

A Pilot Study in Los Angeles to Measure Personal Ozone Exposures During Scripted Activities

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A PILOT STUDY IN LOS ANGELES TO MEASURE PERSONAL OZONE EXPOSURES DURING SCRIPTED ACTIVITIES

Health and Environmental Sciences Department

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CONTRACTOR'S ACKNOWLEDGMENTS

The Los Angeles Personal Ozone Exposure Study was conducted by a team consisting of TRJ Environmental, Inc. (TRJ), the Environmental Health Service (EHS) of the Rancho Los Amigos Medical Center, and the Harvard School of Public Health. The research team was assisted by Dr. Ed Avol of the School of Medicine at the University of Southern California, Jim Mulik of the U.S. Environmental Protection Agency (EPA), and Mr. Curt Miller of the Information Systems Division of the South Coast Air Quality Management District.

TRJ designed the study, developed the scripts and activity diaries, processed and statistically analyzed the acquired data, and prepared this report. The TRJ team consisted of Mr. Ted Johnson, Ms. Jill Mozier, and Mr. Mark Weaver. Ted Johnson served as project director for TRJ and was the principal author of this report.

EHS solicited study subjects, conducted all field activities, and developed the initial data bases. The EHS team consisted of Mr. Ken Clark, Mr. Bill Linn, Ms. Karen Anderson, and Ms. Cheryl Nugent. Ms. Anderson and Ms. Nugent served as study subjects.

Ms. Denise Belliveau of Harvard University prepared the tubes used in the personal ozone monitors. Mr. Mike Wolfson and Ms. Christine Donoghue analyzed the tubes after sample collection. Dr. Alison Geyh modified the personal monitor for collection of one-hour samples, provided guidance in designing the study protocols, and served as a study subject.

Dr. Ed Avol provided guidance in developing the study protocols and served as a study subject.

Mr. Jim Mulik of EPA performed initial tests of the personal ozone monitors prior to use in the field and proposed modifications of the instrument.

Mr. Curt Miller provided one-hour ozone data collected by fixed-site monitors in the Los Angeles area.

Mr. Jim Capel adapted the probabilistic NMQS Exposure Model for Ozone for use in this study.

The TRJ portion of the study was funded by the American Petroleum Institute (API) under Contract No. 0-08200-0601-5H95-005. Dr. Will Ollison, the project director, made significant contributions to the design and implementation of the pilot study.

ABSTRACT

The U.S. Environmental Protection Agency (EPA) has developed a computer-based model for estimating ozone exposures likely to occur in urban populations when a proposed National Ambient Air Quality Standard (NAAQS) is attained. This model, the probabilistic NAAQS Exposure Model for Ozone (pNEM/O₃), simulates typical activities and breathing rates of population groups moving through five microenvironments (indoors - residential, indoors - other, outdoors - near roadways, outdoors - other, and in-vehicle) and determines ozone exposure from ambient monitoring data and microenvironmental adjustment factors. The validity of pNEM/O₃ model results can best be evaluated through use of personal monitoring data. Researchers at Harvard University have developed a personal exposure monitor (PEM) consisting of an active NaNO₂ denuder system that is capable of measuring hourly average ozone exposures as low as 10 ppb. To evaluate this sampler and provide data useful in validating the pNEM/O₃ model, a team of researchers conducted 21 person-days of tests in Los Angeles, California, during September and October, 1995.

During the study, trained subjects collected hourly average PEM data during the 12 daylight hours between 0700 and 1900 each day and multiple-hour average samples (4-8 hours) during the evening hours between 1900 and 0700. During each day, the subject followed a prepared activity script that specified location, microenvironment, and general activity for each sampled period. The subject recorded specific activities and locations in a "real-time" diary and made additional entries describing traffic density in nearby roadways, local temperature, and other weather conditions. Individual hourly PEM values were compared to hourly ozone measurements from the nearest fixed-site ambient monitor, and mean values for specific microenvironments were computed. Statistical analysis of the results indicated that the PEM concentrations were generally lower than fixed-site values, particularly when subjects were indoors, in vehicles, or near roadways.

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) has developed a model which can be used to estimate ozone exposures likely to occur in urban populations when a proposed National Ambient Air Quality Standard (NAAQS) is attained. This model, the probabilistic NAAQS Exposure Model for Ozone (pNEM/O₃), simulates the typical daily activities of defined population groups and determines an ozone exposure for each activity. The validity of pNEM/O₃ and similar models can best be evaluated through the use of data collected by personal exposure monitors (PEM). To provide such data, researchers at Harvard University have developed an active ozone monitor (AOM) consisting of an open denuder tube coated with a nitrite reagent, a filter, and a battery-operated pump. The monitor has been tested in a series of field studies in which ozone measurements were made for periods ranging from two to eight hours.

This report presents the results of a study conducted in Los Angeles and funded by the American Petroleum Institute (API) to evaluate the performance of the Harvard monitor when collecting one-hour samples. The study was also designed to provide data that could be used to evaluate the pNEM/O₃ and similar ozone exposure models. During September 1995, four trained subjects collected PEM data for twenty-one 24-hour monitoring periods, each period beginning at 7 pm on one day and ending at 7 pm on the following day. During each monitoring period, the subject followed a prepared script that specified a location, a microenvironment, and a general activity for each of 14 sampling periods. These sampling periods always began and ended on the hour. Beginning at 7 pm, they included a four-hour period (7 pm to 11 pm), an eight-hour period (11 pm to 7 am), and 12 one-hour periods (7 am to 8 am, 8 am to 9 am, ..., 6 pm to 7 pm). The Harvard AOM was used to collect an air sample during each of the 14 sampling periods listed above plus two multi-hour periods that overlapped 12 of the 14 sampling periods: the four-hour period from 7 am to 11 am and the eight-hour period from 11 am to 7 pm.

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The subject described each actual activity and location in a "real-time" diary that was carried throughout the 24-hour monitoring period. Supplemental data on temperature, traffic, and weather conditions were also entered in the diary. Researchers conducted a series of statistical analyses in which PEM ozone concentrations were evaluated with respect to various sets of candidate predictor variables. The candidate predictor variables included subject identity, geographic location, microenvironment, activity, time of day, duration, weather, window position (open or closed), traffic density, local temperature, and the ozone concentration measured at the nearest fixed-site monitor in Los Angeles. When all PEM values were considered together, the best predictors tended to be (1) ozone concentration at the nearest fixed-site monitor, (2) activity classification, (3) microenvironment, and (4) temperature. When PEM values were grouped by microenvironment, the best predictors were as follows:

Indoors - residence	time of day activity classification geographic location (district) window position weather
Indoors - other locations	time of day
Outdoors - near road	ozone at nearest fixed-site monitor temperature location (district) weather
Outdoors - other locations	ozone at nearest fixed-site monitor temperature activity classification weather
In vehicle	ozone at nearest fixed-site monitor temperature geographic location (district)

In general, PEM values tended to be higher when the ozone concentration at the nearest fixed-site monitor was high, the microenvironment was outdoors, the time of

day was afternoon, the weather was sunny, the temperature was high, and/or windows were open.

The traffic variable (vehicles/min) was a poor predictor of PEM value for the outdoor microenvironments. Researchers had expected traffic to show a relatively high negative correlation with PEM value, as vehicular traffic produces nitric oxide, a known ozone scavenger.

PEM concentrations in each microenvironment tended to be lower than the ozone concentration at the nearest fixed-site monitor. The following values represent the arithmetic mean of RATIO20, the ratio of PEM value to fixed-site value for fixed-site values that equal or exceed 20 ppb.

Indoors - residence	0.28
Indoors - other locations	0.18
Outdoor - near road	0.58
Outdoors - other locations	0.59
In vehicle	0.21

The relatively low value for outdoors - other locations (0.59) was unexpected. Fixed-site monitors tend to be sited in outdoor areas away from roadways, areas that match the definition of the "outdoor - other" microenvironment. Consequently, researchers had expected the ratio to approximate 1.00.

Subjects were instructed to characterize window position (open or closed) and air conditioning status (on or off) for each entry representing an indoor or in-vehicle microenvironment. As indicated below, the mean value of RATIO20 tended to be lower when windows were closed than when open.

<u>Microenvironment</u>	<u>Mean value of RATIO20</u>			
	<u>Windows</u>		<u>Air conditioning</u>	
	<u>Open</u>	<u>Closed</u>	<u>On</u>	<u>Off</u>
Car	0.27	0.09	0.11	0.06
Subject's residence	0.42	0.13	0.08	0.18
School and other indoors	0.24	0.18	0.19	0.11

The effect of air conditioning on RATIO20 varied with microenvironment. In each case, the calculated ratios for "air conditioning off" were based on less than 10 PEM values and may not be representative of general conditions.

Eleven of the PEM values associated with the outdoors - near road microenvironment could be characterized with respect to wind direction. The mean value of the PEM-to-fixed site ratio (RATIO20) was 0.47 for downwind locations and 0.55 for upwind locations, a statistically insignificant difference. A review of the traffic data for the 11 roadside periods showed that traffic flows were low (< 15 vehicles/minute) for nine of the periods. Consequently, traffic was probably too light to affect the RATIO20 values of the downwind locations.

Twenty-three of the scripted sampling periods were represented by pairs of PEM values obtained from replicate analyses (i.e., two analyses performed on the same sample). Analysts calculated the absolute difference between the two values and the relative difference expressed as a percent. The relative difference was defined as the absolute difference divided by the average of the two values; that is

$$\text{relative difference} = (100)(\text{absolute difference}) / (0.5)(\text{sum of values}).$$

To avoid dividing by values near to or equal to zero, the relative difference was calculated only when both replicate values equaled or exceeded 20 ppb. The mean absolute difference for all 23 pairs of replicate samples was 3.0 ppb; the standard deviation was 4.9 ppb. The mean relative difference was 4.9 percent based on the

six sets of replicate analyses which met the minimum concentration requirement (20 ppb). These results indicate a high degree of precision in the ozone concentrations determined by laboratory analysis of the PEM samples.

Twenty of the scripted sampling periods were represented by pairs of PEM values obtained from duplicate samples (i.e., two samples collected at the same location during the same time period). A mean absolute difference of 8.7 ppb was calculated for the entire set of duplicate samples; the standard deviation was 9.0 ppb. The mean relative difference was 35.4 percent, based on seven sets of duplicate samples. Six of the seven sets were pairs of one-hour samples; the remaining set was a pair of two-hour samples. As in the case of the replicate analyses, the relative difference was calculated only when the reported ozone concentrations of both duplicate samples equaled or exceeded 20 ppb.

The scripts typically specified that a four-hour sample be collected from 0700 to 1100 and an eight-hour sample be collected from 1100 to 1900. During these periods, one-hour samples were also collected. Analysts calculated the absolute and relative differences between the ozone concentration obtained from each multihour sample and the average of the values obtained from the corresponding one-hour samples. Classified by sample duration, the mean absolute differences were 3.6 ppb for four-hour samples ($n = 18$), 5.4 ppb for eight-hour samples ($n = 18$), and 4.6 ppb for the four- and eight-hour samples combined ($n = 36$). The average relative difference for the eight-hour samples was 12 percent; relative differences could not be calculated for four-hour samples as none of the cases met the 20 ppb requirement.

Subjects typically carried the PEMs in backpacks with monitor inlets positioned near the subject's breathing zone. These "backpack samplers" were assumed to provide an indication of the subject's personal exposure to ozone. Researchers conducted two special studies to investigate whether the personal exposure of children playing in a confined outdoor area (playground or backyard) would compare closely with the

ozone concentration measured by a single fixed-site monitor located in the same area.

Researchers conducted a special test in which ozone concentrations were measured for one-hour periods by five co-located stationary monitors: four PEMs and a Dasibi® ultraviolet (UV) monitor. The mean relative difference between the Dasibi® concentration and the average of the four PEM concentrations was 12.0 percent over four one-hour test periods; the standard deviation was 4.6 percent. The mean PEM value for the four-hour period (60.8 ppb) was 7.9 percent lower than the corresponding four-hour mean UV value (66.0 ppb).

This observed bias of 7.9 percent was consistent with the results of an earlier test reported by Peters *et al.* (1995). In that study, researchers equipped 39 children with active denuder samplers similar to the PEMs used in this study. The active denuders were carried by the children in backpacks as they participated in a lunch/recreation program at a park in Riverside, CA. Active denuders were also used as stationary monitors in the same area. Two UV monitors were set up about 100 yards apart in the area where the children were playing. When used as stationary monitors, the active denuders measured about 6 percent lower than the UV monitors. When carried by the children, the active denuders measured about 8 percent lower than the UV monitors.

Researchers developed a special version of pNEM/O3 (pNEM/O3/LA) and applied it to a data base obtained from the Los Angeles study. Using appropriate time/activity data and fixed-site monitoring data collected during the study, pNEM/O3/LA produced an estimate of ozone exposure which could be compared to each PEM value obtained from the Los Angeles study.

For each PEM sampling period, analysts calculated MEANRATIO -- the mean of the ratio of measured ozone concentration to estimated ozone concentration based on 10

runs of pNEM/O3/LA. MEANRATIO was interpreted as the average ratio of (1) the ozone exposure measured under a set of specified conditions to (2) the ozone exposure that pNEM/O3 would estimate for the same set of conditions. Ideally, values of MEANRATIO would tend towards 1.00, indicating that pNEM/O3 tends to provide an unbiased estimate of ozone exposure for a given set of conditions.

The report provides arithmetic means for MEANRATIO values classified by various indices. The majority of these arithmetic means fall within the range of 0.30 to 0.80. Few of the arithmetic means exceed 0.80. These results suggest that the pNEM/O3/LA estimates tend to exceed the corresponding PEM values, regardless of data classification, when all PEM values are considered.

In response to a request from EPA, analysts performed a special analysis to determine whether the tabulated ratios of PEM concentration to pNEM concentration would change significantly when PEM values less than 30 ppb were omitted from the analysis. The analysis found that the proportional difference between PEM and pNEM values for most data classifications was reduced after omission of the PEM values below 30 ppb. The difference remained statistically significant for the outdoor microenvironments, however, with the PEM value tending to be less than the corresponding pNEM value.

This Los Angeles study was the first test of a newly developed model validation approach which uses the Harvard ozone PEM to collect one-hour samples while subjects engage in scripted activities. The scripts were constructed to obtain samples simulating the behaviors of population groups of special interest to the researchers while maintaining a realistic sequence of activities for each monitoring period. The data collection instruments (PEM and diary) performed well, and subjects reported few problems with the sampling protocol. The overall success of the study suggests that the new protocol provides an economical means of acquiring targeted ozone samples which represent realistic exposure conditions.

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Section 1

INTRODUCTION

During September of 1995, the American Petroleum Institute (API) funded a pilot study in Los Angeles, California, to test a newly developed instrument for monitoring personal exposure to ozone. The tested personal exposure monitor (PEM) was a refinement of an active pumped monitor developed previously by Dr. Petros Koutrakis and Dr. Alison Geyh of Harvard University (Koutrakis *et al.*, 1993; Geyh *et al.*, 1994; Geyh *et al.*, 1997). The pilot study was conducted to evaluate the ability of the Harvard PEMs to collect one-hour samples. In addition, the study tested a new approach to exposure model validation in which subjects' movements among geographic locations and through microenvironments were guided by prepared scripts.

The pilot study was conducted by a team consisting of TRJ Environmental, Inc. (TRJ), the Environmental Health Service of the Los Amigos Research and Education Institute (EHS-LAREI), and the Harvard School of Public Health. The research team was assisted by Dr. Ed Avol of the University of Southern California, Jim Mulik of the U.S. Environmental Protection Agency (EPA), and Mr. Curt Miller of the Information Systems Division of the South Coast Air Quality District. This report focuses primarily on the research efforts of TRJ and EHS-LAREI.

The report is divided into seven sections. Section 2 describes a series of personal monitoring studies funded by API that culminated in the Los Angeles study. Section 3 provides an overview of the Los Angeles study. The data collection instruments used in the study are described in Section 4. Section 5 provides a summary of study results. Section 6 compares personal ozone exposures measured during the study with exposure estimates for the same conditions obtained from pNEM/O3, a

computer-based simulation model developed by the U.S. Environmental Protection Agency. Section 7 provides a summary and evaluation of the results.

Section 2

BACKGROUND

THE ESTIMATION OF HUMAN EXPOSURE TO OZONE

Various regulatory agencies have developed computer-based models for estimating human exposure to ozone. For example, the U.S. Environmental Protection Agency (EPA) has developed a model which can be used to estimate the ozone exposures likely to occur in urban populations when a proposed National Ambient Air Quality Standard (NAAQS) is attained. This model, the probabilistic NAAQS Exposure Model for Ozone (pNEM/O3), simulates the typical daily activities of defined population groups and determines an ozone exposure for each activity.

The ozone exposure associated with each activity (or "exposure event") is characterized by two parameters: the ozone concentration of the inspired air and the equivalent ventilation rate (EVR). EVR is defined as ventilation rate divided by body surface area and thus provides an indication of breathing rate normalized for body size. The pNEM/O3 model contains special algorithms which provide estimates of ozone concentration based on geographic location, microenvironment and demographic group. Other model algorithms provide estimates of EVR based on demographic group and exertion level.

The validity of pNEM/O3 and similar exposure models can best be evaluated through the use of personal monitoring data. Ideally, these data would be acquired by equipping a large number of randomly selected subjects with personal exposure monitors (PEMs) which measure ozone concentration and ventilation rate on a minute-by-minute basis. Each subject would document his or her daily activities during the monitored period in a real-time diary.

As it is not practical to measure EVR directly while a subject engages in his or her ordinary daily activities, researchers have developed a procedure to estimate one-minute EVR values indirectly. In a series of diary studies [Linn *et al.* (1993); Shamoo *et al.* (1991); Spier *et al.* (1992)], an EHS-LAREI research team equipped subjects with Polar® heart rate monitors which recorded average pulse rates over one-minute intervals. Each minute pulse rate measurement was converted to a corresponding minute ventilation rate (and subsequently to a minute EVR value) through the use of a subject-specific calibration curve. The calibration curve was developed by measuring ventilation rate and pulse rate simultaneously as each subject engaged in a graded series of tasks. Ventilation rate was measured directly using a Magtrac 3 Respirator®.

THE RESEARCH TRIANGLE PILOT STUDY

The American Petroleum Institute (API) has been actively supporting the development of portable monitors capable of taking short-term ozone concentration measurements. The efforts have focused primarily on three instruments:

- The Odyssey Model 2001-O3/M monitor developed by Transducer Research, Inc (TRI).
- The Harvard Active Ozone Monitor developed by Petros Koutrakis of Harvard University.
- The Ogawa Passive Ozone Monitor developed by a Harvard research team directed by Petros Koutrakis.

The TRI monitor is capable of measuring ozone concentration with a one-minute averaging time. The Harvard and Ogawa monitors have typically been used to collect multi-hour samples with averaging times varying from 2 to 36 hours.

During August and September of 1994, API conducted a pilot study in the Research Triangle area of North Carolina to test these three ozone monitors [Johnson *et al.* (1995)]. During the study, each of 10 working adults completed two multi-day

time/activity diaries as he or she engaged in typical activities. During the nominal 36-hour period documented in each diary, each subject was equipped with the three ozone monitors and a pulse-rate monitor.

An exercise physiologist administered a graded series of exercise tests to each subject. Results of these tests were used to convert pulse rate data obtained during the diary periods to ventilation rates.

The EPA assisted in the pilot study by placing fixed-site ozone monitors in two Durham office buildings where subjects worked. EPA also operated an ambient ozone monitor in the Research Triangle Park. The State of North Carolina operated fixed-site monitors in Raleigh and Durham.

A report by Johnson *et al.* (1995) provides a detailed description of the procedures employed in the Research Triangle study and presents the results of a variety of statistical analyses performed on the collected data. These analyses revealed that the TRI monitor intermittently produced anomalous readings, a problem that must be resolved before the monitor is used in a large-scale study.

The authors also noted that the Harvard Active Monitor and Ogawa Passive Monitor performed reliably, although they typically measured relatively low ozone concentrations (10 ppb or less). These low readings resulted from the long sampling periods associated with the Harvard and Ogawa monitors. The Harvard and Ogawa monitors typically collected 36-hour air samples during which the subject spent the majority of time in low ozone environments.

THE LOS ANGELES PILOT STUDY

Following the Research Triangle pilot study, researchers at Harvard University further refined the Harvard Active Monitor with the goal of successfully collecting one-hour samples. API conducted a pilot study during September of 1995 to evaluate the

performance of the Harvard monitor when collecting one-hour samples. The study was also designed to provide data that could be used to evaluate pNEM/O₃ and similar ozone exposure models.

During the Los Angeles study, a team of researchers collected PEM data for twenty-one 24-hour monitoring periods, each period beginning at 7 pm on one day and ending at 7 pm on the following day. During each monitoring period, a trained subject followed a prepared script that specified a location, a microenvironment, and a general activity for each of 16 sampling periods. These sampling periods always began and ended on the hour. Beginning at 7 pm, they included two four-hour periods (7 pm to 11 pm, 7 am to 11 am), two eight-hour periods (11 pm to 7 am, 11 am to 7 pm), and 12 one-hour periods beginning at 7 am, 8 am, 9 am, ..., and 6 pm. The subject described each activity and location in a "real-time" diary that was carried throughout the 24-hour monitoring period. Supplemental data on temperature, traffic, and weather conditions were also entered in the diary.

To better characterize the correlation between personal exposure and ambient (outdoor) ozone concentrations, researchers compared the PEM ozone reading for each sampling period with the average ozone concentration reported for the period by the nearest fixed-site monitor. In addition, each PEM reading was compared with an ozone exposure estimate for the same ambient ozone conditions obtained from the pNEM/O₃ exposure model.

Section 3 provides a more detailed description of the procedures employed by the pilot study. Section 4 describes the principal data collection instruments. Section 5 provides a summary of the results of the pilot study. Section 6 presents the results of a special analysis comparing PEM ozone readings with exposure estimates obtained from the pNEM/O₃ exposure model. Study conclusions and recommendations are presented in Section 7.

Section 3

OVERVIEW OF THE PILOT STUDY

In past personal monitoring studies conducted by EHS-LAREI research teams (C. E. Spier *et al.*, 1992; D. A. Shamoo *et al.*, 1991; and W. S. Linn *et al.*, 1993) and Ted Johnson (T. Johnson, 1984; T. Johnson, 1995), researchers have solicited volunteer subjects to conform to a general set of demographic characteristics (e.g., high school students). The subjects of each study were instructed to engage in their regular activities during each monitoring period. The principal goal of each study was to obtain personal monitoring data representative of typical activity patterns.

The 1995 Los Angeles study described here differed from these earlier studies in that (1) the study employed trained subjects and (2) each subject followed a predetermined activity pattern. The Los Angeles subjects included two employees of Environmental Health Services (Ms. Karen Anderson and Ms. Cheryl Nugent), Dr. Alison Geyh of Harvard University, and Dr. Edward Avol of the University of Southern California. Each subject was instructed to follow a prepared script for a 24-hour monitoring period. The script was incorporated into a real-time diary carried by the subject. The script was divided into sampling periods that lasted from one to eight hours, depending on time of day. The script provided instructions to the subject specifying (1) the air samples to be taken during each sampling period, (2) a general location for the sampling period, and (3) the subject's general activities during the sampling period. Subjects were directed to record individual activities in the diary as they occurred.

This section is divided into subsections that describe the location and time period of the study, the selection of monitoring locations within Los Angeles, the development of scripts, and the scheduling of sampling activities. It also provides a generic

schedule for the monitoring activities associated with a particular subject. The data collection instruments are described in more detail in Section 4.

GENERAL STUDY LOCATION AND TIME PERIOD

The pilot study was conducted in the Los Angeles, California, metropolitan area during September of 1995. Researchers selected Los Angeles for the study site to increase the likelihood of measuring high outdoor ozone concentrations. Fixed-site monitors within Los Angeles typically report summertime ozone concentrations that far exceed 120 ppb, the ozone concentration specified by the current National Ambient Air Quality Standard (NAAQS) for ozone. For this reason, Los Angeles is currently considered to be non-attainment with respect to the NAAQS for ozone.

SELECTION OF LOCATIONS FOR MONITORING ACTIVITIES

The script directions for each sampling period specified a location that consisted of a town (e.g., Upland) and one or more locations within the town (e.g., outdoors in Town Park). Subjects typically spent time in two towns during each 24-hour monitoring period. Evening hours (6 pm to 8 am) were usually spent in the subject's home town (Fullerton, Cypress, or Manhattan Beach). Daytime hours (9 am to 5 pm) were usually spent in one of the following six towns: Upland, Brea, Downey, Arcadia, Pasadena, or Lake Arrowhead (near Blue Jay). These towns have historically reported relatively high ozone concentrations. Table 3-1 provides descriptive statistics for each of the study towns based on 1994 ozone monitoring data.

Prior to the monitoring portion of the study, researchers surveyed each town by car and developed a list of candidate monitoring locations within the town. These locations were selected to be in close proximity to one another and to represent four non-vehicle microenvironments: indoors - residence, indoors - other, outdoors - near road, and outdoors - other. Trips between towns were accounted for by a fifth microenvironment (in vehicle).

Table 3-1. Highest Four Values of Daily Maximum One-Hour Ozone Concentration Reported for 1994 by Fixed-Site Monitors Located in or Near Towns Associated With Personal Monitoring Activities.^a

Town	Nearest monitor	Monitor address and SCAQMD ^b identification number	One-hour ozone concentration, ppb			
			First	Second	Third	Fourth
Arcadia	06-037-2005	Pasadena (88)	259	197	191	184
Brea	06-059-5001	La Habra (3177)	252	212	156	154
Cypress	06-059-0001	Anaheim (3176)	209	160	158	148
Downey	06-037-1301	Lynwood (84)	124	108	87	86
Fullerton	06-059-5001	La Habra (3177)	252	212	156	154
Lake Arrowhead	06-071-0005	Crestline (5181)	265	227	218	216
Manhattan Beach	06-037-5001	Hawthorne (94)	106	103	102	93
Pasadena	06-037-2005	Pasadena (88)	259	197	191	184
San Marino	06-037-2005	Pasadena (88)	259	197	191	184
Upland	06-071-1004	Upland (5175)	253	231	221	220

^aSource: EPA Aerometric Information Retrieval System (AIRS).

^bSouth Coast Air Quality Management District.

SCRIPT DEVELOPMENT

The scripts were developed by a two-step process. In Step 1, researchers developed a database listing time/activity data that had previously been used in EPA exposure assessments [Johnson *et al.* (1996b), Johnson *et al.* (1996c)] to represent the activities of adults who tend to work outdoors ("outdoor workers") and children who tend to play outdoors ("outdoor children"). This database was analyzed to determine the time spent in each of the five "generic" microenvironments by time of day. Researchers used the results as a rough guide in developing a set of twenty-two 24-hour schedules, eleven representing outdoor workers and eleven representing outdoor children. Each 24-hour schedule assigned a subject to a single microenvironment during each clock hour.

In Step 2, each of these initial schedules was converted to a final script by replacing each generic microenvironment with a particular location within a particular town. The locations were selected from the list of candidate monitoring locations discussed above. Vehicle trips were defined by an origin point (town and location) and a destination point (town and location).

The scripts were considered to be somewhat unrealistic in that location assignments were usually specified in terms of clock hours (e.g., 2 pm to 3 pm) rather than as portions of hours (e.g., 2:13 to 2:47). This approach facilitated the comparison of PEM ozone concentrations with the corresponding ozone concentrations measured at nearby fixed-site monitors. As the California fixed-site data are typically reported as average ozone concentration by clock hour, each PEM sample was timed to begin and end "on the hour." In constructing the scripts, researchers attempted to minimize the changes in location that occurred during each sampling period with the goal of characterizing each PEM ozone concentration by a single microenvironment.

SCRIPT COMPOSITION

Each script provided assignments for the 16 sampling periods shown in Table 3-2. Two of these periods (7 am to 11 am, 11 am to 7 pm) were multihour periods which overlapped the 12 one-hour sampling periods between 7 am and 7 pm.

The script was initially laid out using the form in Appendix A. The script for a particular monitoring period was then transferred to the "tabbed pages" of the diary to be used during the monitoring period (see Section 4).

SAMPLING ACTIVITIES

The Harvard Active Ozone Monitor (Figure 3-1) measures ozone by drawing air through an open tube denuder system that is approximately 10 cm in length with an inside diameter of 1.4 cm. The inner etched surface of the tube is coated with a nitrite reagent, which reacts with ozone to produce nitrate ion. The mass of nitrite ion deposited inside the tube is measured using ion chromatography to determine the average ozone concentration of the air passing through the tube. One tube is required for each sample collected.

In the Los Angeles study, subjects carried 22 tubes during each monitoring period, one for each of the 16 sampling periods indicated in Table 3-2 and six as daily blanks. The subject initiated each sample by uncapping a tube and terminated each sample by recapping the tube (see Section 4). Researchers prepared a sampling schedule that listed the identification (ID) numbers of the tubes that were to be uncapped and recapped at the beginning of each sampling period.

Table 3-2. Sampling Periods Used in Script Assignments.

Sampling Period	Nominal Sample Duration, hours
7 pm - 11 pm	4
11 pm - 7 am	8
7 am	1
7 am - 11 am	4
8 am	1
9 am	1
10 am	1
11 am	1
11 am - 7 pm	8
Noon	1
1 pm	1
2 pm	1
3 pm	1
4 pm	1
5 pm	1
6 pm	1

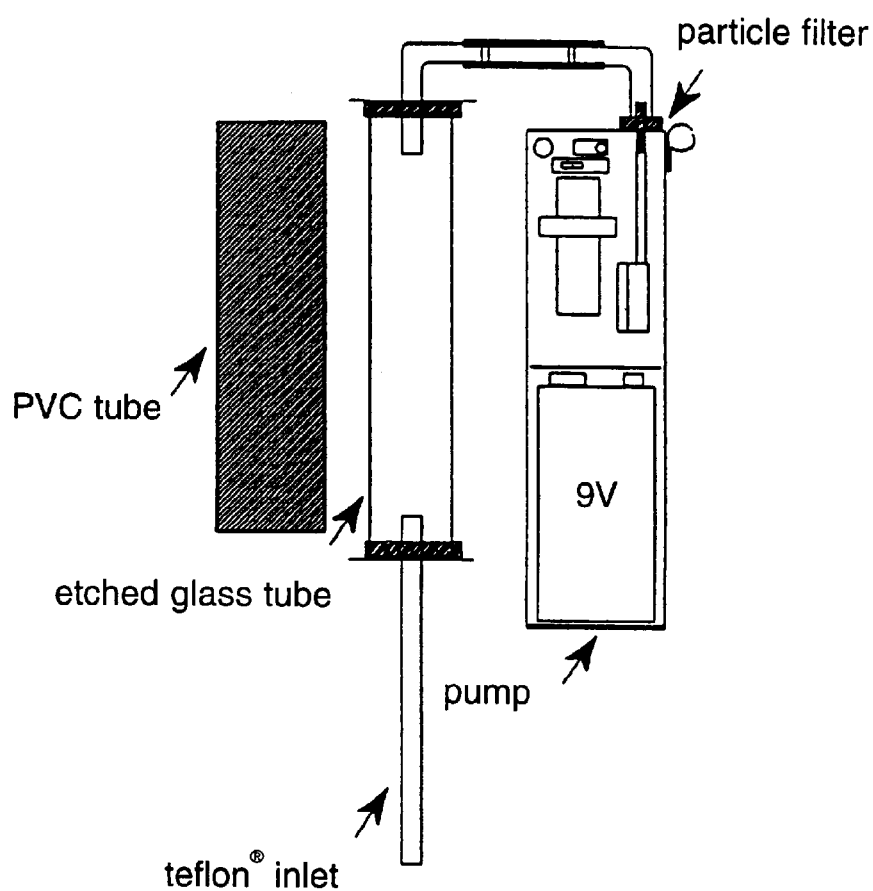


Figure 3-1. The Harvard Active Ozone Monitor.

Each sampling schedule was initially laid out using the form in Appendix A. The schedule was then transferred to the "tabbed pages" of the diary to be used during the corresponding monitoring period (see Section 4).

During each monitoring period, the subject typically carried six tubes which served as blanks. The daily average of the ozone concentrations determined for the blanks was subtracted from the ozone concentration initially determined for each exposed sample.

The pilot study employed four subjects who participated in twenty-one 24-hour monitoring periods. Each monitoring period began at 7 pm on one day and ended at 7 pm on the next day. The monitoring periods were scheduled to include both weekdays and weekends.

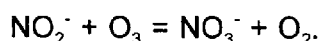
Section 4

DATA COLLECTION INSTRUMENTS

HARVARD ACTIVE OZONE SAMPLER

Description of Instrument

The Harvard active ozone sampler was developed by Petros Koutrakis and Alison Geyh of Harvard University (Koutrakis *et al.*, 1993; Geyh *et al.*, 1994; Geyh *et al.*, 1997). The sampler consists of a hollow tube denuder system approximately 10 cm in length and 1.4 cm ID which is encased in an opaque tube holder and attached to a low-flow battery-operated personal pump of about the same length. The inlet end of the tube is fitted with a 4-inch piece of 5/32-inch ID Teflon® tubing to mitigate turbulence effects during sample collection. The outlet end of the sample tube (attached to the pump) abuts a particle filter which keeps the pump clean. The pump pulls ambient air at a sampling rate of about 65 cm³/min. The sample tube is an etched borosilicate glass tube coated with a NaNO₂/K₂CO₃ reagent, which reacts with ozone to produce nitrate (NO₃⁻). The mass of ozone sampled is determined by measuring the resulting mass of nitrate ion using ion chromatography. The chemical reaction occurring in the tube may be expressed as:



The corresponding ozone concentration can be estimated from the following equation:

$$O_3 = (C) \frac{(MNO_3^-)}{(T)(F)} \quad (1)$$

where

O_3	=	the concentration of ozone measured (ppbv)
MNO_3^-	=	the mass of nitrate collected (μg)
T	=	the exposure time (hours)

- F = the airflow through the denuder (m^3/hr) taken to be the average of the measured sampling start and stop flow rates (approximately $65 \text{ cm}^3/\text{min}$ or $0.0039 \text{ m}^3/\text{hr}$)
- C = a constant (for 1 atm and 25 degrees celsius) consisting of the inverse of the product of the conversion factor ($0.0409 \mu\text{mol}/\text{ppbv} \cdot \text{m}^3$) and the molecular weight of NO_3^- ($62 \mu\text{g}/\mu\text{mol}$)

In the Los Angeles personal monitoring study, each active ozone sampler provided an average ozone concentration for a single sampling period lasting from 1 to 8 hours.

The active ozone sampler is believed to be an improvement over the Ogawa passive ozone sampler (Geyh *et al.*, 1997). The use of a pump with a known and relatively fixed flow rate increases the precision of ozone measurements and reduces effects associated with variations in wind velocity.

Preparation of Sampling Tubes

Each personal ozone monitor consisted of a coated sampling tube and a reusable pump unit. The sampling tubes were prepared by Harvard University in batches according to the procedure described in Appendix B.

Packaging and Shipment to EHS-LAREI

After preparation, the sampling tubes were packed in insulated containers chilled with blue ice. Each tube was capped on both ends and wrapped in a foam sleeve for protection. The tubes were shipped by FedEx priority overnight to the EHS-LAREI facilities in Downey, California. Upon receipt by EHS-LAREI, the tubes were transferred to a lab refrigerator.

Cleaning

EHS technicians washed the inlets, outlets, caps, and protective housings prior to use. Powder-free gloves were worn during all cleaning procedures. All parts were rinsed three times in Milli-Q water followed by a final rinse with reagent grade ethanol

or methanol. Clean parts were spread out on Kimwipes to dry and were covered with another Kimwipe. When the parts were thoroughly dry, they were transferred to a clean resealable bag.

Assembly of Tube Holders

One hour before sampler assembly, technicians removed the sampling tubes from the refrigerator and placed them in an ozone-free chamber where they were allowed to equilibrate to room temperature. Wearing gloves, the technicians removed the protective foam sleeve and caps, replacing these with the inlet tube, outlet tube, and grey PVC protective sleeve of the sampling tube holder assembly. They then checked that the inlet tube was leak-free and fully inserted into the cap. Two numbered ID labels were next transferred from the end caps to the tube holder assembly. The assembled tube holders were placed in the refrigerator until the subject was ready to depart.

Battery Changing and Charging

The 9 volt lithium batteries used by the personal monitors were capable of operating each sample pump for 48 hours. Batteries with less than a 24 hour life expectancy were replaced by fresh batteries. The batteries used in the Buck® flow-rate calibrator were recharged at regular intervals.

Field Sampling

The sampler pumps were started one hour before use to stabilize flows. At the same time, the tube holders were removed from the refrigerator. The pump flow rates were set between 63 and 68 cm³/min. No calibration was required for the sampling tubes.

The assembled tube holders were carried by the subject in a duffel bag with a shoulder strap. On the hour of the first sample period, the subject selected one tube holder, removed one of the two numbered ID labels from the case, and placed the label on the diary page. The subject connected the tube holder to the sample pump

and measured the flow rate using the Buck® flow meter. The subject recorded the flow rate, the ambient temperature, the duffel bag interior temperature, and the subject's location and activity in the diary as indicated.

At the end of the sampling period, the subject measured the final sampling flow rate and recorded the value in the diary. The subject then uncapped a new tube, attached it to the pump, and measured its flow rate. During the flow rate measurement, the old tube holder was capped and placed in a separate bag within the duffel bag. The associated time, temperature, flow rate, location, and activity were then recorded in the diary. Subjects were instructed to complete the entire change-over in five minutes or less. The average change-over time was less than two minutes.

At the completion of the subject's sampling activities, the bag of tube holders was placed in the subject's home refrigerator until transport back to the EHS lab. The tube holders were stored in blue ice during transport to EHS.

Tube Holder Disassembly

Tube holders were placed in the EHS lab refrigerator until disassembly. After removal from the refrigerator, they were allowed to equilibrate to room temperature in EHS's ozone-free chamber for one hour. Using gloves, technicians removed the inlets, outlets, and PVC holder sleeves. The sampler tubes were sealed with closed-end caps and protected with foam sleeves.

Packaging and Shipment to Harvard

The capped sampling tubes were sealed in resealable bags and placed in an insulated box with blue ice. They were shipped back to Harvard (FedEx priority overnight).

Appendix B contains the protocols followed by EHS-LAREI personnel in assembling the ozone samplers, using the sampler in the field, disassembling the sampler after use, and shipping the exposed sample tubes to Harvard for analysis.

Disassembly and Extraction

Harvard personnel equilibrated the wrapped sampling tubes with room temperature before beginning disassembly and extraction in a clean air hood. The ID label was removed from the housing of each sampling tube and placed on a clean vial.

After unwrapping, the denuder tube was capped at one end with a clean EC-10 caplug and then filled with 5 ml of Milli-Q water. The other end was capped with a pierced EC-10 caplug, and a piece of parafilm was placed over the opening to prevent leakage during extraction. Extraction of the denuder tube was performed by repeating the following sequence 12 times: rock the Milli-Q water in the tube back and forth six times and rotate the tube 30 degrees. The extract was then poured into the labeled vial.

Analysis

The extraction samples were analyzed by Ion Chromatography according to the procedure described in Appendix C. Mike Wolfson of Harvard University performed the analysis.

TIME/ACTIVITY DIARY

Description of Document

Appendix D contains enlarged facsimiles of selected pages from the activity diary provided to each subject. The actual diary is 5.5 inches by 8.5 inches in size. The cover of the diary contains spaces for filling in the personal identification number (PID) of the subject, the interviewer's name, the date and time of first diary entry, and the date and time of the last diary entry. Inside the cover are the telephone numbers

of EHS-LAREI employees who could be called if the subject had questions or problems. The diary contained 152 pages divided into the following subsections:

- Instructions (5 pages),
- Example of filled-in tabbed page (1 page),
- Examples of filled-in activity pages (10 pages),
- Blank activity page to be filled-in by the interviewer as a demonstration for the subject (one page),
- Fourteen sample-period sets each consisting of one tabbed page followed by activity pages (eight pages),
- Final tabbed page (one page), and
- Spare activity pages (eight pages).

The tab attached to each tabbed page was labeled as to the time it was to be consulted by the subject. The diary was bound using a plastic spine which permitted the diary to be opened flat.

Instructions for Completion

The first five pages of the diary provide instructions for completing the diary. These instructions also include procedures to be followed by the subjects in changing the tube holder assemblies used in the personal monitors. For simplicity, the diary instructions refer to the tube holder assemblies as "tubes." Consistent with this convention, the discussion which follows refers to the tube holder assemblies as tubes. Strictly speaking, all tube changing activities performed by subjects were performed on tube holder assemblies, rather than the tubes themselves. As described above, trained technicians assembled the tube holders before use by the subjects and disassembled the tube holders after use. Individual tubes were never handled directly by subjects.

At the beginning of each sampling period, the subject is instructed to go to the corresponding tabbed page in the diary and complete all sections as directed. The subject begins in Section 1 by entering the name of his/her current locality (e.g., Upland), entering the street address or nearest intersection, checking the applicable general location (indoors, outdoors near road, outdoors - other locations, or in vehicle), and writing in the specific location. The subject then records the readings of a temperature sensor in the tube storage pack (internal temperature) and a temperature sensor exposed to the ambient air (external temperature).

The subject checks Sections 2 through 5 of the tabbed page to see which, if any, tubes are to be capped (terminating a sample) and uncapped (initiating a sample). A tube identification number is listed in the space labeled "Tube No." whenever a tube is to be capped or uncapped.

If a tube is to be capped, the subject first measures the flow rate and records the value and time in the indicated spaces. The subject then disconnects the tube from the pump and caps it at both ends. The tube is then returned to the refrigerated carrying pack.

If a tube is to be uncapped, the subject reverses the process. The specified tube is removed from the carrying pack and uncapped at both ends. The tube is then connected to the pump and the flow rate is measured. The flow rate and time are recorded in the indicated spaces.

Section 6 of the tabbed page provides instructions to be followed by the subject during the next sampling period. The instructions are either to (1) maintain the location and activity specified by the previous tabbed page or (2) change location and/or activity according to the written directions. The instructions on the last tabbed page in the diary indicate that the subject has completed all activities and that no additional activity pages are to be completed.

The seventh and final section of the tabbed page instructs the subject to go to the first diary page after the tabbed page and complete the page according to the activity he or she is about to begin.

Each tabbed page is followed by eight diary (or "activity") pages. The subject completes one of these pages each time he or she starts a new activity according to the following directions. The subject first enters the start time of the activity in the four boxes at the top left of the page and indicates a.m. or p.m. The subject then briefly describes the activity he/she is beginning in Part A ("ACTIVITY"). Examples of suitable entries include "cooking breakfast," "waiting for the bus," "driving to grocery store," "working at desk," "visiting friends in their living room," and "sleeping in bedroom." These entries were later assigned a numerical code according to the activity classification system in Table 4-1.

Next the subject circles the appropriate LOCATION code. If the subject circles 02 (in transit, other vehicle) or 09 (indoor, other), he is asked to write in a more specific location. These entries were later assigned an appropriate numerical code taken from Table 4-2.

Whenever the subject circles 10 (outdoors within 10 yards of road or street), the subject is instructed to conduct a three-minute count of the number of vehicles passing her location in both directions. The subject then converts this count to the equivalent value of vehicles per minute and enters the result in the indicated space.

The following additional instructions for completing the LOCATION section appear in the diary:

If you are in transit and use more than one mode of transportation, complete a separate page for each mode. If any other activity causes you to move to a location with different characteristics (for example, going from an indoor to an outdoor location at work), complete a separate page for each location.

Table 4-1. Numerical Codes Assigned to Diary Entries for "ACTIVITY."

Subcategory	Code	Description
Travel	1	All destination - oriented travel (including walking)
Work	2	Income - related work
Study	3 4 5 6 7	Day - care Kindergarten - 12th grade College or trade school Adult education and special training Homework
Household Activities	8 9 10 11	Meal Preparation and cleanup Laundry Other indoor chores Yard work and outdoor chores
Child-Centered Activities	12	Child care and child - centered activities
Errands and Shopping	13 14	Errands and shopping Personal care outside home (doctor, hair dresser)
Personal Needs	15 16 17	Eating Sleeping Other personal needs
Civic and Collective Participation Activities	18 19 20	Religious activities Meetings of clubs, organizations, committees, etc. Other collective participation
Spectacles, Entertainment, Social Life	21 22 23 24 25 26	Spectator sports events Movies, concerts, and other entertainment events outside home Cafe, bar, tea room Museums and exhibitions Parties and receptions Visiting friends

(continued)

Table 4-1 (Continued)

Subcategory	Code	Description
Sports and Active Leisure	27	Recess and physical education
	28	Active sports and games outside school, including exercises and aerobics
	29	Hunting, fishing, hiking
	30	Jogging or bicycling
	31	Taking a walk
	32	Artistic creations, music, and hobbies
	33	Other active leisure
Passive Leisure	34	Reading
	35	Television or radio
	36	Conversation and correspondence
	37	Relaxing, reflecting, thinking (no visible activity)
	38	Other passive leisure
Illness or Injury	39	Asthma attack
	40	Other sudden illness or injury
Additional Codes	43	Interview
	44	Wakeup
	45	Baby crying

Always complete a page in the diary when walking in a parking lot or in a parking garage (indoors and outdoors). Always complete a page when walking outdoors between a motor vehicle and an indoor location. (Appears in capital letters in diary instructions for emphasis.)

Be sure to complete a page in your diary when you retire for the night and another when you get up in the morning. (Appears in capital letters in diary.)

The next section on the diary page is BREATHING RATE. Instructions for this section are as follows:

In determining your breathing rate, indicate "slow" if your activity is no more strenuous than sitting, standing, or walking slowly. Indicate "medium" if the activity is equivalent to a brisk walk. Indicate "fast" if you are breathing hard as from jogging or heavy labor. If you are having difficulty breathing because of asthma or other respiratory ailment (e.g., cold, influenza, emphysema), circle 16 and indicate the ailment in the blank next to "Specify."

Table 4-2. Numerical Codes Assigned to Diary Entries for "LOCATION."

Subcategory	Code	Description
In Transit	1	Car
	27	Not specified
	28	Truck
	29	Bus
	30	Van
	31	Motorcycle
	32	Train
	33	Airplane
	34	Motorized boat
	35	Nonmotorized boat
	36	Other vehicle
Indoors	3	Residence
	4	Other residence
	5	Office
	6	Manufacturing facility
	7	School
	8	Store
	37	Not specified
	38	Residential garage
	39	Public garage
	40	Service station or motor vehicle repair facility
	41	Other repair shop
	42	Physical exercise facility (gymnasium, health spa, etc.)
	43	Auditorium, sports arena, concert hall, etc.
	44	Museum or exhibition hall
	45	Movie theater
	46	Restaurant or cafeteria
	47	Church
	48	Shopping mall
	49	Health care facility
	50	Other public building (library, courtroom, bank, etc.)
	51	Bowling alley
	52	Bar
	53	Other indoor location

(continued)

4-11

Table 4-2 (Continued)

Subcategory	Code	Description
Outdoors	10	Outdoors, within 10 yards of road or street
	11	Not specified
	54	Not specified
	55	Residential garage or carport
	56	Public garage
	57	Parking lot
	58	Service station or motor vehicle repair facility
	59	Construction site
	60	Residential grounds
	61	School grounds
	62	Playground
	63	Sports arena, amphitheater, etc.
	64	Park or golf course
	65	Loading vehicle
	66	Not used
	67	Other outdoor location
Uncertain	12	Not specified

Table 4-3 lists the numerical codes assigned to BREATHING RATE entries.

Section D of the diary page pertains only to those activities which take place indoors or in a vehicle. In this section the subject is asked if the windows are open, and if the air conditioning is on. Each of the two questions is answered by circling a code for "Yes," "No," or "Uncertain."

In Section E, the subject is asked to write in the street address of the location where the activity occurred or the nearest intersection to the location. The subject indicates the name of the town in Section F. Table 5-3 in Section 5 lists the town names that were entered in Section F and the numerical code assigned to each town.

Table 4-3. Numerical Codes Assigned to Diary Entries for "BREATHING RATE."

Subcategory	Code	Description
Breathing Rate	13	Slow (e.g., sitting)
	14	Medium (e.g., brisk walk)
	15	Fast (e.g., running)
Breathing Problem	68	Not specified
	69	Asthma
	70	Cold
	71	Influenza
	72	Emphysema
	73	Bronchitis
	74	Hay fever
	75	Other allergy
	76	Coughing (no illness or illness unknown)
	77	Not used
	78	Other breathing problem

Finally, when the subject's activity changes or when any other of the circled answers on the diary page changes (i.e., LOCATION, BREATHING RATE, window and air conditioning status, and LOCALITY), the subject is instructed to record the stop time of that activity in the four boxes at the upper right of the diary page and again indicate a.m. or p.m. Because there should be no unaccounted time gaps in the diary, the stop time of one diary page entry is also the start time of the next entry. This continuous nature of the diary is strongly emphasized to the subjects.

The diary contains ten examples of properly completed activity pages. Following these pages is a blank page labeled "example to be completed by interviewer" which may be filled out jointly by the interviewer and subject as a test that the subject understands the diary instructions.

After a subject's diary was completed, analysts staff coded each diary entry so that the diary information could be converted into a computer file. The resulting activity data file was then combined with concurrent ozone data and statistically analyzed.

Section 5

STATISTICAL ANALYSES

The personal monitoring phase of the study was conducted between September 11 and October 28, 1995. During this period, four subjects produced a total of 21 person-days of personal monitoring data. A person-day consists of the data obtained from one subject for one continuous 24-hour monitoring period. As discussed in earlier sections, each person-day began at approximately 7 pm on one day and ended at approximately 7 pm on the next day. The data collected during each person-day included one-hour and multihour average ozone concentrations obtained from the personal exposure monitors (PEMs), one-hour ozone concentrations measured by nearby fixed-site monitors in the study area, and personal activity diary entries. This section summarizes these data and presents the results of statistical analyses performed on the data.

DATA SUMMARIES ORGANIZED BY SCRIPT AND SAMPLING PERIOD

Twenty-two distinct scripts (numbered 1 through 22) were prepared for use during the personal monitoring phase of the study, although Script No. 2 was not used in the study. Table 5-1 presents the deployment schedule of the remaining 21 scripts. The table indicates the subject associated with each script, the subject's town of residence ("home location"), and a second town used as a daytime commuting destination in the scripted activities ("mid-day location").

Appendix E contains 21 data summary tables. Each table lists data associated with a single script organized by sampling period. The table entries for each sampling period row include the PEM ozone concentration(s) measured during the period, the nominal duration of the period (one hour, four hours, or eight hours), the actual start

Table 5-1. Subject and Primary Locations Associated With Each Script.

Script no.	Sampling dates	Sampling days	Subject's name	Home location	Mid-day location
1	9-11/12	Mon/Tue	Anderson	Fullerton	Upland
3	9-14/15	Thur/Fri	Anderson	Fullerton	Brea
4	9-14/15	Thur/Fri	Nugent	Cypress	Downey
5	9-19/20	Tue/Wed	Nugent	Cypress	Brea
6	9-24/25	Sun/Mon	Geyh	M. Beach ^a	Upland
7	9-24/25	Sun/Mon	Avol	M. Beach	Upland
8	9-28/29	Thur/Fri	Nugent	Cypress	Arcadia
9	9-28/29	Thur/Fri	Anderson	Fullerton	Pasadena
10	10-4/5	Wed/Thur	Nugent	Cypress	Arcadia
11	10-4/5	Wed/Thur	Anderson	Fullerton	Pasadena
12	10-6/7	Fri/Sat	Anderson	Fullerton	Brea
13	10-7/8	Sat/Sun	Anderson	Fullerton	Arcadia
14	10-10/11	Tue/Wed	Nugent	Cypress	Upland
15	10-10/11	Tue/Wed	Anderson	Fullerton	Upland
16	10-14/15	Sat/Sun	Geyh	M. Beach	Arcadia
17	10-14/15	Sat/Sun	Avol	M. Beach	Arcadia
18	10-17/18	Tue/Wed	Nugent	Cypress	Upland
19	10-17/18	Tue/Wed	Anderson	Fullerton	Upland
20	10-21/22	Sat/Sun	Geyh	M. Beach	Pasadena
21	10-21/22	Sat/Sun	Avol	M. Beach	Pasadena
22	10-27/28	Fri/Sat	Nugent	Cypress	Blue Jay

^aManhattan Beach.

and stopping times of the collected sample, the scripted locations and activities associated with the period, and the ozone concentration measured at one or more nearby fixed-site monitors during the period. The fixed-site ozone data were acquired from Curt Miller of the South Coast Air Quality Management District.

PREPARATION OF THE SAMPLING PERIOD DATABASE

Analysts prepared a special database containing study data organized by PEM sampling period. Each row in the database listed the ozone concentration measured by one PEM sample. To achieve maximum time resolution within the database, multihour samples were omitted from the database whenever one-hour samples provided coverage of the same time period. The omitted multihour samples were typically associated with the four-hour periods beginning at 7 am and eight-hour periods beginning at 11 am. Thirty-eight duplicate samples were collected during the study. These samples were represented by separate listings within the database.

In addition to PEM concentration, each database listing included the following data items obtained from the script for the indicated sampling period: the subject's identification number, the date of the sample, the nominal start time, the exact start and end times, the assigned location (town), the assigned microenvironment, and the assigned window status (if applicable). Each database listing also included the average ozone concentration measured at the nearest fixed-site monitor, the temperature measured inside the case in which sampling tubes were stored, the local ambient temperature, the weather conditions noted by the subject, and the average traffic count reported in the activity diary (if applicable). Appendix F presents plots of the PEM and fixed-site ozone concentrations in the database by the start time of the sampling period. The microenvironment associated with the sample is also indicated.

STATISTICAL ANALYSIS OF THE SAMPLING PERIOD DATABASE

Table 5-2 presents descriptive statistics for the sampling period database. Five data items are included in the table: