeles study (the "Los Angeles - high school" study) was conducted during September and October 1990.[27] During this phase, 66 subject-days of real-time activity data were collected from 19 students between the ages 13 and 17 using the Cincinnati diary.

The Hackney research team conducted a fourth study in Los Angeles between July and November 1991. Each of 19 construction workers between the ages of 23 and 42 wore a heart rate monitor during a typical work day. The Cincinnati diary was used to record each subject's activities during this period. The study protocol differed from the other Los Angeles studies in that each diary was completed by a trained observer rather than by the subject. The observer monitored each subject's activities visually and by two-way radio. This approach produced unusually detailed diaries of high accuracy.[50]

Valdez

The Valdez Air Health Study[29] was undertaken by the Alyeska Pipeline Service Company in response to concerns expressed by the citizens of Valdez, Alaska, regarding their potential exposure to certain volatile organic compounds (VOCs). Between November 1990 and October 1991, 405 subjects aged 10 to 72 years were interviewed and requested to report their daily activities for an earlier 24-hour period. In addition to the activity data, researchers collected extensive data on personal exposures to VOC's, ambient air quality, and meteorological conditions.

APPENDIX B

MONTE CARLO MODELS FOR GENERATING EVENT EVR VALUES

Database Types

In the pNEM/O3 methodology, each cohort is represented by an exposure event sequence. The sequence is constructed from data obtained from studies in which subjects recorded their activities over 24-hour periods (person-days) in diaries. Table B-1 lists the seven studies which provided diary data for the application of pNEM/O3 to outdoor children. Appendix A provides brief descriptions of these seven studies and three other studies which have been used in other pNEM applications.

Three of the studies listed in Table B-1 (Cincinnati, Los Angeles - elementary students, and Los Angeles - high school students) employed a diary which used the page format shown in Figure B-1. This page format (referred to as the "Cincinnati" format) provided data which could be used to directly classify each exposure event with respect to five microenvironments and four breathing rates:

Microenvironments	Breathing Rates
Indoors - residence	Sleeping
Indoors - other	Slow
Outdoors - near road	Medium
Outdoors - other	Fast
In vehicle	

The databases obtained from the three studies which used this format were designated Type A1 databases. Time/activity data from Type 1 databases generally can be used "as is" in pNEM/O3 assessments.

One of the studies listed in Table B-2 (Washington) employed the diary page format shown in Figure B-2. This format supports the use of the five

Table B-1. Characteristics of studies associated with the seven time/activity databases.

Database name	Database type	Characteristics of subjects	Number of subject-days	Study calendar periods	Diary type	Diary time period	Breathing rates reported?
California - 11 and under	B	Children ages 1 to 11	1200	April 1989 - Feb. 1990	Retrospective	Midnight to midnight	No
California - 12 and over	B	Ages 12 to 94	1762	Oct. 1987 - July 1988	Retrospective	Midnight to midnight	No
Cincinnati	A1	Ages 0 to 86	2800	March and August 1985	Real-time[a]	Midnight to midnight	Yes
Los Angeles - elem. school	A1	Elementary school students, 10 to 12 years	58	Oct. 1989	Real-time[a]	Midnight to midnight	Yes
Los Angeles - high school	A1	High school students, 13 to 17 years	66	Sept. and Oct. 1990	Real-time[a]	Midnight to midnight	Yes
Valdez	B	Ages 10 to 72	405	Nov. 1990 - Oct. 1991	Retrospective	Varying 24-h period	No
Washington	A2	Ages 18 to 70	705	Nov. 1982 - Feb. 1983	Real-time	7 p.m. to 7 p.m. (nominal)	No

[a]Study employed the Cincinnati diary format.

TIME [| | |] * AM [ ] PM [ ]

A. ACTIVITY (please specify)

____

____

____

B. LOCATION

In transit, car 01

In transit, other vehicle . . 02

Specify ____________________

Indoors, your residence . . . 03

Indoors, other residence. . . 04

Indoors, office 05

Indoors, manufacturing facility. 06

Indoors, school 07

Indoors, store. 08

Indoors, other. 09

Specify ____________________

Outdoors, within 10 yards of road or street. 10

Outdoors, other 11

Specify ____________________

Uncertain 12

C. BREATHING RATE

Slow (e.g., sitting) 13

Medium (e.g., brisk walk). . . 14

Fast (e.g., running) 15

Breathing problem. 16

Specify ____________________

D. SMOKING

I am smoking 17

Others are smoking 18

No one is smoking. 19

E. ONLY IF INDOORS

(1) Fireplace in use?

Yes. 20

No 21

(2) Woodstove in use?

Yes. 22

No 23

(3) Windows open?

Yes. 24

No 25

Uncertain. 26

*Enter MIDN for midnight and NOON for noon. Otherwise enter four-digit time (e.g., 0930 for 9:30 and 1217 for 12:17) and check a.m. or p.m.

Figure B-1. Blank page from Cincinnati activity diary.

Table B-2. Database types.

Type A1:	Time/activity data acquired using the "Cincinnati" diary. Type A1 data support the use of four breathing rate categories (sleeping, slow, medium, and fast) and five microenvironments (indoors - residence, indoors - other, outdoors - near road, outdoors - other, and in vehicle). Applicable studies: Cincinnati, Los Angeles - elementary school, and Los Angeles - high school.
Type A2:	Time/activity data acquired using the "Denver/Washington" diary. Type A2 data support the use of the five Type 1 microenvironments. Breathing rate data (not available in the reported data) were developed through a Monte Carlo algorithm. Applicable study: Washington.
Type B:	Time/activity data acquired using other diary formats. Type B data support the use of four microenvironments: indoors - residence, indoors - other, outdoors, and in vehicle. Breathing rate data (not available in the reported data) were developed through a Monte Carlo algorithm. Applicable studies: California - 11 and under, California - 12 and over, and Valdez.

TIME FROM MONITOR [ ][ ][ ][ ]

A. ACTIVITY

____

____

____

____

B. LOCATION

In transit 1

Indoors, residence 2

Indoors, office 3

Indoors, store 4

Indoors, restaurant 5

Other indoor location 6

Specify: ______________________

____

Outdoors, within 10 yards of road or street 7

Other outdoor location 8

Specify: ______________________

____

Uncertain 9

C. ADDRESS (if not in transit)

____

____

____

D. ONLY IF IN TRANSIT

(1) Start address ______________________

____

(2) End address ______________________

____

(3) Mode of travel:

Walking 1

Car 2

Bus 3

Truck 4

Train/subway 5

Other 6

Specify: ______________________

____

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes 1

No 2

Uncertain 3

(2) Gas stove in use?

Yes 1

No 2

Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes 1

No 2

Uncertain 3

Figure B-2. Blank page from Washington activity diary.

microenvironments listed above but provides no data on breathing rate. Because the pNEM/O3 methodology requires that each exposure event be characterized by breathing rate, ITAQS analysts developed a Monte Carlo technique to estimate breathing rate indirectly from other information provided by the diary. The technique, which is described in Subsection 6.2, randomly assigns a breathing rate to each exposure event based on selection probabilities which vary with activity class, microenvironment, time of day, and duration. The selection probabilities are based on a statistical analysis of the Cincinnati time/activity database. When this technique was applied to the Washington database, the technique produced an "augmented" database which was consistent in format with the Type A1 databases described above. The augmented database for Washington was referred to as a Type A2 database.

The diaries employed by the remaining three studies in Table B-1 (California - children, California - adults, and Valdez) do not permit analysts to identify outdoor locations near roadways. Consequently, only four microenvironments were used to categorize data from these studies: indoors - residence, indoors - other, outdoors, and in vehicle. The California and Valdez diaries also omitted breathing rate information; consequently, the Monte Carlo technique described above was used to randomly assign a breathing rate to each exposure event. The resulting augmented databases were referred to as Type B databases.

Table B-2 provides a brief summary of the characteristics of each database type. In the discussion that follows, Types A1 and A2 are discussed jointly as Type A.

GENERAL PROCEDURE FOR DEVELOPMENT OF MONTE CARLO MODELS

ITAQS analysts developed a special EVR-generator module for the version of pNEM/O3 applicable to outdoor children. The module used one of four Monte Carlo models to generate an EVR value for each exposure event associated with a given cohort. The applied model varied from event-to-event according to (1) the demographic group of the cohort (preteens or teenagers) and (2) the type of database (A or B) from which the associated diary data were obtained.

The Monte Carlo models were based on the results of statistical analyses performed on EVR data obtained from the two Los Angeles studies listed in Table B-1: elementary school students and high school students. Models applicable to the preteens demographic group were based on analyses of data from the elementary school study; models applicable to teenagers were based on analyses of data from the high school study. To permit the use of all seven diary databases listed in Table B-1, analysts developed two Monte Carlo models for each demographic group -- one applicable to Type A databases and one applicable to Type B databases.

Each Monte Carlo model predicted EVR as a function of six or more predictor variables which constituted a "predictor set." Each predictor set was developed by performing stepwise linear regression analyses on one of the two Los Angeles databases. Each of the Los Angeles databases consisted of a collection of "person-days," each person-day containing the data obtained from one subject during one 24-hour period. The data for each person-day were organized into a sequence of exposure events. Each exposure event was characterized by an average EVR value and by a value for each of the 24 variables listed in Table B-3 (as applicable). Exploratory statistical analyses by Johnson and McCoy[34] identified these variables as good candidate variables for the regression analyses.

Two series of regression analyses were performed on the Los Angeles databases. The first series treated each Los Angeles database as being a Type A database with five microenvironments. Each of these regression analyses was performed using the Type A candidate variables listed in Table B-3. The second series treated the Los Angles databases as being Type B databases with four microenvironments.

Table B-3. Candidate variables used in stepwise linear regression analyses.

Variable	Explanation	Candidate variable group	
		A	B
LGM	Natural logarithm of geometric mean of event EVR values for individual subject	*	*
SLEEP	SLEEP=1 if breathing rate = sleeping, 0 otherwise	*	
SLOW	SLOW=1 if breathing rate = slow, 0 otherwise	*	
MEDIUM	MEDIUM=1 if breathing rate = medium, 0 otherwise	*	
FAST	FAST=1 if breathing rate = fast, 0 otherwise	*	
DUR1	DUR1=1 if duration $\le$ 5 minutes, 0 otherwise	*	*
DUR2	DUR2=1 if 6 $\le$ duration $\le$ 10 minutes, 0 otherwise	*	*
DUR3	DUR3=1 if 11 $\le$ duration $\le$ 20 minutes, 0 otherwise	*	*
DUR4	DUR4=1 if 21 $\le$ duration $\le$ 30 minutes, 0 otherwise	*	*
DUR5	DUR5=1 if 31 $\le$ duration $\le$ 45 minutes, 0 otherwise	*	*
DUR6	DUR6=1 if 46 $\le$ duration $\le$ 60 minutes, 0 otherwise	*	*
DUR7	DUR7=1 if duration > 60 minutes, 0 otherwise	*	*
INDOOR	INDOOR = 1 if event occurs in an indoor microenvironment, 0 otherwise	*	*
OUTDOOR	OUTDOOR = 1 if event occurs in an outdoor microenvironment, 0 otherwise	*	*
OUTOTHER	OUTOTHER = 1 if event occurs in the outdoors - other microenvironment, 0 otherwise	*	
VEH	VEH = 1 if event occurs in a vehicle microenvironment, 0 otherwise	*	*
MALE	MALE = 1 if subject is male, 0 otherwise	*	*
WEEKDAY	WEEKDAY = 1 if event occurs on a weekday, 0 otherwise	*	*
HIGHTOWK	HIGHTOWK = 1 if daily maximum temperature exceeds 79°F and event occurs in outdoor microenvironment and activity code = 2 (work), 0 otherwise	*	*
DAYACT	DAYACT = 1 if event begins between 7:00 a.m. and 4:59 p.m., 0 otherwise	*	*
TRAVEL	TRAVEL = 1 if activity code is 1 (travel), 0 otherwise	*	*
HIGHACT	HIGHACT = 1 if activity code is 11, 27, 28, 29, 30, 31, or 33; 0 otherwise	*	*
LOWACT	LOWACT = 1 if activity code is 10, 12, 16, 23, 34, 35, 37, or 44; 0 otherwise	*	*
WORK	WORK = 1 if activity code = 2 (work), 0 otherwise	*	*

These regression analyses were performed using the Type B variables listed in Table B-3. With the exception of the continuous variable LGM, each of the variables listed in Table B-3 is a binary "dummy" variable. A dummy variable equals one when specified conditions are met and equals zero under all other conditions. Among the variables listed in Table B-3 are variables which indicate breathing rate, event duration, microenvironment, subject gender, time of day, day of the week, and temperature. Several variables classify activities according to level of exertion, work status (work/non-work), and travel status (travel/non-travel).

The continuous variable LGM is equal to the natural logarithm of the geometric mean of all event EVR values associated with a subject. Analyses of variance performed on the two Hackney/Linn data sets indicated that inter-subject variability with respect to average EVR was a major source of variability in the event EVR values.[34] LGM is an indicator of average subject EVR which can be related directly to ln(EVR), the dependent variable defined for the regression analyses.

The results of each stepwise regression analysis were used to (1) identify significant predictor variables and (2) estimate the coefficients of a regression equation which included only the significant variables. The regression equation had the general form

$$\ln[EVR(i,j)] = b_0 + (b_1)[VAR_1(i,j)] + (b_2)[VAR_2(i,j)] + \ldots + (b_m)[VAR_m(i,j)] + e(i,j) \quad (1)$$

where EVR(i,j) is the EVR value for event j associated with subject i; b_0, b_1, b_2, ..., b_m are constants; $VAR_1(i,j)$, $VAR_2(i,j)$, ..., $VAR_m(i,j)$ are the values of the predictor variables for the event; and e(i,j) is the residual.

RESULTS OF STEPWISE LINEAR REGRESSION ANALYSES

Tables B-4 and B-5 present the results of the stepwise regression analyses performed on the elementary and high school databases, respectively. As indicated above, the dependent variable in each regression analysis was ln(EVR), i.e., the natural logarithm of the average EVR for the event. Each table lists the results for two regression analyses -- one using the Type A variables and one using Type B variables. The results listed for each regression analysis include the variables selected by the regression procedure as being significant predictors of ln(EVR), the regression coefficient associated with each variable, the p value associated with the coefficient, and the cumulative R^2 value that resulted when the variable was added to the regression equation.

Table B-4 provides the results of the regression analyses performed on the elementary school database. The regression analysis of Type A variable set selected seven variables for the regression equation (LGM, OUTDOOR, FAST, DAYACT, SLEEP, WEEKDAY, and HIGHACT). The cumulative R^2 value for all seven variables is 0.7083. This value indicates that the regression equation explains 70.83 percent of the variation in ln(EVR).

The regression analysis performed on the Type B variable set selected the same seven variables: LGM, OUTDOOR, FAST, DAYACT, SLEEP, WEEKDAY, and HIGHACT. Consequently, the regression equations associated with Types A and B are identical.

Table B-5 presents regression results for the high school database. The regression procedure selected 12 variables from the Type A variable set. The first three variables to be selected were LGM, OUTOTHER, and HIGHACT. These three variables had a cumulative R^2 value of 0.3833. The cumulative R^2 value for all 12 variables is 0.4596.

The regression procedure selected 12 variables from the Type B variable set. The first three variables were LGM, OUTDOOR, and HIGHACT (cumulative R^2 = 0.3848). The cumulative R^2 for all 12 variables is 0.4547. A comparison of the

Table B-4. Results of stepwise linear regression analyses performed on elementary school data set.

Candidate variable set	Selected variable[a]	Regression coefficient	p value	Cumulative R^2
A and B	Constant	-0.08174	0.1544	0.0000
	LGM	0.98606	0.0000	0.6600
	OUTDOOR	0.12156	0.0000	0.6812
	FAST	0.16111	0.0000	0.6939
	DAYACT	0.07188	0.0001	0.7002
	SLEEP	-0.17393	0.0021	0.7037
	WEEKDAY	0.04674	0.0062	0.7063
	HIGHACT	0.05962	0.0159	0.7083

[a]HIGHTOWK not applicable to this data set.

Table B-5. Results of stepwise linear regression analyses performed on high schools data set.

Candidate variable set	Selected variable[a]	Regression coefficient	p value	Cumulative R^2
A	Constant	0.16385	0.0158	0.0000
	LGM	0.91365	0.0000	0.3063
	OUTOTHER	0.11198	0.0000	0.3505
	HIGHACT	0.15447	0.0000	0.3833
	SLOW	-0.07989	0.0000	0.4038
	DAYACT	0.08175	0.0000	0.4209
	DUR7	-0.13637	0.0000	0.4325
	LOWACT	-0.08749	0.0000	0.4408
	WEEKDAY	0.05873	0.0000	0.4462
	DUR5	-0.09184	0.0000	0.4503
	FAST	0.14685	0.0001	0.4545
	DUR6	-0.10629	0.0001	0.4582
	VEH	-0.04650	0.0255	0.4596
B	Constant	0.10646	0.1451	0.0000
	LGM	0.91721	0.0000	0.3063
	OUTDOOR	0.11621	0.0000	0.3495
	HIGHACT	0.15820	0.0000	0.3848
	SLOW	-0.07636	0.0000	0.4014
	DAYACT	0.08131	0.0000	0.4171
	LOWACT	-0.08556	0.0000	0.4276
	DUR7	-0.13256	0.0000	0.4353
	WEEKDAY	0.05898	0.0000	0.4406
	FAST	0.16330	0.0000	0.4454
	DUR5	-0.09306	0.0000	0.4500
	DUR6	-0.10331	0.0000	0.4536
	INDOOR	0.04298	0.0000	0.4547

[a]HIGHTOWK not applicable to this data set.

results presented in Tables B-4 and B-5 finds that six variables appear in both tables: LGM, OUTDOOR, DAYACT, HIGHACT, WEEKDAY, and HIGH. LGM is always the first variable selected. LGM contributed 0.660 to the cumulative R^2 value in Table B-4. In Table A-5, adding LGM increased the R^2 value by 0.306.

These results suggest that variables associated with average subject EVR (LGM), outdoor microenvironments (OUTDOOR), daytime activities (DAYACT), the exertion level of activities (HIGHACT), day of week (WEEKDAY), and breathing rate (HIGH) are particularly useful in predicting event EVR. Note that the duration variables tended to be relatively insignificant predictors. Adding DUR6 or DUR7 to the regression equation never increased the cumulative R^2 value by more than 0.015.

THE DISTRIBUTION OF REGRESSION RESIDUALS

Each regression analysis produced a set of residual values, one for each EVR value. Researchers performed a series of exploratory data analyses in which they attempted to find patterns in the residuals which could be used to characterize random effects in the Monte Carlo approach. Statistical analysis of the residuals indicated that (1) the standard deviation of the residuals varied significantly from subject to subject and (2) the distribution of the subject-specific standard deviations was approximately lognormal.

Based on these findings, researchers assumed that the residual term in Equation 1 could be represented by a normally distributed random variable with mean equal to zero and standard deviation equal to SDRES. The value of SDRES was assumed to vary with subject and to be lognormally distributed among subjects; i.e., the natural logarithm of SDRES [LSDRES = ln(SDRES)] is normally distributed with mean = MU and standard deviation = SIGMA. The values of MU and SIGMA were specific to the data set undergoing the regression analysis.

Consistent with these assumptions, analysts performed the following statistical analysis of the residuals obtained from each regression analysis:

1. Classify residuals by subject.

2. Calculate the standard deviation of residuals associated with each subject (SDRES).

3. Calculate a value of LSDRES for each subject where LSDRES is the natural logarithm of each SDRES value obtained in Step 2.

4. Calculate the mean (MU) and the standard deviation (SIGMA) of the LSDRES values determined for all subjects.

Table B-6 lists the values of MU and SIGMA determined in Step 4.

THE DISTRIBUTION OF LGM VALUES

As indicated above, researchers found that the LGM variable was the single best predictor of ln(EVR) in each regression analysis. An analysis of the LGM values associated with the subjects in each of the Los Angeles studies indicated that the distribution of LGM values for each study was approximately normal. The parameters of these normal distributions were estimated by the following procedure.

1. Classify the event EVR values by subject.

2. Calculate ln(EVR) for each event.

3. Calculate the mean of the ln(EVR) values associated with each subject (LGM).

4. Calculate the arithmetic mean and arithmetic standard deviation of the LGM values determined for all subjects in the database.

The arithmetic mean and standard deviation values determined in Step 4 are listed in Table B-7.

Table B-6. Distribution of LSDRES values.

Database	Number of subjects	Regression model producing residuals	Parameters of normal distribution fit to subject LSDRES values[a]		Wilk-Shapiro[b] statistic for LSDRES	Range	
			MU = mean	SIGMA = standard deviation		Minimum	Maximum
Elementary school	16	A and B	-1.6068	0.4450	0.9540	-2.3066	-0.7251
High school	19	A B	-1.4662 -1.4586	0.2997 0.3054	0.9845 0.9834	-2.0472 -2.0503	-0.7822 -0.7634

[a]LSDRES is the natural logarithm of the standard deviation of the regression residuals associated with one subject.
[b]An indicator of normality (1.0 = normal distribution).

Table B-7. Distribution of LGM values.

Database	Number of subjects	Parameters of normal distribution fit to subject LGM values[a]		Wilk-Shapiro[b] statistic for LGM	Range	
		MEANLGM = mean	SDLGM = standard deviation		Minimum	Maximum
Elementary school	16	2.3629	0.4324	0.9630	1.3713	3.0517
High school	19	2.1621	0.1890	0.9597	1.8135	2.5603

[a]LGM is the natural logarithm of the geometric mean of the event EVR values associated with one subject.
[b]An indicator of normality (1.0 = normal distribution).

GENERAL ALGORITHM FOR EXECUTING THE MONTE CARLO MODEL

The EVR-generator module contained four Monte Carlo models, one for each combination of demographic group and database type. The module processed the exposure event sequence of each cohort as a series of person-days. An EVR value was generated for each event in the first person-day using the Monte Carlo model which matched the demographic group of the cohort and the database type (A or B) of the person-day. The module then generated an EVR value for each event in the second person-day using the Monte Carlo model which matched the new conditions. The process continued until an EVR was assigned to each exposure sequence.

Table B-8 presents the general algorithm incorporated into the EVR-generator module. The algorithm begins by processing the first (or next) person-day in a particular exposure event sequence. The algorithm checks the cohort for demographic group and the source of the diary data for database type. Based on this information, the algorithm identifies the applicable Monte Carlo model for the person-day. Associated with each Monte Carlo model are values for the following parameters:

MEANLGM: mean of the LGM values
SDLGM: standard deviation of LGM values
MU: mean of LSDRES values
SIGMA: standard deviation of LSDRES values
b_o: constant
b_m: coefficient of VAR_m

These values are held constant for each person-day i.

The algorithm determines a value of LGM(i) for person-day i by randomly selecting a value from a normal distribution with mean = MEANLGM and standard deviation = SDLGM (Table B-7). LGM(i) values are not permitted to fall outside the range indicated in Table B-7.

The algorithm also determines a value of LSDRES(i) for person-day i. This value is randomly selected from a normal distribution with mean = MU and standard deviation = SIGMA (Table B-6); the value is not permitted to fall outside the range indicated in Table B-6. The value of LSDRES(i) is exponentiated to produce a corresponding value of RESSIGMA(i).

The algorithm reads the data listings for each exposure event j associated with person-day i to determine the values of the variables VAR_1, VAR_2, ..., VAR_m. The algorithm also determines a residual value [RES(i,j)] for each event j by randomly selecting a value from a normal distribution with mean = 0 and standard deviation = RESSIGMA(i). The equation in Step 11 of Table B-8 is then used to determine a value for LEVR(i,j). This value is exponentiated to determine a value of EVR for the event. The algorithm steps through each event associated with the first person-day and then processes the next person-day. The process continues until all person-days in the exposure event sequence have been completed.

Appendix C presents the results of initial efforts to test this algorithm.

Table B-8. Algorithm used to generate event-specific values of equivalent ventilation rate.

1. Go to first/next person-day i.

2. Determine Monte Carlo model applicable to person-day according to demographic group of cohort and database type of diary data.

3. Model identity determines

   MEANLGM: mean of LGM values
   SDLGM: standard deviation of LGM values
   MU: mean of LSDRES values
   SIGMA: standard deviation of LSDRES values
   b_0: constant
   b_m: coefficient for variable VAR_m

   Denote the value of b_m for variable LGM as b_1.

4. Calculate LGM for person-day i:

   LGM(i) = MEANLGM + (SDLGM)[Z1(i)]

   Z1(i): randomly selected value from unit normal distribution (normal distribution with mean = 0 and standard deviation = 1).

5. If LGM(i) falls outside range indicated in Table B-7, discard value and go to Step 4.

6. Calculate RESSIGMA for person-day i.

   LSDRES(i) = MU + (SIGMA)[Z2(i)]

   RESSIGMA(i) = Exp[LSDRES(i)]

   Z2(i): randomly selected value from unit normal distribution.

7. If LSDRES(i) falls outside range indicated in Table B-6, discard value and go to Step 6.

8. Go to first/next event associated with person-day i.

(continued)

Table B-8 (Continued)

9. Read values of variables VAR_2, VAR_3, ..., VAR_m for event j of person-day i from input data file.

10. Calculate residual value for event j of subject i.

$$RES(i,j) = [RESSIGMA(i)][Z(i,j)]$$

Z(i,j): randomly selected value from unit normal distribution.

11. Calculate LEVR for event j of person-day i:

$$LEVR(i,j) = b_0 + (b_1)[LGM(j)] + (b_2)[VAR_2(i,j)] + (b_3)[VAR_3(i,j)] + ... + (b_m)[VAR_m(i,j)] + RES(i,j)$$

12. Calculate EVR for event j of person-day i:

$$EVR(i,j) = Exp[LEVR(i,j)]$$

13. Write EVR(i,j) to output file.

14. If last event of person-day i, go to Step 1. If not, go to Step 8.

APPENDIX C

TESTING OF MONTE CARLO MODELS

At the time of this report (October 1994), the two Los Angeles databases (elementary school and high school) provided the only means of testing the reasonableness the Monte Carlo approach described in Appendix B. These were the only databases available which included high quality time/activity data together with EVR values determined from heart rate measurements. This appendix summarizes the results of initial efforts to test the Monte Carlo approach using these two databases.

APPLICATION OF THE ALGORITHM TO THE HACKNEY/LINN DATABASES

Table B-8 in Appendix B presents an algorithm which can be used to generate an EVR value for each event in a time/activity database, given that the database is Type A or Type B. Both of the Los Angeles diary studies (elementary school and high school) produced Type A databases. Consequently, the application of the algorithm to these databases should provide an indication of model performance with respect to Type A databases.

The algorithm was applied to the elementary school database in the following manner. Researchers used the regression results listed in Table B-4 for Candidate Variable Set A to determine the set of predictor variables, the coefficient of each variable, and the constant. The selected predictor variables were LGM, OUTDOOR, FAST, DAYACT, SLEEP, WEEKDAY, and HIGHACT. The constant was -0.082, the coefficient for LGM was 0.986, the coefficient for OUTDOOR was 0.122, and so on. The resulting EVR generator equation was

$$\ln(EVR) = -0.082 + (0.986)(LGM) + (0.122)(OUTDOOR) + (0.161)(FAST) + (0.072)(DAYACT) + (-0.174)(SLEEP) + (0.047)(WEEKDAY) + (0.060)(HIGHACT) + e.$$

This equation was applied to each event listed in the elementary school database. The values of OUTDOOR, FAST, DAYACT, SLEEP, WEEKDAY, and HIGHACT for each event were determined by diary entries associated with the event. The value of LGM was constant for each of the 16 subjects, but was allowed to vary among subjects. The LGM value for each subject was randomly selected from a normal distribution with mean = 2.3629 and standard deviation = 0.4324, the normal distribution specified in Table B-7 for elementary school students.

The value of e was selected from a normal distribution with mean = 0 and standard deviation = SDRES. The value of SDRES was constant for each subject. Subject-specific SDRES values were selected from a lognormal distribution defined by the parameters MU = -1.6068 and SIGMA = 0.4450. These parameter values were obtained from Table B-6 (elementary school).

Table C-1 provides descriptive statistics for the event EVR values generated by three applications (runs) of the model to the elementary school database. The results vary from run to run because of the random elements incorporated into the Monte Carlo algorithm. Table C-1 also presents the average of the three runs and descriptive statistics for the observed event EVR values. A comparison of the three-run model averages with the corresponding observed statistics indicates good agreement (less than a 10 percent difference) with respect to arithmetic mean, standard deviation, and percentiles up to the 99th percentile. The model underestimates the 99.5th percentile (36.32 $l \cdot min^{-1} \cdot m^{-2}$ versus 48.18 $l \cdot min^{-1} \cdot m^{-2}$) and the maximum value (52.70 $l \cdot min^{-1} \cdot m^{-2}$ versus 86.04 $l \cdot min^{-1} \cdot m^{-2}$).

This analysis was repeated for the high school database. In this case, the EVR generator equation included a constant (0.16385) and 12 variables. The first

Table C-1. Descriptive statistics for modeled and observed event EVR values (elementary school database).

Statistic[a]	Modeled data				Observed data
	Run 1	Run 2	Run 3	Average of three statistics	
Number of event EVR values	870	870	870	870	870
Arithmetic mean	13.57	11.94	12.84	12.78	12.45
Arithmetic std. dev.	7.11	5.95	6.18	6.41	6.53
Skewness[b]	1.67	1.05	1.44	1.39	3.71
Kurtosis[b]	4.78	1.14	3.67	3.20	30.71
Minimum	4.07	2.03	2.57	2.89	2.80
25th percentile	8.44	7.64	9.20	8.43	8.64
50th percentile	11.63	10.10	11.65	11.13	11.22
75th percentile	16.81	15.37	15.48	15.89	15.21
90th percentile	23.55	20.31	20.30	21.39	19.72
95th percentile	27.79	23.26	24.16	25.07	21.98
98th percentile	33.15	27.36	32.13	30.88	27.36
99th percentile	36.03	30.19	35.86	34.03	30.52
99.5th percentile	40.27	31.63	37.05	36.32	48.18
Maximum	67.05	41.23	49.81	52.70	86.04

[a]Units are liters$\cdot$ min^{-1} $\cdot$ m^{-2} unless otherwise indicated.
[b]Dimensionless.

grouping in Table B-5 lists these variables and the associated coefficients. For example, the table indicates that OUTOTHER is one of the variables and that its coefficient is 0.11198. Consistent with Table B-7, LGM values for the high school database were selected from a normal distribution with mean equal to 2.1621 and standard deviation equal to 0.1890. MU was set equal to -1.4662; SIGMA was 0.2997 (Table B-6).

Table C-2 presents descriptive statistics for three applications of the algorithm to the high school database, averages of these statistics, and descriptive statistics for the observed EVR values. The modeled and observed data compare favorably with respect to the mean, standard deviation, and percentiles up to the 99th percentile. The model underestimates the 99.5th percentile (21.28 $l \cdot min^{-1} \cdot m^{-2}$ versus 28.81 $l \cdot min^{-1} \cdot m^{-2}$) and the maximum value (31.61 $l \cdot min^{-1} \cdot m^{-2}$ versus 48.67 $l \cdot min^{-1} \cdot m^{-2}$).

The reader will note that the tests discussed above consisted of applying the algorithm to the same databases from which the algorithm's parameters were earlier derived. Although these tests provide a test of the general performance of the EVR algorithm, they do not constitute a true validation of the approach. To be properly validated, the algorithm should be applied to other Type A databases which have measured EVR values. As previously indicated, the two Los Angles studies produced the only Type A databases with measurement-derived EVR values applicable to the two demographic groups of interest.

Table C-2. Descriptive statistics for modeled and observed event EVR values (high school database).

Statistic[a]	Modeled data				Observed data
	Run 1	Run 2	Run 3	Average of three statistics	
Number of event EVR values	2055	2055	2055	2055	2055
Arithmetic mean	9.30	9.55	9.34	9.40	9.21
Arithmetic std. dev.	2.82	3.31	2.99	3.04	3.75
Skewness[b]	1.00	2.59	0.92	1.50	3.30
Kurtosis[b]	2.13	15.53	1.24	6.30	22.07
Minimum	2.47	3.31	3.36	3.05	3.73
25th percentile	7.37	7.52	7.21	7.37	6.96
50th percentile	8.95	8.99	8.85	8.93	8.41
75th percentile	10.78	10.89	11.05	10.91	10.59
90th percentile	12.71	13.15	13.21	13.02	13.27
95th percentile	14.58	14.98	14.81	14.79	15.51
98th percentile	16.97	17.42	17.33	17.24	18.25
99th percentile	18.50	21.67	18.42	19.53	20.80
99.5th percentile	19.21	24.68	19.94	21.28	28.81
Maximum	27.66	43.02	24.14	31.61	48.67

[a]Units are liters $\cdot$ $min^{-1} \cdot m^{-2}$ unless otherwise indicated.
[b]Dimensionless.

APPENDIX D

SAMPLE OUTPUT OF pNEM/O3 APPLIED TO OUTDOOR CHILDREN (HOUSTON, 1-HOUR, DAILY MAXIMUM 0.12 PPM STANDARD [CURRENT NAAQS])

Table 1.
Cumulative Numbers of People at Hourly O3 Exposures
during O3 Season by Equivalent Ventilation Rate

O3 Level Equalled or Exceeded, ppm	Equivalent Ventilation Rate, l/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0	0	0	0	0	0
.381	0	0	0	0	0	0
.361	0	0	0	0	0	0
.341	0	0	0	0	0	0
.321	0	0	0	0	0	0
.301	0	0	0	0	0	0
.281	0	0	0	0	0	0
.261	0	0	0	0	0	0
.241	0	0	0	0	0	0
.221	0	0	0	0	0	0
.201	0	0	0	0	0	0
.181	0	0	0	0	0	0
.161	0	0	0	0	0	0
.141	0	0	0	0	0	0
.121	32985	16177	737	0	0	46741
.101	138239	62718	12837	1361	223	147325
.081	199071	159375	38956	12074	1726	199877
.061	200795	198912	120332	40966	21311	200795
.041	200795	200795	164154	126712	86588	200795
.021	200795	200795	177364	159649	128260	200795
.001	200795	200795	191899	169544	149209	200795
0.000	200795	200795	192185	169621	149209	200795

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 2.
Occurrences of People at Hourly Exposures
During O3 Season by Equivalent Ventilation Rate

O3 Interval, ppm	Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0.	0.	0.	0.	0.	0.
.381-.400	0.	0.	0.	0.	0.	0.
.361-.380	0.	0.	0.	0.	0.	0.
.341-.360	0.	0.	0.	0.	0.	0.
.321-.340	0.	0.	0.	0.	0.	0.
.301-.320	0.	0.	0.	0.	0.	0.
.281-.300	0.	0.	0.	0.	0.	0.
.261-.280	0.	0.	0.	0.	0.	0.
.241-.260	0.	0.	0.	0.	0.	0.
.221-.240	0.	0.	0.	0.	0.	0.
.201-.220	0.	0.	0.	0.	0.	0.
.181-.200	0.	0.	0.	0.	0.	0.
.161-.180	0.	0.	0.	0.	0.	0.
.141-.160	0.	0.	0.	0.	0.	0.
.121-.140	35566.	18215.	737.	0.	0.	54518.
.101-.120	289456.	87374.	13095.	1361.	223.	391509.
.081-.100	2092982.	501015.	32032.	10713.	1503.	2638245.
.061-.080	11045318.	2952005.	230470.	39110.	24268.	14291171.
.041-.060	54341980.	13332051.	845236.	206308.	106006.	68831581.
.021-.040	214922779.	38215530.	1828990.	493109.	198571.	255658979.
.001-.020	1187831007.	115687023.	3584640.	880108.	337160.	1308319938.
0.000	100749878.	7746919.	230200.	30271.	20991.	108778259.
						1758964200.

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 1A.
Cumulative Numbers of People at 1hr Daily Max. Exposure
During O3 Season by Equivalent Ventilation Rate

O3 Level Equalled or Exceeded, ppm	Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0	0	0	0	0	0
.381	0	0	0	0	0	0
.361	0	0	0	0	0	0
.341	0	0	0	0	0	0
.321	0	0	0	0	0	0
.301	0	0	0	0	0	0
.281	0	0	0	0	0	0
.261	0	0	0	0	0	0
.241	0	0	0	0	0	0
.221	0	0	0	0	0	0
.201	0	0	0	0	0	0
.181	0	0	0	0	0	0
.161	0	0	0	0	0	0
.141	0	0	0	0	0	0
.121	32985	14514	737	0	0	46741
.101	130318	53011	7259	1361	223	147325
.081	198968	147265	24443	10252	685	199877
.061	200795	193853	98331	27522	4467	200795
.041	200795	200795	149552	78056	38071	200795
.021	200795	200795	159632	118578	55979	200795
.001	200795	200795	159632	122138	63185	200795
0.000	200795	200795	159632	122138	63185	200795

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 2A.
Occurrences of People at 1hr Daily Max. Exposure
During O3 Season by Equivalent Ventilation Rate

O3 Interval, ppm	Equivalent Ventilation Rate, l/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0.	0.	0.	0.	0.	0.
.381-.400	0.	0.	0.	0.	0.	0.
.361-.380	0.	0.	0.	0.	0.	0.
.341-.360	0.	0.	0.	0.	0.	0.
.321-.340	0.	0.	0.	0.	0.	0.
.301-.320	0.	0.	0.	0.	0.	0.
.281-.300	0.	0.	0.	0.	0.	0.
.261-.280	0.	0.	0.	0.	0.	0.
.241-.260	0.	0.	0.	0.	0.	0.
.221-.240	0.	0.	0.	0.	0.	0.
.201-.220	0.	0.	0.	0.	0.	0.
.181-.200	0.	0.	0.	0.	0.	0.
.161-.180	0.	0.	0.	0.	0.	0.
.141-.160	0.	0.	0.	0.	0.	0.
.121-.140	34071.	15794.	737.	0.	0.	50602.
.101-.120	177630.	52623.	7517.	1361.	223.	239354.
.081-.100	1147474.	316691.	17407.	8891.	462.	1490925.
.061-.080	4861607.	1339265.	115031.	21835.	3782.	6341520.
.041-.060	17066439.	4311111.	297854.	61978.	37902.	21775284.
.021-.040	27047686.	5767317.	350094.	118233.	26420.	33309750.
.001-.020	8661407.	1346967.	53064.	12471.	8831.	10082740.
0.000	0.	0.	0.	0.	0.	0.
						73290175.

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts =   11
First day of O3 season =   1
Last day of O3 season =   365
No. days in O3 season =   365

Table 1B.
Cumulative Numbers of People at 1-Hr Daily Max. Dose
During O3 Season by 1-Hr O3 and EVR.

O3 Level Equalled or Exceeded, ppm	Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0	0	0	0	0	0
.381	0	0	0	0	0	0
.361	0	0	0	0	0	0
.341	0	0	0	0	0	0
.321	0	0	0	0	0	0
.301	0	0	0	0	0	0
.281	0	0	0	0	0	0
.261	0	0	0	0	0	0
.241	0	0	0	0	0	0
.221	0	0	0	0	0	0
.201	0	0	0	0	0	0
.181	0	0	0	0	0	0
.161	0	0	0	0	0	0
.141	0	0	0	0	0	0
.121	17621	11048	737	0	0	28669
.101	99632	51453	12837	1361	223	128518
.081	192813	153532	38052	11625	1726	198747
.061	200795	198912	109423	37937	21311	200795
.041	200795	200795	161301	123489	85558	200795
.021	200795	200795	175587	158838	117307	200795
.001	200795	200795	178108	160947	127902	200795
0.000	200795	200795	178108	160947	127902	200795

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 2B.
Occurrences of People at 1-Hr Daily Max. Dose
During O3 Season by 1-Hr O3 and EVR.

O3 Interval, ppm	Equivalent Ventilation Rate, l/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0.	0.	0.	0.	0.	0.
.381-.400	0.	0.	0.	0.	0.	0.
.361-.380	0.	0.	0.	0.	0.	0.
.341-.360	0.	0.	0.	0.	0.	0.
.321-.340	0.	0.	0.	0.	0.	0.
.301-.320	0.	0.	0.	0.	0.	0.
.281-.300	0.	0.	0.	0.	0.	0.
.261-.280	0.	0.	0.	0.	0.	0.
.241-.260	0.	0.	0.	0.	0.	0.
.221-.240	0.	0.	0.	0.	0.	0.
.201-.220	0.	0.	0.	0.	0.	0.
.181-.200	0.	0.	0.	0.	0.	0.
.161-.180	0.	0.	0.	0.	0.	0.
.141-.160	0.	0.	0.	0.	0.	0.
.121-.140	18707.	12328.	737.	0.	0.	31772.
.101-.120	129380.	51506.	12100.	1361.	223.	194570.
.081-.100	746113.	303758.	28178.	10264.	1503.	1089816.
.061-.080	3453558.	1466922.	173323.	35606.	22538.	5151947.
.041-.060	13639830.	5422353.	545593.	170182.	89751.	19867709.
.021-.040	24904343.	8553473.	794265.	278722.	141828.	34672631.
.001-.020	9397037.	2547775.	224343.	61142.	51433.	12281730.
0.000	0.	0.	0.	0.	0.	0.
						73290175.

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 3.
Number of People at Their Highest 1hr Daily Max. Exposure
During O3 Season by Ventilation Rate Categories

O3 Level Equalled or Exceeded, ppm	Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.401+	0	0	0	0	0	0
.381-.400	0	0	0	0	0	0
.361-.380	0	0	0	0	0	0
.341-.360	0	0	0	0	0	0
.321-.340	0	0	0	0	0	0
.301-.320	0	0	0	0	0	0
.281-.300	0	0	0	0	0	0
.261-.280	0	0	0	0	0	0
.241-.260	0	0	0	0	0	0
.221-.240	0	0	0	0	0	0
.201-.220	0	0	0	0	0	0
.181-.200	0	0	0	0	0	0
.161-.180	0	0	0	0	0	0
.141-.160	0	0	0	0	0	0
.121-.140	32985	14514	737	0	0	46741
.101-.120	97333	38497	6522	1361	223	100584
.081-.100	68650	94254	17184	8891	462	52552
.061-.080	1827	46588	73888	17270	3782	918
.041-.060	0	6942	51221	50534	33604	0
.021-.040	0	0	10080	40522	17908	0
.001-.020	0	0	0	3560	7206	0
0.000	0	0	0	0	0	0

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 4.
Cumulative Numbers of People at 8-Hr Daily Max. Exposure
During O3 Season by 8-Hr Equivalent Ventilation Rate

O3 Level Equalled or Exceeded, ppm	8hr Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.201+	0	0	0	0	0	0
.191	0	0	0	0	0	0
.181	0	0	0	0	0	0
.171	0	0	0	0	0	0
.161	0	0	0	0	0	0
.151	0	0	0	0	0	0
.141	0	0	0	0	0	0
.131	0	0	0	0	0	0
.121	0	0	0	0	0	0
.111	0	0	0	0	0	0
.101	0	0	0	0	0	0
.091	8727	0	0	0	0	8727
.081	34682	2907	0	0	0	37589
.071	118314	29241	0	300	0	125362
.061	191737	85482	1492	300	0	195230
.041	200795	152651	11745	300	0	200795
.021	200795	163895	38761	300	0	200795
.001	200795	171251	50236	300	0	200795
0.000	200795	171251	50236	300	0	200795

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 5.
Occurrences of People at 8-Hr Daily Max. Exposure
During O3 Season by 8-Hr Equivalent Ventilation Rate

O3 Interval, ppm	8hr Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.201+	0.	0.	0.	0.	0.	0.
.191-.200	0.	0.	0.	0.	0.	0.
.181-.190	0.	0.	0.	0.	0.	0.
.171-.180	0.	0.	0.	0.	0.	0.
.161-.170	0.	0.	0.	0.	0.	0.
.151-.160	0.	0.	0.	0.	0.	0.
.141-.150	0.	0.	0.	0.	0.	0.
.131-.140	0.	0.	0.	0.	0.	0.
.121-.130	0.	0.	0.	0.	0.	0.
.111-.120	0.	0.	0.	0.	0.	0.
.101-.110	0.	0.	0.	0.	0.	0.
.091-.100	8727.	0.	0.	0.	0.	8727.
.081-.090	26437.	2907.	0.	0.	0.	29344.
.071-.080	135233.	29070.	0.	300.	0.	164603.
.061-.070	454366.	108833.	1492.	0.	0.	564691.
.041-.060	5272620.	1128984.	10253.	0.	0.	6411857.
.021-.040	27544063.	4750842.	30545.	0.	0.	32325450.
.001-.020	29954696.	3817777.	12836.	0.	0.	33785309.
0.000	194.	0.	0.	0.	0.	194.
						73290175.

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 4A.
Cumulative Numbers of People at 8-Hr Daily Max. Dose
During O3 Season by 8-Hr O3 and 8-Hr EVR.

O3 Level Equalled or Exceeded, ppm	8hr Equivalent Ventilation Rate, l/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.201+	0	0	0	0	0	0
.191	0	0	0	0	0	0
.181	0	0	0	0	0	0
.171	0	0	0	0	0	0
.161	0	0	0	0	0	0
.151	0	0	0	0	0	0
.141	0	0	0	0	0	0
.131	0	0	0	0	0	0
.121	0	0	0	0	0	0
.111	0	0	0	0	0	0
.101	0	0	0	0	0	0
.091	8727	0	0	0	0	8727
.081	27626	2907	0	0	0	30533
.071	112823	29534	0	300	0	119871
.061	190333	85920	1699	300	0	194323
.041	200795	154503	12620	300	0	200795
.021	200795	173945	45921	300	0	200795
.001	200795	178604	59947	300	0	200795
0.000	200795	178604	59947	300	0	200795

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 5A.
Occurrences of People at 8-Hr Daily Max. Dose
During O3 Season by 8-Hr O3 and 8-Hr EVR

O3 Interval, ppm	8hr Equivalent Ventilation Rate, 1/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.201+	0.	0.	0.	0.	0.	0.
.191-.200	0.	0.	0.	0.	0.	0.
.181-.190	0.	0.	0.	0.	0.	0.
.171-.180	0.	0.	0.	0.	0.	0.
.161-.170	0.	0.	0.	0.	0.	0.
.151-.160	0.	0.	0.	0.	0.	0.
.141-.150	0.	0.	0.	0.	0.	0.
.131-.140	0.	0.	0.	0.	0.	0.
.121-.130	0.	0.	0.	0.	0.	0.
.111-.120	0.	0.	0.	0.	0.	0.
.101-.110	0.	0.	0.	0.	0.	0.
.091-.100	8727.	0.	0.	0.	0.	8727.
.081-.090	19088.	2907.	0.	0.	0.	21995.
.071-.080	133884.	29363.	0.	300.	0.	163547.
.061-.070	404172.	107590.	1699.	0.	0.	513461.
.041-.060	4834807.	1206173.	12424.	0.	0.	6053404.
.021-.040	25707664.	5267757.	38409.	0.	0.	31013830.
.001-.020	30043074.	5450445.	18796.	0.	0.	35512315.
0.000	1965.	931.	0.	0.	0.	2896.
						73290175.

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 6.
Number of People at Their Highest 8-Hr Daily Max. Exposure
During O3 Season by 8-Hr Ventilation Rate Categories

O3 Level Equalled or Exceeded, ppm	8hr Equivalent Ventilation Rate, l/min-m**2 <15	15-24	25-29	30-34	35+	ANY
.201+	0	0	0	0	0	0
.191-.200	0	0	0	0	0	0
.181-.190	0	0	0	0	0	0
.171-.180	0	0	0	0	0	0
.161-.170	0	0	0	0	0	0
.151-.160	0	0	0	0	0	0
.141-.150	0	0	0	0	0	0
.131-.140	0	0	0	0	0	0
.121-.130	0	0	0	0	0	0
.111-.120	0	0	0	0	0	0
.101-.110	0	0	0	0	0	0
.091-.100	8727	0	0	0	0	8727
.081-.090	25955	2907	0	0	0	28862
.071-.080	83632	26334	0	300	0	87773
.061-.070	73423	56241	1492	0	0	69868
.041-.060	9058	67169	10253	0	0	5565
.021-.040	0	11244	27016	0	0	0
.001-.020	0	7356	11475	0	0	0
0.000	0	0	0	0	0	0

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 7.
Cumulative Numbers of People at 8-Hr Daily Max.
Seasonal Mean (April to October) Exposure

O3 Level Equalled or Exceeded, ppm	
.071+	0
.066	0
.061	0
.056	0
.051	0
.046	0
.041	0
.036	293
.031	16543
.026	171987
.021	200514
.011	200795
.001	200795
0.000	200795

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 8.
Occurrences of People at 8-Hr Daily Max.
Seasonal Mean (April to October) Exposure

O3 Interval, ppm	
.071+	0
.066-.070	0
.061-.065	0
.056-.060	0
.051-.055	0
.046-.050	0
.041-.045	0
.036-.040	293
.031-.035	16250
.026-.030	155444
.021-.025	28527
.011-.020	281
.001-.010	0
0.000	0

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 9.
Number of People at Daily Max Dose that Exceed
Specified 1-HR O3 Levels 1 or More Times per Year

O3 Level Equalled or Exceeded, ppm	Days / Year 1	2	3	4	5	>5
.401+	0	0	0	0	0	0
.381	0	0	0	0	0	0
.361	0	0	0	0	0	0
.341	0	0	0	0	0	0
.321	0	0	0	0	0	0
.301	0	0	0	0	0	0
.281	0	0	0	0	0	0
.261	0	0	0	0	0	0
.241	0	0	0	0	0	0
.221	0	0	0	0	0	0
.201	0	0	0	0	0	0
.181	0	0	0	0	0	0
.161	0	0	0	0	0	0
.141	0	0	0	0	0	0
.121	25566	3103	0	0	0	0
.101	62512	40156	20619	4494	737	0
.081	9014	16381	4226	17004	30921	121201
.061	0	0	0	0	645	200150
.041	0	0	0	0	0	200795
.021	0	0	0	0	0	200795
.001	0	0	0	0	0	200795
0.000	0	0	0	0	0	200795

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 10.
Number of People at Daily Max 8-HR Dose that Exceed
Specified 8-hr O3 Levels 1 or More Times per Year

O3 Level Equalled or Exceeded, ppm	Days / Year 1	2	3	4	5	>5
.201+	0	0	0	0	0	0
.191	0	0	0	0	0	0
.181	0	0	0	0	0	0
.171	0	0	0	0	0	0
.161	0	0	0	0	0	0
.151	0	0	0	0	0	0
.141	0	0	0	0	0	0
.131	0	0	0	0	0	0
.121	0	0	0	0	0	0
.111	0	0	0	0	0	0
.101	0	0	0	0	0	0
.091	8727	0	0	0	0	0
.081	30344	189	0	0	0	0
.071	61949	44102	11353	2278	189	0
.061	24028	31750	41910	40920	30957	24758
.041	0	0	0	0	0	200795
.021	0	0	0	0	0	200795
.001	0	0	0	0	0	200795
0.000	0	0	0	0	0	200795

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 11.
Number of People that Exceed Specified O3 Levels
at 1-HR Daily Max Dose 1 or More Times per Year
with Ventilation Rates of 30 or Higher

O3 Level Equalled or Exceeded, ppm	Days / Year 1	2	3	4	5	>5
.401+	0	0	0	0	0	0
.381	0	0	0	0	0	0
.361	0	0	0	0	0	0
.341	0	0	0	0	0	0
.321	0	0	0	0	0	0
.301	0	0	0	0	0	0
.281	0	0	0	0	0	0
.261	0	0	0	0	0	0
.241	0	0	0	0	0	0
.221	0	0	0	0	0	0
.201	0	0	0	0	0	0
.181	0	0	0	0	0	0
.161	0	0	0	0	0	0
.141	0	0	0	0	0	0
.121	0	0	0	0	0	0
.101	1584	0	0	0	0	0
.081	13351	0	0	0	0	0
.061	44585	10758	1798	0	0	0
.041	41485	52718	13963	26927	4936	1705
.021	21033	20887	7862	27412	16794	69081
.001	20265	8764	10460	24171	17606	83308
0.000	20265	8764	10460	24171	17606	83308

Study Area = HOUSTON 1 1H NAAQS   Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

Table 12.
Number of People that Exceed Specified 8-HR O3 Levels
at Daily Max 8-HR Dose 1 or More Times per Year
with 8 Hour Ventilation Rates from 13 through 27

O3 Level Equalled or Exceeded, ppm	Days / Year 1	2	3	4	5	>5
.201+	0	0	0	0	0	0
.191	0	0	0	0	0	0
.181	0	0	0	0	0	0
.171	0	0	0	0	0	0
.161	0	0	0	0	0	0
.151	0	0	0	0	0	0
.141	0	0	0	0	0	0
.131	0	0	0	0	0	0
.121	0	0	0	0	0	0
.111	0	0	0	0	0	0
.101	0	0	0	0	0	0
.091	6055	0	0	0	0	0
.081	8962	0	0	0	0	0
.071	37727	13413	1179	0	0	0
.061	40668	39607	15988	13904	1180	293
.041	19611	11717	3357	1033	4014	141100
.021	1437	3421	3914	16988	10298	164421
.001	785	236	3247	1663	8055	186809
0.000	785	236	3247	1663	8055	186809

Study Area = HOUSTON 1 1H NAAQS Active Children
No. exposure districts = 11
First day of O3 season = 1
Last day of O3 season = 365
No. days in O3 season = 365

APPENDIX E

ONE-HOUR EXPOSURE DISTRIBUTIONS

FIGURE E-1. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN PHILADELPHIA, PA

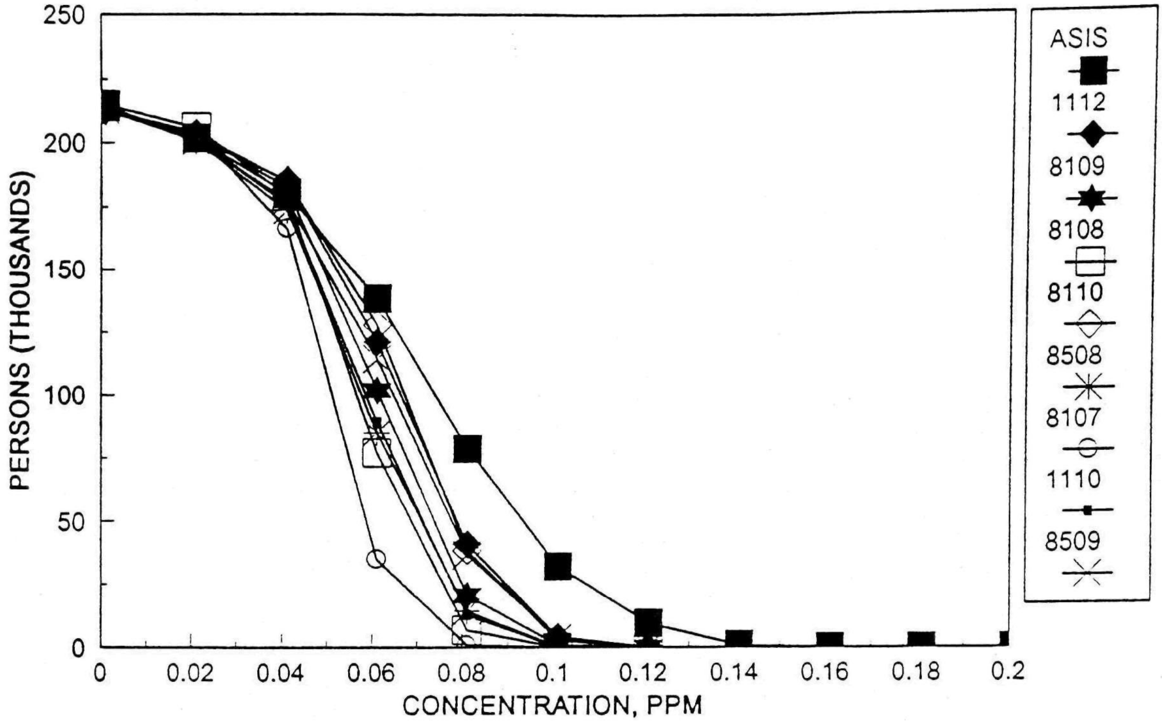


FIGURE E-2. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN PHILADELPHIA, PA

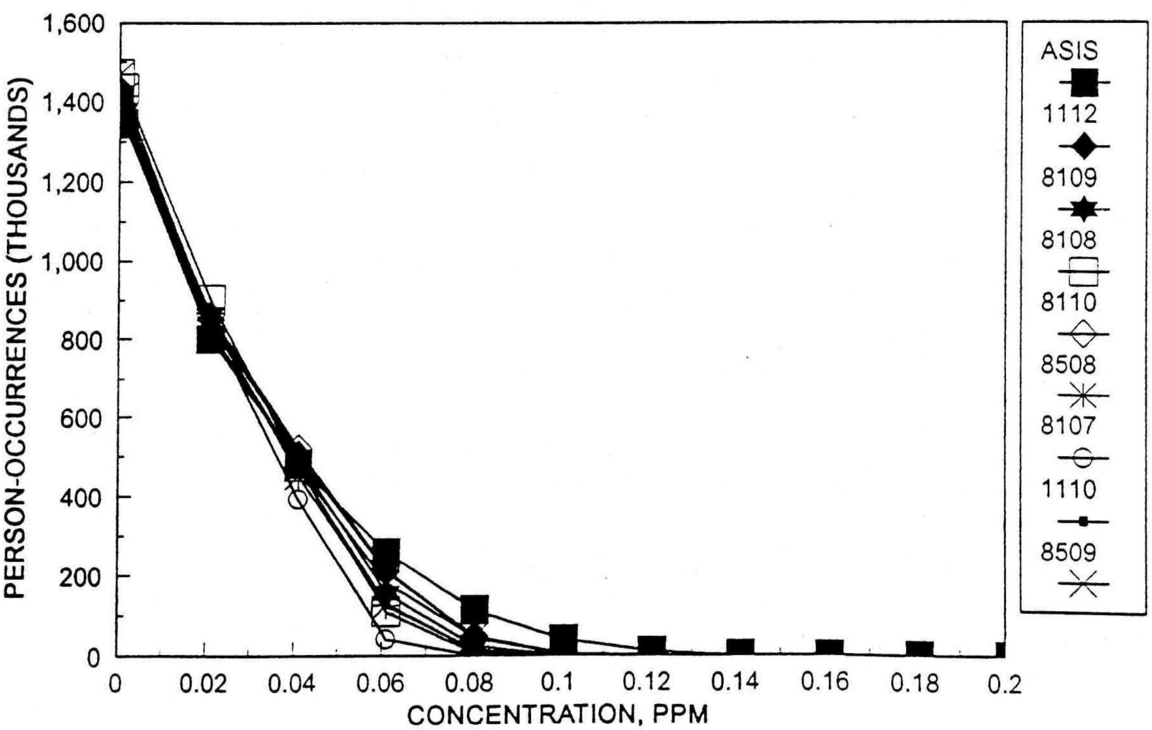


FIGURE E-3. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN HOUSTON, TX

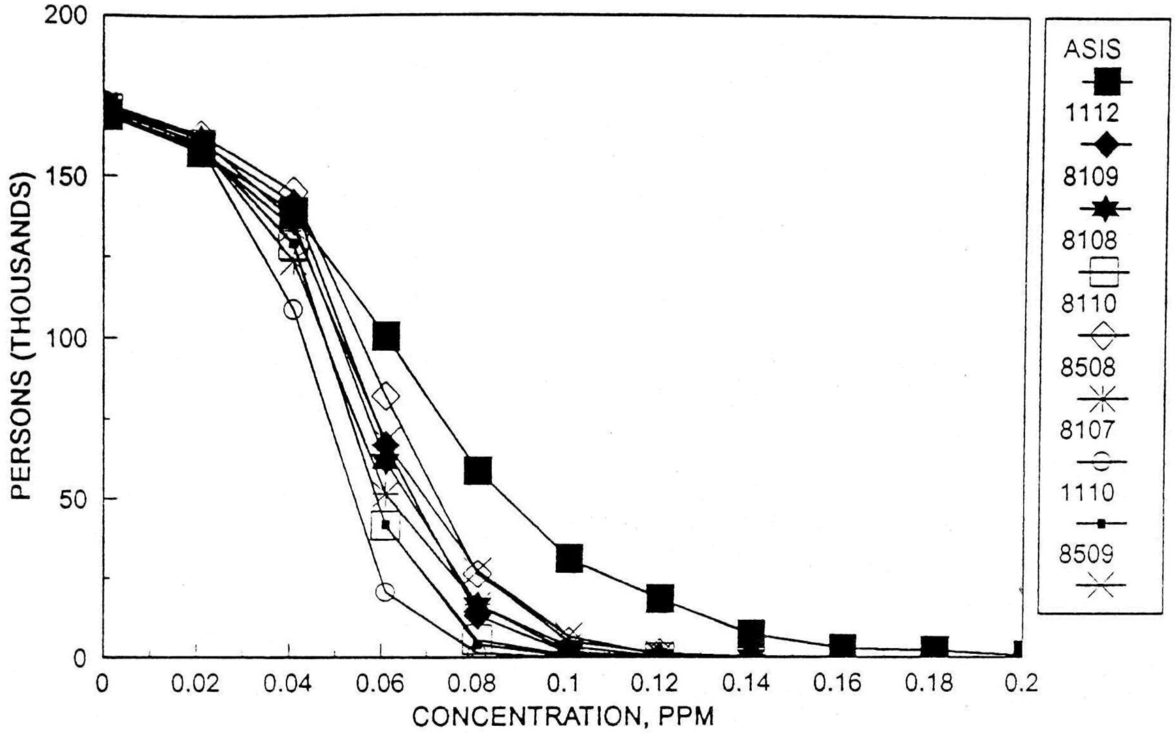


FIGURE E-4. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN HOUSTON, TX

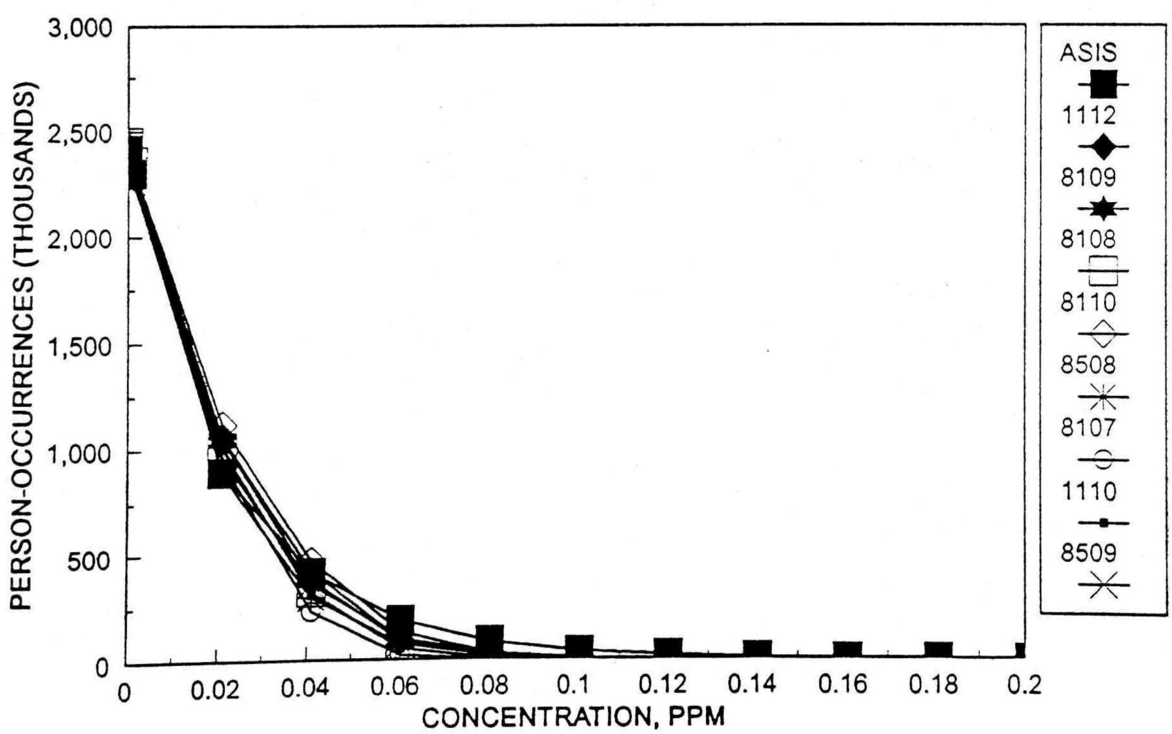


FIGURE E-5. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN NEW YORK, NY

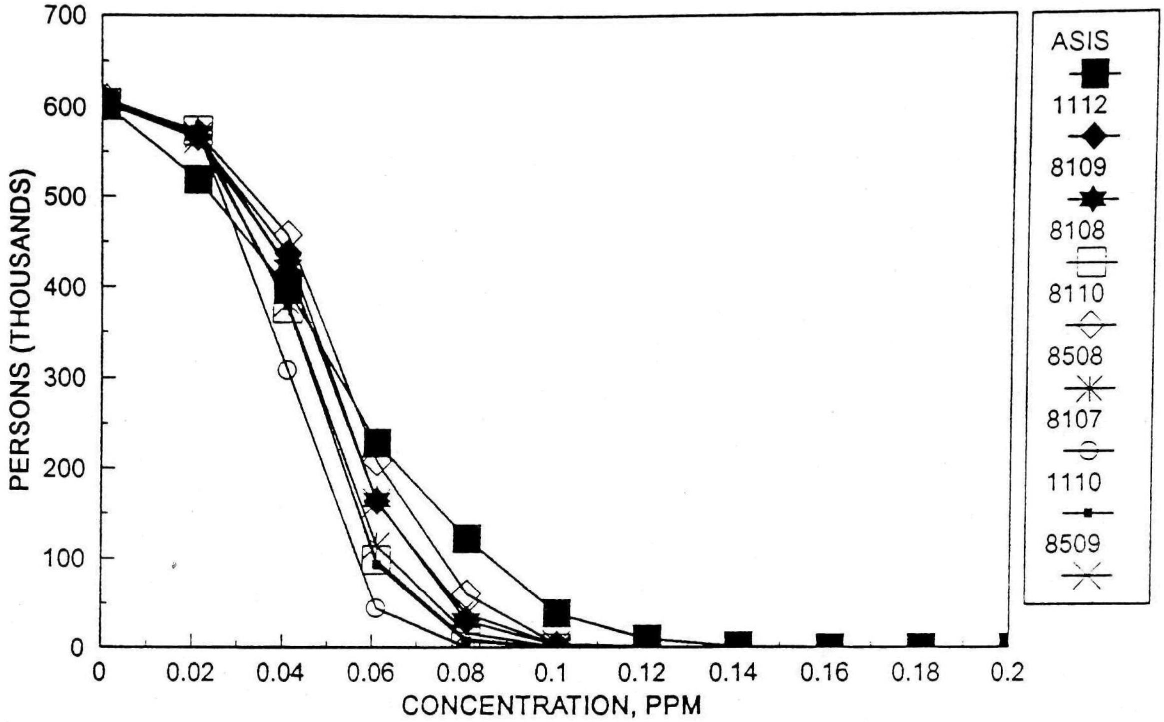


FIGURE E-6. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN NEW YORK, NY

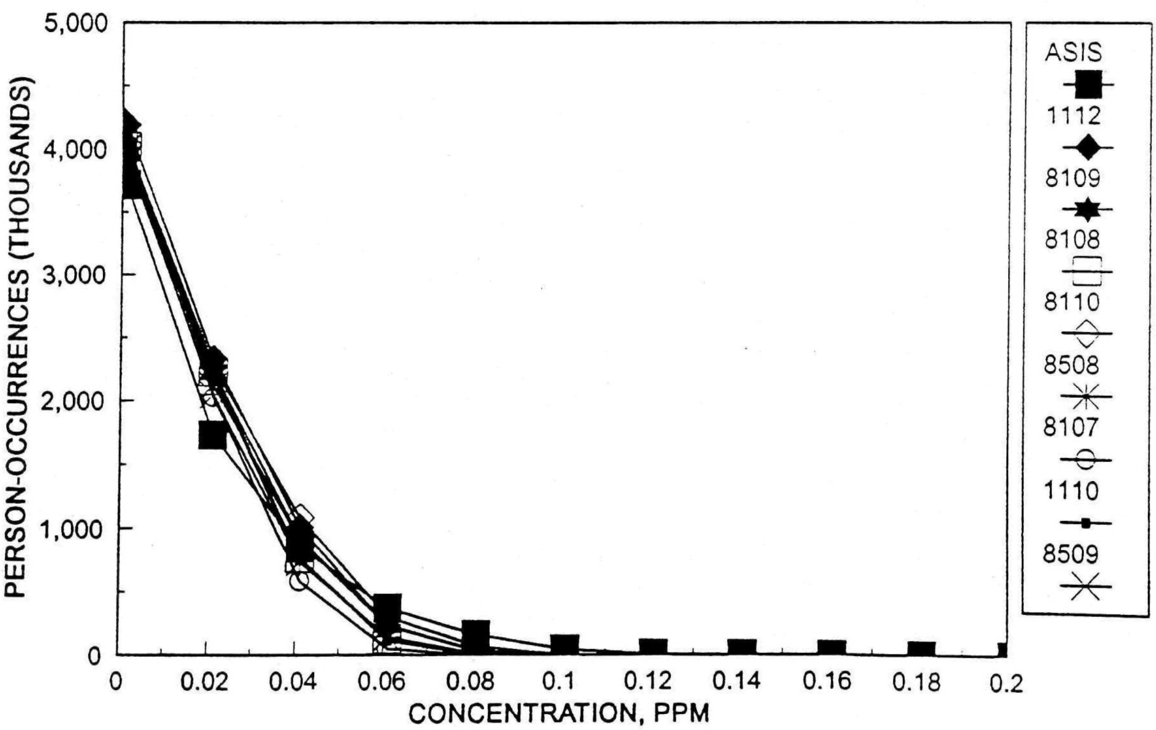


FIGURE E-7. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN WASHINGTON, D.C.

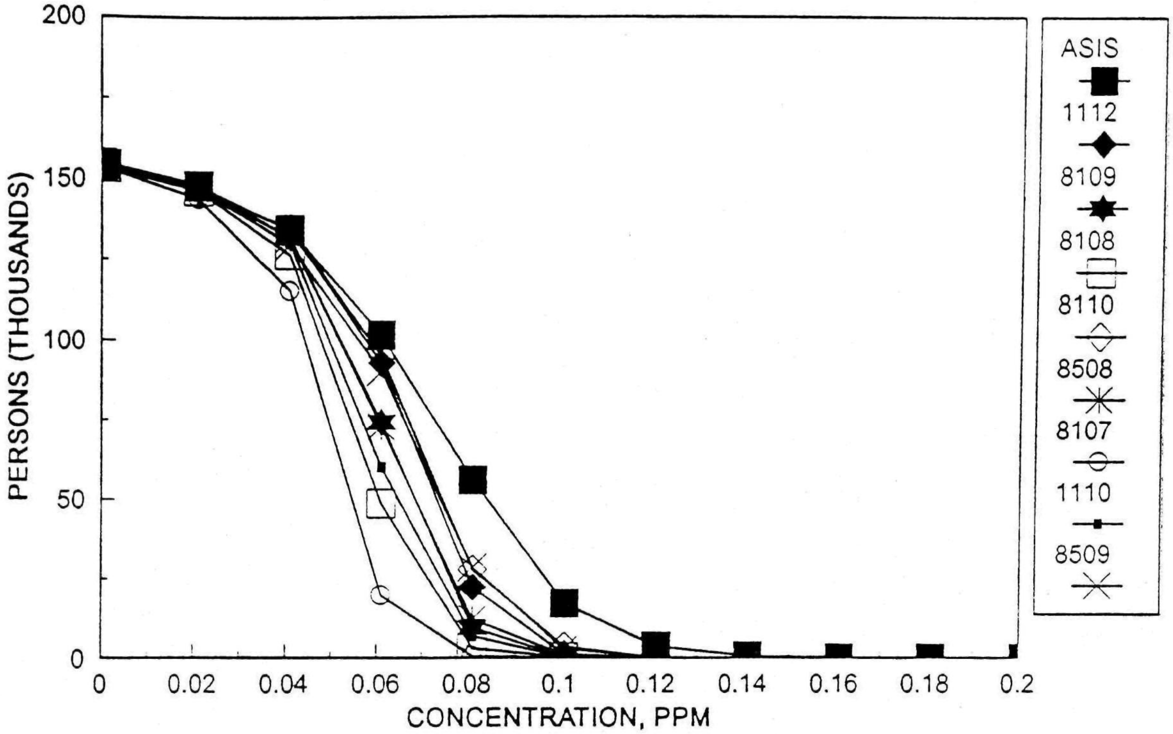


FIGURE E-8. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER HEAVY EXERTION (EVR 30+ LITERS/MIN-M2) IN WASHINGTON, D.C.

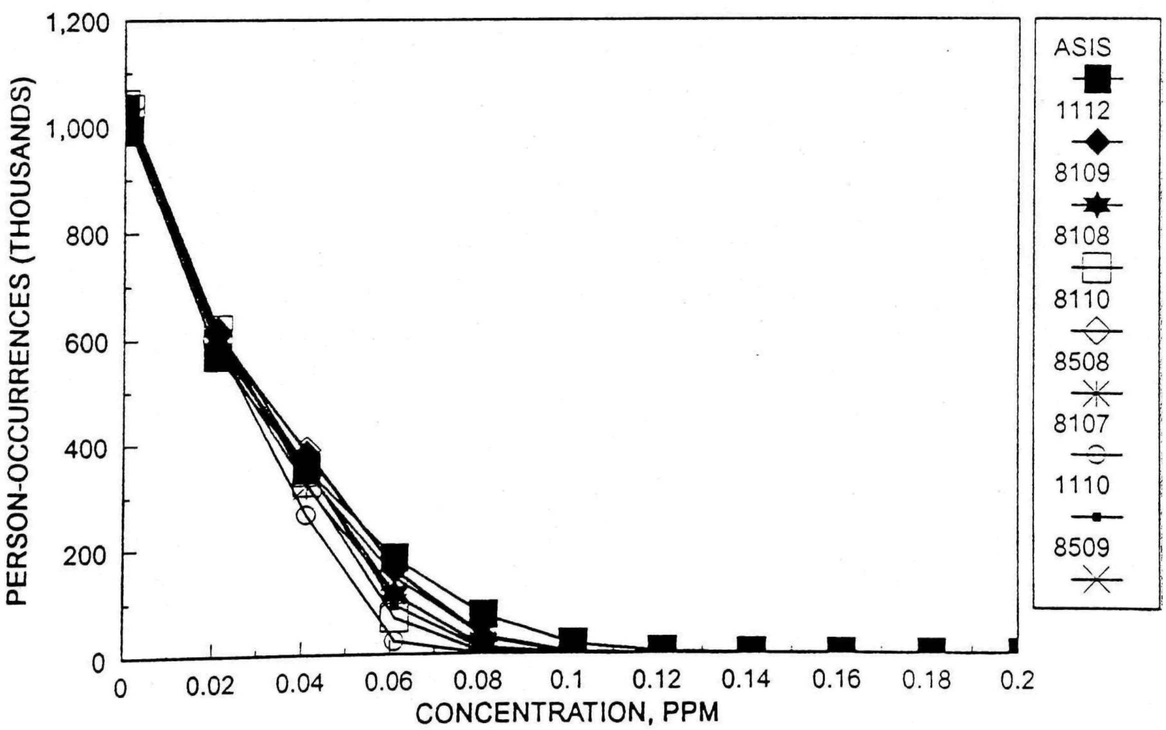


FIGURE E-9. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN PHILADELPHIA, PA

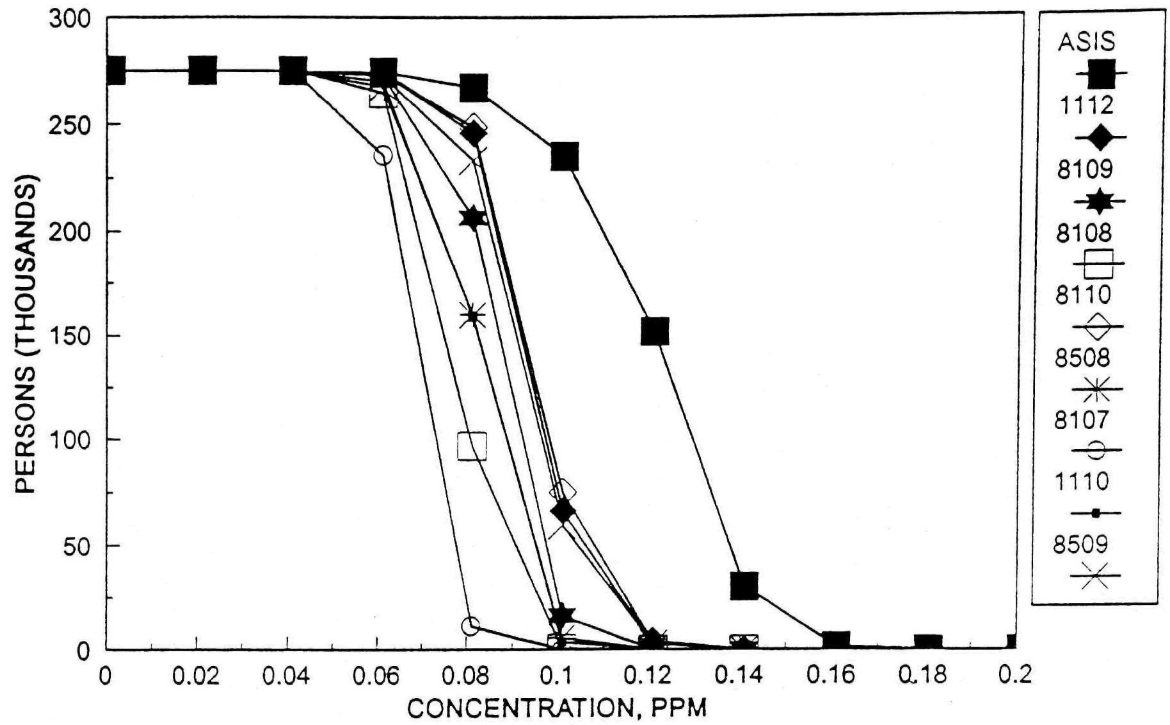


FIGURE E-10. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN PHILADELPHIA, PA

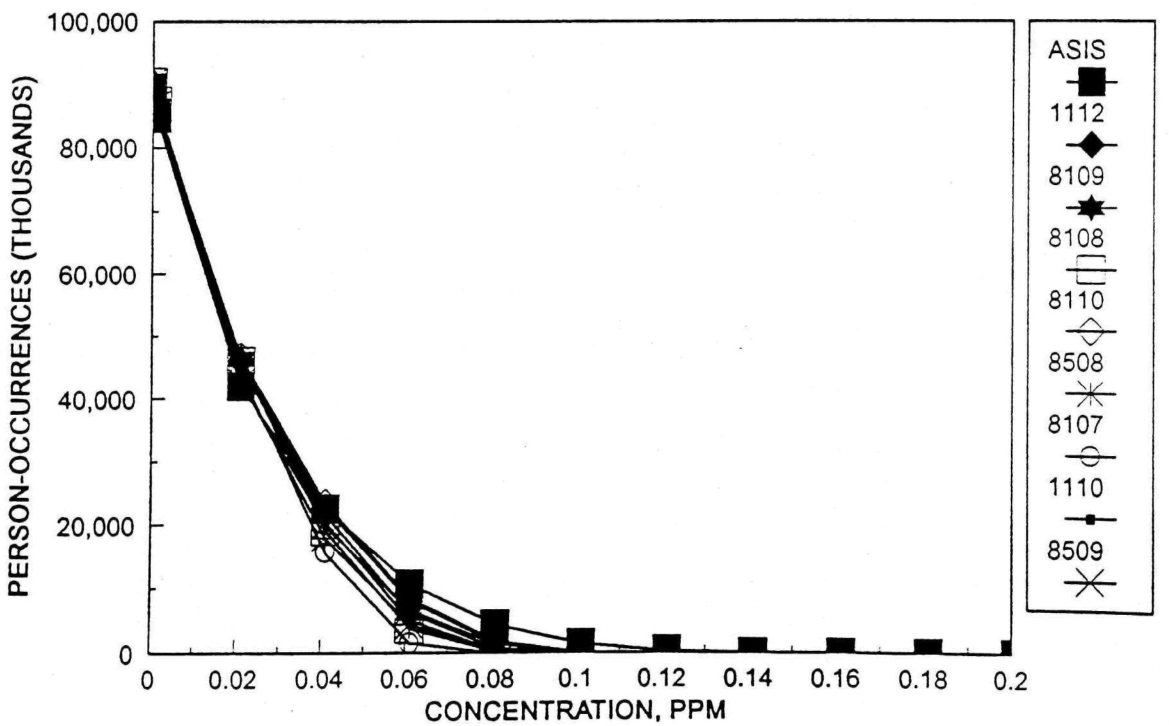


FIGURE E-11. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN HOUSTON, TX

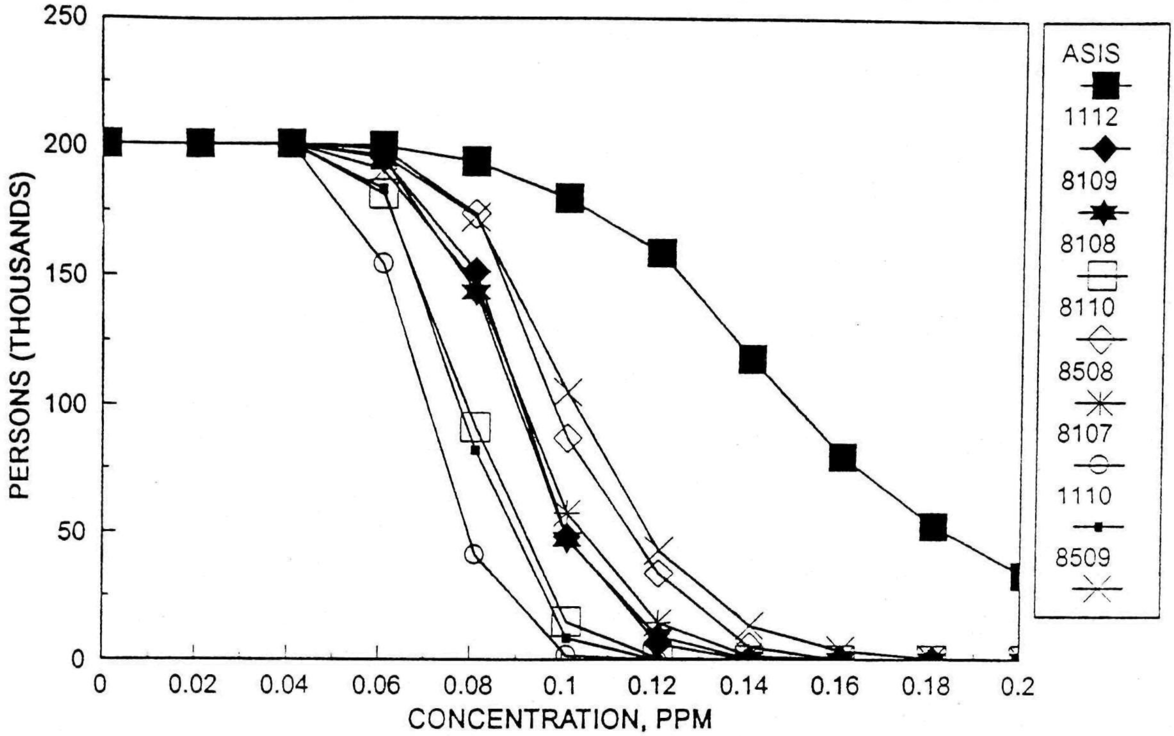


FIGURE E-12. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN HOUSTON, TX

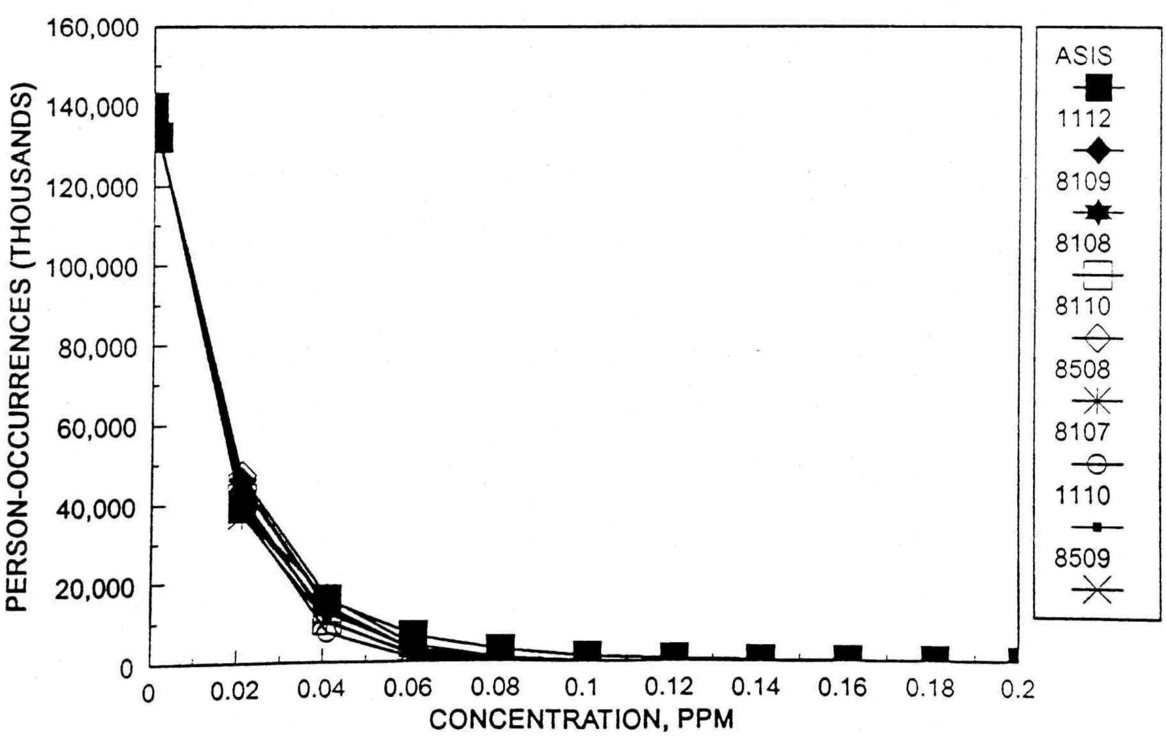


FIGURE E-13. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN NEW YORK, NY

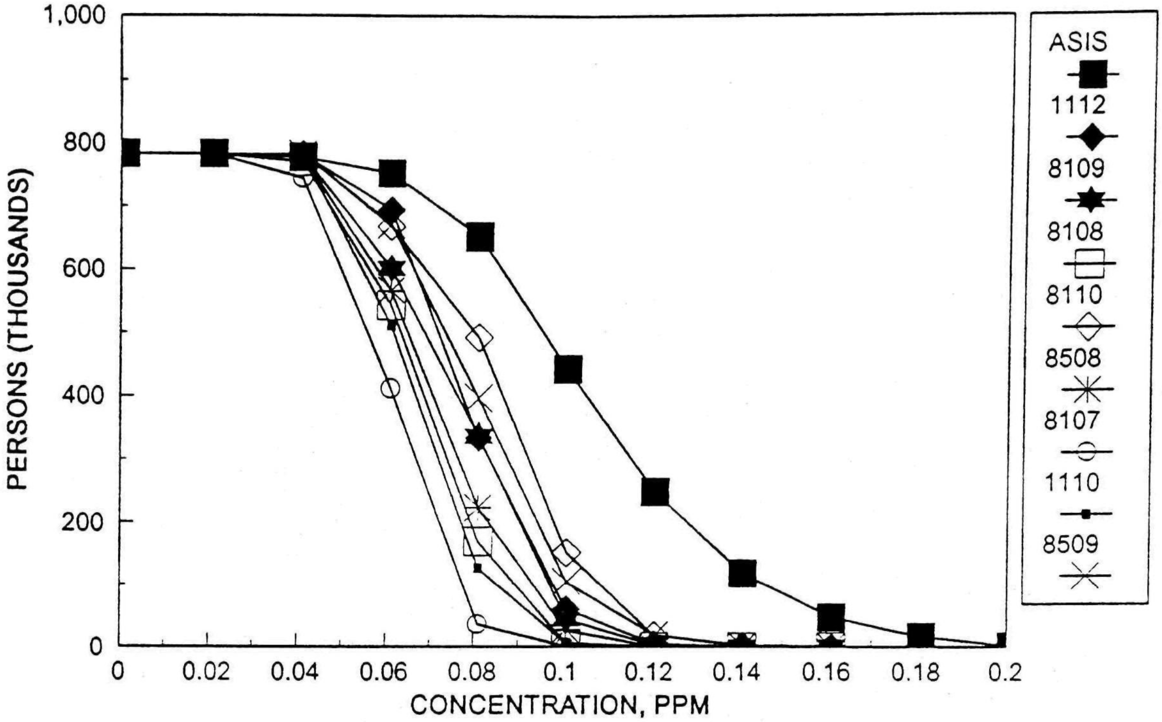


FIGURE E-14. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN NEW YORK, NY

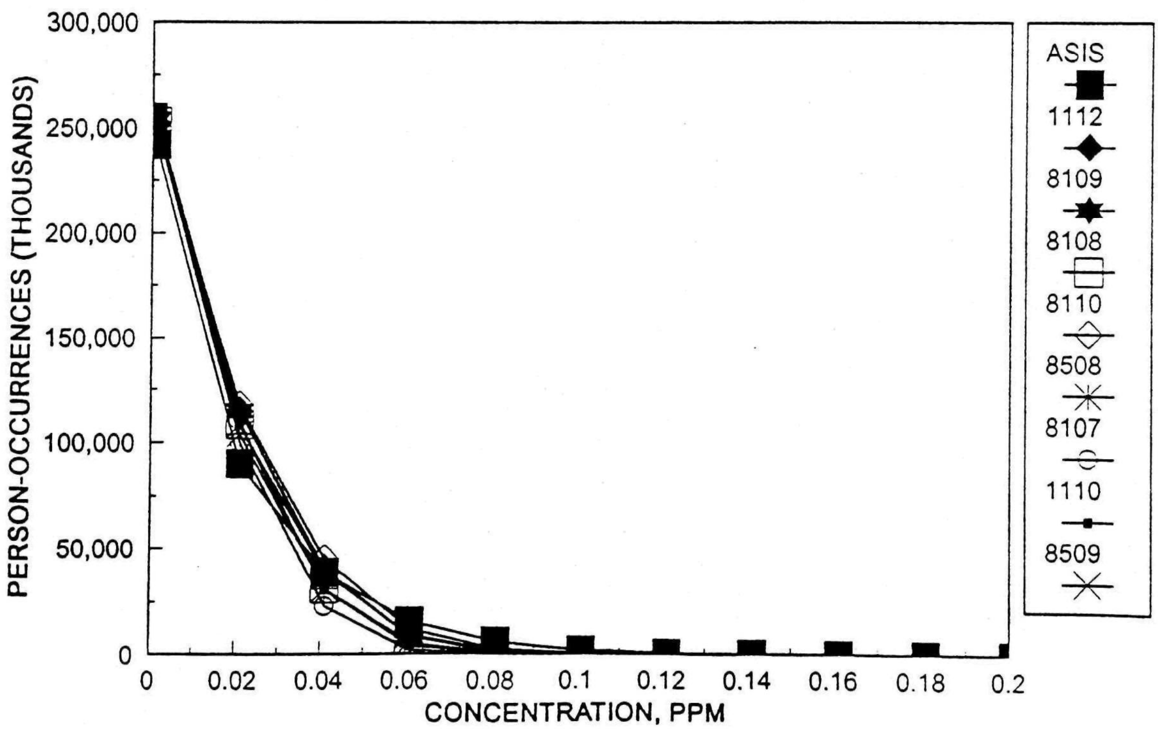


FIGURE E-15. ONE-HOUR EXPOSURE DISTRIBUTIONS FOR OUTDOOR CHILDREN EXPOSED ON ONE OR MORE DAYS UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN WASHINGTON, D.C.

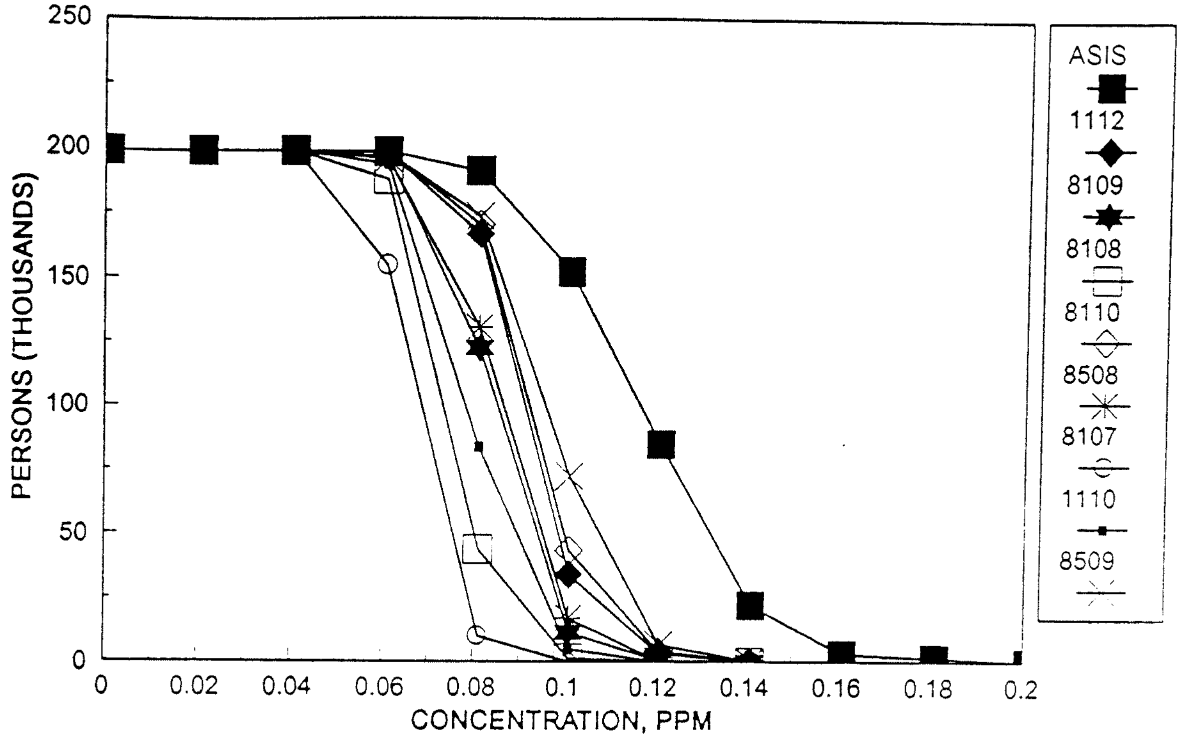
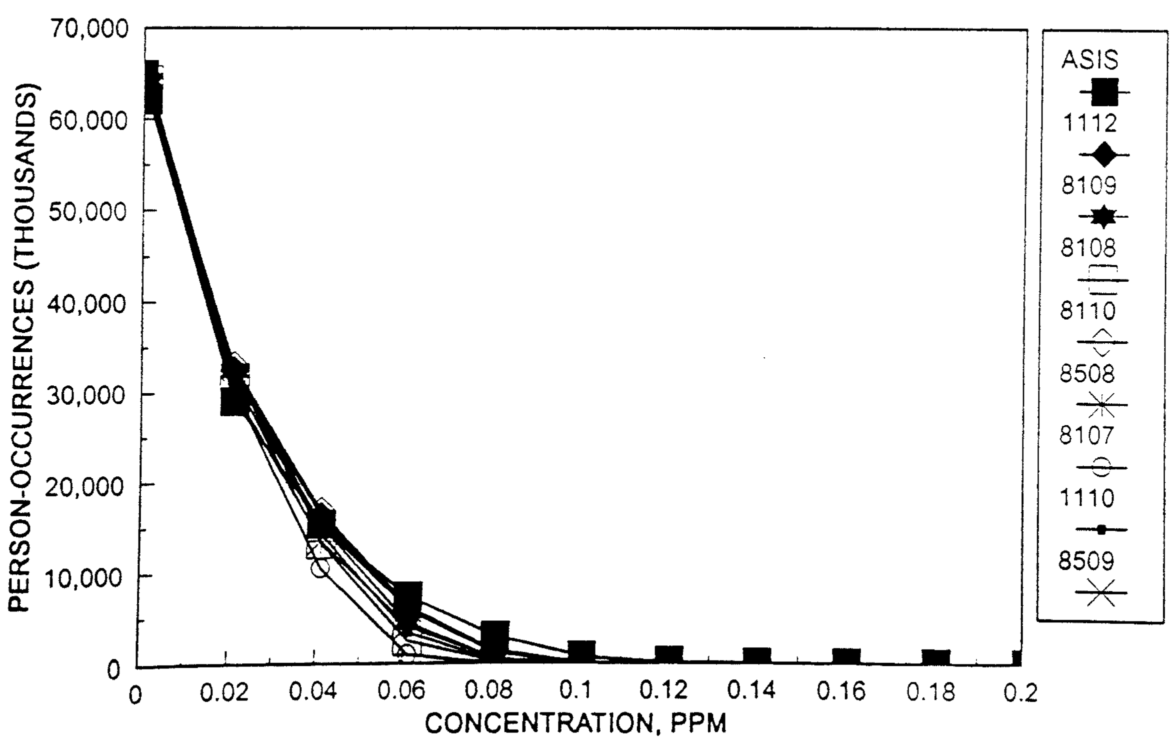


FIGURE E-16. ONE-HOUR EXPOSURE DISTRIBUTIONS OF TOTAL OCCURRENCES FOR OUTDOOR CHILDREN EXPOSURE UNDER MODERATE EXERTION (EVR 16-30 LITERS/MIN-M2) IN WASHINGTON, D.C.



APPENDIX F

ESTIMATION OF OZONE EXPOSURES IN OUTDOOR CHILDREN FOR SPECIAL 8H10EX-80 SCENARIO

INTERNATIONAL TECHNOLOGY CORPORATION

February 23, 1996

IT Project No. 763997-7

Mr. Harvey Richmond
U.S. Environmental Protection Agency
OAQPS, MD-12
RTP, North Carolina 27711

Estimation of Ozone Exposures in Outdoor Children for Special 8H10EX-80 Scenario

Dear Harvey:

Under Work Assignment 2-7 of EPA Contract No. 68-D3-0094, IT Air Quality Services (ITAQS) has performed a sensitivity analysis using the outdoor children version of pNEM/O3. In this analysis, ITAQS examined the ozone exposures that would occur in each of seven study areas when ozone levels meet a special set of conditions: the number of daily maximum eight-hour concentrations exceeding 80 ppb equals 10. This letter provides a summary of the procedures used in this sensitivity analysis and summarizes the results.

Background

The Office of Air Quality Planning and Standards (OAQPS) has conducted a series of exposure assessments using pNEM/O3 in which the ozone levels within a specified study area have been adjusted to meet a particular formulation of the ozone NAAQS. One of the standards under review (designated 8H5EX-80) states that the expected exceedance rate for daily maximum 8-hour ozone concentrations above 80 ppb shall not be more than five. To evaluate this standard, ITAQS adjusted the ozone monitoring data representing each study area using the Air Quality Adjustment Procedure (AQAP) described in recent pNEM/O3 project reports. As a result of this procedure, the ozone data reported by each monitor was adjusted so that the sixth highest daily maximum 8-hour concentration equaled a specified air quality indicator (AQI). The sixth highest value of the historical "high ozone" monitor was adjusted to equal 80 ppb.

This adjustment procedure is intended to limit the average exceedance rate of the high ozone monitor to five exceedances of 80 ppb per year, based on a single year of monitoring data. EPA has recently begun to evaluate an alternative form of this standard which limits the average value of the fifth highest daily maximum 8-hour concentration to 80 ppb (here designated 8H5AVG-80). Under this standard, there is no explicit limit to the number of exceedances that can occur in a given year. However, a recent analysis by Warren Freas of OAQPS found that very few ozone monitors report more than 10 exceedances during a single year in an area that meets the 8H5AVG-80 standard over a three-year period. As a result of this analysis, EPA directed ITAQS to develop a procedure for adjusting the monitoring data in an area to simulate conditions in which 10 exceedances occur at the historical high-ozone monitor. These data would then be used in a pNEM/O3 analysis to estimate the ozone exposures that could occur under these conditions. The next section of this letter briefly describes the AQAP developed by ITAQS.

The Air Quality Adjustment Procedure

The AQAP for the 10 exceedance scenario is similar to that used for adjusting ozone data to simulate attainment of an 8H5EX standard. In essence, the data are adjusted to meet an 8H10EX-80 standard, i.e., the expected number of daily maximum eight-hour ozone concentrations exceeding 80 ppb shall not exceed ten. The procedure is outlined in Table 1 of this letter. Note that supplementary material concerning Step 6 of the procedure can be found in Section 5.3 of the ITAQS project report describing the application of pNEM/O3 to outdoor children.

Section 5.4 of the outdoor children report describes the application of an AQAP for the 8H5EX-80 standard to Philadelphia. The new procedure described in this letter is essentially identical to the procedure in Section 5.4 when one makes the following substitutions throughout the discussion: substitute 11th highest value for sixth highest value and substitute RATIO3 for RATIO2. Table 2 lists values of RATIO3 by study area.

The adjustment procedure was applied to the ozone monitoring data which have been used in previous pNEM/O3 analyses of seven study areas: Chicago, Houston, Los Angeles, New York, Philadelphia, St. Louis, and Washington, D.C. The two remaining pNEM/O3 study areas (Denver and Miami) were omitted from the analysis because the ozone levels in these cities were relatively low with respect to the levels permitted by the 8H5AVG80 standard.

TABLE 1. AIR QUALITY ADJUSTMENT PROCEDURE USED TO SIMULATE SPECIAL ATTAINMENT CONDITIONS (CONDITIONS EQUIVALENT TO ATTAINMENT OF 8H10EX STANDARD)

1. Determine the following quantities.

EH11LDM(i,j):	the 11th largest eight-hour daily maximum concentration of the i-th ranked site in City j for the baseline year.
MAXEH11LDM(j):	the largest EH11LDM of all sites in City j for the baseline year.
AMAXEH11LDM(j):	the largest EH11LDM value permitted under the standard (i.e., 80 ppb).

2. Select five years prior to the baseline year and determine the value of EH11LDM at each site m in City j for each year. Rank these values by city and year. Let RANK(m,j,y) indicate the rank of site m in city j in year y. Let MEANRANK(m,j) indicate the mean value of RANK(m,j,y) over the five years. Rank the MEANRANK(m,j) values and let RELRANK(m,j) indicate the relative rank of MEANRANK(m,j).

3. Calculate an adjusted EH11LDM for the i-th ranked site in City j by the expression

AEH11LDM(i,j) = [EH11LDM(i,j)][AMAXEH11LDM(j)]/[MAXEH11LDM(j)].

4. If RELRANK(m,j) = i, then m will be the i-th ranked site in City j under attainment. That is,

AEH11LDM(m,j) = AEH11LDM(i,j) if RELRANK(m,j) = i.

5. Use the equation

ACLV1 = (RATIO3)(AEH11LDM)

to estimate the characteristic largest one-hour value (CLV1) associated with each AEH11LDM(m,J) value. Denote this value as ACLV1(m,j). Values of RATIO3 are listed by city in Table 2.

6. The one-hour data for Site m are adjusted so that a Weibull distribution fit to the adjusted data will have a CLV1 equal to ACLV1(i,j) where i = RELRANK(m,j). Subsection 5.3 of the outdoor children pNEM/O3 report provides a method for estimating the parameters of this distribution and making the adjustment.

TABLE 2. RATIO3 VALUES BY STUDY AREA

City	RATIO3[a]
Chicago	1.583
Denver	1.627
Houston	2.346
Los Angeles	1.945
Miami	1.697
New York	1.647
Philadelphia	1.465
St. Louis	1.598
Washington	1.596

[a]RATIO3 = (ACLV1)/(AEH11LDM)

Exposure Estimates for Selected Study Areas

The pNEM/O3 model incorporates a number of stochastic (random) elements which directly affect the exposure estimates produced by the model. Consequently, exposure estimates are likely to vary from run to run. Consistent with earlier analyses, ITAQS ran the model 10 times for each of the seven study areas. Tables 3 through 10 provides means and ranges for selected exposure indicators based on these runs. In each case, the exposure estimates apply to the population group previously designated as "outdoor children" and use the adjusted ozone data described above. The exposure indicators are defined in Sections 7.2 and 7.4 of the pNEM/O3 project report for outdoor children.

In Tables 3 through 10, the attainment scenario is described in terms of a "8H10EX-80" scenario, as the ozone monitoring data were adjusted to simulate attainment of this indicator. In using this designation, it is understood that the scenario is actually intended to represent a special high-ozone situation that could occur during a single year when a 8H5AVG-80 standard is attained over a three-year period.

Table 3 lists exposure estimates for number and percent of outdoor children experiencing one or more one-hour daily maximum ozone exposures above 120 ppb at any ventilation rate. These results for the 8H10EX-80 scenario can be compared with similar estimates for nine other scenarios in Table 50 of the pNEM/O3 project report for outdoor children. The values for 8H10EX-80 listed for each city in Table 3 fall between the corresponding values for 8H5EX-80 and 8H5EX-90 in Table 50, regardless of study area.

TABLE 3. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE ONE-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 120 PPB AT ANY VENTILATION RATE UNDER 8H10EX-80 SCENARIO

Study Area	Number of Persons at Risk	Mean		Range	
		Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	169,006	35.75	137,422 - 213,679	29.07 - 45.20
Houston	200,795	127,114	63.31	120,022 - 132,678	59.77 - 66.08
Los Angeles	798,290	41,507	5.20	33,105 - 46,365	4.15 - 5.81
New York	782,600	66,393	8.48	56,842 - 73,325	7.26 - 9.37
Philadelphia	275,320	553	0.20	0 - 3,244	0.00 - 1.18
St. Louis	128,250	23,331	18.19	19,971 - 29,932	15.57 - 23.34
Washington, DC	198,860	24,811	12.48	16,941 - 30,047	8.52 - 15.11

TABLE 4. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 60 PPB AT ANY VENTILATION RATE UNDER THE 8H10EX-80 SCENARIO

Study Area	Number of Persons at Risk	Mean		Range	
		Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	471,354	99.71	467,714 - 472,710	98.94 - 100.00
Houston	200,795	175,837	87.57	168,175 - 184,677	83.75 - 91.97
Los Angeles	798,290	223,914	28.05	217,662 - 232,082	27.27 - 29.07
New York	782,600	593,320	75.81	582,353 - 600,824	74.41 - 76.77
Philadelphia	275,320	263,827	95.83	259,451 - 268,140	94.24 - 97.39
St. Louis	128,250	113,782	88.72	111,825 - 116,372	87.19 - 90.74
Washington, DC	198,860	195,024	98.07	189,346 - 197,510	95.22 - 99.32

TABLE 5. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 80 PPB AT ANY VENTILATION RATE UNDER THE 8H10EX-80 SCENARIO

Study Area	Number of Persons at Risk	Mean		Range	
		Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	243,097	51.43	215,145 - 278,767	45.51 - 58.97
Houston	200,795	95,348	47.49	85,124 - 109,717	42.39 - 54.64
Los Angeles	798,290	55,361	6.93	51,975 - 62,295	6.51 - 7.80
New York	782,600	158,065	20.20	145,057 - 173,013	18.54 - 22.11
Philadelphia	275,320	85,648	31.11	74,059 - 99,292	26.90 - 36.06
St. Louis	128,250	41,380	32.27	37,006 - 45,013	28.85 - 35.10
Washington, DC	198,860	86,127	43.31	79,912 - 94,154	40.19 - 47.35

TABLE 6. NUMBER AND PERCENT OF OUTDOOR CHILDREN EXPERIENCING ONE OR MORE EIGHT-HOUR DAILY MAXIMUM OZONE EXPOSURES ABOVE 100 PPB AT ANY VENTILATION RATE UNDER THE 8H10EX-80 SCENARIO

Study Area	Number of Persons at Risk	Mean		Range	
		Number of Persons Exposed	Percent of Total	Number of Persons Exposed	Percent of Total
Chicago	472,710	10,210	2.16	2,736 - 18,662	0.58 - 3.95
Houston	200,795	19,023	9.47	7,284 - 27,127	3.63 - 13.51
Los Angeles	798,290	114	0.01	0 - 1,139	0.00 - 0.14
New York	782,600	7,706	0.98	3,881 - 11,406	0.50 - 1.46
Philadelphia	275,320	0	0.00	0 - 0	0.00 - 0.00
St. Louis	128,250	872	0.68	133 - 1,794	0.10 - 1.40
Washington, DC	198,860	2,535	1.27	381 - 4,924	0.19 - 2.48

TABLE 7. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN UNDER THE 8H10EX-80 SCENARIO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS $\cdot$ $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Study area		
	Chicago	Houston	Los Angeles
Mean Estimate of the Number of Outdoor Children	806	1,731	1,200
Percent of Total Outdoor Children Population	0.17	0.86	0.15
Range in this percentage for 10 runs	0.00 - 1.23	0.00 - 2.06	0.00 - 0.51
Mean Estimate of Person-Occurrences	806	1,924	1,200
Percent of Total Person-Occurrences	c	c	c
Range in this percentage for 10 runs	0.00 - 0.01	0.00 - 0.01	d
Mean Estimate of Occurrences/Person Exposed	1.00	1.11	1.00
Percentage exposed for indicated number of days			
1 Day	100.00	89.40	100.00
2 Days	0.00	10.60	0.00
>2 Days	0.00	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Less than 0.01 percent.
[d]All values less than 0.01 percent.

TABLE 8. ESTIMATES OF ONE-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN UNDER THE 8H10EX-80 SCENARIO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.12 ppm AND EVR[a] EQUALED OR EXCEEDED 30 LITERS · $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Study Area			
	New York	Philadelphia	St. Louis	Washington, DC
Mean Estimate of the Number of Outdoor Children	0	0	85	0
Percent of Total Outdoor Children Population	-	-	0.07	-
Range in this percentage for 10 runs	-	-	0.00 - 0.55	-
Mean Estimate of Person-Occurrences	0	0	85	0
Percent of Total Person-Occurrences	-	-	c	-
Range in this percentage for 10 runs	-	-	d	-
Mean Estimate of Occurrences/Person Exposed	-	-	1.00	-
Percentage exposed for indicated number of days				
1 Day	-	-	100.00	-
2 Days	-	-	0.00	-
>2 Days	-	-	0.00	-

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O^3.
[c]Less than 0.01 percent.
[d]All values less than 0.01 percent.

TABLE 9. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN UNDER THE 8H10EX-80 REGULATORY SCENARIO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · MIN^{-1} · M^{-2} TO 27 LITERS · MIN^{-1} · M^{-2}

Statistic[b]	Study Area		
	Chicago	Houston	Los Angeles
Mean Estimate of the Number of Outdoor Children	80,968	40,022	25,566
Percent of Total Outdoor Children Population	17.13	19.93	3.20
Range in this percentage for 10 runs	13.22 - 21.52	14.60 - 28.41	2.50 - 3.92
Mean Estimate of Person-Occurrences	94,630	49,775	32,992
Percent of Total Person-Occurrences	0.09	0.07	0.01
Range in this percentage for 10 runs	0.08 - 0.12	0.04 - 0.09	0.01 - 0.02
Mean Estimate of Occurrences/Person Exposed	1.17	1.24	1.29
Percentage exposed for indicated number of days			
1 Day	84.44	79.86	76.77
2 Days	13.73	16.53	18.83
3 Days	1.83	3.21	3.20
>3 Days	0.00	0.40	1.20

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.

TABLE 10. ESTIMATES OF EIGHT-HOUR MAXIMUM DOSAGE EXPOSURES EXPERIENCED BY OUTDOOR CHILDREN UNDER THE 8H10EX-80 SCENARIO DURING WHICH OZONE CONCENTRATION EXCEEDED 0.08 ppm AND EVR[a] RANGED FROM 13 LITERS · $MIN^{-1} \cdot M^{-2}$ TO 27 LITERS · $MIN^{-1} \cdot M^{-2}$

Statistic[b]	Study Area			
	New York	Philadelphia	St. Louis	Washington, DC
Mean Estimate of the Number of Outdoor Children	55,012	27,866	11,354	27,087
Percent of Total Outdoor Children Population	7.03	10.12	8.85	13.62
Range in this percentage for 10 runs	5.89 - 8.34	6.93 - 14.92	5.24 - 12.45	9.75 - 19.51
Mean Estimate of Person-Occurrences	69,198	32,216	12,914	31,118
Percent of Total Person-Occurrences	0.04	0.05	0.05	0.07
Range in this percentage for 10 runs	0.03 - 0.05	0.04 - 0.08	0.03 - 0.06	0.06 - 0.10
Mean Estimate of Occurrences/Person Exposed	1.26	1.16	1.14	1.15
Percentage exposed for indicated number of days				
1 Day	77.82	84.63	86.91	85.37
2 Days	18.54	14.17	11.73	13.45
3 Days	3.53	1.20	1.35	1.18
>3 Days	0.10	0.00	0.00	0.00

[a]Equivalent ventilation rate = (ventilation rate)/(body surface area).
[b]Mean or range for 10 runs of pNEM/O3.

Table 4 lists exposure estimates for the number and percent of outdoor children experiencing one or more eight-hour daily maximum ozone exposures above 60 ppb at any ventilation rate. These results are comparable to the estimates in Table 51 of the outdoor children project report. For each study area, the 8H10EX-80 estimates in Table 4 fall between the estimates for 8H5EX-80 and 8H5EX-90 in Table 51.

The pattern holds for Tables 5 and 6. In both tables, the exposure estimates for the 8H10EX-80 scenario fall between the corresponding estimates for 8H5EX-80 and 8H5EX-90 in Section 7 of the project report for outdoor children.

Each ozone exposure estimated by pNEM/O3 includes a value for ozone concentration and a value for equivalent ventilation rate (EVR). The product of ozone concentration and EVR provides an indication of ozone dose. The "daily maximum dose" is assumed to occur each day during the period when this product is highest. Consistent with this concept, pNEM/O3 provides dose estimates for two averaging times: the one-hour maximum daily dose and the eight-hour daily maximum dose. Analysts have previously evaluated two specific dose indicators:

- The number of outdoor children who experienced one or more one-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.12 ppm (120 ppb) and the EVR equalled or exceeded 30 liters min^{-1} m^{-2}.

- The number of outdoor children who experienced one or more eight-hour maximum daily dosage exposures during which the ozone concentration exceeded 0.08 ppm (80 ppb) and the EVR ranged from 13 liters min^{-1} m^{-2} to 27 liters min^{-1} m^{-2}.

Tables 7 and 8 provide exposure estimates for the first of these two exposure indicators. Exposure estimates for the second exposure indicator are presented in Tables 9 and 10.

When the one-hour dose estimates in Tables 7 and 8 for the 8H10EX-80 scenario are compared with similar estimates for other scenarios in the project report, the 8H10EX-80 values are found to always equal or exceed the 8H5EX-80 estimates. The 8H10EX-80 estimates are less than the corresponding 8H5EX-90 estimates for all study areas except Houston. A similar evaluation of the eight-hour dose estimates in Tables 9 and 10 indicates that the 8H10EX-80 values fall between the corresponding 8H5EX-80 and 8H5EX-90 estimates for all seven study areas.

The overall pattern of results indicates that ozone exposures expected under the 8H10EX-80 scenario always exceed those of the 8H5EX-80 scenario and almost always are less than those under the 8H5EX-90 scenario.

I hope that you find these results useful. Please call me if you have any questions or comments.

Sincerely,

IT Corporation

Ted Johnson

cc: J. Capel
J. Mozier
T. Palma