ASSESSMENT OF ENVIRONMENTAL PARAMETERS

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ABSTRACT

A simple empirical model for describing an individual's daily air pollutant exposure has been formulated. Predicted exposure is based on answers to a self-administered or interviewer-administered questionnaire, local meteorological and traffic data and previously-existing information on short-range transport of pollutants. This work was conducted in conjunction with a pulmonary-function screening of a well-defined Los Angeles urban working population. Carbon monoxide (CO) was used as the initial trace pollutant.

Calculated daily CO challenge--the sum of working, commuting, and at-home periods--was compared in selected representative individuals with actual exposure as determined by continuous monitoring of the personal environment, and also compared with predicted challenge based on fixed monitoring station data. The model tended to overestimate commuting exposure and underestimate home exposure, but its overall predictions were in fair agreement with measured total daily exposures. Monitoring-station data consistently underestimated total exposures, indicating that traffic and in-home CO sources contribute more than ambient background levels to total CO exposure, at least for many individuals.

Preliminary calculations extending the model to prediction of daily ozone exposures indicated that, while outside workers may receive high doses during photochemical pollution episodes, individuals remaining indoors usually receive only a small fraction of the dose expected on the basis of outside concentrations.

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National Heart and Lung Institute
Contract Number N01-HR3-2901

(SUBMITTED AS A SEPARATE DOCUMENT)

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GLOSSARY

CO	CARBON MONOXIDE
NO	NITRIC OXIDE
SO_2	SULPHUR DIOXIDE
NO_2	NITROGEN DIOXIDE
O_3	OZONE
HC	HYDROCARBONS
pb	LEAD

CONCLUSIONS

Information obtained from a brief questionnaire relating to an individual's home-air environment, commuting habits and work place were used to describe that individual's total exposure to CO over an average 24-hour weekday period. Comparisons of questionnaire-predicted exposures with actual monitored exposures in typical central Los Angeles officeworkers who commuted various distances from home by automobile reveal that the estimated values correlate well with the data obtained from personal environmental monitoring. In a second approach, data obtained from stationary monitoring stations near the individuals' homes, the commuting routes, and the work location were used to calculate an individual's CO exposure.

Significant factors influencing the home-air environment (with respect to CO) include the proximity to major highways and the average prevailing wind direction present at the residence. Internally generated pollution sources include many processes involving combustion or fuel evaporation. These can have a varying detrimental influence upon the cleanliness of the home-air environment.

Some combustion processes within the home that can have an important effect upon the indoor air quality are: the use of poorly ventilated fireplaces, gas wall heaters, excessive burning of food products, and poorly adjusted gas stoves and ovens.

RECOMMENDATIONS

Public Health

The public should be informed of the possible short-term increases in CO concentrations within the home when certain types of regular activities such as cooking, heating, and barbecuing are conducted within the home. An additional warning should be issued regarding the methods of entry and removal of motor vehicles from garages attached to the home. Persistence in the home of pollutants from this source can be extended over considerable periods of time subsequent to the entry or exit of the vehicle. The modern (post-1960) California single family home almost invariably has an attached garage.

Certain apartment and single family residences are particularly vulnerable to excessive concentrations of traffic-generated pollutants. The estimator model would permit issuance of guidelines for estimating possible risks to older persons, who may be afflicted by chronic cardio-pulmonary disorders and, therefore, could be more susceptible to these pollutant concentrations.

Information revealed that high concentrations of CO plus other pollutants in a closed vehicle moving slowly along a heavily traveled artery can be made worse by smoking inside the vehicle, and the public should be apprised of this potential hazard.

Continuing Research

The estimator model for CO should be adapted and extended to take other major pollutants into consideration. Because oxidants are thought to be the most toxic compounds in the South Coast Air Basin polluted atmosphere, special efforts should be made to estimate the individual 24-hour challenge from oxidants. Validation of these estimates should be made using the proposed semi-portable monitoring equipment.

The air pollutant concentration at individual school sites can be estimated with respect to CO and other pollutants. This data may show that some school sites within a generally highly polluted area are relatively free of pollutants due to favorable orientation with respect to highways, wind direction and topography. On the other hand, some school sites in clean air regions of the South Coast Air Basin may be heavily challenged by emissions from major arteries and industries adjacent or upwind of the schools. The importance of the micro-meteorological factors in assessing the individual air environments should be emphasized.

The estimator model can be utilized in the development of environmental impact reports required prior to the initiation of industrial plants, parks, residential communities or commercial centers. A prediction of highway needs and loads is presently required. Pollutant loads from these line sources are not at present being estimated. The orientation of future highways with respect to direction and distance from the potentially affected areas should be optimally designed to take advantage of average prevailing wind patterns and shielding topographic features.

In population studies correlation of the CO estimator for each individual with health effects data might yield meaningful dose-response relationships. If the individual has resided in the same home and commuted over the same route for a long period of time, this could include estimates of accumulated dose.

A validation study of exposure estimation is needed under varying conditions of home use. This information can serve to delineate the effects of specific methods of minimizing exposure to oxidants, CO, and other pollutants within individual homes. Also, a possible result of this study could be improved guidelines for home design which would minimize internal concentrations of CO and oxidants. An associated issue of interest is that methods of minimizing indoor air pollutants could possibly result in minimizing energy losses with respect to heating or cooling.

PROGRAM OVERVIEW AND PURPOSE

This study was a part of a larger program involved with the assessment of potential community health effects of atmospheric pollution in a well-defined employee population. The population is located in two of California's principal metropolitan areas and can be characterized as being fairly representative of a typical group of urban, white-collar employees. The office locations represent two extremes of atmospheric pollution: one population is located in a "high-pollution" area (i.e., Los Angeles); and, the second in a "low-pollution" area (i.e., San Francisco).

The overall goals of the program can be summarized as follows:

1. To compare the prevalence of suspected respiratory abnormality (as defined by symptoms and pulmonary function testing) in two California metropolitan areas, one having high levels of air pollution (i.e., Los Angeles) and one having low levels of atmospheric pollution (i.e., San Francisco);
2. To relate the prevalence of respiratory abnormality to different regions within both cities which can be shown to have divergent air pollution exposures;
3. To ascertain whether there is a relationship between length of exposure (or duration of residence in the high-pollution area) and the prevalence of respiratory abnormalities; and
4. To determine if there is a combined effect of tobacco smoke and ambient atmospheric pollution in the development of pulmonary abnormalities.

There is considerable evidence supporting the contention that reliance upon data from fixed monitoring stations is unsatisfactory for the purposes of relating health effects to atmospheric pollution. In order to adequately evaluate the effects of atmospheric pollution upon various indices of human health it is critical to provide an accurate and reliable characterization of the dose levels of pollution to which individuals have been exposed. Accordingly, the purpose of the current study was to develop and assess an empirical approach by which an estimation can be made of the cumulative pollutant exposure experienced by a given individual. If the empirical estimator is found to be within an acceptable range of accuracy, then efforts to relate human health effects to atmospheric pollution could be accomplished with greater precision. The use of such an estimator would be more economical and certainly more practical than attempting to employ individual personal pollution monitors.

The empirical estimator for exposure to primary pollutants was based upon information obtained from meteorology, air pollution (both indoor and outdoor), residential location, commuting routes, home living habits (such as average temperature, humidity and window opening), hobbies, and many other factors which were pooled to estimate the total CO an individual was exposed to during an average 24-hour period. An additional emphasis of this work entailed verification of the personal pollutant estimator. This included efforts in the area of the development of instrumentation of personal pollution monitoring. As a part of this study, a subgroup of the employee population was selected and their cumulative exposure was estimated and correlated with the value obtained from personal environmental monitoring and data from the nearest air pollution monitoring stations.

INTRODUCTION AND BACKGROUND

The need to conduct carefully designed surveys of the potential public health effects on populations residing in areas where heavy atmospheric pollution is found has become increasingly evident. In this regard results from a number of investigations have been reported in which a variety of measures of health effects have been related to summarized air pollution data gathered from fixed air monitoring stations.[1-3]

A serious problem in interpreting this work has been that data from such fixed air pollution monitoring stations have been assumed to be representative of the pollution dose to which particular individuals have been exposed. However, due to the numerous micrometeorological and microenvironmental features of the individual's personal air environment, there will be wide variability in the pollution levels among individuals residing within the same region of any urban area. Therefore, efforts to correlate measures of health effects with air pollution dose level would not be particularly meaningful if the level of exposure is based solely upon fixed monitoring station data. The degree of variance in pollutant concentrations as a function of direction and distance from a monitoring station has been illustrated by previous work.[4,5]

The most precise way to correlate health effects with pollution concentration would be to continuously monitor the individual's immediate air environment, thus reflecting all possible variations in personal dose levels. This would obviously be quite impractical to accomplish even with one individual, let alone large population groups. The unavailability of reliable miniaturized monitoring instrumentation that is relatively unobtrusive is a major limiting factor.

The current study represents a compromise between relying upon data from fixed monitoring stations and conducting individual monitoring of all subjects in the study group. Specifically, a primary objective of the work was to test whether or not reliance upon data from fixed monitoring stations can be erroneous, and to test the value of an empirical approach to the estimation of time-weighted exposure levels. Such an estimation would be based upon many aspects of the individual's home and work environment, plus specific commuting habits.

Previous work has shown that there is a need to take into account influences such as micrometeorology and local traffic patterns. One study compared the concentrations of CO at a fixed monitoring station and a large number of samples which were collected individually at locations somewhat removed from the station.[5] The relationship between meteorological variables (such as wind direction and speed) and the distance from heavily traveled streets, whether a person is inside a vehicle or in an office building, or walking on a sidewalk, can contribute to large differences between the monitoring station data and the actual exposures experienced by individuals.[6] Specific studies relating traffic density and variations in CO concentrations have confirmed the view that air quality as measured from widely-dispersed monitoring stations does not adequately reflect individual nonoccupationally acquired exposure.[7-10]

Initially we decided to focus on one primary pollutant found in urban atmospheres. For several reasons CO was selected. Subsequent efforts will be directed toward the development of empirical methods to estimate other pollutants. A number of factors were taken into consideration in focusing upon CO as the "tracer gas." Carbon monoxide is essentially free of atmospheric chemical interaction and is almost completely permeable to homes and office buildings.[11] In addition, there is evidence indicating that levels of concentration of other important pollutant gases including lead (Pb), low molecular weight HC, NO, NO_2, SO_2 and particulates will covary with levels of recorded CO concentrations so that information pertaining to CO should provide some indication of the relative levels of the other pollutants by use of nomographic correlations.[12,26] Furthermore, a number of indoor activities contributing to elevated CO levels have been identified and described in previous work.[13] This information was useful in terms of indicating those factors that should be incorporated into the estimator.

It was assumed that an individual spends approximately one-third of each day at work, one-two hours commuting to and from work, and the remainder of each day near or in his home. This partitioning of the day was used to divide the contributory factors that can influence a person's activities leading to possible periods of CO exposures. Consideration was given to the home environment with respect to any locally generated traffic CO which might raise the concentration of this pollutant within the home. Studies have shown such situations will significantly alter the home CO concentration.[14] In addition, the individual is also subjected to internally generated CO by virtue of the type of fuel used for cooking and heating. Some contribution to home CO environments are also made by the presence of smokers. The commuting CO challenge is subject to the length of the individual's trip and the type of route chosen. Additional commuting exposures can be gained by the presence of smokers in the vehicle. The work environment is strictly controlled by the location of the place of business, whether located on a pollutant-generating traffic artery or near a polluting industry.[15] The air-conditioning system in most buildings is not considered capable of removing much of the CO when drawn in through the average air intake filtration systems.[16,17] For certain air purification systems this may not always be true for oxidants or oxides of nitrogen.[18] The individual can also be challenged by CO when working near a smoker during the day.

Essential to the development of an empirical estimate of personal pollutant challenge is the use of test apparatus to measure the personal microenvironments in the home, while traveling and while at work. Previous attempts to miniaturize reliable equipment that can be used for such studies have met with only limited success.[19,20] A possible compromise would be to use semi-portable monitoring instruments with appropriate continuous recording which could be placed in the home, car or at work. This study used such an approach for monitoring personal environments.

METHODS

In general, verification of the estimator was carried out by deriving the estimate for a specially selected group of subjects and then comparing these values with results obtained from monitoring studies conducted in each subject's home, at work, and while commuting.

Selection of Subjects: The nature of the Los Angeles area demands long commuting distances for a large percentage of citizens, and places their homes in areas of widely varying levels of air pollution. Those persons residing near the coastline are typically exposed to lower concentrations of air pollutants than those residing in the central basin or its eastern suburbs. With these considerations in mind, an effort was made to carefully select individuals whose places of residence reflect widely dispersed geographical locations within the South Coast Air Basin.

The individual subjects were selected so that two lived on or very close to heavily traveled arteries; one with prevailing wind conditions such that the CO generated by this traffic would directly affect the immediate environment of his home; the other situated in such a way that the resultant prevailing wind would blow the pollutants away from his home. Other subjects were chosen to represent those living in the central Los Angeles area but somewhat removed from the direct influences of high traffic volume arteries. Consequently, one subject was chosen to represent a person who commutes only a short distance within the central city. In addition, an effort was made to have representatives of apartment and single family homes, and to take into consideration the influences of gas or electric cooking and heating including the presence of forced air or wall gas heating units. The effect of smokers, whether the subject himself or family members was another important parameter considered in the selection of subjects.

Environmental Factors and Basis for Assumptions in Personal Pollution Estimation of CO: In general, an individual employee's day was defined as being comprised of three components: 1) At residence (approximately 13 hours); 2) while commuting (approximately 2 hours); and 3) at work (8 hours plus one-hour lunch). The average hourly CO level obtained from each area was multiplied by the appropriate amount of time to calculate the estimated exposure in ppm hours over a 24-hour period. An exposure to 1 ppm CO for one hour would be defined at 1 ppm hour.

Residence Exposure (Approximately 13 hours weighting)

1. Traffic Effects

Carbon monoxide concentration from nearby arteries was estimated on the basis of the number of vehicles passing a given point. The prediction equation was derived from data obtained in a recent study which correlated occupancy factors with roadside CO concentrations.[21] Table 1 was developed from this prediction equation and was used to estimate the concentration of traffic-generated CO that would influence the individual's residence. This table was also used to estimate traffic generated CO during commuting and at work.

The relationship was:

$$[CO] = -1.3+0.0041 \text{ (background* X traffic volume)}.$$

Two examples can illustrate the equation: one with traffic of 3000/hr or 750 for 15-min period, and the second with traffic of 7500/hr or 1875 for 15-min period.

Case 1:
$$\begin{aligned}[CO] &= -1.3+0.0041 \text{ (background X 15 min volume)} \\ &= -1.3+0.0041\ (12 \times 750) \\ &= -1.3+0.0041\ (9000) \\ &= -1.3+36.9 \\ &= 36 \text{ ppm}\end{aligned}$$

Case 2:
$$\begin{aligned}[CO] &= -1.3+0.0041\ (12 \times 1875) \\ &= -1.3+0.0041\ (22{,}500) \\ &= -1.3+92.25 \\ &= 91.0\end{aligned}$$

These values apply to peak hours, night off-peak and day off-peak hours if the prevailing wind is in the direction (i.e., within 90^{o} arc) and at a minimum velocity (>3 MPH) such that the subject residence or work place is downwind from the artery.

* Average background CO was assumed to be 12 ppm.

Table 3 lists the averaged seasonal prevailing wind directions and speeds for the principal monitoring stations applicable to the study populations.[22]

a. Based upon a Gaussian dispersion model[23] it was assumed that for any person living .1 mile or less from a main artery the CO exposure concentration will drop by 30 percent from roadside concentrations. The designation "main artery" refers to freeways or major thoroughfares. With increasing distances from the artery there would be a further decrease in the CO concentration. Table 2 presents the estimated percentage drop in CO as a function of distances from the artery which was used to correct the estimated artery-generated CO levels inside the residence.

The reduction of CO concentration as a function of distance from a line source (highway) assumes that the point sources (vehicles) are considered as being of equal emitting strength sitting on a single line. The concentration of CO generated by this point source flow is assumed to be uniform along the line of flow but decreases as a function of wind direction and distance of the sampling site (home). The generalized Gaussian diffusion model describes the reduction in species concentration as a function of distance,

$$X = \frac{Q}{\sqrt{2\Pi\alpha}_{2}\mu}$$

where X = pollutant concentration, gms/sec

Q = emission rate, gms/sec/meter

α_2 = standard deviation of the concentration of CO in the horizontal direction

μ = wind speed, meters/sec

when a plot is made of the concentration of CO(X) as a function of distance in meters of the moving line source from the home or receptor site (assuming a directionally favorable low wind speed, ≥ 3 mph) then a relationship can be established between the reduction in CO concentration and the distance of the home from the line source.

b. A major component in this model is the density of traffic on nearby arteries. Therefore, it is important to distinguish between different periods of the day when greatly varying traffic flow occurs.

Peak traffic hours are defined as those between 6:00-9:00 a.m. and 4:00-7:00 p.m. It was assumed that a subject was home during one hour for each peak period (6:00-7:00 a.m., 6:00-7:00 p.m.). However, if a subject is found to take longer than one hour to commute back and forth to work (as indicated by response to questionnaire) then the amount of time at the residence during peak hours would be adjusted accordingly. Similarly, the amount of time at home during the peak hours was adjusted if commuting time was less than one hour each way.

During the off-peak hours the contribution of traffic generated CO will be reduced in proportion to the reduction in traffic volume which is estimated to be 28 percent of the daily total between 7:00 p.m. and 6:00 a.m. Daytime off-peak (10:00 a.m. to 4:00 p.m.) was assumed to be 28 percent of the daily 24 hour total. The peak hours (6:00 a.m.-9:00 a.m. and 4:00 p.m.-7:00 p.m.), therefore, generate 44 percent of the 24 hour total.[24]

The reduction of CO concentration as a function of average traffic speed shows that major decreases can be achieved by variations in average vehicle speed. Speeds above 20-25 mph do not usually constitute stop and go traffic. Timing of surface street signal lights is often synchronized for smooth flow at these velocities. At speeds below 20 mph, stop and go movement is usually experienced. These cycles of acceleration and deceleration are the driving modes most conducive to high levels of CO and other pollutant emissions. For this reason a plot of CO emissions (in lbs/mi or average CO roadside concentration) versus average vehicle speed shows much larger variations in the emission totals as speed is reduced below 20 mph.[23] Using this data a relationship was established between speed and CO concentrations. Table 1 relates CO concentrations (obtained as function of vehicle flow) to the average speed range of this flow. The values used in determining these increases in CO with reductions in speed were as follows:

Average Vehicle Speed	Increase in CO(X) Concentration
20-30	2.7X+X
31-40	.37X+X
41-60	.12X+X
>60	X

2. Home Heating Effects

This is applicable only if heating is by gas (as indicated by questionnaire response) and windows are kept closed most of the time (≤ 20 percent on questionnaire). An average rise of 1 ppm CO for 8 hours of the 13 hours at home is assumed. Previous studies have indicated that the influence of home heating on internal pollution levels is minimal.[11]

3. Home Cooking Effects

Such effects are applicable only if gas cooking is employed (obtained from questionnaire) and if most of the windows are kept closed. Assume 1-1/2 hours of cooking is done per day. Carbon monoxide will be assumed to rise an average of 5 ppm during this period.[11] It is recognized that CO levels in the immediate vicinity of food preparation with gas will be appreciably higher than 5 ppm; however, this estimate assumes some diffusion of CO throughout the residence and therefore the average rise in concentration would be reduced.

4. Attached Garage Effects

If the garage is attached to the house or if it is less than 10 feet away (from questionnaire) internal pollution levels will be influenced whenever vehicles are driven into or out of the garage. Effect from this source will be felt for 1-1/2 hours per day with a rise of 10 ppm CO.[11]

5. Effect from Smokers in Residence

This effect is applicable only if there are smokers present within the home (from questionnaire). The effect is assumed to raise CO 5 ppm for a period of 5 hours of the 13 hours at home.[6]

Commuting Exposure (Nominally 2 hours weighting - adjusted according to questionnaire response.)

1. Traffic Effects

Carbon monoxide during commuting trip was estimated by obtaining the traffic volumes on the streets and freeways used and estimating the CO levels above background by reference to Table 1. The route used to get to work was obtained by assuming the most direct connection between the subjects' residence and place of work. This was determined by reference to a map. This CO level (adjusted for average speed) was obtained for each individual (Table 1). The obtained concentration was multiplied by the amount of time spent commuting. Appropriate traffic counts obtained from traffic data published by state, county and city transportation departments have been used.

2. Effects from Smokers (In Car)

If windows in the vehicle are open less than 20 percent of the time during travel and anyone in the vehicle is a smoker, the CO concentration was increased by 15 ppm during the total daily commuting time.[6]

Work Exposure (9 hours weighting)

This is applicable to persons working in an air conditioned and/or air filtered building and not leaving the building more than 40 percent of the day (from questionnaire).

1. Traffic Effects

Person is assumed to be in work environment 9 hours (8 hours work plus one hour lunch). Traffic generated CO within the working environment is based on 6 hours of average off-peak daylight traffic volume plus 3 hours of peak volume. Carbon monoxide concentration is estimated by reference Table 1 as with "residence traffic effects". A building of 100 feet in height should show a drop in interior CO levels of about 30 percent assuming the principal air intake is on the roof.[14]

2. Effects from Smokers

If person smokes or is in close proximity of others who smoke (questionnaire response) then a further rise of 5 ppm CO for 8 hours is assumed.[6]

3. Outside Effects

If person leaves the office during the day more than 40 percent of the time then the challenge is equal to the CO generated by the traffic count present during the off-peak daylight hours. It is assumed that the person spends all of this time near or on major traffic arteries if he works in a typical urban downtown area. This value will be added to the level of CO obtained for each person within the office.

On the basis of the considerations above the following procedures were taken to derive individual estimates. The initial step was to locate the individual's residence on a map with respect to its distance from the nearest possible major surface street or freeway and to establish whether the prevailing wind would be in such a direction that the residence would be influenced by such artery generated pollutants. If the residence was within four blocks of such an artery then traffic generated CO was estimated by reference to Table 1 and depending upon distance from the artery the final contribution was adjusted by reference to Table 2. The influence of traffic effects at the residence were summed for the approximately two hours of peak traffic (i.e., 6-7 a.m., and 5-6 p.m.) and the 11 hours of off-peak traffic while the subject was assumed to be at his residence. The other sources of internal CO while at home were obtained from answers obtained in the questionnaire. These include whether gas cooking and heating are used, whether the garage is attached and whether there are smokers in the residence.

The next area was calculation of effects from commuting to and from work. The person's route, commuting time and distance traveled to and from work was obtained from the questionnaire and maps. The route was determined on the basis of the location of the residence and the most logical route to the place of work. The traffic volume data (from Los Angeles Traffic Department, Cal Trans, etc.) were tabulated for major thoroughfares and were used to determine the amount of vehicular traffic on the routes used to get to and from work. The estimated CO based on these traffic counts was then obtained from Table 2. These values were then weighted according to the amount of time the individual spent commuting both ways. If the subject was a smoker or other smokers were in the car, the estimated CO was increased during the time of commuting.

The third stage was to estimate the CO exposure at the place of work. If the subject spends most of his time in the office, the traffic effects (during two hours of peak and seven hours daytime off-peak) were based on traffic counts on the main artery on which the office is located. Since the air-conditioning intake ducts are located on top of the building, a 30 percent drop in concentration was assumed. In addition, if the subject indicated on the questionnaire that he worked in close proximity to smokers, an additional concentration was added to the estimator. If the subject indicated that he left the office frequently during the day, the CO generated by the daylight off-peak traffic on the nearest artery was taken as the estimated CO level during that period of the day.

Validation of Estimator: In order to determine if the estimate of pollutant challenge accurately reflects the personal cumulative dose, a measurement of a typical 24-hour period was made for each person. Carbon monoxide levels in the individual's home, during his commuting trips, and while at work, were measured and summed over the same 24-hour period. A direct comparison between the actual measured value and the estimated dosage could then be made. A final comparison between these two values and those obtained by summing the 24-hour monitoring station was then conducted. The station nearest the person's residence was used to obtain the recorded hourly average CO for the 13 hours while the person was at home. The station nearest the downtown office location was used to obtain the recorded CO concentrations for the nine hours while the person was at work. Finally, the average of the CO recorded at the station nearest the residence and the CO recorded at the downtown station was used to reflect the CO dose during the commuting trip. The three values were then summed for the cumulative 24-hour dosage for comparison with the estimator and the results of the personal environmental monitoring.

Temperature and humidity were also measured continuously using a recording hygrothermograph. The subject was asked to keep a careful record of all events that might cause the indoor concentration of CO to change. The subjects' homes were monitored, if possible, for a minimum of 48 hours including at least one 24-hour period. The commuter trip was monitored using the same instrumentation and following the route designated by the subject as his normal route from home to work.

Care was taken to conduct such monitoring runs during a period when the individual would actually be driving to and from work. The work environment was monitored at various times during the day and on different floors of the building.

Independent Verification of the Pollutant Estimator: Criticism may be raised that the monitoring of personal environments done in the study may have had an influence on the derivation of the estimator because it was conducted concurrently with the refinement of the estimator. Therefore, independent verification of the estimator was needed to more thoroughly ascertain the adequacy of data considered and the validity of all underlying assumptions. For this purpose similar selection criteria were used to obtain three additional subjects. Subjects were chosen to estimate individual cumulative 24-hour pollutant dosage prior to the conduct of personal environmental monitoring. In this way information from the monitoring study could not have an influence on the calculation of the estimator.

Personal Pollution Monitoring

The concentration of CO was measured using continuous flow-through electrochemical CO analyzers (Ecolyzer Modes 2100 and 2400A) and a small Hewlett-Packard, Model No. 1210, multirange strip chart recorder, plus a recording thermohygrograph for temperature and humidity measurement. Home and work place monitoring was performed using the above instrument group, while vehicular commuting trips were monitored using the CO analyzer plus a trained observer for regular data recording.

Home Monitoring: The Ecolyzer plus recorder were placed in the vicinity of the family room-kitchen area, care was taken so that it was some distance from the immediate cooking area. The analyzer was calibrated daily using certified CO-air mixtures supplied by Airco or Energetics Science. The recorder zero was established during this calibration procedure. The time of day and date was recorded on the chart and thermohygrograph when monitoring was initiated. Each subject was instructed on how to use the event log chart during the total measuring period. It was urged upon the volunteers not to change their home life procedures in any manner. Opening of windows, cooking times and the heat cycle observed in the home should be maintained in a normal manner.

Special attention was paid to evidence of daily rush-hour traffic generated increases in CO and to those events that could only be attributable to internally generated pollution (cooking, heating and smoking). The log-event chart (see appendix) was matched to changes in the indoor CO concentration.

Work place Monitoring: The same instrumentation was placed on different floors in the insurance company building, both in the principal work areas and in the central stairwell areas. The data was recorded over several days to give a representative ambient indoor CO concentration. Placement of the instrumentation was such that CO generating activity (such as smoking) could be assessed.

Commuter Monitoring: The CO analyzer was used without the strip chart recorder. The procedure required two observers, one as driver and vehicular speed observer, the other to record the CO concentration on a minute-by-minute interval. The latter also observed the cross streets along the route of travel. The subject's route was mapped out prior to initiating the trip. The mileage and time spent along surface streets and freeways were noted. The sensor tube was placed near the window of the vehicle being used. Care was taken prior to the beginning of the trip to rule out any pollutants generated by the vehicle itself. A record was made of the instantaneous CO concentration each minute, while the vehicle speed and the route position of the vehicle were also noted. Intermediate peak CO concentrations were recorded if they were greatly different or out-of-line with the minute values. A plot of CO in ppm and vehicular speed as a function of time was made for each commuting trip.

RESULTS

Calculation of Individual Personal Pollution Estimation

The results and data entered into the calculation of the personal pollution estimate for the seven selected subjects are presented in Tables 4 and 5. In these tables columns 1-5, 11, 13, 15, and 16 were obtained from questionnaire responses. These items are defined in the column headings. Items 6 and 7, which relate to the prevailing wind speed and direction, were obtained from LAAPCD annual wind rose summaries. Items 8 and 9 were obtained by locating the individual's residence on a detail map, determining whether a principal artery was near the home. If so,it was determined whether the prevailing wind direction was such that artery generated CO would have an influence upon the air environment around and within the home. The traffic on this artery was then obtained from summarized data for peak and night time off-peak hours expressed in vehicles per hour in both directions. This data was entered in column 10. The commuting time was computed from the questionnaire answers for item 11. This was calculated on the assumption that surface travel in rush hours is conducted at an average speed of 25 MPH. The freeway time was similarly computed by assuming an average speed of 35 MPH during rush hours. These items were entered in item 12. The traffic load at the place of work was obtained for the peak hour and daytime off-peak hours and entered in item 14.

The residence exposure was calculated in column 17 and was based on information recorded under columns 1-11. The commuting exposure was calculated under column 18 and was based on information from items 11-13. Work exposure was calculated under column 19 and was derived from information entered under columns 14-16. Finally the total estimated exposure was calculated under column 20. This was simply the sum of columns 17, 18 and 19.

Results from the first group of four subjects yielded estimations of CO exposure from 194 to 321 ppm-hrs. This group consisted of individuals living in widely dispersed areas of the Los Angeles Basin. The second group of subjects yielded estimated values varying from 209 to 305 ppm-hrs. Again, these subjects resided in widely dispersed sections of the South Coast Air Basin.

Monitoring Data Results

Presented below are the data obtained from the first group of four subjects where pollutant monitoring was performed during the final refinement of the estimator model. The results of residential monitoring are plotted as a function of time in Figures 1 and 2.

The second group of subjects were monitored subsequent to the completion of the estimator model in order to further test the validity of the estimator. Results from the home monitoring studies performed with these subjects are presented in Figure 3.

Comparison of Estimator Values with Monitoring Data and Air Pollution Monitoring Stations

The results of the estimator calculation, personal pollution monitoring and the data derived from the nearest monitoring station are compared for the first four subjects in Figure 4. The data from the LAAPCD monitoring stations were derived from hourly average data recorded: 1) At the station nearest the residence (for the time while the person was at home); 2) at the station nearest the place of work (for the nine hours while the person was at work); and, 3) the average of the value recorded at the station nearest the residence and the station nearest the place of work was taken as the value for the time while the person commuted to and from work.

In the second group of three subjects the personal environments were monitored subsequent to the derivation of their estimates to provide further verification of the estimator. These results are presented in Figure 5.

Detailed Analysis of Commuting Monitoring

The commuting data is presented to illustrate the effect of vehicle speed upon pollutant concentration. Figures 6 to 12 illustrate the variation of CO concentration and speed versus time of commuting. In general, the recorded CO concentration was inversely related to vehicular speed.

Application of Estimator Model to Part of the Continental Insurance Company Population

Estimated personal CO exposures have been calculated in a Los Angeles insurance company employee group* (See Addendum to Report of Research, page 71.) Los Angeles subjects were chosen (rather than those from San Francisco) because of the expected larger CO exposure gradient in Los Angeles.

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* NHLI Grant No. 73-2901 - "Combined Effects of Smoking and Other Atmospheric Pollutants in Chronic Airways Obstruction."

DISCUSSION

Results from the first four subjects indicated that the empirical estimation of pollutant dosage provides a reasonably accurate value when compared to the actual dosage received. This supports the contention that individual habits and environments can have a significant influence on the dosage received by a resident in a particular urban environment. Furthermore, the results show that these factors must be taken into account in any effort to obtain an accurate assessment of individual pollutant dosage. The data also indicate that sole reliance upon air pollution data from fixed monitoring stations is inadequate to describe an individual's immediate air environment. The additional testing of three subjects, where monitoring was performed independently of the estimator development, lends further support for the use of this approach in estimating personal pollutant challenges.

Some internal inconsistencies are present in the estimator. Too great a pollutant dose is assigned to commuting while residential exposure is underestimated. Despite these inconsistencies, the 24-hour estimated exposures are reasonably close to the personal environmental monitoring data and, in most cases, closer than that obtained from fixed monitoring station data from sites near the home and place of work.

Some interesting observations can be made from this work. It is significant that a person living in the center of a large urban city can receive a far lower pollutant challenge than an individual living in a "clean" suburban bedroom community. Three major factors contribute to this. One, the proximity of the residence downwind from a heavily traveled artery can greatly influence the individual's exposure within the home. Accordingly, a person living in a suburban community can be in a much poorer air environment than a person living in the center of a city where his residence is somewhat sheltered from major arteries and the prevailing wind is generally driving any traffic-generated pollutants away from his home. An additional factor is that the suburbanite will be exposed to a greater pollutant challenge during his longer commuting trips than the city dweller. Finally, it is also noted from the commuting data that greater exposures would occur if a long-distance commuter used surface routes instead of freeways. The steady, possibly quite slow movement on the freeway, generates less pollutants than the accelerating and decelerating driving cycles of sign or light-controlled surface streets.

Other Air Pollutants - The relationship between the concentrations of CO found in an individual's environment and other pollutants such as hydrocarbons (HC), nitric oxide (NO), nitrogen dioxide (NO_2), can be shown but this correlation would be more difficult in the case of oxidants and particulates. Carbon monoxide, hydrocarbons, nitric oxide and nitrogen dioxide are usually the major pollutants generated by traffic sources. Neither NO nor HC is generated to any great extent by personal activities, although small concentrations of NO or NO_2 may be present in environments of heavy smoking. However, the concentrations of CO, NO_x, and vehicular generated HC generally have a steady distribution on or near a major highway. The influence of locally generated industrial NO_x or HC will usually be masked on a busy highway. If the CO level can be estimated then the indoor concentrations of NO and HC from a nearby artery could also be predicted within reasonable limits of error assuming that no significant indoor-outdoor gradients exist. The exact relationship is as yet unknown although one study showed reasonably consistent relationships for NO_2, CO and SO_2.[12] With respect to oxidants, one problem is that they are not primary pollutants. The concentrations of these compounds are greatly influenced by air pollutant interactions, meteorology and solar radiation levels. For any particular area an estimate of personal oxidant environments might initially be obtained from a broad division of the region under study into 24-hour oxidant regions. From the individual's particular hours at home, commuting and at work, an estimate can be made of average exposure assuming he spends most of his time outside. The reason for this is that oxidants are greatly reduced once they have entered the home. Interior air is cleansed of oxidants if a normal intake air scrubbing system is utilized. It is also reasonable to assume a person working in our population group receives relatively little oxidant exposure due to his lack of presence in the open air environment during periods of maximum oxidant exposure (12-5 p.m.). An exception might be those individuals living in the foothill section of the eastern South Coast Basin, extending hours of oxidant exposure to 9:00 p.m. A correlation between CO and oxidant concentrations may be possible in these areas during the last hours because oxidants are no longer being formed by photochemical reactions.

Sources of Internally Generated Air Pollution - The results from these monitoring studies of personal environments reveal some surprisingly large contributions from gas cooking which appears to generate considerable CO for short-time periods. Even electric cooking such as rotisserie barbecues generate some pollutants. This happens when fat partially burns upon short-term contact with the hot elements. Smoking in the home or at work appears to contribute less CO than generally claimed by others. One reason for this is the relatively small volume of polluted air generated by cigarettes. Also, this is diluted in the process of diffusion throughout the internal volume of a home or work place. Smoking in a vehicle with windows closed can generate high interior CO concentrations because of the more limited dilution space. A small gas stove or heater in a room will consume significant quantities of fuel in a fixed-time interval and tends to raise internal concentrations of CO rapidly.

Suggestive Applications of Empirical Estimator - One potential use for the personal environmental estimator is the mapping of contours of pollution districts within an urban area. It has already been noted that home environments can exhibit widely varying air pollutant concentrations if particular internal activities are conducted. Even more important however is the effect of externally traffic-generated pollutants.

Therefore it would be possible to construct a detailed urban map composed of grids or pockets of CO pollution estimated from traffic density, wind direction, and speed factors alone. Conceivably a residence very close to a major urban artery, but in a favorable position with respect to wind direction, could be significantly less challenged by CO than a similar residence in a suburban community near a major highway. The urban map would depict contours of estimated average daily CO in ppm-hours assumed to be challenging the person if he were present in his home for the whole 24-hour day. Traffic densities on residential streets in downtown areas are typically quite low and do not contribute measurably to increases in indoor home CO concentrations. It is believed that the estimation of individual home CO concentrations can be closer to the true level of personal exposure than that estimated by using local governmental monitoring data.

In the current study estimation was based upon a relatively simple empirical approach, unlike other efforts where elaborate computerized models of regional air mass movements superimposed upon topographical features of the regions were used. This is illustrated by the computerized construction of time-resolved pollutant isopleths over large regions of an air basin, assigning gross pollutant concentrations to different areas.[25] It has already been noted in this study that such data is frequently, or even usually, inapplicable to any particular person living within a region outlined by such isopleths. Local micrometeorological and traffic effects can have a much greater influence upon an individual's home than the regional pollutant concentration obtained from this type of study.

Another potential application would entail an attempt to correlate the relationship between air pollution and pulmonary health data derived from large scale surveys, such as those conducted by the Breathmobile project. A census tract map could be contoured in the manner described here and major differences in internally generated levels of pollution could be determined for each participant. At present monitoring data used by the Breathmobile project were obtained from fixed monitoring sites. It would be of interest to attempt to delineate the differences in exposures experienced by a census tract population for the purposes of relating pulmonary function test results to degrees of air pollution challenge. All that would be needed is the administration of the brief questionnaire used in this study.

A further use for the estimator model is in planning future residential communities. The requirements for environmental impact statements might be capable of including an assessment of future pollutant exposures expected to be experienced by future residents. If the final road network to be added to existing highways is known, then a map of the residential area could be drawn. This would be supplemented with estimates of future traffic loads on these arteries plus long-term meteorological data relating to wind direction and speed. This data would permit a preliminary drawing of contoured map surfaces of estimated future pollutant exposures within these homes. Consequently it would be possible to construct such a community in a manner where future pollutant exposures to the residents would be greatly reduced. For example, it may be possible to orient a major highway in such a way that the prevailing winds would tend to move pollutants away from the planned community.

A final application concerns health warnings issued by official state, county or city agencies. The school exercise restriction program can serve as an example. The individualization of air pollutant assessment based upon empirical estimation for each school by a contour display of pollution would permit a more accurate application of any exercise restriction program.

Design Considerations for a Semi-Portable Monitoring Station

Results from the monitoring experience gained in this study (while in the home, commuting and at work) have suggested design criteria for a reasonably portable group of instruments which could be used to greatly expand the number of pollutants measured. Some basic criteria to be observed include the accuracy and reliability of concentration data obtained; the ability to operate all instrumentation on either battery, portable generator or 12V auto electric power, in addition to the normal 110V line voltage. The instrumentation must be capable of measuring CO, O_3, NO, NO_2, total particulates, temperature, humidity, wind speed and direction. These would be employed to define the most important factors necessary to describe an average individual's micro air environment especially those items that would be used to validate an expanded empirical estimate or of environmental pollutant challenge. The addition of wind gauge instrumentation would permit a more accurate validation of the meteorological data used at present.

A specific design using available off-the-shelf equipment that probably would require only minor modifications for field use includes the following:

a) CO: Use present instrumentation, Energetics Science Ecolyzer

b) NO, NO_2: Use soon to be available dual instrument, Energetics Science Enolyzer.

c) O_3: Use Dasibi analyzer, modify for remote power use.

d) Dual or single channel recorders, Esterline (on battery power).

e) For home or work applications use a Hewlett-Packard multi-range strip chart recorders. This type of recorder is especially useful because of its' small size and light weight. This instrument was used in the present work.

f) A portable wind vane and anemometer available from various suppliers.

g) A recording thermohygrograph as presently used.

h) A small light weight cascade impactor for total particulates.

The instruments can be mounted on a small rollaway cart for transportation to the home or work. The assembly should be highly compact to permit placement into a home without too much disturbance. Each unit of instrumentation should be capable of detachment for separate use (for example, the wind data would be gathered outside the home while indoor monitoring is occurring).

Artery or commuting data would be obtained using a small enclosed panel truck (similar to the vehicle presently being used to transfer the portable pulmonary function equipment) for transport of all the cabinet mounted apparatus.

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TABLE 1

ESTIMATED CO CONCENTRATIONS AS A FUNCTION OF TRAFFIC VOLUMES AND AVERAGE VELOCITY (Surface streets or freeways)

ESTIMATED CO (ppm)	TRAFFIC VOL. (Peak/Hr or off peak)	AVERAGE VEL. (mph)
5	187	20-30
5		31-40
5		41-60
		>60
5	375	20-30
5		31-40
5		41-60
5		>60
10	750	20-30
5		31-40
5		41-60
		>60
15	1125	20-30
8		31-40
6		41-60
		>60
19	1500	20-30
10		31-40
8		41-60
7		>60
24	1875	20-30
12		31-40
10		41-60
9		>60
29	2250	20-30
15		31-40
12		41-60
11		>60
33	2625	20-30
17		31-40
14		41-60
13		>60
38	3000	20-30
19		31-40
15		41-60
13		>60
43	3375	20-30
22		31-40
18		41-60
16		>60
48	3750	20-30
24		31-40
20		41-60
18		>60
92	7500	20-30
46		31-40
37		41-60
33		>60
118	≥9375	20-30
60		31-40
48		41-60
43		>60

TABLE 2

ESTIMATION OF REDUCTION IN CO CONCENTRATION AS A FUNCTION OF DISTANCE FROM ARTERY

CO (PPM)	DISTANCE IN MILE	DISTANCE IN METERS	CORRECTED CO LEVEL	% DROP IN CO
10	≤0.1	162	7	30
10	≤0.2	324	4	60
10	≤0.3	486	3	70
10	≤0.4	646	2.2	78
		1000	2	80
15	≤.1	162	11	30
15	≤.2	324	6	60
15	≤.3	486	5	70
15	≤.4	646	3.3	78
15		1000	3	80
20	≤.1	162	12	30
20	≤.2	324	8	60
20	≤.3	486	6	70
20	≤.4	646	4.4	78
20		1000	4	80
25	≤.1	162	16	30
25	≤.2	324	10	60
25	≤.3	486	8	70
25	≤.4	646	5.5	78
25		1000	5	80
30	≤.1	162	21	30
30	≤0.2	324	12	60
30	≤0.3	486	9	70
30	≤0.4	646	6.6	78
30		1000	6	80
35	≤0.1	162	25	30
35	≤0.2	324	14	60
35	≤0.3	486	11	70
35	≤0.4	646	7.7	78
35		1000	7	80

TABLE 2 (continued)

CO (PPM)	DISTANCE IN MILES	DISTANCE IN METERS	CORRECTED CO LEVEL	% DROP IN CO
40	≤0.1	162	28	30
40	≤0.2	324	16	60
40	≤0.3	486	12	70
40	≤0.4	646	8.8	78
40		1000	8	80
45	≤0.1	162	32	30
45	≤0.2	324	18	60
45	≤0.3	486	14	70
45	≤0.4	646	9.9	78
45		1000	9	80
50	≤0.1	162	35	30
50	≤0.2	324	20	60
50	≤0.3	486	15	70
50	≤0.4	646	11	78
50		1000	10	80

TABLE 3

PREVAILING WIND DIRECTION AND SPEED FOR PRINCIPAL METEOROLOGICAL STATIONS

STATION	AVERAGE DIRECTION	AVERAGE VELOCITY
Azusa	W	4
Burbank	SE	6
Compton	W	7
LA Central	SW	5
LA International	W	10
Lennox	W	5
Long Beach	WNW	5
Lynwood	W	4
Pasadena	S	4
Pico Rivera	SW	6
Pomona	WSW	5
Redondo Beach	WSW	8
Reseda	E	3
Vernon	W	7
West LA	SW	5
Whittier	SW	4

SUBJECT NUMBER	(1) Smoke in Residence (27 or 50)	(2) Windows Open ≤ 20% (57)	(3) Gas Cooking (99 old 0)	(4) Gas Heating (100)	(5) Attached Garage (59)	(6) Prevailing Wind Speed >3 mph	(7) Prevailing Wind Direction	(8) Distance Home to Artery	(9) Direction Home to Artery	(10) Artery Traffic Nr. Res. *a) Peak Hr. b) Off Peak*	(11) Commute Miles on *a) Surface b) Freeway*	(12) Commute Time on *a) Surface b) Freeway*	(13) Smokers in Car (66)	(14) Work Traffic *a) Peak b) Off Peak*	(15) Leave Office	(16) Work Near Smokers (72)	(17) Residence Exposure	(18) Commute Exposure	(19) Work Exposure	(20) Total Estimated Exposure (ppm/hrs)
1 Downtown	No	Yes	Yes	Yes	No	Yes	225	2 blks	270	a)1800 b)621	a) 5 b) 0	a) .5M b) 0	No	a) 1800 b) 930	No	Yes	8+7.5+35 +22=73	12	34+35+ 40=109	73+12+109= 194
										a)24(.4) (3.5)=35		a)24(.5) =12		a)24(.7) (2)=34						
										b)5(.4)(11) =22				b)7(.7) (7)=35						
2 ElSegundo	Yes	Yes	Yes	Yes	No	Yes		1 blk		a)15400 b)2,566	a)20 b)30	a)20 b)40	Yes	a)1800 b)930	No	Yes	25+8+8+44 +44=146	51+15 =66	34+35+ 40=109	146+66+109= 321
										a)32(.7) (2)=44		a)32(1/6) (2)=11		a)24(.7) (2)=34						
										b)6(.7) (11)=44		b)60(.3) (2)=40		b)7(.7) (7)=35						
3 Seal Beach	Yes	Yes	No	Yes	Yes	NA	NA	1 blk	NA	NA	a)5 b)20	a)30 b)90	No	a)1800 b)930	No	Yes	25+8+15= 48	90+19=109	34+35+40= 109	48+109+109= 266
												a)38(.5) =19		a)24(.7) (7)=34						
												b)60(.75) (2)=90		b)7(.7) (7)=35						
4 Upland	Yes	Yes	Yes	Yes	No	NA	NA	NA	NA	NA	a)2 b)43	a)5 b)84	Yes	a)1800 b)930	No	Yes	25+8+8= 41	168	34+35+40= 109	41+168+109= 318
												a)- b)60(2) (84)= 168		a)24(.7) (7)=34						
														b)7(.7) (7)=34						

TABLE 4

ESTIMATOR CALCULATIONS - GROUP 1

SUBJECT NUMBER	(1) Smoke in Residence (27 or 50)	(2) Windows Open ≤ 20% (57)	(3) Gas Cooking (99 old 0)	(4) Gas Heating (100)	(5) Attached Garage (59)	(6) Prevailing Wind Speed >3 mph	(7) Prevailing Wind Direction	(8) Distance Home to Artery	(9) Direction Home to Artery	(10) Artery Traffic Nr. Res. *a) Peak Hr.* *b) Off Peak*	(11) Commute Miles on *a) Surface* *b) Freeway*	(12) Commute Time on *a) Surface* *b) Freeway*	(13) Smokers in Car (66)	(14) Work Traffic *a) Peak* *b) Off Peak*	(15) Leave Office	(16) Work Near Smokers (72)	(17) Residence Exposure	(18) Commute Exposure	(19) Work Exposure	(20) Total Estimated Exposure (ppm/hrs)
5 Downey	No	Yes	Yes	Yes	Yes	Yes	225	1 blk	270	a)2,232 b)710	a)17 b)1	a)55 min b)5 min	No	a)1800 b)930	No	Yes	8+7.5+15+ 61+44=136	(60)(1)=60	34+35+40= 109	136+60+109= 305
										a)29(.7) (3)=61				a)24(.7) (2)=34						
										b)(5)(.7) (11)=44				b)7(.7) (7)=35						
6 Long Beach	Yes	Yes	Yes	Yes	No	NA	NA	>4	NA	NA	a)1.25 b)25	a)15min b)42min	No	a)1800 b)930	No	Yes	25+8+7.5= 41	(60)(2) (2/3)=80	34+35+40= 109	41+80+109= 230
														a)24(.7) (2)=34						
														b)7(.7) (7)=35						
7 La Habra	Yes	Yes	No	No	No	NA	NA	>5	NA	NA	a)5 b)20	a)15 b)60	No	a)1800 b)930	No	Yes	25	(60)(1)+ (30)(.5)=75	34+35+40= 109	25+75+109= 209
														a)24(.7) (2)=34						
														b)7(.7) (7)=35						

TABLE 5

ESTIMATOR CALCULATIONS - GROUP 2

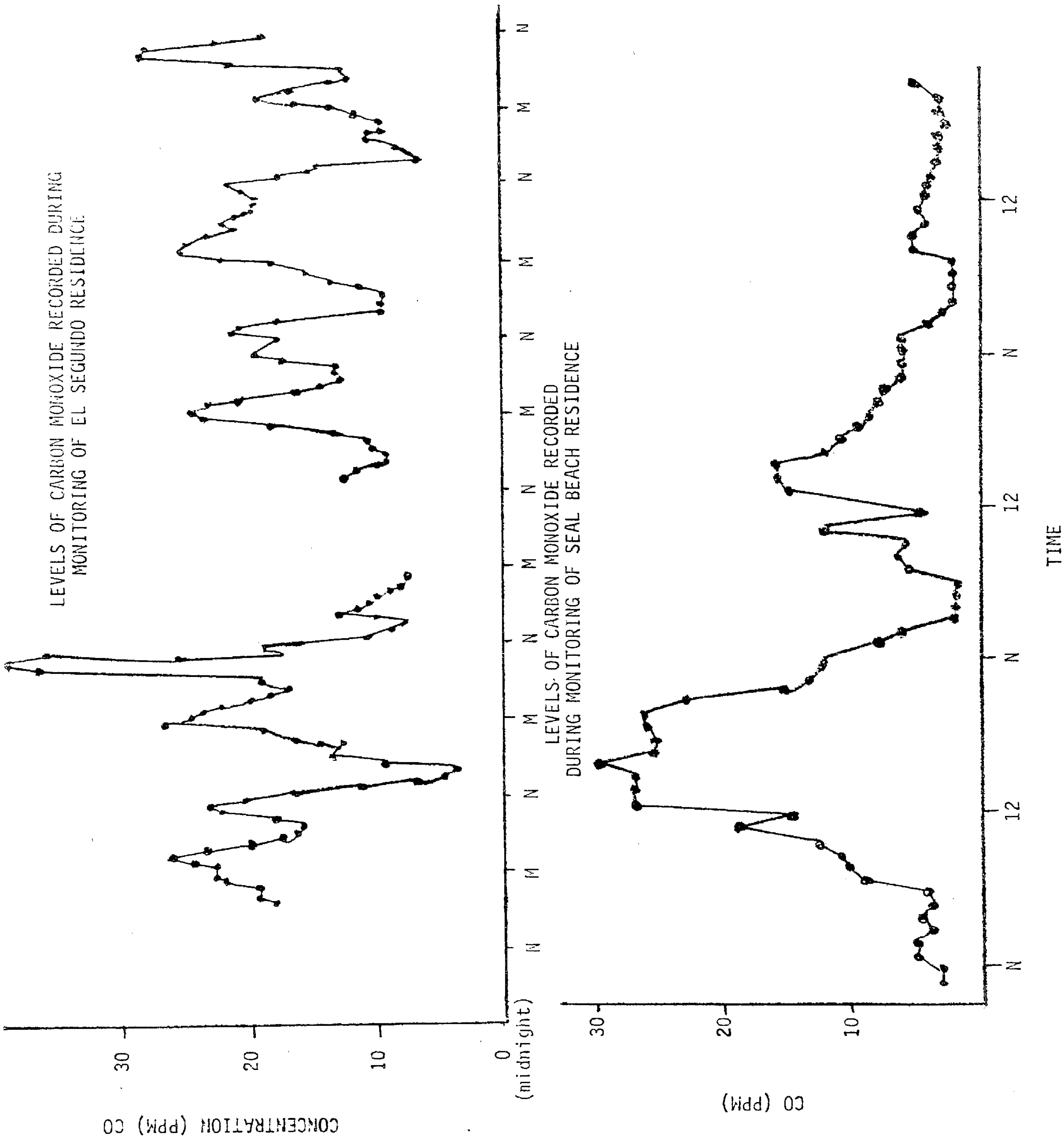
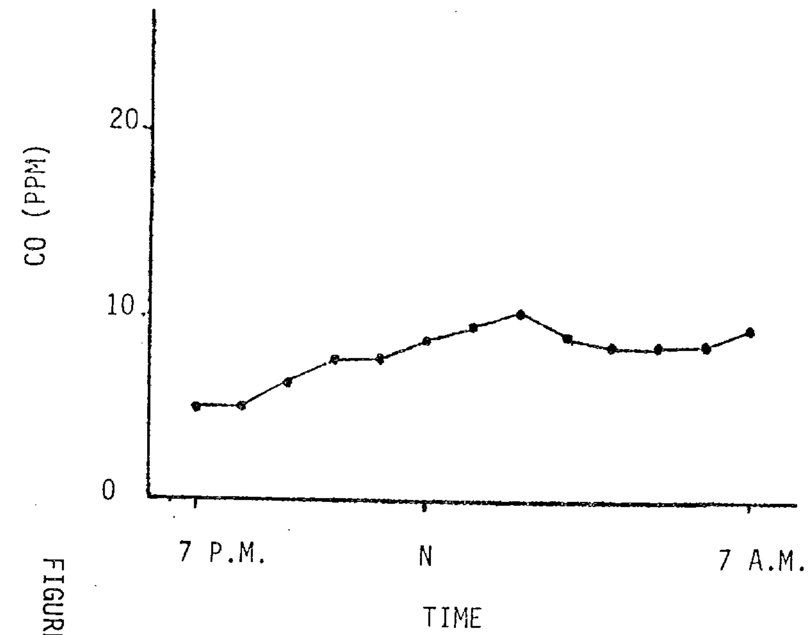

LEVELS OF CARBON MONOXIDE RECORDED DURING MONITORING OF EL SEGUNDO RESIDENCE
CONCENTRATION (PPM) CO
0 (midnight)
10
20
30
N
M
LEVELS OF CARBON MONOXIDE RECORDED DURING MONITORING OF SEAL BEACH RESIDENCE
CO (PPM)
12
TIME

FIGURE 1

LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF CENTRAL
LOS ANGELES RESIDENCE



LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF INSURANCE
COMPANY OFFICE BUILDING

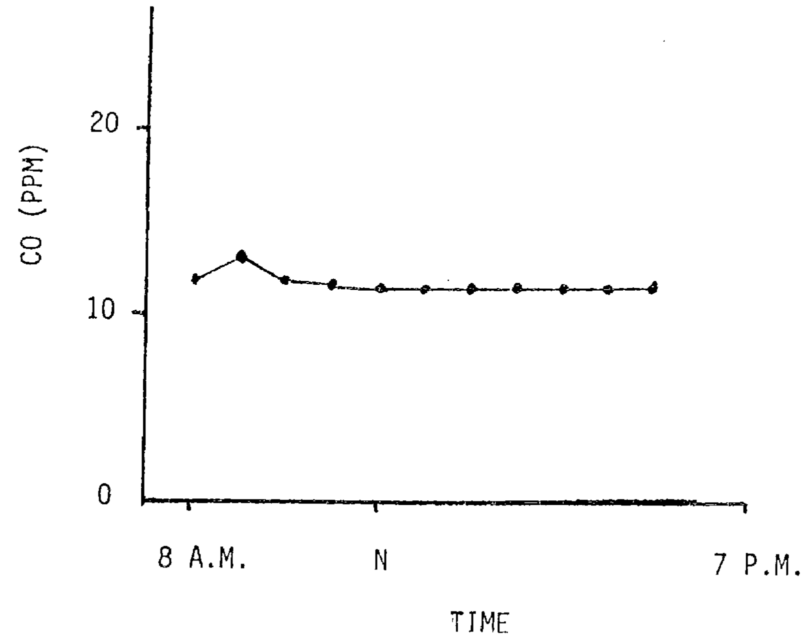
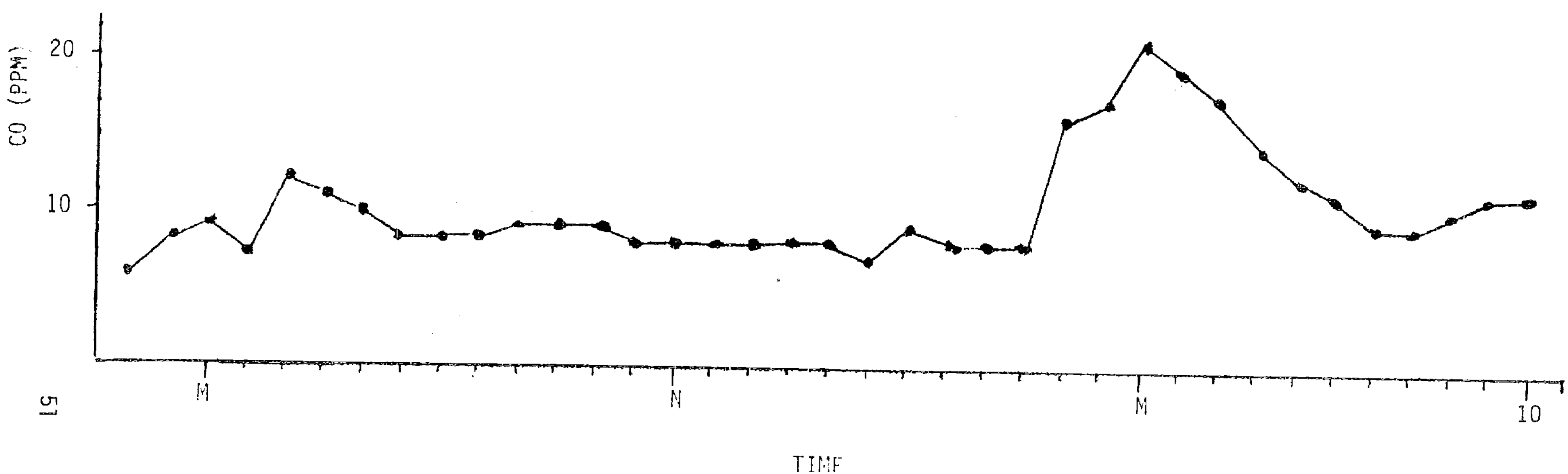
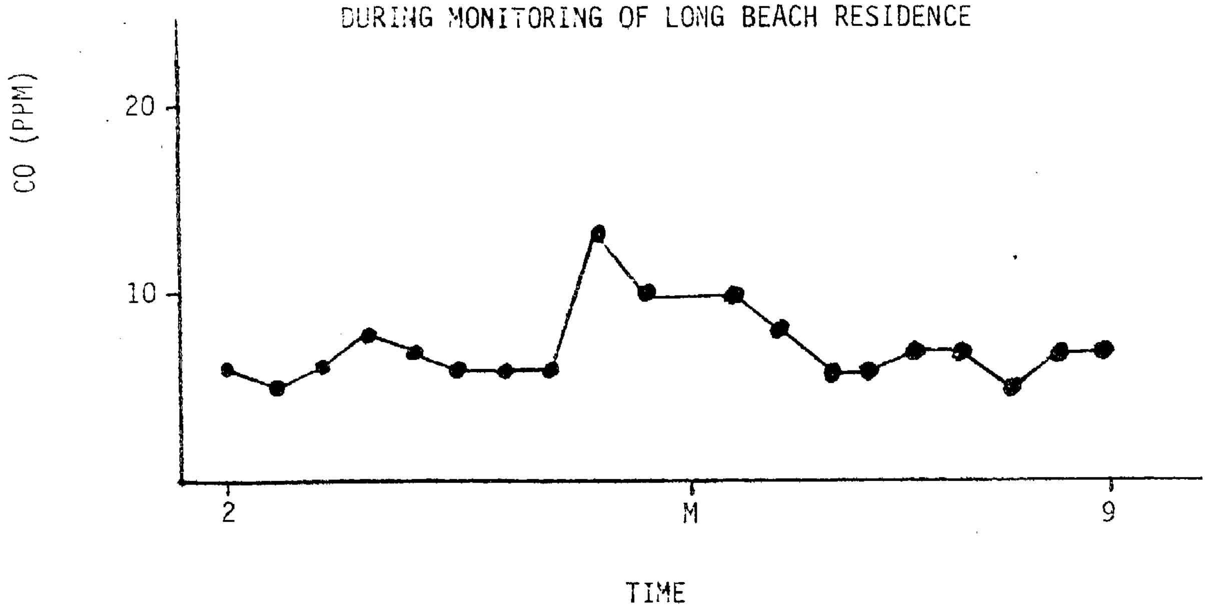


FIGURE 2

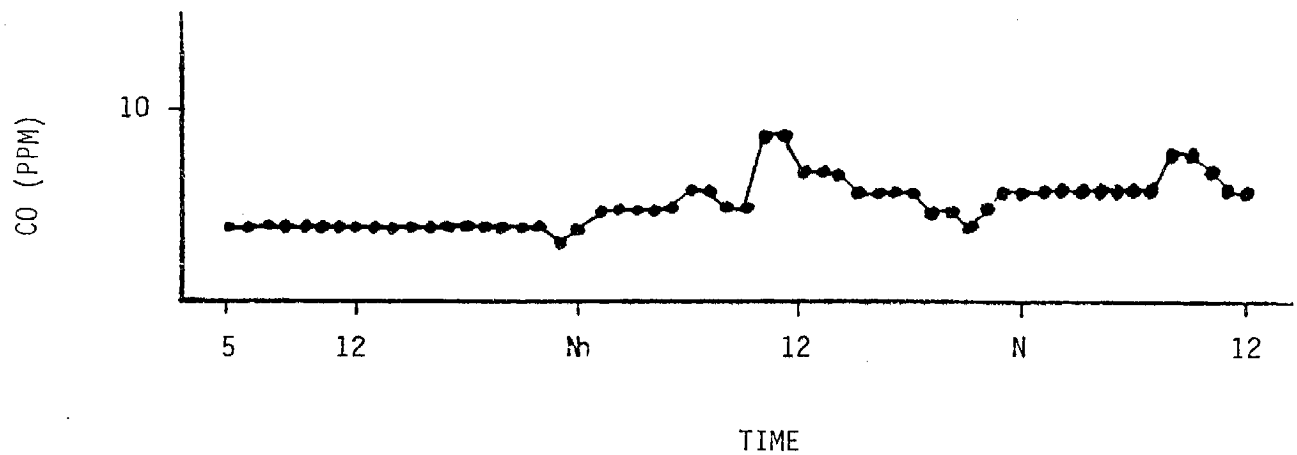
LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF UPLAND RESIDENCE



LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF LONG BEACH RESIDENCE



LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF LA HABRA RESIDENCE



LEVELS OF CARBON MONOXIDE RECORDED
DURING MONITORING OF DOWNEY RESIDENCE

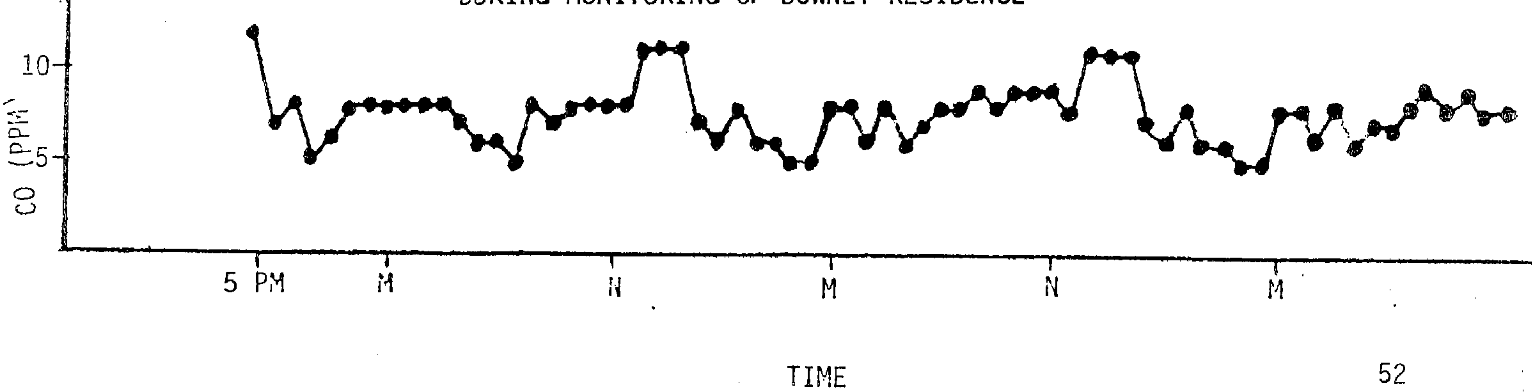


FIGURE 3

INDIVIDUAL 24-HOUR CO EXPOSURE AS MEASURED BY
ESTIMATOR MODEL (1), PERSONAL MONITORING (2) AND NEAREST MONITORING STATION (3)

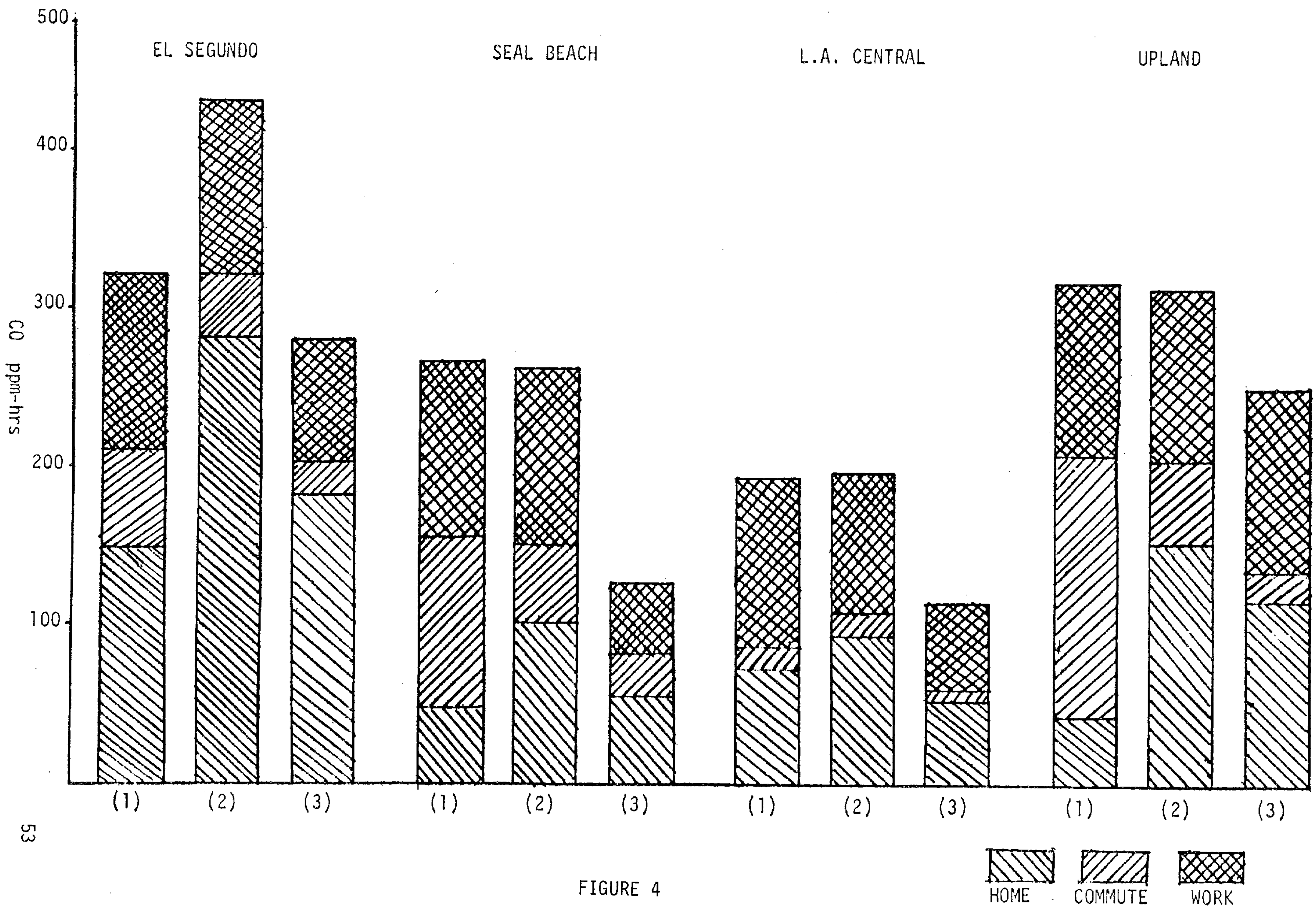


FIGURE 4

INDIVIDUAL 24-HOUR CO EXPOSURE AS MEASURED BY
ESTIMATOR MODEL (1), PERSONAL MONITORING (2) AND NEAREST MONITORING STATION (3)
SECOND GROUP OF SUBJECTS

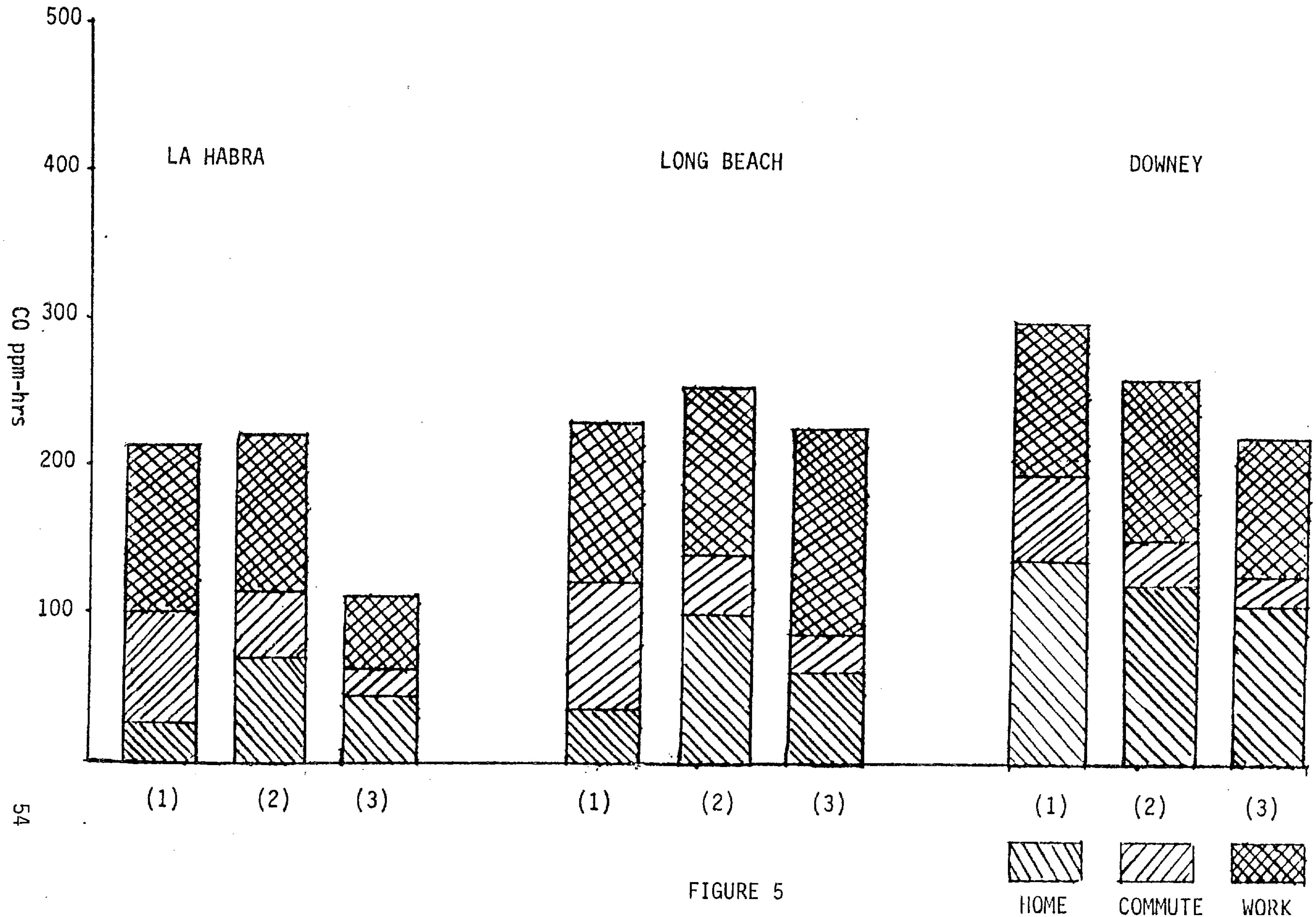


FIGURE 5

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED ON COMMUTING TRIP FROM EL SEGUNDO TO DOWNTOWN

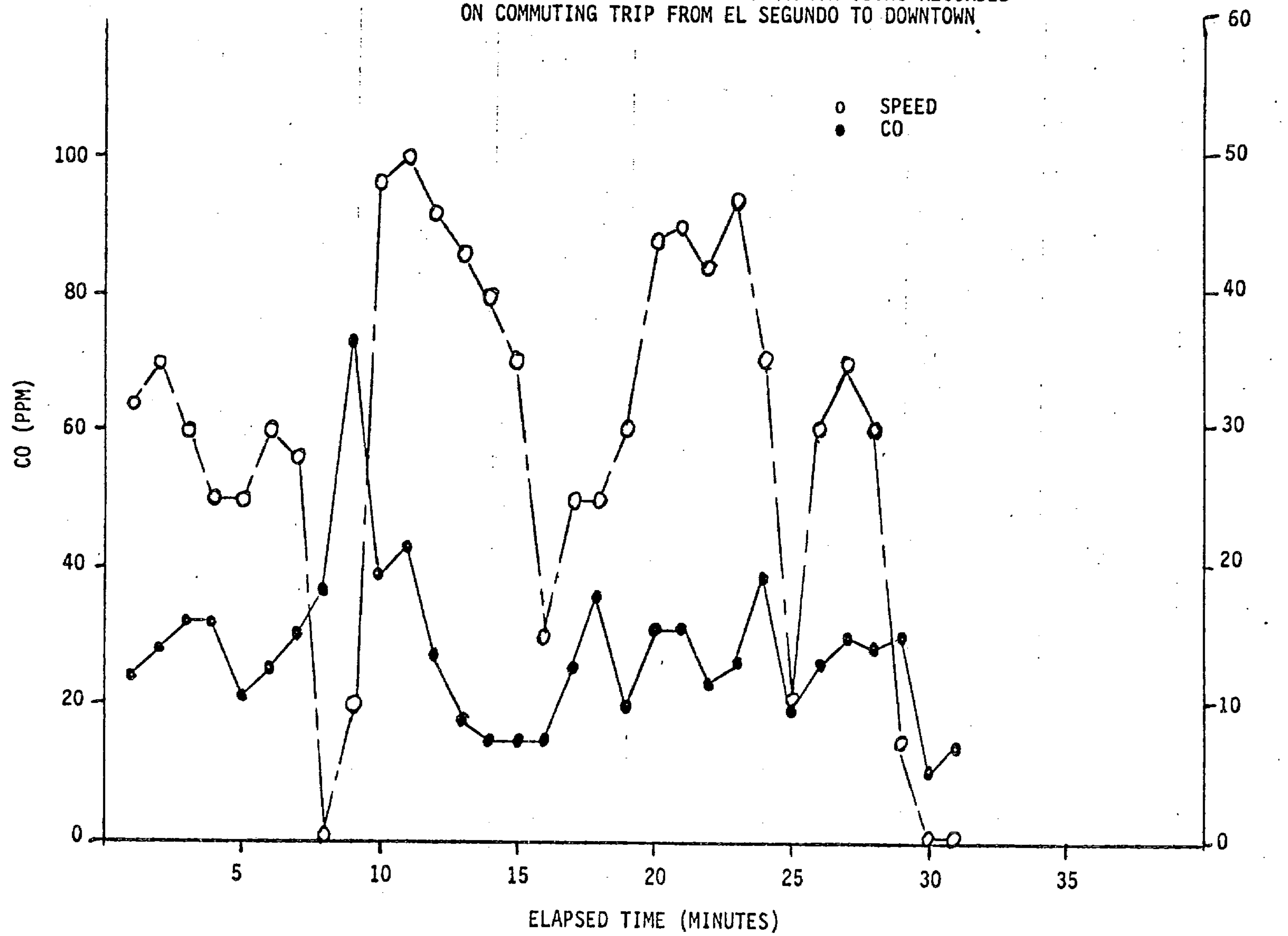


FIGURE 6

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED ON COMMUTING TRIP FROM SEAL BEACH TO DOWNTOWN

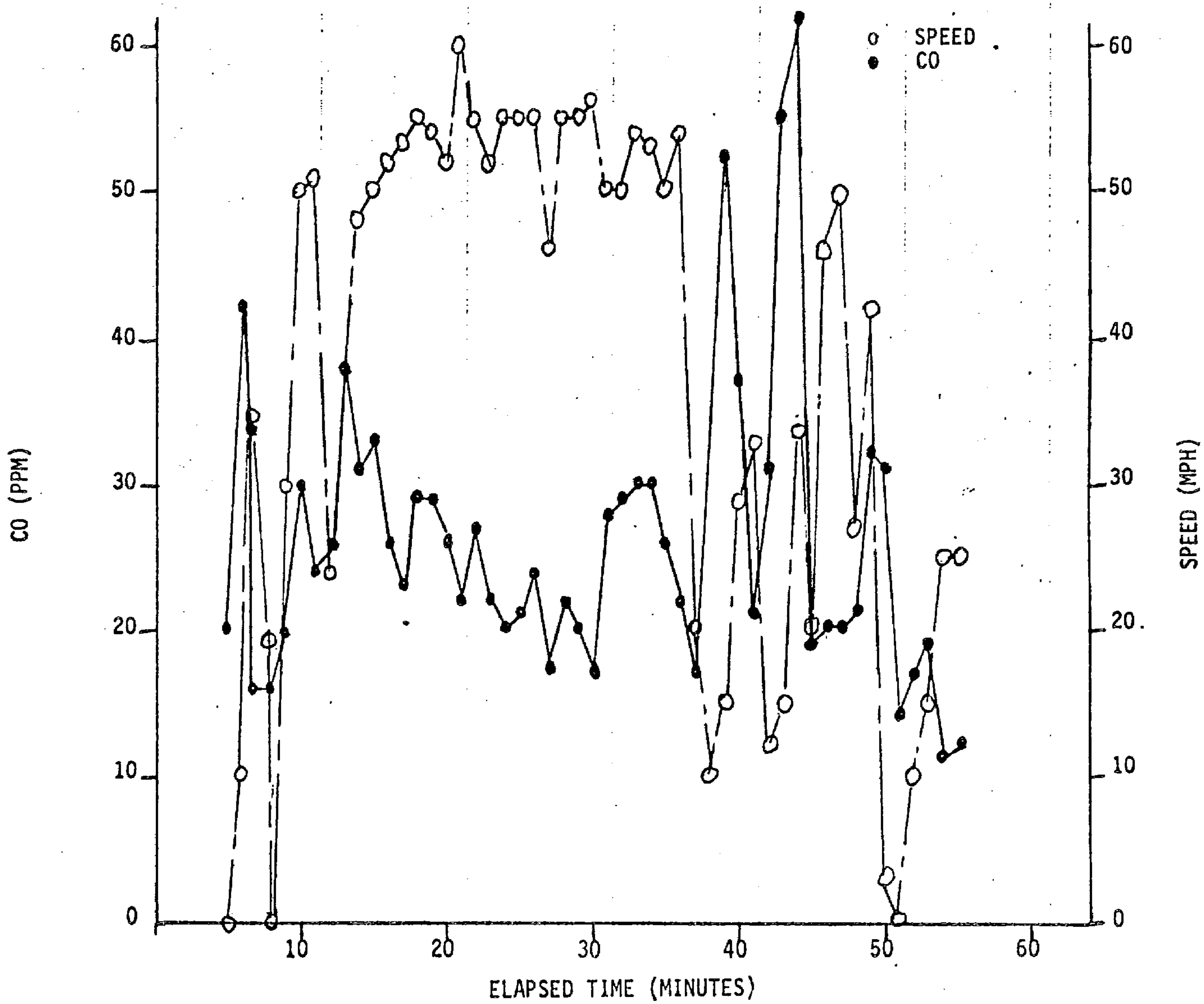


FIGURE 7

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED
ON COMMUTING TRIP FROM DOWNTOWN RESIDENCE

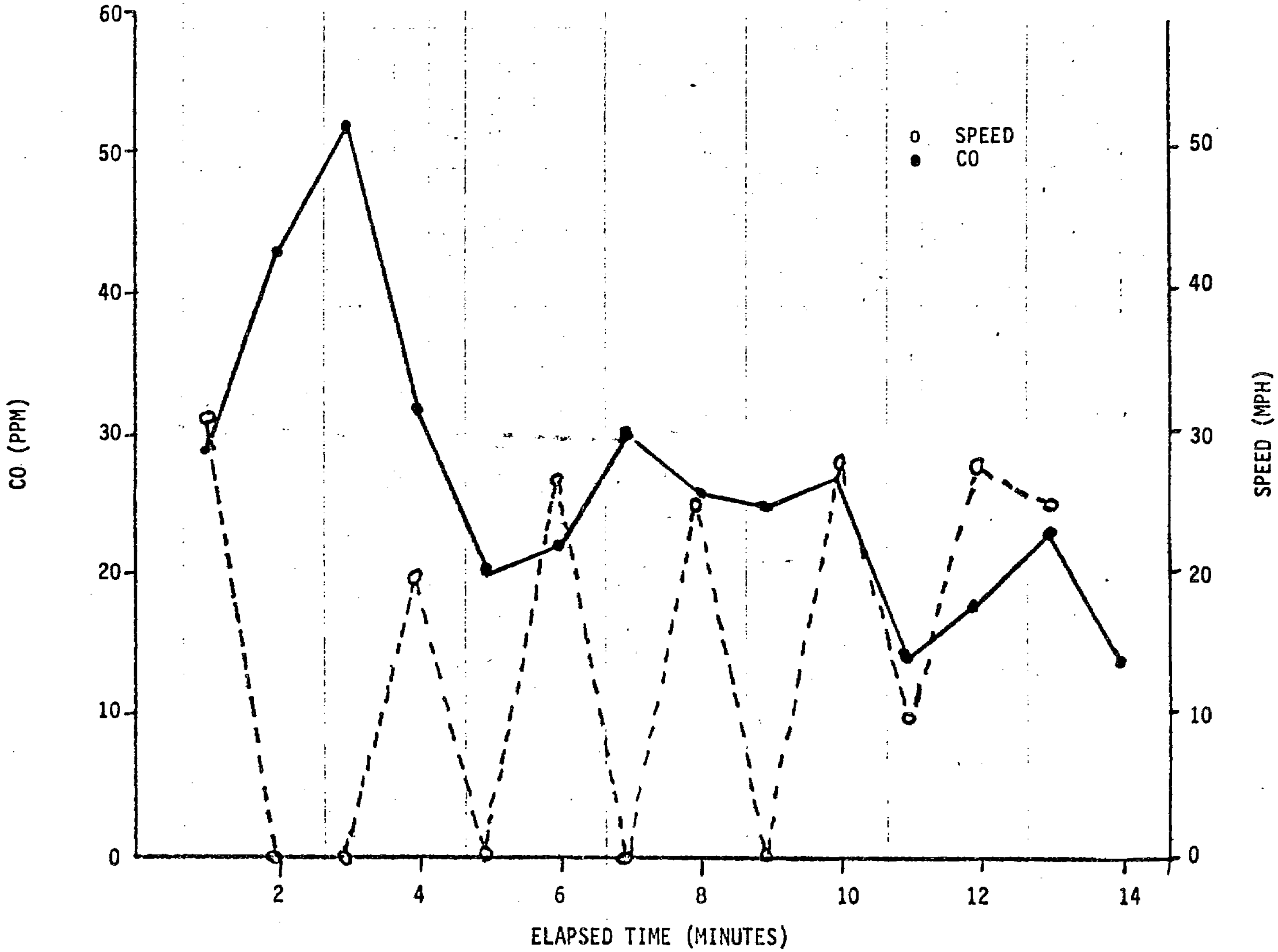


FIGURE 8

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED ON COMMUTING TRIP FROM UPLAND TO DOWNTOWN

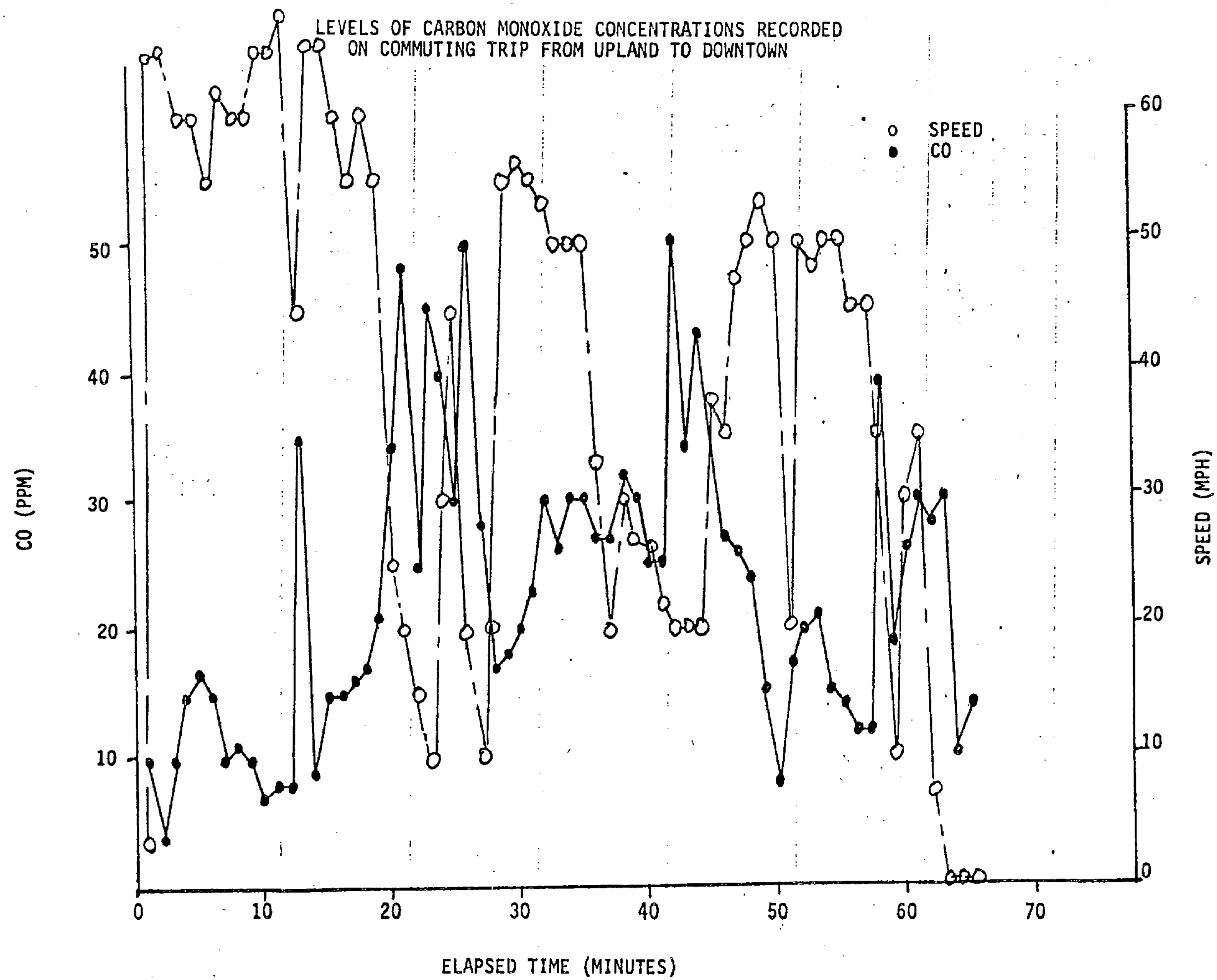


FIGURE 9

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED ON COMMUTING TRIP FROM LONG BEACH TO DOWNTOWN

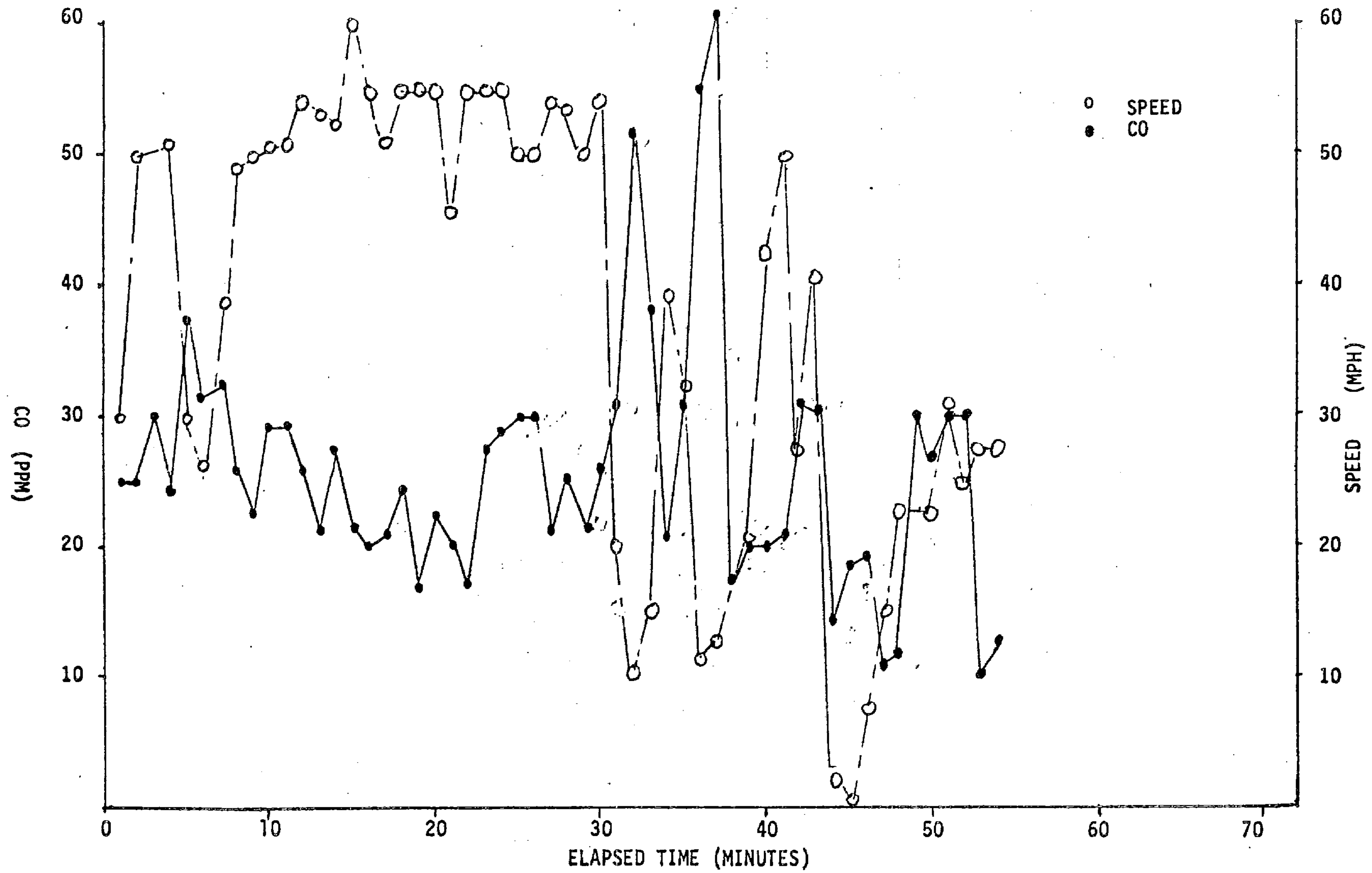


Figure 10

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED
ON COMMUTING TRIP FROM LA HABRA TO DOWNTOWN

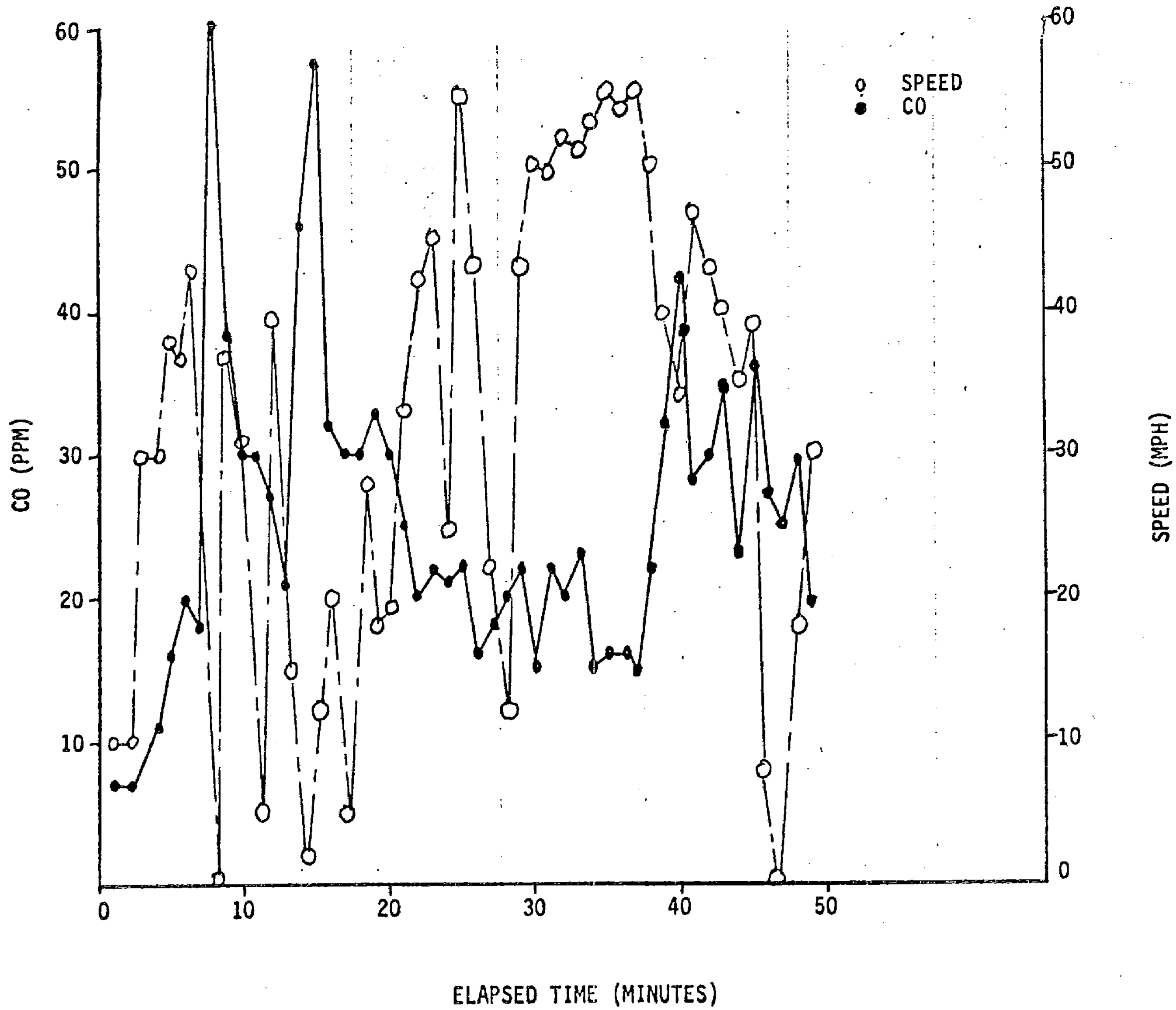


FIGURE 11

LEVELS OF CARBON MONOXIDE CONCENTRATIONS RECORDED
ON COMMUTING TRIP FROM DOWNEY TO DOWNTOWN

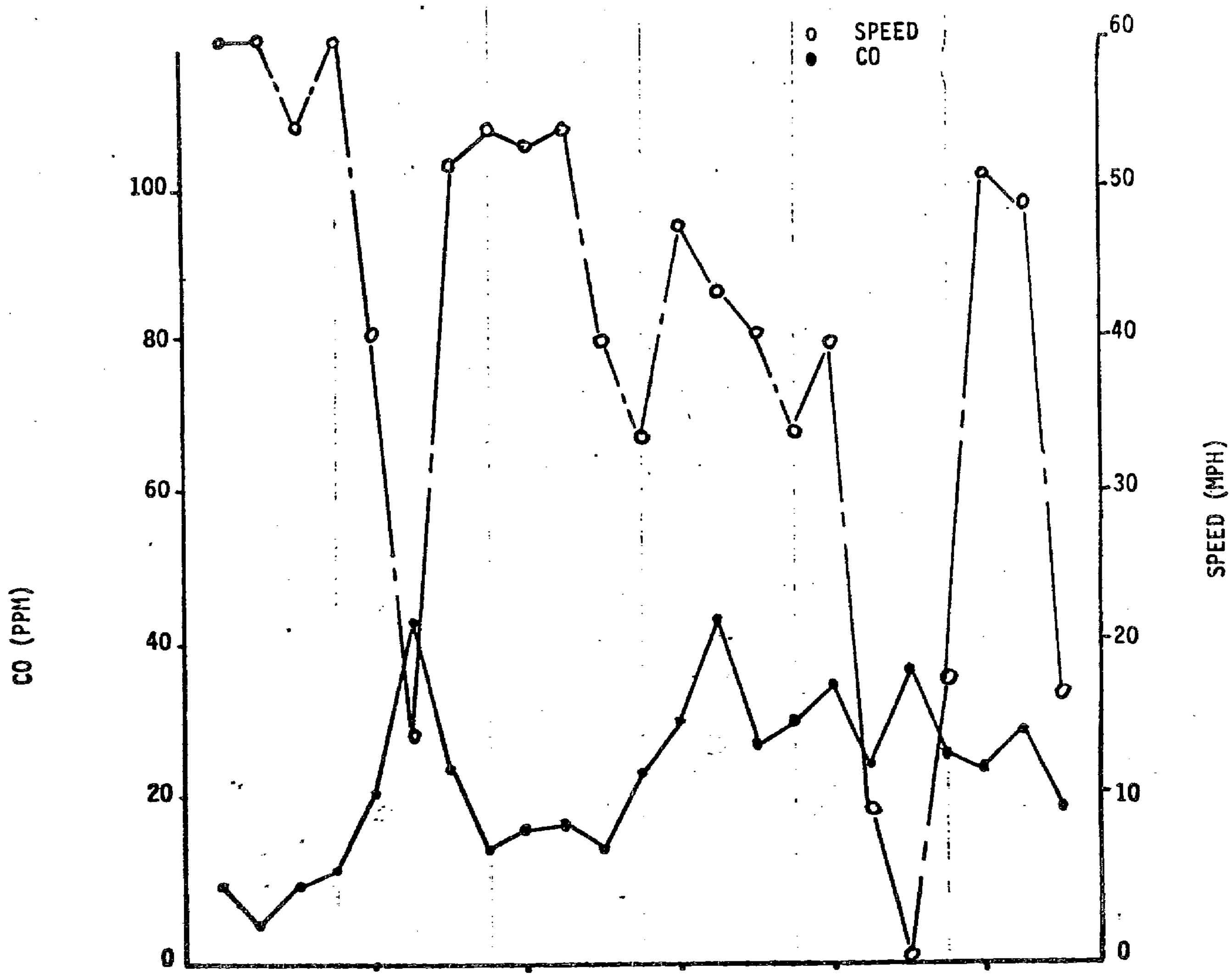


FIGURE 12

APPENDIX A

TABLES OF AVERAGED TRAFFIC DATA

AVERAGED TRAFFIC COUNTS
-CENTRAL-
EAST-WEST TRAFFIC

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM, PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Beverly	- Robertson-Vermont	25,181	1,847	1,175	588
Coldwater	- Sunset-Mulholand	16,000	1,173	747	373
8th	- Crenshaw-Vermont	14,000	1,027	653	327
Exposition	- Crenshaw-Vermont	18,000	1,320	840	420
Franklin	- Highland-Vermont	18,000	1,320	840	420
48th	- Crenshaw-Vermont	7,000	513	327	164
54th	- Crenshaw-Vermont	9,000	660	420	210
Fountain	- LaCienga-Vermont	13,777	1,010	643	321
Hollywood	- Laurel Canyon-Vermont	24,636	1,806	1,149	575
Jefferson	- LaCienga-Vermont	13,000	953	607	303
Laurel Canyon	- Sunset-Mulholand	27,000	1,980	1,260	630
Los Feliz	- Western-San Fernando	33,600	2,464	1,568	784
Melrose	- Robertson-Vermont	27,083	1,986	1,263	632
Olympic	- Robertson-Vermont	28,916	2,120	1,349	674
Pico	- Robertson-Vermont	18,888	1,385	881	441
Rodeo	- LaCienga-Crenshaw	26,000	1,907	1,213	607
Stocker	- LaCienga-Leimert	13,600	997	635	317
Sunset	- San Vicente-Vermont	39,928	2,928	1,863	932
6th	- LaCienga-Vermont	14,818	1,087	892	346
3rd	- Robertson-Vermont	22,857	1,676	1,067	533
Santa Monica	- Robertson-Vermont	27,750	2,035	1,295	648
Slauson	- LaCienga-Vermont	24,916	1,827	1,163	581

AVERAGED TRAFFIC COUNTS
-CENTRAL-
EAST-WEST TRAFFIC
(continued)

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM, PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
San Vincente	- Sunset-Pico	13,000	867	607	303
Santa Barbara	- Crenshaw-Vermont	26,285	1,928	1,227	613
Venice	- Pico-Vermont	16,000	1,173	747	373
Venice	- Robertson-San Vincente	19,800	1,452	924	462
Vernon	- Crenshaw-Vermont	14,166	1,038	661	330
Washington	- Robertson-Vermont	18,400	1,349	859	439
Wilshire	- Robertson-Vermont	31,727	2,326	1,481	740

AVERAGED TRAFFIC COUNTS
-WESTERN AREA-
EAST-WEST TRAFFIC

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM, PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Broadway	- Ocean-Bundy	11,000	807	513	257
Burton Way	- Beverly-Robertson	18,000	1,320	840	420
Colorado	- Ocean-Bundy	11,000	807	513	257
Culver Blvd.	- Vista Del Mar-Robertson	16,083	1,179	750	375
Jefferson Blvd.	- Culver-LaCienga	19,272	1,413	899	450
Montana	- Ocean-San Vincente	11,000	807	513	257
National Blvd.	- Bundy-Overland	18,833	1,381	879	439
Ocean Park Blvd.	- Beach-Pico	10,000	733	467	233
Olympic	- 4th-Robertson	27,916	2,047	1,302	651
Palms	- Washington- Santa Monica Frwy	9,000	660	420	210
Pico	- Ocean-Robertson	24,040	1,762	1,222	561
San Vicente	- Ocean-Federal	21,818	1,599	1,018	509
Santa Monica	- Ocean-Robertson	28,115	2,062	1,312	656
Sunset	- Pacific Coast Hwy-Robertson	24,913	1,827	1,163	581
Venice	- Pacific Ave-Robertson	24,533	1,799	1,145	572
Washington Blvd.	- Beethoven-Robertson	17,710	1,299	626	413
Washington Blvd.	- Brooks-Washington St.	10,000	733	467	23[illegible]
Washington Place	- Washington St.-Sepulveda	17,700	1,298	826	413
Washington St.	- Pacific-Washington Blvd.	17,000	1,247	793	397
Wilshire	- Ocean-Robertson	38,583	2,829	1,801	900

AVERAGED TRAFFIC COUNTS
-WESTERN AREA-
NORTH-SOUTH TRAFFIC

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM,PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Barrington Ave.	- Sunset-Palms Ave.	12,000	880	560	280
Beverly Dr.	- Cold Water-Pico	16,333	1,197	762	381
Bundy Dr.	- Sunset-National	20,300	1,488	947	473
Cloverleaf	- Santa Monica-Ocean Park Blvd.	17,000	1,246	793	397
Centinella	- Airport Ave-Jefferson	21,000	1,540	980	490
Doheny	- Sunset-Pico	13,714	1,005	639	320
Fourth St.	- San Vicente-Washington Blvd.	10,000	733	467	233
Inglewood Blvd.	- National-Jefferson	9,000	660	420	210
Jefferson Blvd.	- Sawtelle-LaCienga	22,000	1,613	1,026	513
Lincoln Blvd.	- Wilshire-Jefferson	35,411	2,597	1,652	826
Mandeville	- Sunset-Mulholand	6,000	440	280	140
Ocean Ave.	- Montana-Pico	14,000	1,026	653	327
Overland	- Santa Monica-Jefferson	15,454	1,133	721	360
Pacific Ave.	- Ocean Park Blvd.-Marina	15,000	1,100	700	350
Pacific Coast Hwy	- Topanga Canyon-Chautauqua	41,333	3,031	1,929	964
Robertson	- Santa Monica-National	19,909	1,460	929	465
Sepulveda	- Sunset-Jefferson	19,400	1,423	905	452
Sawtelle	- Wilshire-Jefferson	14,000	1,026	653	326
Topanga	- Mulholand-Pacific Coast Hwy	9,000	660	420	210
20th	- San Vincente-Ocean Park Blvd.	12,000	880	560	280
26th	- San Vincente-Colorado	13,000	953	606	303
Westwood	- Le Conte-Exposition Blvd.	23,750	1,741	1,108	554

AVERAGED TRAFFIC COUNTS
-CENTRAL AREA-
NORTH-SOUTH TRAFFIC

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM,PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Alvarado	- Venice-Sunset	20,000	1,467	933	467
Arlington	- Slauson-Franklin	10,900	799	509	254
Crenshaw	- Slauson-Wilshire	34,769	2,549	1,623	811
Crescent Hights	- 18th-Hollywood Blvd.	16,875	1,238	788	394
Colorado	- Eagle Rock-Fig.	37,000	2,713	1,727	863
Cypress	- Verdugo-Fig.	8,000	587	373	187
Cahuenga	- Melrose-Franklin	11,600	851	541	271
Eagle Rock	- San Fernando-Colorado	18,555	1,361	866	433
Fletcher	- Glendale-Verdugo	11,000	807	513	257
Figueroa	- San Fernando-Colorado	16,200	1,188	756	378
Fairfax	- LaCienga-Hollywood	21,000	1,540	980	490
Glendale	- Sunset-San Fernando Road	22,000	1,613	1,027	513
Gardner	- Franklin-3rd	4,714	346	220	110
Gower	- Melrose-Franklin	12,500	916	583	292
	- Hollywood-San Fernando	12,000	953	607	303
Hauser	- Jefferson-3rd	9,222	676	430	215
Highland	- LaBrea-Barhan	16,168	1,186	755	377
La Brea	- Slauson-Franklin	36,890	2,705	1,722	861
La Cienga	- Slauson-Sunset	33,222	2,436	1,550	716
Larchmont	- 3rd-Melrose	7,500	550	350	175
Normandie	- Slauson-Los Feliz	13,600	1,003	635	317

AVERAGED TRAFFIC COUNTS
-CENTRAL AREA-
NORTH-SOUTH TRAFFIC
(continued)

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) AM, PM PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Rossmore	- Wilshire-Franklin	17,600	3,006	821	411
Redondo	- Jefferson-Atlantic	9,666	708	451	226
Robertson	- Venice-Santa Monica Blvd.	17,600	1,291	821	411
Rampart	- Hoover-Temple	11,500	5,060	637	268
Riverside	- Figueroa- Los Feliz	11,400	836	532	266
Rowena	- Glendale-Los Feliz	9,000	660	420	210
San Fernando	- Figueroa-Los Feliz	20,200	1,481	943	471
Silver Lake	- Sunset-Glendale	11,000	807	513	257
Vermont	- Slauson-Los Feliz	26,000	1,895	1,213	520
Virgil	- Wilshire-Sunset	14,000	1,027	653	327
Western	- Slauson-Los Feliz	27,100	1,987	1,264	632
Wilton	- Olympic-Franklin	10,900	799	509	254
York Blvd.	- Eagle Rock-Figueroa	17,000	1,247	793	397
Yosemite	- Eagle Rock-Figueroa	7,000	513	327	163

AVERAGED TRAFFIC COUNTS
-SOUTHERN AREA-
NORTH-SOUTH TRAFFIC

SURFACE STREET	SEGMENT	24 HR AVERAGE	(6 hrs) A.M. P.M. PK HR	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Alameda St.	- Firestone-Imperial Hwy	20,400	1,496	952	476
Avalon	- Slauson-Imperial Hwy	15,916	1,167	743	371
Broadway	- Slauson-Imperial Hwy	15,625	1,145	729	364
Broadway	- Imperial-Victoria	5,555	370	185	130
Central Ave.	- Slauson-Imperial Hwy	19,100	1,400	891	445
Crenshaw Blvd.	- Slauson-Imperial	29,100	2,134	1,358	679
Figueroa	- Slauson-Imperial	14,250	1,045	665	333
Figueroa	- Imperial-Anaheim	7,388	541	344	172
Main	- Slauson-Imperial	12,375	907	578	288
Normandie	- Slauson-Pacific Coast Hwy	12,653	928	590	295
San Pedro	- Slauson-Imperial	9,888	724	461	230
Van Ness	- Slauson-Imperial	9,333	684	435	217
Vermont	- Artesia-Anaheim	12,000	880	560	280
Vermont	- Slauson-Artesia	19,055	1,397	889	444
Western	- Slauson-Pacific Coast Hwy	20,500	1,503	556	478

AVERAGED TRAFFIC COUNTS
-SOUTHERN AREA-
EAST-WEST TRAFFIC

SURFACE STREET	SEGMENT	24 HR. AVERAGE	(6 hrs) AM, PM PK.HR.	(6 hrs) MID-DAY OFF PK HR	(12 hrs) EVENING OFF PK HR
Alondra Blvd.	- Normandie-Main	15,660	1,148	731	365
Artesia	- Western-Main	34,428	2,524	1,606	803
Anaheim Street	- Western-Terminal Island Frwy	19,125	1,402	893	446
Carson St.	- Western-Main	21,000	1,540	980	490
Century Blvd.	- Crenshaw-Alameda	25,916	1,900	1,209	605
El Segundo Blvd.	- Western-Main	30,428	2,231	1,419	709
Florence Ave.	- Crenshaw-Central	31,923	2,341	1,489	745
Gardena	- Western-Main	4,750	348	222	111
Imperial Hwy	- Crenshaw-Férnwood	30,444	2,232	1,420	710
Lomita	- Western-Wilmington	17,285	1,267	634	317
Manchester	- Crenshaw-Central	37,800	2,772	1,764	882
Pacific Coast Hwy	- Western-Terminal Island Frwy	29,333	2,151	1,417	684
Palos Verdes Dr. N.	- To Gaffey	17,000	1,246	793	397
Rosecrans	- Western-Main	32,500	2,383	1,516	758
Redondo Beach Blvd.	- Western-Avalon	13,750	1,008	642	321
Slauson	- Crenshaw-Central	26,845	1,969	1,252	683
San Diego Frwy	- Western-Alameda	161,200	11,821	7,522	3,761
Sepulveda Blvd.	- Western-Terminal Island Frwy	27,000	1,980	1,260	630
Torrance	- Western-Main	11,333	831	529	264

APPENDIX B

PERSONAL POLLUTION DIARY (EVENT LOG)

PERSONAL POLLUTION DIARY (EVENT LOG)

DATE OF LOG ______

LOCATION OF HOME SAMPLER ______ (SPECIFY ROOM)

PERSONNEL SAMPLER, WORN BY ______ (INITIAL)

SMOKERS IN HOUSE ______ (NUMBER)

ATTACHED GARAGE ______ (YES/NO)

$T^{o}C$ SAMPLING ROOM (HRLY PK) ______

R.H. SAMPLING ROOM (HRLY PK) ______

GAS HEATING ______ (YES/NO)

NUMBER OF PERM RESIDENTS ______

NUMBER OF WINDOWS ALWAYS OPEN VICINITY OF SAMPL LOCATION ______

GAS COOKING ______

HOUR \ EVENT	MEAL PREPARATIONS	AEROSOL USE IN CONJUNCTION WITH COOKING	OUTDOOR OR INDOOR USE OF BARBEQUE OR HIBACHI	ARRIVAL OR DEPARTURE OF MOTOR VEHICLES (OWN OR GUEST)	MAIN OUTSIDE DOOR OPENING & WINDOW OPENING	FIREPLACE USE ON/OFF	HEATING SYSTEM ON/OFF	AIR COND. ON/OFF	ARRIVAL OF NEW PEOPLE	HOBBY (SUCH AS WOODWORKING, PAINTING START	HOUSEHOLD (OTH TH. COOKING) USE OF AEROSOL SPRAYS.
12:00 A.M.											
1:00											
2:00											
3:00											
4:00											
5:00											
6:00											
7:00											
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ADDENDUM TO REPORT OF RESEARCH

THIS ADDENDUM COVERS ACTIVITIES DURING MARCH 1, 1975 THRU OCT. 1, 1975

ESTIMATION OF CO EXPOSURE BY THE QUESTIONNAIRE METHOD IN A LOS ANGELES INSURANCE COMPANY EMPLOYEE GROUP

Estimated personal CO exposures have been calculated for company employees previously found to have abnormal pulmonary function tests and later tested a second time. Calculations were also made for a group of control subjects with no function abnormalities matched for age, sex, and smoking history. Results are summarized in Table 1. A wide range of calculated CO exposures was found, with considerable overlap between subgroups divided according to test results and smoking habit. Smokers tended to have higher values than non- and ex-smokers, although exposure from an individual's own smoking was not included in the estimate. The mean difference between abnormal smokers and normal nonsmokers was statistically significant ($t = 2.54$, $P = .01$). Overall, however, abnormal subjects did not appear to differ substantially from normal subjects in calculated exposure.

The estimated CO exposures calculated for the members of this employee group are believed to reflect reasonable empirical estimations of individual exposures to CO. The principal contributing factors leading to high or low exposures in this group are, in order of significance, the exact physical distance of an individual home to major traffic arteries, taking into account the average prevailing wind direction between home and artery and/or the actual length of time spent commuting each day. Internally generated sources of CO in this group do not play a major part in contributing to individual exposures. CO levels within the work environment for this population were quite low. The building has an excellent air cleanup system which utilizes only 10 percent makeup air. Rush-hour traffic did not reflect itself in temporary elevations in indoor concentrations. It is noted that the only air intake port to the building is located on the south side of the building which is 180^{o} removed from the principal highway on which the office building is located.

TABLE 1. ESTIMATED CUMULATIVE CO EXPOSURE FOR A 24-HOUR WEEKDAY IN SUBGROUPS OF LOS ANGELES INSURANCE COMPANY WORKERS

GROUP		CO, PPM-HR, MEAN ±S.D.
Abnormal nonsmokers	N = 18	447±142
Normal nonsmokers	N = 10	357±143
Abnormal smokers	N = 13	512±135
Normal smokers	N = 11	491±250
Abnormal exsmokers	N = 6	380±114
Normal exsmokers	N = 8	453±168

PRELIMINARY WORK ON EXTENTION OF THE CO EXPOSURE ESTIMATOR MODEL TO THE ESTIMATION OF OXIDANT EXPOSURE IN REPRESENTATIVE INDIVIDUALS

Preparation has been made to extend this work to include pollutants other than CO in the individual estimation of personal pollutant exposures. It is hypothesized that many persons living in the South Coast Air Basin are generally exposed to considerably less O_3 than indicated by monitoring station data. The basis for this hypothesis is that very few persons will spend all of their day outdoors. For others, exposures would be attenuated by an air-conditioned work environment, or the O_3 confines of the average home. Ozone or NO_2 are secondary pollutants, thus, the geographical location of the home or the routes taken back and forth to work will be less likely to moderate of affect the dosages received of these pollutants. More significant is the time of day spent in a particular region of the Basin. Also important is the time spent inside and outside, as well as the activity level. Thus, if a person lived and worked in Riverside, his daily O_3 exposure would reflect the daily O_3 concentrations present in this area, with the important reductions already referred to with respect to the actual time spent within the home and work environment.

The model already developed for CO possesses all the necessary information needed to describe an individual's average daily movements within the Basin. We also have data regarding each home, such as whether or not it is air-conditioned, extent of window openings and the presence and use of gas fueled appliances. With respect to O_3 some major additional factors must be considered since O_3, as opposed to CO, is a highly reactive compound which can be effectively reduced in concentration within a structure by proper intake air treatment, or simply by chemical deactivation on the interior surfaces of a building. Previous work by others[1] has measured the indoor-outdoor gradients of O_3 within schools, hospitals, shopping centers and private homes. Significant variations in interior ozone levels were noted as a function of the type of air makeup and purification systems used. Within private homes the opening of windows or activation of fans tended to increase the indoor-outdoor gradient of ozone. Another study derived a theoretical model relating indoor concentrations of O_3 to outside levels[2] as a function of total air changes within a structure. The applicability of this model to private homes is limited unless some approximate data can be obtained regarding residential air ventilation rates. Recently a considerable amount of work has been directed towards identifying means of obtaining greater efficiencies in the utilization of energy in private homes.[3] The greatest single source of energy loss is through infiltration and exfiltration of air through the home. Air flows into and out of a house because of slight pressure differences. These pressure differences are caused by mechanical ventilation equipment (air-conditioners, window fans), opening of doors and windows, fans drawing combustion air into gas fired appliances (gas dryers, furnaces, and water heaters), exhaustion of flue gases through vents (bathroom, stove fans), the chimney or stack effect and the influence of wind passing over and around the home. Infiltration volumes in individual homes will therefore be a function of the occurrence of any or all of the above events.

Much of the needed data is already available from the CO study and is being used to derive the first appropriate estimate of O_3 exposure during those hours when each individual is at home in the morning or evening. Attention must be given to the average length of time a newly infiltrated mass of polluted air remains within the structure. The decay rate of O_3 within typical structures has been measured[4] and shows that approximately 50 percent of entering ozone is reacted within six minutes in a typical bedroom or other private home living area. It is therefore approximately correct to state that if a complete air change occurs within a home every six minutes, then the maximum reduction in interior O_3 concentration would be about half. It is therefore important to reduce the infiltration rate as much as possible in order to decrease the indoor-outdoors O_3 gradient further.

Discussions have been held with investigators at the Statewide Air Pollution Research Center at the University of California-Riverside to utilize their program for establishing the exterior O_3 concentrations as a function of the time of day, and as a function of the actual O_3 levels at all stations within the basin. A series of closely spaced "hypothetical" days could be programmed to include all possible extremes of oxidant present anywhere within the basin. Depending upon where the individual resides, a summation of exposures based on an estimated division of annual oxidant days can be made. If a particular person lives within a contour area where the O_3 reaches peak levels of 0.1, 0.2, 0.3 and 0.4 ppm then his estimated esposures will be moderated by the actual values present for those hours when he is at home. Estimates of O_3 reduction within the home will also further reduce the actual dosage received. Reduction of O_3 within a vehicle is a function of air-conditioning and window opening, the time of travel and through which contour areas he passes. All of the needed information to formulate individual travel times and conditions were developed in the CO study.

RESULTS - Preliminary Data from O_3 Monitoring and Individual O_3 Estimation Studies

Only recently has a Dasibi O_3 monitor become available for monitoring the insurance company office building or individual homes within the population. One reason we did not extend the monitoring procedures for O_3 during the CO tests was the inability to monitor simply for this pollutant. Results of preliminary monitoring of the insurance company office building are reported below. In the next section a brief outline of the simplified home O_3 estimation model is described. Finally, the preliminary application of this model to actual subjects is described.

INDOOR-OUTDOOR O_3 GRADIENT IN AN INSURANCE COMPANY OFFICE BUILDING

A preliminary survey of the O_3 concentrations inside the office building was performed. A Dasibi monitor was placed on the roof of the building and periodically moved to the inside on the 8th and 4th floors.

The air purification system was 10 percent makeup air and 90 percent recirculation. A single 4' x 6' air intake port is located on the south side of the building. Some fluctuations in exterior O_3 readings were found, probably due to rapid fluctuations in wind directions. Short-term exterior O_3 averages were therefore used to compare with interior levels.

A first approximation indicates that interior O_3 levels are reduced by 50 - 90 percent from exterior levels. The 90 percent recirculation rate is probably partly responsible for this excellent air quality. The makeup and recirculated air is passed through a triple filter system, the last one in each trio is a charcoal filter. All materials are changed once a year. The recirculated air has therefore been passed through two sets of filters on the first return cycle.

Future surveys of this building could be made using rapid sample line switching valves to obtain more closely spaced interior-exterior pollutant values. These results do show that a subject within this building during a normal working day is probably well protected from high ambient ozone exposure. Previous work[1] would generally confirm these results.

Time	Dir. Wind	Ext O_3 ppm (Avg. 5 mins)	Int O_3 ppm (Avg. 5 mins)	(I) Floor	Indoor/ Outdoor
10:55 am	90°	.032	.015	8	.47
12:50 pm	270°	.096	.041	8	.42
1:40 pm	240°	.135	.016	8	.12
2:20 pm	240°	.201	.045	8	.22
2:25 pm	240°	.201	.023	4	.11

B) OZONE MODEL (PRELIMINARY DESIGN)

A presumption is made that no "local" sources of O_3 exist. This generally simplified the problem somewhat since no attention need be paid to internal or nearby external sources of pollutants as was the case with CO. As discussed earlier more careful analysis of the general air circulation within a home or workplace must be made in order to be able to make meaningful indoor O_3 estimates. Outdoor concentrations of O_3 should follow the general pattern of diurnal change occurring during a typical summer day. As a temporary measure a representative simulated profile of changing hourly O_3 concentrations will be used to make this initial estimation of individual indoor exposures at particular residential locations. The data obtained from individuals at present includes the following:

i) Approximate area of residence (sq. ft.)

ii) Ceiling height (this is usually the standard eight feet)

III) Window sizes (also maximum opening area)

IV) Average number of windows open (daytime and nighttime)

v) Air-conditioning? Average use?

vi) Window fans? Average use?

vii) Clothes dryer, hot water heater, furnace if gas operated, are they within the structure.

viii) Exterior doors, size, average number of openings daily.

From this data a very rough estimate of the infiltration rate is calculated in cu. ft. per unit time. From the calculated volume of the residence an estimated time for a complete air turnover within each home can be calculated. If for example this time turns out to be 30 minutes then the O_3 decay should be at least 94% complete if the concentration of O_3 in newly infiltrated indoor air can be reduced to 50% of its concentration within 6 minutes[4].

The hourly infiltration rate in a typical home can be expressed as

$$I = A + BV + C(\Delta T)$$

where I - Infiltration rate in air changes per hour

V - wind speed, m.p.h.

T - temperature difference between the interior and outside of the home

A, B and C are empirical constants characteristic of the residence being measured. For a typical house these constant have values A = 0.25, B = 0.02165 and C = 0.0083.

If the temperature difference between inside and outside is zero, the $C(\Delta T)$ drops out. If the wind speed is zero then BV drops out. The term A represents a constant infiltration rate made up of window and door openings, fan operation and applicance use. The following are approximate infiltration volumes that are being assumed at this time.[5]

_____A door of average size (20 ft^2) permits 900 ft^3 of outside air to enter upon each opening. A window of average size opening (6 ft^2) introduces 270 ft^3/min of outside air.

_____A 250 ft^3/min kitchen fan in operation for 1 hour introduces 600 ft^3 of outside air.

_____A hot water heater of average capacity (35,000 Btn/hr) introduces 8.5 ft^3/min of outside air.

_____A bathroom fan introduces 20 ft^3/hour of outside air.

_____A clothes dryer of average size causes infiltration of about 3.5 f^3/min

Wind caused infiltration is related to wind speed (V) by $0.02165(V)\frac{\text{Home Volume}}{60}$. This air input is due exclusively to passage through openings such as cracks on walls and door or window seals.

Temperature differences between the inside of the house and the exterior cause an additional air infiltration path. During the hot summer season, inside air escapes through the crackage in the lower section of the house while outside air enters through the higher or upper levels of the home. The amount of entering air is,

$$I = C(\Delta T)\frac{(\text{home air volume})}{\text{hour}}$$

$$I = 0.00833\ \frac{(\text{approx. vol. of home})}{60}\Delta T$$

All of these air infiltration factors are estimated below for those employee homes located in the eastern, central and western sections of the South Coast Basin. From this sum a very preliminary interior O_3 level will be estimated based on a typical ozone concentration history for a typical oxidant season day. The outdoor concentration is assumed to vary sinusoidally starting from 9 AM to zero, peaking at 2 PM at 0.2 ppm and returning to a zero level at 9 PM. The concentration of O_3 is assumed to stay at zero until 9 AM.

Conc. O_3 (ppm)	Time
0.00	9 am
0.01	10
0.06	11
0.12	12 noon
0.16	1 pm
0.19	2
0.20	3
0.18	4
0.16	5
0.12	6
0.08	7
0.01	8
0.00	9

		Home No. 1	Home No. 2	Home No. 3
Area (ft^2)		2,000	960	1,460
Ceiling Height (ft)		8.5	8	9.25
Volume		17,000	7,680	13,605
Doors		1	2	2
Door sizes (ft^2)		23.4	21	21
Door openings/day		2	6	5
Window sizes, (ft^2)		12	18, 6	6,7,15,17.5
Window open areas (ft^2)		6	9, 3	6,2,15,17.5
No. windows open (avg.)		6	2(9), 1(3)	1(6),2(2),3(15),1(17.5)
Clothes dryer (gas)		No	No	No
Furnace (gas)		No	Yes	Yes
Kitchen hood fan		No	Yes	No
Bathroom fan		No	Yes	No
Hot water heater (gas)		No	No	Yes
Avg. summer interior T^o		72	75	75
Air conditioned		No	Yes	No
Avg. Max T^o(July-Aug) Outside		85	88	81.5
Wind speed (avg.) mph		4	3	5
ft^3/day A	Door openings	2106	5670	4725
A	Window openings	3,888,000	2,288,000	7,830,000
BV	Wind Effect (summer)	58,800	19,953	58,476
CΔT	T^o Effect (summer)	73,630	32,920	29,246
A	Dryer	---	---	---
A	Furnace (summer)	---	---	---
A	Kitchen fan	---	---	---
A	Bathroom fan	---	---	---
A	Air Conditioning	---	---	---
A	Hot water heater	---	---	20,400
Total infiltration/ft^3/day		4,022,506	2,340,873	7,938,122
Infiltration/ft^3/min		1,676	979	3,307
Minutes/Air Change		10·1	7·8	4.1
O_3 Reduction (Interior)		67%	60%	36%

The effects of air conditioning are presently ignored since detailed estimations of unit air recirculation volume are not known and the use rate is quite irregular.

In all homes significant ventilation is created by a large number of window openings. The residence time of pollutant-laden air within the home is relatively short but still results in a 60-70% reduction of interior ozone levels. These preliminary calculations probably over-estimate total infiltration since it has been assumed that all opened windows contribute to infiltration which would not be true if a cross-draft were created while some windows would actually act as exfiltration openings. The results of this initial estimation are not in disagreement with some past measurements in homes.[6] In one experiment a residence was completely filled with outside air which contained 0.23 ppm O_3. The home was then sealed to outside air as much as possible. Within 30 minutes the concentration of O_3 had been reduced 82% to 0.04 ppm.

The predicted O_3 concentrations in homes No. 1, 2, and 3 are related below to the idealized day described earlier.

Time	Outside O_3 PPM	Continental Insurance	Home #1	Inside Home #2	Home #3
9:00 AM	0.00	0.00	0.00	0.00	0.00
10:00 AM	0.01	0.001	0.003	0.004	0.006
11:00 AM	0.06	0.01	0.02	0.02	0.04
12:00 noon	0.12	0.01	0.04	0.05	0.08
1:00 PM	0.16	0.02	0.05	0.06	0.10
2:00 PM	0.19	0.02	0.06	0.08	0.12
3:00 PM	0.20	0.02	0.07	0.08	0.13
4:00 PM	0.18	0.02	0.06	0.07	0.12

6 R. H. Sabersky, D. A. Sinema, F. H. Shair: "Concentrations, Decay Rates and Removal of O_3 and Their Relation to Establishing Indoor Air" *Env Sci and Tech* 7(4): 347-353, 1973.

Time	Outside O_3 PPM	Continental Insurance	Home #1	Inside Home #2	Home #3
5:00 PM	0.16	0.02	0.05	0.06	0.10
6:00 PM	0.12	0.01	0.04	0.05	0.08
7:00 PM	0.08	0.01	0.03	0.04	0.05
8:00 PM	0.01	0.001	0.003	0.004	0.006
9:00 PM	0.00	0.00	0.00	0.00	0.00

In home #1, at no time is it predicted that exposures to ozone at levels greater than the national standard (0.08 ppm - 1 hr.) would occur. These estimates are in need of considerable refinements and experimental validation under controlled home use conditions and more detailed accounts of appliance usage and variations in local meteorological conditions.

Let us now assume that employees living in these homes either work at the insurance company or work outside near to their homes. Again, using the idealized oxidant day all persons would receive no ozone exposures between 9 PM and 9 AM. Since they are inside the office building until 5 PM and assuming the best value measured within the building (89% reduction of outside O_3) then their total exposure until 5 PM is very low (0.02 ppm max. at 3 PM). From 5 PM until 9 PM slightly higher exposures would occur (0.05 ppm max. at 5 PM). An assumption is made that the commuting trip exposure is the same as would occur if at home. If on the other hand the subject worked outside, then a large increase in exposure would occur. For comparison the hourly exposure values are simply summed up to give 24-hour cumulative dosages.

	O_3 Exposure Total/Day in ppm/hrs.		
Dosages	Work at Continental	Work Outside	Stay Indoor At Home All Day
Subject No. 1	0.224	1.249	0.426
Subject No. 2	0.255	1.249	0.518
Subject No. 3	0.337	1.249	0.832

This suggests that the majority of indoor office workers and those remaining at home all day probably are seldom exposed to concentrations of ozone as high as those measured at the monitoring stations. It will be necessary to improve this very simple model and to validate the results of these personal O_3 exposure estimates.

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