PARTICULATE AIR POLLUTION AND MORBIDITY IN THE CALIFORNIA CENTRAL VALLEY: A HIGH PARTICULATE POLLUTION REGION

Final Report
Contract 97-303

Principal Investigator:
Stephen K. Van Den Eeden, PhD
Division of Research
Kaiser Permanente, Northern California Region
3505 Broadway, 13th Floor
Oakland, CA 94611-5714

Kaiser Permanente, Northern California Region
Stephen K. Van Den Eeden, PhD
Charles P. Quesenberry, Jr., PhD
Jun Shan, PhD

Sonoma Technology, Inc
Fred Lurmann, MS

12 July 2002

Stephen K. Van Den Eeden, PhD
Principal Investigator

DISCLAIMER

Stephen K. Van Den Eeden, PhD
Principal Investigator

ACKNOWLEDGEMENTS

The investigative team wishes to thank members of the California Air Resources Board staff that have made helpful and constructive comments from the initiation of this study to the drafting of this Final Report. Specifically we thank Helene Margolis, Diane Mitchell, Dane Westerdahl, Tracy Hysong and Barbara Weller. The study team also acknowledges study design input to an earlier version of the study by Ira B. Tager, MD and Jennifer Mann, MPH, of the University of California, Berkeley.

We would also like to thank EPA Region IX for their generous support of this project.

This Report was submitted in fulfillment of contract No. 97-303 entitled “Particulate Air Pollution and Morbidity in the California Central Valley: A High Particulate Pollution Region” by the Kaiser Foundation Research Institute under the sponsorship of the California Air Resources Board. Work was completed as of 31 January 2002.

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LIST OF ABBREVIATIONS

ADT	Admission, Discharge and Transfer (hospitalization) database for KPNC
CAAQS	California Ambient Air Quality Standards
CARB	California Air Resources Board
CF mass	coarse fraction mass of PM (calculated as PM_{10}-$PM_{2.5}$)
CO	carbon monoxide
COH	coefficient of haze
COPD	chronic obstructive pulmonary disease
CV	Central Valley (also see SJV)
DOR	Division of Research (Kaiser Permanente, Northern California Region)
EPA	United States Environmental Protection Agency
ER	emergency room
GEE	generalized estimating equations
HiVol	High volume air sampler
KFRI	Kaiser Foundation Research Institute
KP	Kaiser Permanente
KPMCP	Kaiser Permanente Medical Care Program
KPNC	Kaiser Permanente, Northern California Region
LA	Los Angeles
LAAB	Los Angeles Air Basin
MI	myocardial infarction
NO_2	nitrogen dioxide
NO_3 (PM_{10})	nitrate component species for PM_{10}
O_3	ozone
ppb	parts per billion
PM	particulate matter
$PM_{2.5}$	particulate matter with aerodynamic diameters less than 2.5 µm
PM_{10}	particulate matter with aerodynamic diameters less than 10 µm
SCAQMD	South Coast Air Quality Management District
SCKP	Southern California Kaiser Permanente
SJV	San Joaquin Valley
SO_2	sulfur dioxide
SO_4 (PM_{10})	sulfate component species for PM_{10}
SoCAB	South Coast Air Basin
STI	Sonoma Technology Inc.
TEOM	tapered element oscillating microbalance (TEOM), a continuous PM_{10} monitor
TSP	total suspended particulate matter
TC	Total carbon
TC (PM_{10})	Total carbon component species for PM_{10}

Stephen K. Van Den Eeden, PhD
Principal Investigator

SECTION 1. ABSTRACT

The purpose of this study was to evaluate the relationship between particulate air pollution and morbidity among the Kaiser Permanente (KP) membership who reside in the Central Valley (CV) of California. Daily augmented particulate matter (PM) monitoring in the Central Valley was instituted as of November 1996 as part of a special monitoring program by the California Air Resources Board (CARB). The combination of the ambient air pollution data collected as part of the enhanced monitoring and the morbidity data from Kaiser Permanente provided an excellent opportunity to explore this relationship in an area with varied particulate matter.

We conducted time-series analyses examining the association between daily ambient measures of particulate matter (including PM chemical components), other criteria air pollutants (e.g., ozone, NO_2, and CO), and daily admissions to the emergency room or hospitalization for respiratory and cardiovascular conditions among members of Kaiser Permanente, Northern California Region (KPNC) living in the Central Valley of California. Only those KPNC members who resided in an area where exposure could be assigned using one or more of the PM monitoring stations were included in the study. The study period was from January 1996 to December 2000.

Exposure was assigned based on each KP member's residential zip code and linked to the city where a monitoring station was in place. Morbidity data were derived from computerized data sources at Kaiser Permanente. Each health event of interest was identified and the age, gender and diagnosis ascertained. Outcome events were classified into one of three categories; cardiovascular, acute and chronic respiratory conditions, and two types of admissions; hospitalizations and emergency room visits. Preliminary analyses of the data included graphical techniques and bivariate analyses. Non-parametric smooths were developed that first fit confounding variables to each set of outcome data. These factors included long-wave terms (time), day-of-week, temperature, and humidity. In addition, because there were four population centers in this study a set of indicator variables for center was also included. Following the derivation of these first models, individual pollutants were then entered in the model.

Consistent adverse health effects were observed between a variety of air pollution metrics and acute and chronic respiratory hospitalizations and emergency room visits among Kaiser Permanente members living in the Central Valley of California. These associations were consistent across type of analysis and type of admission (hospitalization or emergency room visit). Of the pollutants studied PM_{10} and $PM_{2.5}$ were consistently associated with increases in hospitalizations and emergency room visits for acute and chronic respiratory conditions. To a lesser extent CO and NO_2 were associated with increases in admissions for all outcomes in our study. In contrast to the PM_{10} and $PM_{2.5}$ results, we did not find convincing evidence of an association between the coarse fraction of PM and our outcomes. In addition, our results for cardiovascular admissions were inconsistently or not at all associated with the pollutants were studied. Finally, some of our pollutant-outcome associations were in the opposite direction from what we expected, most notably ozone.

SECTION 2. EXECUTIVE SUMMARY

Introduction

There continues to be uncertainty in which air pollutants cause what adverse health effects. Few studies have had access to daily measurements for the range of particulate matter (PM) measures that are of increasing concern. Furthermore, standard single time-series studies of adverse health effects can misspecify exposure in important ways in this area due to geography and microclimates. To address these and other issues we conducted a study to investigate the relationship between particulate and other air pollutants and acute cardiopulmonary morbidity. The primary objective of this study was to conduct time-series studies to assess how daily ambient measures of PM_{10}, $PM_{2.5}$, the coarse fraction of PM ($PM_{10-2.5}$), selected PM chemical components, NO_2, and ozone were correlated with daily hospital admissions and emergency room visits for cardiovascular, chronic respiratory and acute respiratory diseases. A multiple time-series approach was used to incorporate an exposure assignment protocol that assigned exposure to account for daily variation over time and space in the study area. The study population was the Kaiser Permanente, Northern California (KPNC) membership who resided in the San Joaquin Valley of California. The study period was from 1 January 1996 to 31 December 2000.

The approach taken in assigning exposure in this study was based on residential data for the KPNC membership. Specifically, each member of the health plan is assigned a unique medical record number (MRN). This MRN is the linking variable for all membership and utilization databases, including residential address and hospitalizations. Thus, we were able to geographically map all members of the health plan, both with and without the events of interest. In addition, the monitoring network for particle mass and gaseous pollutants is quite dense in the San Joaquin Valley. Exposure was assigned on a geographic basis using a grid pattern of 10 kilometers (km) by 10 km squares that was overlaid on the study area. Air pollution and meteorologic values were assigned to a grid centroid using data from a monitor within 5 km of a grid centroid or from interpolation using data from the two or three monitors nearest the grid centroid. We then grouped all grids into four community centers, including Sacramento, Stockton, Modesto and Fresno. The at risk population and daily event counts in each population center was obtained from computerized data sources at KPNC and assigned to a center based on the residential zip code of the member. Outcome data were stratified by age, gender and diagnosis for each day.

Statistical Approach and Issues

The general statistical methods we used in our study of the relationship between pollutants and daily hospitalization rates have been used in numerous similar studies. Namely, semiparametric Poisson regression techniques were used to estimate adverse health effects associated with air pollution exposure after accounting for trends over time and weather. Because of the key difference in our study design and exposure assignment, however, we have applied these regression techniques to multiple parallel time series.

The statistical models used to assess the associations under study sought to control for the long-term time effects, day-of-week, and meteorologic variables. Analyses that included adjustments for these factors provide estimates for the air pollution-outcome effects. Other factors such as practice variation, and socioeconomic status were outside the scope of our study given limitations in time and resources but could modify the results obtained here. While a term for each community center was included in most of our analyses, there may be residual effects for these and other factors that may explain some part of our results. Thus, it is important that these other factors be considered in future studies to the extent feasible.

Due to the large number of analyses conducted in this study, the interpretation of the results were largely based on the patterns and consistency of the exposure-outcome relationship across pollutants and types of analyses.

Cardiovascular Results

Overall few consistent associations were observed between any pollutant and admissions for cardiovascular diseases. The most consistent exposure outcome finding was with CO. Excess risk was observed in most of our analyses. The highest risk was in the spring and summer season. When we limited our analyses for cardiovascular events to those over 50 years of age we did find CO to be related to admissions for cardiovascular diseases in this age group. In two pollutant models we found somewhat variable results but that CO was positively related to cardiovascular outcomes with other pollutants in the model.

Acute Respiratory Results

Consistent associations between many of the pollutants and acute respiratory admissions were observed. PM_{10}, $PM_{2.5}$, CO, NO_2, and NO_3 (PM_{10}), were associated with an increase in acute respiratory hospitalizations or emergency room visits. Other pollutants, for example, TC (PM_{10}), were associated in only the emergency room data. Ozone was associated with a decreased risk of admissions due to acute respiratory conditions. Acute respiratory hospitalizations were associated with many of the pollutants in winter, including PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), SO_4 (PM_{10}), and TC (PM_{10}). Associations were observed in spring, summer and winter for most of these pollutants for emergency room visits. In general the associations for hospitalization were limited to those over the age of 50 years, whereas there were more consistent associations across the age spectrum for emergency room visits. Most of the associations were reasonably stable in the presence of other pollutants. Few associations were observed for the coarse fraction of PM.

Chronic Respiratory Results

The results for chronic respiratory results were quite similar overall to the acute respiratory results. PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), SO_4 (PM_{10}), and total carbon (TC (PM_{10})) were associated with an increase in chronic respiratory hospitalizations. Ozone was associated with a decrease risk of admissions. Seasonally, most pollutants were associated during the winter period. More of the pollutants were associated during the spring and summer as well as winter for the chronic respiratory emergency room visits. Associations were observed for chronic respiratory hospitalizations by these pollutants for age. Associations were observed for nearly all of the pollutants (e.g., PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), SO_4 (PM_{10}), and TC (PM_{10})) for individuals 20 or more years old for hospitalizations, while the findings were more consistent across all age categories for emergency room visit. The PM_{10} and $PM_{2.5}$ effect estimates were generally very stable when other pollutants were in the model. The coarse fraction of PM effect estimate was considerably lower when CO and NO_2 were also in the model. The inverse association observed with ozone was essentially unchanged with any other pollutant in the model.

PM Chemical Component Analysis

Limited analyses were performed on PM species such as NO_3, organic and elemental carbon, and SO_4, and provide an intriguing glimpse of pollutants that are increasingly of interest. In analytic models that include regional effects, the most consistent observed associations were with the elemental carbon component of PM_{10} and cardiovascular, and chronic and acute respiratory hospitalizations. We also observed associations between the organic carbon component of PM_{10} and cardiovascular hospitalizations. Additional data, if possible, would be highly desirable.

Future Research

These results suggest that increasing attention needs to be given to time-series studies of adverse health effects that account for daily spatial variation in the exposure assessment and assignment. Furthermore, these studies should include daily data for the full range of air pollutants that are of interest for sufficiently long time periods. Finally, studies that include data on specific diagnostic categories and host characteristics will greatly improve our knowledge in how air pollution adversely affects health status.

Conclusions

In summary, we found strong and consistent air pollution effects between particulate matter, and acute and chronic respiratory hospitalizations among Kaiser Permanente members living in the San Joaquin Valley study area. The most consistent results were associations were between PM_{10}, $PM_{2.5}$, and CO and these outcomes.

SECTION 3. TECHNICAL APPROACH

SPECIFIC AIMS

The primary objective of this study was to evaluate the relationship between exposure to ambient particulate pollution and morbidity from selected respiratory and cardiovascular diseases among members of the Kaiser Permanente, Northern California Region (KPNC) who reside in the Central Valley of California. To do so, we utilized daily particulate data collected from particulate matter (PM) monitors placed by the CARB for the period from January 1996 to December 2000. Health outcome data was derived from computerized Kaiser Permanente databases for members who reside in the geographic area covered by these monitors.

To accomplish this objective we sought to:

1) characterize the relationship between different measures of ambient PM, selected component species of PM, and other co-pollutants, and the rate of emergency room visits for selected respiratory and cardiovascular diseases among the membership of Kaiser Permanente, Northern California who reside in the Central Valley of California; and

2) characterize the relationship between different measures of ambient PM, selected component species of PM, and other co-pollutants, and the rate of hospitalizations from selected respiratory and cardiovascular diseases among the membership of Kaiser Permanente, Northern California who reside in the Central Valley of California.

STUDY POPULATION

The population for the study was defined as members of the Kaiser Permanente Medical Care Program (KPMCP), Northern California Regions, a pre-paid group practice model health maintenance organization. The region provides care for over 3 million residents of California. For the areas of interest in the Central Valley, the region provides care for over 600,000 individuals in 2000 who resided in the Valley, primarily in the Sacramento metropolitan area and the Highway 99 corridor of the San Joaquin Valley. The primary population centers are the cities of Sacramento, Stockton, Modesto, and Fresno. The original intent of the study was to also include the Bakersfield service area of KPMCP in the Southern California Region. Several reasons developed after the start of the study that prevented us from doing so. First, the data for that region was not comparable to that from KPNC in that both the emergency room and hospitalization data would be derived from claims data or the database that the Southern California region uses to pay claims for services rendered at non-KP facilities. For KPNC these data were directly obtained from the clinical databases. The emergency room clinical data for KPNC were from a database that was newly phased in just prior to the study period and is considered more robust than claims database in either region. Second, the original collaborator for our work with the KP Southern California region was no longer with the research group and no other collaborator in the group was found which made obtaining any data difficult, at best. Nonetheless, we believe this had a minimal impact on our study as we would have expected the Bakersfield data to add only about 7-8% more cases to our study.

Table 3-1 and 3-2 contain the membership distribution by age, sex and population center for this study. The membership of KPNC is generally considered to be representative of the population of the geographic areas it serves. This is, in part, because approximately 25-30% of the general population is served by KPNC in these areas. The membership of KPNC has been found to be reasonably representative of the underlying population with regard to sociodemographic characteristics.[1] Individuals with low and very high incomes, and who are unemployed are somewhat underrepresented in the KPMCP membership. In addition, the KPMCP membership includes a slightly higher proportion of individuals who have a college education or higher educational attainment compared to the general population.

The Northern California Region of Kaiser Permanente has over seven Medical Office Buildings (MOB) in this area and four comprehensive medical centers (outpatient and inpatient facility) - one each in Sacramento, South Sacramento, Roseville, and Fresno. In addition, KP contracted with Damron Community Hospital in Stockton to provide selected inpatient services to KP members who live in that area for a portion of the study period. Although Damron Community Hospital is not owned or operated by KP, all admissions of KP members are included in the computerized database. Sacramento provided the largest group and made up approximately 77% of the total population for the study. There were over 2.6 million person-years include in this study.

Table 3-1. Membership in study area by age and sex, Kaiser Permanente Central Valley Study, 1996-2000.

Age & Gender	1996	1997	1998	1999	2000	Total person-years
<18	114,308	125,629	136,569	151,842	159,254	687,602
Male	58,452	64,202	69,640	77,075	81,072	350,441
Female	55,856	61,427	66,929	74,767	78,182	337,161
18-39	127,843	144,127	158,678	175,543	184,308	790,499
Male	59,170	67,404	75,221	82,843	87,495	372,133
Female	68,673	76,723	83,457	92,700	96,813	418,366
40-64	140,238	152,311	163,803	182,084	193,201	831,637
Male	65,411	71,197	76,782	85,347	90,918	389,655
Female	74,827	81,114	87,021	96,737	102,283	441,982
65+	49,812	54,893	59,350	67,629	76,597	308,281
Male	22,800	24,966	26,859	30,436	34,173	139,234
Female	27,012	29,927	32,491	37,193	42,424	169,047

Table 3-1. Membership in study area by age and sex, Kaiser Permanente Central Valley Study, 1996-2000.

Age & Gender	1996	1997	1998	1999	2000	Total person-years
Total	432,201	476,960	518,400	577,098	613,360	2,618,019

Table 3-2. Membership (in person-years) in study area by population center, Kaiser Permanente Central Valley Study, 1996-2000.

	1996	1997	1998	1999	2000	Total person-years	Percent of total
Sacramento	345,556	374,331	400,224	443,467	464,019	2,027,597	77.4
Stockton	35,418	40,145	45,620	51,897	59,603	232,683	8.9
Modesto	5,590	10,826	19,227	26,315	33,354	95,312	3.6
Fresno	45,637	51,658	53,329	55,419	56,384	262,427	10.0
Total	432,201	476,960	518,400	577,098	613,360	2,618,019	100.0

STUDY DESIGN

The primary objective of the study was to characterize the relationship between various measures of particulate matter (PM), such as PM_{10} mass, $PM_{2.5}$ mass and other PM constituents, and other criteria air pollutants, such as ozone, NO_2 and CO, and the rates of emergency room visits and hospitalizations for selected respiratory or cardiovascular diseases. Consideration of the potential modifying and/or confounding effects of long- and short-term trends (e.g., changes in hospitalization patterns, and influenza outbreaks), other relevant pollutants and the effects of environmental conditions such as temperature and humidity were required. The time series approach used to analyze these data provides several advantages for the type of data that were available. Because both exposure to ambient air pollution and health outcomes were measured on the same population on a daily basis we were able to take advantage of certain features of this design. First, we were able to run multiple parallel time series for each population center (e.g., Sacramento, Modesto, Stockton, and Fresno) and arrive at a single effect estimate across center in order to maximize exposure variability. The four population centers have different pollution profiles and our analytic approach was to classify exposure, population and outcomes by these centers so the maximum variability were captured in the analysis. This would contrast with an analysis that was either limited to one population center or where all four were analyzed as a single area. In our approach the population center essentially becomes its own control since one day's exposure and outcomes are compared to another day's for the same population over the study period. Characteristics of the population, such as the prevalence of underlying disease or smoking status, are not likely to change over the (short) time frame of this study and therefore are not likely to be sources of bias. However, because of the multiple time series approach there is the possibility of spatial confounding. To account for this to some extent we included a term for each population center. Nonetheless, there is concern that spatial distribution in other potentially confounding factors can influence the study results.

Several important assumptions will be made in this study. First, relevant personal factors, such as exercise, will not change over the study period. Second, for the study period, the number of individual members with a specific diagnosis such as asthma will not change appreciably. Third, the membership of Kaiser Permanente do not choose their residence location based on risk and exposure category. All of these assumptions are very plausible, given the relatively short time period over which the health effects data will be collected. Nonetheless, statistical techniques that adjust for long term trends were used.

EXPOSURE ASSIGNMENT

While the ideal pollution metric is an individual-level personal exposure measure over the study period, this is obviously an impossible goal for large time-series studies. In virtually all past time-series studies single city- or county-wide metrics have been used. In these studies the daily metric used in the analysis is usually derived as some average of two or more ambient monitors that are located in or near the study area. The large study area for this investigation, approximately 180 miles or more can separate the population included in the study, would result in considerable misclassification of exposure being introduced given known daily variations in pollutant levels that occur in this area. Thus, we sought to better characterize exposure using the residence of the individuals included in this study.

The basic approach for exposure assignment was to assign exposure to all at-risk members of KPMCP based on their residential zip code. Based on historical data for spatial variations in ambient PM, ozone, NO_2, and CO concentrations in the Central Valley, the KPMCP study population included in this study, as a whole and within exposure areas, were subjected to a range of exposure on any given day. A portion of the population during the study period experienced poor air quality conditions for PM and ozone because CAAAQS and Federal ambient air quality standards were exceeded at selected locations for these pollutants. The ambient air pollution mix in the Central Valley differs from that found in either the San Francisco Bay Area or the LA Basin. For example, fall and winter PM levels are lower in the Bay Area than in the Central Valley. Therefore, examining adverse health effects in the Central Valley provides important additional data in assessing the relationships in question. The particular pollutant mix in these areas, combined with our analytic approach that seeks to maximize such differences, allows a closer examination of specific pollutant-adverse health outcome relationships. The CARB operates air pollution monitoring stations that conduct extensive routine monitoring of ozone, CO, NO_2, and other criteria air pollutants throughout the region. The CARB and the U.S. EPA's enhanced PM monitoring during the study period provided higher quality and more frequent PM data than previously available for this area. The availability of the daily PM data along with the routinely available gaseous pollutant data represents an important opportunity to concurrently characterize exposure of the population to all of these pollutants, and to make area-wide exposure assignments based on residential zip code for a large number of zip codes that cover diverse temporal and spatial patterns of ambient air pollution. Data from other studies suggest that this approach is most consistent with improving the exposure assignment process in time-series studies [2].

The estimation of any health effect for PM without detailed consideration of the health effects of other ambient pollutants (or vice versa) would be difficult to defend given the coincidence of ozone and PM pollution in the areas to be studied. Simultaneous consideration of multiple pollutants, especially PM and ozone, has become a pressing need to fully evaluate the association between air pollution and adverse health outcomes. The air quality data that were available for the study period will facilitate more reliable assignments of PM and ozone exposures than generally has been possible and, therefore, provide a more reliable foundation on which to investigate the associations of air pollution and adverse health effects.

The analytic air monitoring database created for this study was assembled by Sonoma Technology, Inc. (STI) using available data collected by CARB, U.S. EPA and other studies. Details of the monitoring sites and measures are presented in Appendix C. The database included, at a minimum, ozone, NO_2, CO, $PM_{2.5}$ mass, PM_{10} mass, and the following chemical constituents of PM: sulfate, nitrate, ammonium ions, elemental carbon, organic carbon, and other PM constituents (lumped). A variety of daily exposure metrics were constructed from the hourly data, including the 1-hr daily maxima, 8-hr daily maxima, and the 2-6 pm, 10-6 pm, and 24-hr average concentrations. Since the coarse fraction is not measured directly we calculated it by subtracting the $PM_{2.5}$ mass from the PM_{10} mass measurement for each area. In addition, all relevant meteorological data (i.e., 1-hour minimum and maximum, and the 24-hour mean of temperature and relative humidity) were included in the dataset. These data are available for one or more sites in each community center (i.e., Sacramento, Stockton, Modesto, and Fresno). We will focus on the following metrics; temperature (24 hour average), relative humidity (24 hour average), NO_2 (one hour peak), CO (8 hour average), $PM_{2.5}$ (8 hour average), PM_{10} (8 hour average), O_3 (8 hour average), and 8 hour averages of the nitrate, sulfate and total carbon components of PM_{10}.

The method of assignment has been developed previously and is based on distance of monitors from zip code centroids and intervening topography [2]. To do this the study area was first divided into a pattern of 10 x 10 kilometer (km) squares. This approach has been used and validated in several studies conducted by Sonoma Technology, Inc. to model air pollution patterns for both the Los Angeles and San Francisco Bay Areas [3-5]. Each of the exposure and meteorologic variables were spatially interpolated to the centroids of each of the 10 x 10 km grid squares. No interpolation was performed when a monitor with valid data was located within 5 km of the grid centroid; in this case the monitoring data from the single monitor was assigned to the grid square. When there were no monitors with valid data within this distance, interpolation was based on inverse distance-squared weighting of data from the three closest monitors with valid data, provided all were within 50 km of the grid centroid. If there were fewer than three monitors with valid data for that day and that were located within 50 km of the grid centroid, the interpolation only used the data from the one or two monitors that met these criteria. This approach has been assessed and found to provide good estimates of exposure over the LA Air Basin [3-6].

The assignment of exposures to individuals was based on their residential zip code of record in the membership databases of Kaiser Permanente. Four basic exposure assignment units were created and included the Sacramento, Stockton, Modesto, and Fresno population centers. All appropriate grid squares within the each of these areas were grouped and the metrics averaged. Appropriate zip codes for Kaiser members were assigned to each of these analytic regions by the study investigators in consultation with CARB personnel. The residential pattern of Kaiser members in the Central Valley is such that most live near a city located on US Highway 99, which functionally bisects the Central Valley, or in the greater Sacramento area. Since the PM monitoring stations being used in this study have been, for the most part, placed in one of these cities, this approach to exposure assignment appeared most prudent.

The monitoring sites within the study area provided very reasonable spatial coverage for these pollutants. We believe it is appropriate to consider the PM data (especially the $PM_{2.5}$) to be representative of air quality conditions within about 20-30 km of the sites. For purposes of this study, we defined the study population as the subset of the KPMCP members that live within about 20 to 30 km of a monitoring site in order to minimize the potential for PM exposure misclassification.

This exposure assignment approach does not, however, avoid misclassification of exposure due to differences in personal versus ambient monitoring. Activity patterns within the residential area, across or outside of exposure areas (e.g., Sacramento, Stockton, Modesto, and Fresno), and conditions at work and home all will potentially introduce some level of misclassification. Studies of personal exposure compared to ambient measurement have found that certain pollutants are more misclassified than others. Gaseous pollutants such as ozone and NO_2 are generally thought to diffuse more easily indoors than particulate matter. Furthermore, there are relatively few significant indoor sources of the ambient gas pollutants compared to particulate matter. The correlation between personal and ambient measurements has been found to be larger for the fine fraction (e.g., $PM_{2.5}$) compared to either PM_{10} or the coarse fraction ($PM_{10-2.5}$) [7-10], however this pattern may vary by season [11]. Not all studies have found good correlations between outdoor and personal monitors [12] or reported variation by specific microclimates [11]. In addition, in areas where the ratio of coarse to fine particulate matter is high, up to about a third of the PM may be systematically missed [13]. Interestingly, a study in British Columbia found that ambient data was equally or better able to predict some potential health outcomes than personal monitoring data [14]. While efforts have been made to adjust time-series studies by personal monitoring data [15], there remains much to be known before the use of ambient data is supplanted in large time-series studies such as this one. Thus, exposure misclassification undoubtedly exists in our data but the evidence to date suggests this would likely result in attenuating our results and would not have much of an effect on outcomes associated with selected pollutants such as $PM_{2.5}$.

METEOROLOGICAL DATA

As noted above, STI assembled a database of temperature and humidity data for use in the study. These data were obtained from the CARB's meteorological network, the National Weather Service, the

Federal Aviation Administration, and regional air quality management district meteorological measurement stations. These data sources have geographic coverage that is comparable or better than the PM monitoring network. The analytic meteorological database included the minimum, maximum, and mean daily temperature and relative humidity spatially interpolated to each exposure unit and thus was entirely consistent with the air quality database.

EMERGENCY ROOM DATA

Patient admissions to a Kaiser Permanente, Northern California emergency room or outpatient clinic are registered in computerized databases. The database system that captures these visits is called the Outpatient Services Clinical Record or OSCR and has been in place since 1995. The system is based on a series of coding sheets that the treating physician in the ER completes at the end of the ER visit. Each clinical area or specialty has one or more specific forms with each form having approximately 50 to 70 diagnoses on each sheet available for the clinician to code the reason for visit. For the emergency room there are four different coding sheets, although any physician has the opportunity to use any of the available OSCR forms. These sheets are in an optical scanning format and undergo high speed scanning into the database each evening. Internal studies have found that over 98% of clinical visits are properly recorded in the OSCR system. The codes used on the forms were adapted from ICD-9 codes and modified for use within the KPNC setting. The data collected at the time of each visit includes name; medical record number; address; sex; date of birth; all relevant diagnoses and procedures, treating physician and disposition.

The following categories were chosen to be consistent with the hospitalization data:

Acute Respiratory;
- croup,
- acute bronchitis,
- pneumonia

Chronic Respiratory;
- asthma,
- COPD,
- emphysema,
- chronic bronchitis,

Cardiovascular;
- ischemic heart disease,
- cardiac failure,
- arrhythmias and other conduction disturbances

HOSPITALIZATION DATA

Systematic capture and data storage of every hospitalization greatly facilitates the identification and classification of these data for research purposes. Within the KPNC region, each hospitalization is tracked in the Admission, Discharge and Transfer (ADT) database. This is a real-time system in that when the patient is admitted to the hospital this database is used to register the patient and track his or her progress. Upon discharge appropriate information is attached to the visit and includes race/ethnicity, admission date, discharge date, admitting diagnosis, principal discharge diagnosis, up to 14 other diagnoses, procedures codes, and facility. Only the principal diagnosis field was searched and classified. Diagnostic categories (ICD-9) used in this study included:

Acute Respiratory Disease; ICD-9: 381, 382, 460-466, 480-487.

Chronic Respiratory Disease; ICD-9: 490-496.

Cardiovascular disease; ICD-9: 410-417, 420-429, 440, 451-453.

DATA ANALYSIS

In nearly all prior time-series investigations of the health effects of air pollution, individuals residing within a large geographic (study) area (or being seen at a given set of hospitals) were assigned the same level of exposure for each day. The total number of events (e.g., deaths, hospitalizations) in the area or region on a given day were regressed on the exposure for that day. Rather than calculating an average exposure obtained from the multiple monitors across our large study area, we assigned air quality and weather measurements on the basis of mapping the zip code of residence to a 10 square kilometer grid. In this study we have further aggregated the groups into centers as noted in the exposure assignment section above. Thus, for each such exposure unit we have both a time series of health events and of environmental exposures. Our goal is an analysis that uses all such simultaneous or parallel series in assessing the relationship between particulate air pollution and acute respiratory and cardiovascular events. As Burnett and Krewski [16] noted, such an analysis can result in increased power to detect air pollution effects.

For each day during the study period, rates of acute health outcome events were calculated by determining the number of at-risk health plan members residing in each geographic area and the number of hospitalizations among those members. The number of individuals at risk in a given geographic area was determined by using computerized membership databases that contain age, sex and zip code of residence for each member in the Health Plan. Cardiovascular, and chronic and acute respiratory events were ascertained as described previously. Analyses presented here are based on daily measurements on the four population centers, as described in the Exposure Assignment section.

Preliminary analyses included graphical techniques to explore the trends over time in the air quality measures, (e.g., PM_{10}, ozone, and nitrogen dioxide), the meteorological variables, (e.g., humidity and temperature), and the event rates. This allowed visual inspection to evaluate the coincidence of any time trends and provided a basic understanding of our data, elucidating any seasonal effects, potential outliers and unusual episodes.

Because the outcomes of interest were in the form of positive counts, we focused much of our analysis efforts on fitting Poisson regression models with allowance for extra-Poisson variation (over-dispersion). In general, these models were fit in the context of generalized additive models [17]. The use of the generalized additive model allowed the use of nonparametric smoothing techniques, providing flexibility by not requiring specification of the functional form of the association between a given variable and outcome. This model has been used extensively in the analysis of the health effects of air pollution similar in design to this study [18-22]. In our regression analyses we initially fit models with the nuisance variables (e.g., time, temperature and humidity). The usual fitting of these models does not account for potential autocorrelation, and we examined residuals and estimates of overdispersion (a measure of variation not accounted for in the model) to assess for such nonindependence. These analyses indicated no such autocorrelation in our models after careful and flexible adjustment for long-term time trends and weather.

In order to minimize the possibility of incorrectly attributing adverse health effects to a given pollutant, we used a modelling strategy for each outcome of interest that first focused on fitting terms for time and day of week. A flexible nonparametric approach was first used by fitting a smoothing spline function of time and then indicator variables for day of week. We then concentrated our efforts on the modelling of temperature and relative humidity, again using smoothing splines. For each outcome of interest we considered various metrics of temperature and relative humidity (24 - hour average, maximum and minimum). Only after fitting these variables did we attempt to measure the association between pollutant and hospitalizations.

In general, we compared competing models with the aid of Akaike's information criteria (AIC), particularly in our choice of degrees of freedom in our nonparametric smooths of time and weather variables and in our choice of metric of the meteorologic variables. This statistic is expressed as the deviance penalized for the number of parameters estimated in the model and overdispersion (unaccounted variation). Values closer to zero for the AIC are preferred when judging two plausible models [18-21]. Choice on the degrees of freedom (df) was an area of concern given that analyses indicated the best fitting model for respiratory hospitalizations with respect to AIC had a relatively large number of degrees of freedom for the smooth of time. The minimum AIC regression model for chronic respiratory emergency room visits, for example, resulted in a spline smooth of time approximately equivalent to fitting indicator variables for every two and one half week period in our series. This may constitute over-fitting in the sense that these shorter term time effects may be in fact related to pollutant levels thereby absorbing such effects into the nonparametric smooth of time. Nonetheless, the results used in this study were derived from the Poisson models where the AIC was minimized. The exception to this were the seasonal analyses where Poisson models smoothing splines with three degrees of freedom were used for time, temperature and humidity.

Tables 3-3 and 3-4 show the degrees of freedom for the smoothing splines for the hospitalization and emergency room data, respectively. As expected, the respiratory categories for each included more degrees of freedom that capture the increased periodicity of these health outcomes relative to cardiovascular outcomes. Also as expected the degrees of freedom for emergency room visits are larger than hospitalization data because of the greater periodicity of the former.

Table 3-3: Degrees of freedom for smoothing splines, and core variables, and metric for meteorologic variables as determined by minimizing Akaike's information criteria, by hospitalization category, Kaiser Permanente Central Valley Study, 1996-2000.

Confounder	Outcome		
	Cardiovascular	Acute Respiratory	Chronic Respiratory
Center	3	3	3
Day of week	6	6	6
Time	15	60	67
Temperature (24 hour average)	4	1	1
Relative humidity (24 hour average)	1	1	4

Table 3-4: Degrees of freedom for smoothing splines, and core variables, and metric for meteorologic variables as determined by minimizing Akaike's information criteria, by emergency room visit category, Kaiser Permanente Central Valley Study, 1996-2000.

Confounder	Outcome		
	Cardiovascular	Acute Respiratory	Chronic Respiratory
Center	3	3	3
Day of week	6	6	6
Time	46	89	94
Temperature (24 hour average)	1	1	1
Relative humidity (24 hour average)	1	1	1

We approached the assessment of associations between each outcome and each pollutant by first fitting separate models examining the pollutant on the same day, and each lag up to five days prior to the event day. Each pollutant was initially considered separately (i.e. no control for other pollutants). Presented here are the coefficients resulting from fitting a simple linear term for the pollutant, controlling for current day weather. In addition, we estimated coefficients for the four-day moving average of each pollutant (same day, and days one, two, and three prior to the index day included) since relatively complete data for all pollutants was available. In this approach the exposure metric was calculated by averaging the values for the four days included for each exposure unit (e.g., population center). We did not attempt to impute missing values, and thus, the moving average is taken over the days with at least one nonmissing data point. In addition, we stratified our analyses on season, age, and gender since these factors have been found to be important modifiers of pollutant effects in some studies. We then considered two pollutant models for each outcome of interest, a model for each pair of the pollutants under consideration.

Although there were a large number of analyses conducted in this study, we chose to not perform any adjustments for multiple comparisons, as we believe this unnecessarily restricts the interpretation of the results. Instead the results were interpreted based on the patterns and consistency of the exposure-outcome relationship across pollutants and types of analyses. Specifically, we looked for both significance and consistency within specific analyses where, for example, the results for several lags were associated and others had similarly high exposure effect estimates. Care was also given to see that associations in lag analyses were reflected in the moving average and the more stratified analyses (e.g., age or season).

QUALITY ASSURANCE FOR AIR POLLUTION AND HEALTH OUTCOME DATA

Air Quality Data

Air quality data used in the study were ambient concentrations data measured by the local air pollution control agencies, and CARB, which included CARB's enhanced PM monitoring program data. These data are subjected to routine quality control and quality assurance checks at the district level and again at the California Air Resources Board (CARB) before being distributed to the U.S. Environmental Protection Agency (U.S. EPA) and other users. The data are collected in a standardized fashion and meet or exceed U.S. EPA monitoring standards.

CARB and STI applies standard quality assurance checks, such as checking for minimum, mean, and maximum values against historical data, for all of the hourly concentration data incorporated into the database. These data include, at a minimum, the hourly ozone, PM_{10}, $PM_{2.5}$, NO_2, and CO data. Consistent criteria for data completeness were applied in the calculation of daily exposure metrics from the hourly values (e.g., 75% or 18 out of 24 hours of valid data were needed to compute a valid 24-hr average for a given day).

KPMCP Data

The morbidity data to be used are routinely collected as part of the operation of Kaiser Permanente. The emergency room data have been used in other studies looking at admissions and found to be robust. The hospitalization data are those collected for both internal and regulatory purposes. As such, these data are required to undergo routine quality control measures. No further 'data-cleaning' was performed with these data.

SECTION 4. RESULTS AND DISCUSSION

Our initial approach was to conduct a variety of descriptive analyses to characterize our data. These were designed to both allow simpler forms of assessing data quality and to familiarize ourselves with the data. To this end we examined exposure and outcome data separately and together in simple descriptive statistics and visual approaches.

DESCRIPTIVE ANALYSIS OF POLLUTANTS AND METEOROLOGIC VARIABLES

The number of center-days (four centers x 365 days x approximately five years), mean, median, interquartile range and range for each weather variable, pollutant, and outcome are shown in Table 4-1. As can be seen, data were essentially available for all days over the entire study regions for weather data, and the gaseous pollutants. Particulate mass pollution data were available for approximately 61% of the days while PM chemistry data were available for about 44% of the study period. One can see in the means the fall and winter predominance of particulate matter and highs in summer.

Table 4-2 shows the correlations between air pollutants, temperature and humidity over the entire study area and period. As expected there are generally high correlations between the PM_{10} and $PM_{2.5}$ (r=0.80). The correlations between CF mass and PM_{10} is relatively high (r=0.62) whereas between CF mass and $PM_{2.5}$ it is very low (r=0.03). This likely represents a difficulty in obtaining high quality simultaneous measures of both PM_{10} and $PM_{2.5}$ since the CF mass is a calculated metric. There are obviously high correlations with the PM chemical components with PM_{10} and $PM_{2.5}$. CO and NO_2 correlate with PM at a relatively high level.

These correlations varied by center (Table 4-3). While some correlations exhibited quite similar correlations across center (e.g., PM_{10} and NO_2), others correlations showed wide variation (e.g., CO and SO_4 (PM_{10}). The least consistent correlations across center involve CF mass and, as discussed above, may represent measurement error between the two metrics used to calculate coarse fraction. There was also some variability in the correlations across centers for pollutant-meteorologic variable correlations.

Table 4-1. Summary Statistics for Exposure Data, Kaiser Permanente Central Valley Study, 1996-2000.

			Quantile						
Variable	N*	Min	0.05	0.25	0.50	0.75	0.95	Max	Mean
Weather (24hr)									
Temperature (^{o}F)	7308	28.91	43.58	51.75	60.89	71.00	81.73	93.21	61.58
Relative Humidity (%)	7308	18.23	40.61	53.59	66.93	81.55	94.91	99.97	67.38
Air pollution									
PM_{10} 24hr (µg/m^3)									
Spring	1817	3.52	9.74	15.11	21.44	28.47	39.66	66.94	22.51
Summer	1816	7.31	13.62	20.61	26.07	33.30	47.81	147.88	27.92
Fall	1812	5.68	14.77	25.19	35.70	50.71	84.54	148.18	40.64
Winter	1793	1.87	9.71	18.03	28.99	45.48	91.28	187.59	35.99
$PM_{2.5}$ 24hr (µg/m^3)									
Spring	1768	2.26	5.00	7.30	9.31	13.37	24.44	52.53	11.30
Summer	1778	2.40	5.68	7.83	9.70	12.61	19.22	79.12	10.79
Fall	1801	0.23	6.96	10.90	16.45	25.40	53.50	107.37	21.11
Winter	1783	1.21	7.51	14.33	24.08	38.00	74.55	187.33	30.05
CF Mass 24hr (µg/m^3)									
Spring	1760	0.00	1.66	5.82	10.11	15.89	24.15	51.46	11.28
Summer	1776	0.00	6.80	11.82	16.21	21.04	31.94	68.76	17.30
Fall	1797	0.00	0.95	8.60	17.19	27.44	47.96	108.99	19.94
Winter	1777	0.00	0.00	1.39	4.87	9.32	22.11	111.37	6.98
Ozone 8hr (ppb)									
Spring	1840	9.34	26.77	36.01	42.44	49.99	67.86	104.09	44.05
Summer	1840	8.37	31.86	45.19	57.01	70.70	92.82	118.61	58.71
Fall	1820	1.39	14.02	24.99	35.75	50.57	78.73	115.96	39.75
Winter	1808	1.63	5.44	12.99	19.37	26.35	35.47	49.38	19.81
NO_2 1hr (ppb)									
Spring	1840	5.87	15.19	22.40	28.91	36.52	49.69	74.59	30.12
Summer	1840	3.65	12.25	18.98	25.28	33.62	47.34	87.66	27.02
Fall	1820	6.97	19.30	29.19	37.69	49.70	71.99	102.32	40.67
Winter	1808	8.08	20.16	28.48	34.07	39.94	53.21	78.77	34.91
CO 8hr (ppm)									
Spring	1840	0.30	0.32	0.41	0.52	0.73	1.22	2.70	0.61
Summer	1840	0.30	0.31	0.35	0.44	0.55	0.79	1.76	0.48
Fall	1820	0.30	0.38	0.58	0.85	1.43	2.64	6.28	1.11
Winter	1808	0.30	0.46	0.76	1.12	1.66	2.96	6.62	1.34
Chemical constituents PM_{10}									
Nitrate (g/m^3)	5381	0.12	0.89	2.63	4.54	7.04	14.57	41.75	5.64
Sulfate (g/m^3)	5305	0.17	0.70	1.06	1.42	1.88	3.05	6.80	1.57
Total carbon (µg/m^3)	7237	0.93	2.15	3.42	4.74	6.98	13.97	46.22	5.99

* Represents number of centers (n=4) times the number of days with data available. Maximum number is 7,308 for the study or approximately 1,840 exposure days per season.

Table 4-2. Correlation coefficients between pollutants and meteorologic variables, Kaiser Permanente Central Valley Study, 1996-2000.

	PM_{10}	$PM_{2.5}$	CF Mass	Ozone	CO	NO_2 1hr	NO_3 (PM_{10})	SO_4 (PM_{10})	TC (PM_{10})	Temp	Rel. Hum.
PM_{10}	1.00	0.80	0.62	0.01	0.66	0.66	0.90	0.79	0.89	-0.05	-0.04
$PM_{2.5}$		1.00	0.03	-0.35	0.76	0.53	0.82	0.53	0.90	-0.43	0.33
CF Mass			1.00	0.48	0.10	0.41	0.42	0.65	0.29	0.49	-0.51
Ozone 8hr				1.00	-0.38	0.07	-0.19	0.14	-0.23	0.83	-0.76
CO 8hr					1.00	0.62	0.66	0.42	0.73	-0.45	0.32
NO_2 1hr						1.00	0.61	0.52	0.58	-0.06	-0.02
NO_3 (PM_{10})							1.00	0.73	0.86	-0.20	0.10
SO_4 (PM_{10})								1.00	0.59	0.18	-0.17
TC (PM_{10})									1.00	-0.31	0.19
Temp										1.00	-0.74
Rel. Hum.											1.00

Table 4-3. Correlation coefficients between pollutants and meteorologic variables by center, Kaiser Permanente Central Valley Study, 1996-2000.

	Center	PM_{10}	$PM_{2.5}$	CF Mass	Ozone	CO	NO_2 1hr	NO_3 (PM_{10})	SO_4 (PM_{10})	TC (PM_{10})	Temp	Rel. Hum.
PM_{10}	Sacramento	1.00	0.73	0.59	0.12	0.57	0.60	0.78	0.62	0.89	0.12	-0.22
	Stockton	1.00	0.82	0.63	-0.18	0.73	0.63	0.89	0.71	0.95	-0.18	0.08
	Modesto	1.00	0.82	0.73	-0.14	0.69	0.66	0.95	0.94	0.97	-0.11	0.04
	Fresno	1.00	0.79	0.47	0.00	0.69	0.66	0.89	0.85	0.84	-0.08	0.00
$PM_{2.5}$	Sacramento		1.00	-0.12	-0.37	0.76	0.46	0.84	0.47	0.86	-0.37	0.27
	Stockton		1.00	0.09	-0.43	0.80	0.51	0.77	0.43	0.89	-0.46	0.36
	Modesto		1.00	0.21	-0.45	0.80	0.55	0.86	0.72	0.89	-0.46	0.40
	Fresno		1.00	-0.17	-0.39	0.79	0.52	0.91	0.68	0.94	-0.49	0.40
CF Mass	Sacramento			1.00	0.62	-0.10	0.32	-0.09	0.30	0.27	0.63	-0.67
	Stockton			1.00	0.29	0.20	0.42	0.49	0.67	0.44	0.34	-0.41
	Modesto			1.00	0.30	0.23	0.48	0.59	0.75	0.60	0.36	-0.42
	Fresno			1.00	0.57	-0.04	0.32	0.15	0.50	0.00	0.59	-0.59
Ozone	Sacramento				1.00	-0.39	0.16	-0.41	0.10	-0.17	0.82	-0.76
	Stockton				1.00	-0.40	0.05	-0.16	0.21	-0.35	0.82	-0.77
	Modesto				1.00	-0.42	-0.03	-0.22	-0.02	-0.26	0.83	-0.72
	Fresno				1.00	-0.43	0.03	-0.38	0.18	-0.40	0.88	-0.81
CO	Sacramento					1.00	0.62	0.68	0.30	0.74	-0.43	0.26
	Stockton					1.00	0.60	0.65	0.35	0.80	-0.44	0.33
	Modesto					1.00	0.58	0.71	0.58	0.76	-0.46	0.34
	Fresno					1.00	0.68	0.77	0.51	0.82	-0.52	0.43
NO_2	Sacramento						1.00	0.45	0.25	0.58	0.03	-0.14
	Stockton						1.00	0.58	0.49	0.60	-0.08	-0.03
	Modesto						1.00	0.63	0.63	0.65	-0.10	0.05
	Fresno						1.00	0.63	0.49	0.54	-0.11	0.04
NO_3 (PM_{10})	Sacramento							1.00	0.46	0.84	-0.37	0.21
	Stockton							1.00	0.71	0.85	-0.18	0.09
	Modesto							1.00	0.88	0.96	-0.22	0.13
	Fresno							1.00	0.67	0.94	-0.45	0.23
SO_4 (PM_{10})	Sacramento								1.00	0.48	0.18	-0.11
	Stockton								1.00	0.55	0.24	-0.26
	Modesto								1.00	0.88	0.00	-0.03
	Fresno								1.00	0.71	0.12	-0.21
TC (PM_{10})	Sacramento									1.00	-0.18	0.04
	Stockton									1.00	-0.37	0.26
	Modesto									1.00	-0.25	0.16
	Fresno									1.00	-0.46	0.38
Temperature	Sacramento										1.00	-0.73
	Stockton										1.00	-0.76
	Modesto										1.00	-0.72
	Fresno										1.00	-0.80
Relative Humidity	Sacramento											1.00
	Stockton											1.00
	Modesto											1.00
	Fresno											1.00

DESCRIPTIVE ANALYSIS OF OUTCOMES

On average, there were about 13.3 cardiovascular (CVD), 3.1 chronic respiratory (CR), and 5.7 acute respiratory (AR) hospitalizations per day over the study period. Time series plots show that there was little periodicity in the CVD admissions while for both of the respiratory categories winter increases are observed (data not shown). These reflect the well-known patterns in winter influenza and respiratory infections and outbreaks. Each day there were 10.6, 11.4 and 11.1 emergency room visits on average for cardiovascular, acute respiratory and chronic respiratory conditions, respectively. Tables 4-4 and 4-5 show the number and rate per 1,000 overall admissions for hospitalization and emergency room visit data, respectively, categorized by season, center, and age group. The rates varied by season for chronic and acute respiratory hospitalizations that occurred more often during the winter months, while there was no seasonal pattern observed for CVD, regardless of outcome type. We found slight differences at best in hospitalization rates by our centers (e.g., Sacramento, Stockton, Modesto, and Fresno). However, for the emergency room visit data Sacramento and Fresno were similar and about three and four times that of Stockton or Modesto. This may be due, in part, to the proximity of a Kaiser Permanente emergency room to each of these centers. However, given the essentially equal access to health care combined with the general seriousness of the diseases being studied, this is unlikely to affect the pollutant-outcome relationship examined in a time-series study such as this one.

Table 4-4. Summary statistics for hospitalization rate per 1,000 members by season, center and age, Kaiser Permanente Central Valley Study, 1996-2000.

	Cardiovascular		Acute Respiratory		Chronic Respiratory	
	N	Rate*	N	Rate*	N	Rate*
Total	24,359	9.30	10,469	4.00	5,586	2.13
Season**						
Spring	6,228	9.52	2,813	4.30	1,444	2.21
Summer	5,819	8.89	1,899	2.90	966	1.48
Fall	6,034	9.22	2,099	3.21	1,299	1.98
Winter	6,278	9.59	3,658	5.59	1,877	2.87
Center						
Sacramento	19,126	9.43	8,594	4.24	4,370	2.16
Stockton	1,905	8.19	706	3.03	525	2.26
Modesto	761	7.98	381	4.00	234	2.46
Fresno	2,567	9.78	788	3.00	457	1.74
Age Group						
< 20	62	0.08	3,965	5.17	747	0.97
20 - 49	2,336	2.08	1,011	0.90	885	0.79
50 +	21,961	30.27	5,493	7.57	3,954	5.45

* Rate per 1,000

** Spring= March, April, May; Summer=June, July, August; Fall=September, October, November; Winter=December, January, February.

Table 4-5. Summary statistics for emergency room visit rate per 1,000 members by season, center and age, Kaiser Permanente Central Valley Study, 1996-2000.

	Cardiovascular		Acute Respiratory		Chronic Respiratory	
	N	Rate*	N	Rate*	N	Rate*
Total	19,370	7.40	20,749	7.93	20,354	7.77
Season**						
Spring	4,956	7.57	5,385	8.23	5,890	9.00
Summer	4,719	7.21	3,328	5.08	3,536	5.40
Fall	4,888	7.47	4,722	7.21	4,606	7.04
Winter	4,807	7.34	7,314	11.17	6,322	9.66
Center						
Sacramento	17,604	8.68	18,139	8.95	17,383	8.57
Stockton	197	0.85	379	1.63	385	1.65
Modesto	127	1.33	201	2.11	216	2.27
Fresno	1,442	5.49	2,030	7.74	2,370	9.03
Age Group						
< 20	128	0.17	7,888	10.29	4,503	5.87
20 - 49	2,207	1.96	4,764	4.23	6,624	5.88
50 +	17,035	23.48	8,097	11.16	9,227	12.72

* Rate per 1,000

** Spring= March, April, May; Summer=June, July, August; Fall=September, October, November; Winter=December, January, February.

TIME SERIES ANALYSES

Introduction

For each of the three outcomes of interest and two types of admissions, a standard suite of analyses was conducted and is presented here. For each outcome the initial analysis presented is the lag analysis with estimated regression coefficients (multiplied by 1,000) and significance probabilities modeled for the same day exposure (lag 0), and exposure lags of 1 to 5 days prior to hospital and emergency room admissions. This analysis was followed by one that used four day moving averages for exposure and included the same day, plus the three days prior to the hospitalization or emergency room admission. These results are presented as the percent change in the rate of admissions associated with a ten-unit increase in pollutant value. Finally, four-day moving averages were used to calculate the pollution effect by season and then age for each outcome.

Hospitalization Results

Lag Analyses

Table 4-6 shows the lag analysis for each of the hospitalization outcomes. Clear associations were observed between PM_{10} and $PM_{2.5}$ and chronic respiratory admissions. Carbon monoxide (CO) and cardiovascular hospitalizations were associated for same and prior day exposure. PM_{10} and the coarse fraction (PM_{10}-$PM_{2.5}$) were inversely associated with cardiovascular hospitalizations. Of the PM_{10} chemistry components, the three presented were generally associated with chronic respiratory admissions, particularly NO_3 and total carbon (TC). While most pollutants were positively associated with acute respiratory hospitalizations, few of the associations were significant.

Table 4-6. Regression coefficients (β x 1,000) between air pollutants and hospitalizations by lag, Kaiser Permanente Central Valley Study, 1996-2000.

		Cardiovascular		Acute Respiratory		Chronic Respiratory	
Pollutant	Lag	β	p	β	p	β	p
PM_{10}	0	0.796	0.187	1.255	0.458	2.869	0.058
	1	0.471	0.498	1.502	0.590	3.319	0.017
	2	-0.450	0.266	1.370	0.714	3.302	0.013
	3	-0.918	0.040	1.834	0.174	4.218	0.000
	4	-0.970	0.033	1.868	0.111	2.768	0.031
	5	-0.873	0.055	2.112	0.043	4.378	0.000
$PM_{2.5}$	0	1.240	0.081	1.347	0.198	2.727	0.674
	1	1.621	0.014	2.910	0.035	5.030	0.003
	2	0.444	0.637	2.268	0.561	3.490	0.184
	3	0.000	0.882	2.579	0.375	6.111	0.000
	4	0.117	0.773	2.096	0.190	3.864	0.160
	5	0.493	0.545	2.804	0.042	6.508	0.000
CF Mass	0	-0.154	0.810	0.581	0.757	4.578	0.035
	1	-1.919	0.032	-0.913	0.800	-0.143	0.923
	2	-2.233	0.012	0.071	0.607	2.655	0.147
	3	-3.116	0.000	0.109	0.574	1.195	0.468
	4	-3.504	0.000	1.391	0.297	1.308	0.461
	5	-3.494	0.000	2.036	0.213	0.811	0.680
Ozone 8hr	0	-0.010	0.907	-0.191	0.930	-2.896	0.102
	1	-0.283	0.844	-2.299	0.054	-0.679	0.641
	2	-0.249	0.814	-1.917	0.016	-3.387	0.251
	3	-0.763	0.305	-0.151	0.133	-4.160	0.063
	4	-1.273	0.055	0.731	0.504	-2.710	0.130
	5	-0.745	0.314	-1.032	0.032	-0.759	0.046
CO 8hr	0	38.787	0.017	47.807	0.020	53.260	0.207
	1	39.047	0.015	12.177	0.204	64.332	0.455
	2	20.031	0.271	36.787	0.122	80.826	0.228
	3	11.604	0.616	66.316	0.036	106.753	0.015
	4	0.331	0.790	43.043	0.192	65.158	0.424
	5	-9.140	0.413	35.413	0.158	92.088	0.058
NO_2 1hr	0	1.966	0.010	2.331	0.113	3.489	0.170
	1	1.741	0.023	1.811	0.092	2.165	0.091
	2	0.684	0.525	1.390	0.155	1.779	0.373
	3	-0.145	0.715	1.125	0.313	1.821	0.611
	4	-0.319	0.487	0.361	0.439	1.108	0.565
	5	-0.686	0.190	0.210	0.542	2.435	0.223

Table 4-6. Regression coefficients (β x 1,000) between air pollutants and hospitalizations by lag, Kaiser Permanente Central Valley Study, 1996-2000.

		Cardiovascular		Acute Respiratory		Chronic Respiratory	
Pollutant	Lag	β	p	β	p	β	p
NO_3 (PM_{10})	0	4.876	0.127	1.308	0.577	10.746	0.187
	1	3.312	0.357	9.968	0.817	21.693	0.001
	2	1.487	0.782	6.143	0.490	24.497	0.000
	3	-0.048	0.912	12.858	0.241	24.043	0.000
	4	-4.108	0.143	8.348	0.657	21.909	0.002
	5	-2.311	0.376	16.552	0.030	24.623	0.000
SO_4 (PM_{10})	0	33.418	0.038	3.907	0.829	38.057	0.286
	1	-16.984	0.265	30.162	0.306	23.293	0.628
	2	-18.118	0.228	29.394	0.373	70.929	0.039
	3	-27.412	0.072	-8.666	0.565	84.833	0.010
	4	-13.343	0.363	22.792	0.581	85.253	0.015
	5	-24.597	0.093	37.113	0.262	81.748	0.017
TC (PM_{10})	0	3.834	0.159	4.819	0.257	14.045	0.094
	1	2.708	0.355	5.880	0.244	19.038	0.002
	2	-0.068	0.938	6.073	0.280	17.691	0.005
	3	-3.195	0.106	9.043	0.285	23.306	0.000
	4	-2.847	0.156	8.514	0.292	16.379	0.011
	5	-2.875	0.155	9.889	0.095	24.163	0.000

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Four Day Moving Average Analyses

Tables 4-7 to 4-9 present the four-day moving average results by each outcome. For each of the tables the pollutant-outcome associated is presented with the regression (beta) coefficient, the standard error for the coefficient (STD), percent change in the rate of admissions associated with a ten unit increase in pollutant level, and the 95% confidence interval (CI) for the rate change. The null value in the percent change would be zero. Positive values for the percent change result indicates an increase in the rate while a negative value indicates a decrease in the rate with a ten unit increase in pollutant value or level.

As with the lag analysis, the coarse fraction was inversely associated with cardiovascular disease (Table 4-7). CO and NO_2 were associated with cardiovascular disease admissions. Again reflecting the lag analyses, PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), and total carbon (TC PM_{10}) were associated with an increase in acute respiratory hospitalizations, while ozone was associated with a decrease (Table 4-8).

Results were quite similar for chronic respiratory hospitalizations (Table 4-9). In addition, SO_4 (PM_{10}) was also associated with an increase in chronic respiratory admissions.

Table 4-7. Percent change in rate of cardiovascular hospitalizations per 10 unit increase in pollutant level for four-day moving average, cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	-0.051	0.502	-0.051	-1.030	0.938
$PM_{2.5}$	1.176	0.622	1.183	-0.042	2.423
CF Mass	-2.947	1.053	-2.904	-4.888	-0.879
Ozone 8hr	-0.722	0.782	-0.720	-2.229	0.813
CO 8hr	46.467	15.578	59.149	17.273	115.978
NO_2 1hr	1.845	0.715	1.862	0.445	3.300
NO_3 (PM_{10})	2.956	3.501	3.000	-3.831	10.315
SO_4 (PM_{10})	-16.446	20.948	-15.165	-43.732	27.907
TC (PM_{10})	1.166	2.335	1.173	-3.352	5.910

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-8. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	2.290	0.761	2.317	0.803	3.853
$PM_{2.5}$	4.031	0.908	4.114	2.278	5.983
CF Mass	-0.380	1.735	-0.380	-3.710	3.066
Ozone 8hr	-2.820	1.257	-2.781	-5.147	-0.355
CO 8hr	84.793	23.412	133.481	47.559	269.433
NO_2 1hr	4.051	1.201	4.134	1.712	6.613
NO_3 (PM_{10})	12.127	5.116	12.893	2.122	24.800
SO_4 (PM_{10})	39.135	30.464	47.897	-18.596	168.705
TC (PM_{10})	9.944	3.514	10.456	3.103	18.332

Table 4-8. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Table 4-9. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, chronic respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	5.374	0.921	5.521	3.633	7.443
$PM_{2.5}$	7.240	1.112	7.509	5.190	9.879
CF Mass	3.622	2.157	3.689	-0.604	8.167
Ozone 8hr	-6.280	1.672	-6.087	-9.116	-2.958
CO 8hr	149.618	29.504	346.459	150.404	696.015
NO_2 1hr	5.111	1.557	5.244	2.081	8.505
NO_3 (PM_{10})	31.897	6.032	37.571	22.232	54.836
SO_4 (PM_{10})	185.418	37.381	538.645	206.950	1228.777
TC (PM_{10})	27.595	4.152	31.779	21.479	42.952

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Season Analyses

Tables 4-10 to 4-12 show the associations between pollutants and each hospitalization outcome by season. For cardiovascular disease there were no clear patterns observed (Table 4-10). $PM_{2.5}$ was associated with cardiovascular hospitalizations in the summer, ozone in the winter, and CO and NO_2 in the spring. The coarse fraction of PM was inversely associated in the fall.

In contrast to cardiovascular hospitalizations, acute respiratory hospitalizations were associated with many of the pollutants in winter, including PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), SO_4 (PM_{10}), and TC (PM_{10}) (Table 4-11). Chronic respiratory hospitalizations (Table 4-12) were associated with the same pollutants as acute respiratory admissions during winter, plus the coarse fraction of PM.

Stephen K. Van Den Eeden, PhD
Principal Investigator

Table 4-10. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutant	Season	β (x1000)	STD (x1000)	Percent change	Lower	Upper
PM_{10}	Spring	0.083	2.531	0.083	-4.760	5.173
	Summer	2.951	2.053	2.995	-1.067	7.223
	Fall	-1.317	0.982	-1.309	-3.189	0.608
	Winter	-0.518	0.887	-0.517	-2.232	1.228
$PM_{2.5}$	Spring	5.501	3.885	5.655	-2.091	14.014
	Summer	10.239	4.031	10.781	2.365	19.889
	Fall	0.361	1.316	0.361	-2.193	2.983
	Winter	0.113	0.956	0.113	-1.745	2.006
CF Mass	Spring	-3.788	3.068	-3.717	-9.336	2.250
	Summer	1.479	3.132	1.489	-4.553	7.915
	Fall	-4.314	1.700	-4.222	-7.360	-0.978
	Winter	-5.179	3.024	-5.047	-10.511	0.750
Ozone 8hr	Spring	4.101	2.226	4.186	-0.261	8.831
	Summer	1.183	1.515	1.190	-1.771	4.241
	Fall	-3.532	1.646	-3.470	-6.534	-0.306
	Winter	4.832	2.212	4.951	0.498	9.601
CO 8hr	Spring	178.929	67.683	498.522	58.836	2155.333
	Summer	174.979	124.902	475.340	-50.257	6554.472
	Fall	18.644	29.023	20.496	-31.778	112.824
	Winter	33.473	27.339	39.756	-18.218	138.829
NO_2 1hr	Spring	9.041	1.955	9.463	5.347	13.739
	Summer	3.362	2.044	3.419	-0.642	7.646
	Fall	-1.058	1.356	-1.052	-3.648	1.614
	Winter	-0.225	2.382	-0.225	-4.777	4.545
NO_3 (PM_{10})	Spring	-21.850	24.231	-19.628	-50.014	29.231
	Summer	-60.550	33.557	-45.420	-71.726	5.360
	Fall	14.000	7.327	15.027	-0.360	32.792
	Winter	-2.246	4.814	-2.221	-11.025	7.455
SO_4 (PM_{10})	Spring	110.658	119.129	202.399	-70.723	3023.396
	Summer	-171.801	133.759	-82.058	-98.696	146.862
	Fall	-4.025	42.092	-3.945	-57.905	119.185
	Winter	-50.961	31.781	-39.927	-67.778	11.996
TC (PM_{10})	Spring	-11.729	10.625	-11.067	-27.786	9.522

Table 4-10. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
	Summer	7.150	13.748	7.412	-17.959	40.629
	Fall	-0.372	4.596	-0.372	-8.954	9.020
	Winter	-0.868	3.882	-0.865	-8.129	6.973

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in μg/m^3, and gas pollutants in ppb.

Table 4-11. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Spring	1.961	4.088	1.981	-5.872	10.489
	Summer	-1.787	4.047	-1.771	-9.262	6.338
	Fall	-0.823	1.660	-0.820	-3.995	2.460
	Winter	4.057	1.149	4.140	1.821	6.512
$PM_{2.5}$	Spring	-8.833	6.387	-8.454	-19.226	3.754
	Summer	-9.752	8.608	-9.292	-23.374	7.378
	Fall	0.046	2.235	0.046	-4.242	4.526
	Winter	5.462	1.247	5.614	3.064	8.227
CF Mass	Spring	6.395	4.913	6.604	-3.182	17.379
	Summer	2.644	5.922	2.680	-8.573	15.317
	Fall	-1.497	2.890	-1.486	-6.911	4.256
	Winter	0.535	4.081	0.537	-7.192	8.909
Ozone 8hr	Spring	1.116	3.595	1.122	-5.757	8.504
	Summer	0.998	2.802	1.003	-4.394	6.705
	Fall	-1.711	2.823	-1.696	-6.987	3.895
	Winter	2.453	2.959	2.483	-3.291	8.602
CO 8hr	Spring	-142.199	106.377	-75.877	-97.001	94.061
	Summer	132.572	235.460	276.490	-96.272	37921.847
	Fall	-30.954	49.592	-26.621	-72.239	93.956
	Winter	101.548	35.667	176.068	37.217	455.421
NO_2 1hr	Spring	1.192	3.131	1.199	-4.824	7.603

Table 4-11. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
	Summer	-0.930	3.826	-0.925	-8.083	6.790
	Fall	-0.354	2.349	-0.353	-4.837	4.342
	Winter	7.565	3.188	7.858	1.325	14.813
NO_3 (PM_{10})	Spring	31.697	39.593	37.296	-36.812	198.319
	Summer	83.524	60.093	130.536	-29.007	648.619
	Fall	-16.399	13.468	-15.125	-34.816	10.515
	Winter	19.359	6.345	21.359	7.168	37.430
SO_4 (PM_{10})	Spring	28.034	194.629	32.358	-97.082	5904.322
	Summer	-296.132	270.919	-94.825	-99.974	947.177
	Fall	-29.406	69.961	-25.477	-81.086	193.639
	Winter	117.735	41.634	224.576	43.521	634.033
TC (PM_{10})	Spring	2.149	17.154	2.172	-27.002	43.005
	Summer	-4.684	26.475	-4.576	-43.207	60.332
	Fall	-5.514	7.959	-5.365	-19.034	10.612
	Winter	16.878	5.108	18.386	7.108	30.853

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Table 4-12. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, chronic respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutant	Season	β (x1000)	STD (x1000)	Percent change	Lower	Upper
PM_{10}	Spring	-1.319	5.332	-1.310	-11.103	9.562
	Summer	-1.224	5.277	-1.217	-10.923	9.548
	Fall	3.201	2.061	3.253	-0.835	7.509
	Winter	6.881	1.379	7.123	4.267	10.058
$PM_{2.5}$	Spring	-8.555	8.263	-8.199	-21.925	7.940
	Summer	-6.096	10.763	-5.914	-23.809	16.184
	Fall	3.942	2.756	4.021	-1.448	9.794
	Winter	8.162	1.559	8.504	5.238	11.872
CF Mass	Spring	-1.525	6.507	-1.513	-13.305	11.882
	Summer	2.217	7.875	2.241	-12.382	19.305
	Fall	3.923	3.633	4.001	-3.146	11.676
	Winter	10.510	4.737	11.082	1.233	21.889
Ozone 8hr	Spring	-4.278	4.698	-4.187	-12.616	5.054
	Summer	-1.723	3.846	-1.708	-8.844	5.987
	Fall	-6.544	3.713	-6.335	-12.909	0.736
	Winter	-3.027	4.141	-2.981	-10.545	5.222
CO 8hr	Spring	260.168	135.914	1248.641	-6.033	19256.110
	Summer	-168.949	323.615	-81.539	-99.968	10393.709
	Fall	84.854	62.214	133.624	-30.986	690.852
	Winter	148.735	46.454	342.535	78.042	999.952
NO_2 1hr	Spring	0.604	4.045	0.606	-7.063	8.908
	Summer	-9.742	5.346	-9.283	-18.307	0.739
	Fall	0.242	3.054	0.243	-5.582	6.426
	Winter	14.374	4.111	15.458	6.520	25.146
NO_3 (PM_{10})	Spring	56.049	48.698	75.153	-32.565	354.931
	Summer	-135.964	79.409	-74.325	-94.585	21.748
	Fall	-0.028	17.024	-0.028	-28.391	39.569
	Winter	36.100	7.395	43.477	24.119	65.854
SO_4 (PM_{10})	Spring	266.997	233.028	1343.949	-85.004	138936.132
	Summer	-172.832	300.206	-82.242	-99.951	6279.805
	Fall	43.083	89.907	53.854	-73.588	796.216
	Winter	241.923	51.088	1023.715	312.844	2958.628
TC (PM_{10})	Spring	-5.761	22.389	-5.599	-39.131	46.406

Table 4-12. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, chronic respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
	Summer	9.133	34.525	9.563	-44.309	115.547
	Fall	12.734	9.900	13.580	-6.453	37.904
	Winter	32.115	6.063	37.872	22.423	55.270

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Age Analyses

Table 4-13 is the four-day moving average for cardiovascular hospitalizations. This table is limited to those over 50 years of age since there were very few such admissions under this age. Associations were observed for $PM_{2.5}$, CO, and NO_2, while the coarse fraction was inversely associated.

Table 4-14 shows the associations for acute respiratory hospitalizations by age. In general, there were associations with many pollutants (e.g., PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), and TC (PM_{10})) for the 50 years or older group. These hospitalizations are virtually all due to pneumonia diagnoses. Table 4-15 shows the associations for chronic respiratory hospitalizations by age. Associations were observed for nearly all of the pollutants (e.g., PM_{10}, $PM_{2.5}$, CO, NO_2, NO_3 (PM_{10}), SO_4 (PM_{10}), and TC (PM_{10})) for individuals 20 or more years old.

Table 4-13. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	50 +	0.221	0.524	0.221	-0.803	1.256
$PM_{2.5}$		1.426	0.648	1.436	0.157	2.732
CF Mass		-2.493	1.103	-2.462	-4.548	-0.331
Ozone 8hr		-0.647	0.822	-0.645	-2.233	0.970
CO 8hr		53.989	16.351	71.582	24.536	136.402
NO_2 1hr		2.157	0.752	2.180	0.686	3.696
NO_3 (PM_{10})		3.676	3.668	3.744	-3.452	11.477
SO_4 (PM_{10})		-18.674	22.114	-17.034	-46.216	27.980
TC (PM_{10})		1.506	2.436	1.518	-3.216	6.483

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Table 4-14. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	< 20	-0.535	1.400	-0.533	-3.225	2.233
	20-49	1.663	2.310	1.677	-2.825	6.387
	50 +	2.946	0.933	2.990	1.123	4.891
$PM_{2.5}$	< 20	0.294	1.755	0.295	-3.096	3.804
	20-49	4.063	2.771	4.147	-1.358	9.959
	50 +	4.114	1.104	4.200	1.969	6.479
CF Mass	< 20	-2.022	2.976	-2.001	-7.554	3.885
	20-49	1.176	5.118	1.183	-8.474	11.860
	50 +	0.593	2.230	0.595	-3.708	5.090
Ozone 8hr	< 20	-4.930	2.071	-4.810	-8.597	-0.867
	20-49	-2.737	3.794	-2.700	-9.673	4.811
	50 +	-0.071	1.665	-0.071	-3.279	3.244
CO 8hr	< 20	16.452	41.128	17.883	-47.354	163.957
	20-49	141.664	70.449	312.324	3.649	1540.252
	50 +	91.017	30.076	148.475	37.807	348.016
NO_2 1hr	< 20	0.248	1.994	0.248	-3.595	4.244
	20-49	1.711	3.558	1.725	-5.127	9.073
	50 +	5.962	1.589	6.143	2.890	9.500
NO_3 (PM_{10})	< 20	5.131	9.770	5.265	-13.080	27.483
	20-49	-19.043	16.084	-17.340	-39.690	13.293
	50 +	12.751	6.321	13.599	0.363	28.581
SO_4 (PM_{10})	< 20	-7.829	55.133	-7.530	-68.617	172.461
	20-49	-9.110	89.467	-8.708	-84.192	427.216
	50 +	36.202	38.890	43.622	-32.983	207.794
TC (PM_{10})	< 20	-3.464	6.743	-3.405	-15.363	10.243
	20-49	2.881	10.758	2.923	-16.644	27.083
	50 +	12.779	4.205	13.632	4.643	23.393

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.

Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-15. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, chronic respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	< 20	-0.359	2.910	-0.358	-5.883	5.491
	20-49	7.810	2.269	8.123	3.419	13.041
	50 +	5.271	1.038	5.412	3.290	7.578
$PM_{2.5}$	< 20	1.443	3.662	1.454	-5.572	9.002
	20-49	10.518	2.831	11.091	5.094	17.430
	50 +	6.928	1.241	7.173	4.599	9.812
CF Mass	< 20	-5.320	6.090	-5.181	-15.849	6.839
	20-49	6.861	5.175	7.102	-3.229	18.536
	50 +	4.470	2.492	4.571	-0.414	9.806
Ozone 8hr	< 20	-11.744	4.605	-11.081	-18.755	-2.682
	20-49	-3.131	4.111	-3.082	-10.585	5.050
	50 +	-6.074	1.940	-5.893	-9.404	-2.245
CO 8hr	< 20	122.202	80.251	239.403	-29.595	1536.159
	20-49	233.332	70.661	931.207	158.149	4019.281
	50 +	135.668	34.577	288.330	97.184	664.767
NO_2 1hr	< 20	2.310	4.236	2.337	-5.816	11.196
	20-49	10.052	3.770	10.575	2.699	19.055
	50 +	4.269	1.821	4.362	0.703	8.154
NO_3 (PM_{10})	< 20	6.290	19.959	6.493	-27.985	57.476
	20-49	41.676	14.263	51.704	14.707	100.633
	50 +	31.286	6.783	36.733	19.710	56.176
SO_4 (PM_{10})	< 20	-29.261	110.370	-25.369	-91.421	549.246
	20-49	278.417	85.973	1518.635	200.148	8628.949
	50 +	194.081	42.806	596.441	200.965	1511.581
TC (PM_{10})	< 20	13.716	14.133	14.701	-13.051	51.312
	20-49	41.504	10.345	51.444	23.649	85.485
	50 +	24.731	4.630	28.058	16.948	40.223

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Two Pollutant Analyses

Two pollutant models for hospitalization data are presented in Tables 4-16 to 4-18. For comparison, the single pollutant results from tables 4-7 to 4-9 can be used to assess the effect of inclusion of a second pollutant in the model. For example, from the single pollutant models the percent change in cardiovascular admission rates for PM_{10} and NO_2 were –0.051 and 1.862, respectively, with the confidence interval of PM_{10} overlapping zero and the interval for NO_2 excluding the null value (Table 4-7). In the two pollutant model below (Table 4-16), the percent change (and confidence interval) for PM_{10} and NO_2 were –1.459 and 3.296, with both estimates of change excluding zero indicating that NO_2 is a associated with the outcome over and above what PM_{10} may (or may not) contribute.

For cardiovascular hospitalizations, CO and NO_2 were robust when in models that contained other pollutants (Table 4-16). The effect estimate for these two pollutants was either stable or strengthened when other pollutants were entered into the model.

Acute respiratory hospitalizations results are shown in Tables 4-17. In general, $PM_{2.5}$, CO and NO_2 remained robust in the presence of other pollutants. The PM_{10} effect estimate was lower and the $PM_{2.5}$ estimates slightly lower in the presence of CO and NO_2. The effect of CO was greatly reduced when $PM_{2.5}$ was in the model.

Table 4-18 presents the data for chronic respiratory hospitalizations. The PM_{10} and $PM_{2.5}$ effect estimates were generally very stable when other pollutants were in the model. The coarse fraction of PM effect estimate was considerably lower when CO and NO_2 were also in the model. The inverse association observed with ozone was essentially unchanged with any other pollutant in the model.

Table 4-16. Two pollutant models for four day moving averages for cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	0.007	0.502	0.007	-0.973	0.996
Ozone 8hr	-0.721	0.783	-0.718	-2.230	0.817
PM_{10}	-2.312	0.800	-2.286	-3.807	-0.741
CO 8hr	98.068	24.755	166.628	64.128	333.141
PM_{10}	-1.469	0.687	-1.459	-2.777	-0.122
NO_2 1hr	3.243	0.980	3.296	1.331	5.299
$PM_{2.5}$	1.133	0.636	1.139	-0.114	2.408
Ozone 8hr	-0.428	0.808	-0.427	-1.992	1.163

Table 4-16. Two pollutant models for four day moving averages for cardiovascular hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
$PM_{2.5}$	-0.302	1.038	-0.302	-2.310	1.748
CO 8hr	49.741	26.166	64.445	-1.532	174.630
$PM_{2.5}$	0.612	0.760	0.614	-0.873	2.123
NO_2 1hr	1.322	0.884	1.331	-0.410	3.102
CF Mass	-3.094	1.089	-3.046	-5.094	-0.954
Ozone 8hr	0.316	0.817	0.316	-1.278	1.935
CF Mass	-3.942	1.109	-3.865	-5.933	-1.753
CO 8hr	61.761	16.653	85.448	33.803	157.028
CF Mass	-5.046	1.190	-4.921	-7.112	-2.678
NO_2 1hr	3.489	0.827	3.551	1.886	5.243
Ozone 8hr	-0.546	0.797	-0.544	-2.087	1.022
CO 8hr	45.410	15.894	57.475	15.325	115.031
Ozone 8hr	-1.388	0.790	-1.379	-2.894	0.160
NO_2 1hr	2.212	0.723	2.237	0.799	3.695
CO 8hr	36.163	23.130	43.567	-8.764	125.915
NO_2 1hr	0.707	1.060	0.710	-1.362	2.824

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-17. Two pollutant models for four day moving averages for acute respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	2.771	0.759	2.810	1.291	4.352
Ozone 8hr	-3.514	1.267	-3.453	-5.822	-1.026
PM_{10}	1.065	1.223	1.071	-1.322	3.522
CO 8hr	60.540	37.631	83.199	-12.380	283.039
PM_{10}	1.541	1.016	1.553	-0.449	3.595
NO_2 1hr	1.972	1.607	1.991	-1.172	5.255
$PM_{2.5}$	4.159	0.946	4.247	2.331	6.199
Ozone 8hr	-3.126	1.331	-3.077	-5.573	-0.516
$PM_{2.5}$	3.358	1.546	3.415	0.329	6.596
CO 8hr	23.021	40.178	25.886	-42.724	176.683
$PM_{2.5}$	3.456	1.109	3.516	1.289	5.792
NO_2 1hr	1.254	1.490	1.262	-1.652	4.263
CF Mass	1.095	1.769	1.101	-2.344	4.667
Ozone 8hr	-3.345	1.305	-3.290	-5.732	-0.784
CF Mass	-2.230	1.825	-2.205	-5.642	1.357
CO 8hr	94.158	24.922	156.403	57.320	317.889
CF Mass	-2.924	1.934	-2.882	-6.495	0.871
NO_2 1hr	4.826	1.368	4.944	2.168	7.796
Ozone 8hr	-3.115	1.303	-3.067	-5.512	-0.559
CO 8hr	90.493	24.232	147.176	53.723	297.444
Ozone 8hr	-4.691	1.266	-4.583	-6.921	-2.186
NO_2 1hr	5.618	1.207	5.779	3.305	8.312
CO 8hr	61.792	33.966	85.506	-4.669	260.979
NO_2 1hr	1.716	1.740	1.731	-1.680	5.260

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-18. Two pollutant models for four day moving averages for chronic respiratory hospitalizations, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	6.004	0.923	6.187	4.284	8.126
Ozone 8hr	-7.918	1.686	-7.612	-10.615	-4.508
PM_{10}	3.998	1.498	4.079	1.067	7.180
CO 8hr	64.355	47.564	90.322	-25.077	383.459
PM_{10}	5.682	1.245	5.847	3.295	8.461
NO_2 1hr	-0.719	2.102	-0.717	-4.723	3.458
$PM_{2.5}$	7.112	1.159	7.371	4.959	9.839
Ozone 8hr	-6.497	1.755	-6.290	-9.459	-3.010
$PM_{2.5}$	6.458	1.889	6.671	2.795	10.694
CO 8hr	27.139	50.224	31.179	-50.983	251.061
$PM_{2.5}$	7.706	1.367	8.011	5.154	10.944
NO_2 1hr	-1.075	1.935	-1.069	-4.751	2.755
CF Mass	7.165	2.182	7.427	2.930	12.122
Ozone 8hr	-8.567	1.728	-8.210	-11.267	-5.048
CF Mass	0.740	2.285	0.743	-3.669	5.357
CO 8hr	144.602	31.502	324.619	129.008	687.317
CF Mass	0.966	2.446	0.971	-3.756	5.930
NO_2 1hr	5.145	1.792	5.280	1.646	9.044
Ozone 8hr	-6.469	1.731	-6.265	-9.391	-3.030
CO 8hr	150.921	30.539	352.317	148.591	723.000
Ozone 8hr	-8.984	1.682	-8.592	-11.556	-5.529
NO_2 1hr	7.805	1.565	8.118	4.852	11.486
CO 8hr	169.732	43.127	445.928	134.440	1171.278
NO_2 1hr	-1.422	2.275	-1.412	-5.711	3.083

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Emergency Room Visits

Lag Analyses

The systematic analyses used for hospitalization data were repeated for the emergency room visit data. Table 4-19 shows the associations between the pollutants and each outcome by lag. There were few notable associations with cardiovascular visits. However, most of the PM metrics were associated with increases in both acute and chronic respiratory visits. In addition, ozone was associated with an inverse association with the respiratory visits as it was with hospitalizations for these conditions.

Table 4-19. Regression coefficients (β x 1,000) between air pollutants and emergency room visits by lag, Kaiser Permanente Central Valley Study, 1996-2000.

		Cardiovascular		Acute Respiratory		Chronic Respiratory	
Pollutant	Lag	β	p	β	p	β	p
PM_{10}	0	0.345	0.791	2.003	0.017	2.389	0.059
	1	0.152	0.705	1.773	0.092	2.593	0.035
	2	-0.037	0.921	2.381	0.002	2.469	0.031
	3	-0.330	0.533	2.594	0.000	2.086	0.113
	4	-0.314	0.569	2.448	0.000	1.907	0.016
	5	-0.379	0.520	1.777	0.009	2.044	0.006
$PM_{2.5}$	0	0.491	0.577	2.601	0.024	3.128	0.052
	1	1.269	0.346	1.994	0.249	3.525	0.028
	2	1.285	0.369	3.148	0.012	3.400	0.053
	3	0.787	0.665	3.895	0.000	4.480	0.000
	4	1.062	0.535	3.899	0.000	4.272	0.000
	5	0.774	0.783	3.229	0.003	3.901	0.002
CF Mass	0	-0.188	0.870	0.613	0.581	1.046	0.459
	1	-2.442	0.090	1.009	0.318	0.653	0.596
	2	-2.369	0.108	0.537	0.654	1.147	0.283
	3	-2.212	0.164	-0.642	0.160	-3.398	0.546
	4	-3.293	0.021	-0.757	0.124	-3.411	0.133
	5	-2.501	0.119	-2.214	0.093	-1.536	0.213
Ozone 8hr	0	-0.529	0.641	-0.253	0.701	-2.972	0.107
	1	-1.097	0.272	0.090	0.409	1.375	0.057
	2	-1.283	0.172	-1.233	0.063	0.077	0.422
	3	-1.859	0.025	-1.478	0.019	-1.204	0.090
	4	-1.503	0.100	-2.369	0.018	-1.284	0.005
	5	-0.915	0.618	-2.545	0.019	-1.340	0.005

Table 4-19. Regression coefficients (β x 1,000) between air pollutants and emergency room visits by lag, Kaiser Permanente Central Valley Study, 1996-2000.

		Cardiovascular		Acute Respiratory		Chronic Respiratory	
Pollutant	Lag	β	p	β	p	β	p
CO 8hr	0	9.326	0.635	35.880	0.206	42.458	0.031
	1	20.757	0.475	22.315	0.066	67.858	0.143
	2	7.374	0.637	42.352	0.088	65.913	0.078
	3	13.035	0.868	71.791	0.050	71.523	0.112
	4	2.914	0.679	67.223	0.070	59.459	0.077
	5	18.978	0.513	62.919	0.150	70.499	0.461
NO_2 1hr	0	1.116	0.429	2.612	0.381	1.667	0.016
	1	0.348	0.543	1.887	0.073	3.434	0.307
	2	-1.098	0.104	2.622	0.171	3.456	0.166
	3	-0.911	0.192	3.137	0.007	3.459	0.004
	4	-0.691	0.328	1.896	0.139	2.851	0.154
	5	-0.391	0.574	1.759	0.151	3.240	0.026
NO_3 (PM_{10})	0	5.072	0.356	10.442	0.019	9.193	0.168
	1	4.277	0.516	14.892	0.001	12.526	0.038
	2	4.945	0.404	13.654	0.003	7.049	0.273
	3	0.675	0.701	15.340	0.000	10.873	0.132
	4	4.278	0.511	16.400	0.000	8.441	0.150
	5	1.724	0.930	16.568	0.001	15.952	0.001
SO_4 (PM_{10})	0	25.598	0.244	55.586	0.001	1.534	0.925
	1	-3.698	0.870	33.048	0.090	17.818	0.431
	2	14.356	0.502	37.376	0.071	3.920	0.932
	3	-9.889	0.634	33.846	0.130	11.842	0.678
	4	-10.707	0.635	15.978	0.555	12.754	0.709
	5	9.235	0.649	33.829	0.147	43.530	0.065
TC (PM_{10})	0	2.263	0.787	8.677	0.029	12.249	0.004
	1	3.571	0.487	9.237	0.037	13.169	0.002
	2	3.061	0.587	11.432	0.001	11.733	0.014
	3	1.045	0.712	12.705	0.000	12.826	0.002
	4	2.019	0.806	13.514	0.000	12.988	0.001
	5	0.483	0.780	11.421	0.000	12.946	0.001

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Four Day Moving Average Analyses

Tables 4-20 to 4-22 show the four day moving average for each of the pollutants with cardiovascular, acute respiratory and chronic respiratory emergency room visits, respectively. In Table 4-20, $PM_{2.5}$ was nearly significant whereas the coarse fraction of PM and ozone were inversely associated with cardiovascular emergency room visits.

For acute respiratory emergency room visits, all pollutants but coarse fraction of PM and ozone were associated with emergency room visits (Table 4-21). Ozone was inversely associated with these emergency room visits. This was essentially the same pattern observed for chronic respiratory emergency room visits (Table 4-22), except that SO_4 (PM_{10}) was not associated.

Table 4-20. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, cardiovascular emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	0.089	0.637	0.089	-1.153	1.347
$PM_{2.5}$	1.512	0.777	1.524	-0.011	3.083
CF Mass	-3.189	1.328	-3.138	-5.627	-0.584
Ozone 8hr	-2.689	0.910	-2.654	-4.375	-0.901
CO 8hr	23.798	19.231	26.869	-12.972	84.948
NO_2 1hr	-0.237	0.876	-0.237	-1.935	1.490
NO_3 (PM_{10})	5.822	5.219	5.995	-4.311	17.411
SO_4 (PM_{10})	42.440	30.248	52.867	-15.504	176.562
TC (PM_{10})	4.120	2.933	4.206	-1.616	10.371

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-21. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	3.392	0.544	3.450	2.354	4.558
$PM_{2.5}$	5.057	0.636	5.187	3.885	6.507
CF Mass	0.324	1.297	0.324	-2.195	2.908
Ozone 8hr	-2.035	0.953	-2.015	-3.828	-0.168
CO 8hr	95.043	17.792	158.682	82.522	266.623
NO_2 1hr	6.173	0.920	6.368	4.467	8.303
NO_3 (PM_{10})	17.665	3.755	19.321	10.855	28.434
SO_4 (PM_{10})	131.312	23.910	271.776	132.677	494.032
TC (PM_{10})	15.641	2.398	16.931	11.563	22.558

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-22. Percent change in rate per 10 unit increase in pollutant level for four-day moving average, chronic respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	3.708	0.557	3.778	2.650	4.917
$PM_{2.5}$	6.268	0.658	6.469	5.104	7.851
CF Mass	-0.431	1.332	-0.430	-2.996	2.204
Ozone 8hr	-1.502	0.992	-1.491	-3.389	0.444
CO 8hr	133.519	18.680	280.071	163.549	448.112
NO_2 1hr	7.113	0.932	7.373	5.429	9.352
NO_3 (PM_{10})	9.099	3.838	9.526	1.589	18.083
SO_4 (PM_{10})	41.156	25.147	50.917	-7.811	147.055
TC (PM_{10})	18.393	2.424	20.193	14.617	26.040

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Season Analyses

Table 4-23 to 4-25 present similar analyses stratified by season for each outcome. For cardiovascular emergency room visits (Table 4-23), $PM_{2.5}$ in spring and coarse fraction of PM in winter were associated with an increase in visits, while the coarse fraction of PM was inversely associated with these visits in fall.

For acute respiratory emergency room visits (Table 4-24) many of the pollutants (e.g., PM_{10}, $PM_{2.5}$, CO, NO_2, and NO_3 (PM_{10})) were associated with an increase in emergency room visits for spring, summer and winter. Of the other pollutants, the coarse fraction of PM and ozone, SO_4 (PM_{10}), and TC (PM_{10}) were associated in the winter. SO_4 (PM_{10}) and TC (PM_{10}) were also associated with visits in the spring.

For chronic respiratory emergency room visits (Table 4-25), PM_{10}, and $PM_{2.5}$, were associated with an increase in visits in all seasons, but coarse fraction was not associated in any season. Other pollutants were associated with a winter season having the most consistent associations across the pollutants.

Table 4-23. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, cardiovascular emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Spring	1.895	3.236	1.913	-4.349	8.586
	Summer	-2.083	2.476	-2.061	-6.702	2.810
	Fall	-0.821	1.118	-0.818	-2.968	1.380
	Winter	1.147	1.158	1.153	-1.117	3.476
$PM_{2.5}$	Spring	14.339	4.981	15.418	4.682	27.255
	Summer	3.109	5.001	3.158	-6.474	13.782
	Fall	1.741	1.438	1.756	-1.073	4.666
	Winter	0.161	1.232	0.161	-2.230	2.610
CF Mass	Spring	-2.457	3.796	-2.427	-9.424	5.110
	Summer	-5.849	3.779	-5.681	-12.416	1.570

Table 4-23. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, cardiovascular emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
	Fall	-4.910	1.993	-4.792	-8.440	-0.998
	Winter	7.826	3.788	8.140	0.402	16.474
Ozone 8hr	Spring	-1.875	2.767	-1.858	-7.038	3.611
	Summer	-0.871	1.780	-0.868	-4.267	2.652
	Fall	-6.238	1.771	-6.047	-9.253	-2.728
	Winter	0.151	2.633	0.151	-4.885	5.455
CO 8hr	Spring	115.922	83.541	218.745	-38.009	1538.922
	Summer	-126.133	158.141	-71.672	-98.723	528.548
	Fall	29.999	32.091	34.985	-28.035	153.192
	Winter	16.785	34.604	18.276	-39.974	133.052
NO_2 1hr	Spring	1.624	2.454	1.637	-3.136	6.645
	Summer	-3.892	2.458	-3.817	-8.342	0.931
	Fall	-1.605	1.553	-1.592	-4.542	1.449
	Winter	2.609	2.987	2.644	-3.192	8.831
NO_3 (PM_{10})	Spring	51.409	38.883	67.212	-21.965	258.298
	Summer	-20.430	96.496	-18.479	-87.701	440.330
	Fall	15.426	12.209	16.679	-8.153	48.225
	Winter	7.377	6.650	7.656	-5.500	22.643
SO_4 (PM_{10})	Spring	58.956	196.086	80.320	-96.137	8317.069
	Summer	-176.245	406.423	-82.838	-99.994	49345.023
	Fall	26.444	65.242	30.270	-63.735	367.951
	Winter	68.945	40.633	99.261	-10.144	341.873
TC (PM_{10})	Spring	21.038	13.420	23.415	-5.128	60.547
	Summer	-3.999	16.049	-3.920	-29.851	31.597
	Fall	1.746	5.122	1.762	-7.958	12.508
	Winter	5.852	5.038	6.027	-3.943	17.032

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-24. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutant	Season	β (x1000)	STD (x1000)	Percent change	Lower	Upper
PM_{10}	Spring	6.552	3.111	6.771	0.455	13.484
	Summer	3.153	2.814	3.204	-2.334	9.055
	Fall	-0.980	1.307	-0.976	-3.480	1.593
	Winter	5.320	0.806	5.464	3.811	7.143
$PM_{2.5}$	Spring	18.806	4.689	20.690	10.092	32.308
	Summer	12.308	5.494	13.098	1.551	25.957
	Fall	0.959	1.637	0.964	-2.225	4.257
	Winter	5.923	0.902	6.102	4.243	7.995
CF Mass	Spring	2.907	3.691	2.950	-4.236	10.675
	Summer	-0.421	4.409	-0.420	-8.664	8.568
	Fall	-3.985	2.299	-3.907	-8.140	0.522
	Winter	10.495	2.735	11.065	5.268	17.182
Ozone 8hr	Spring	2.093	2.721	2.115	-3.188	7.708
	Summer	1.107	2.147	1.113	-3.054	5.459
	Fall	-1.464	2.174	-1.453	-5.564	2.837
	Winter	5.880	2.314	6.056	1.354	10.977
CO 8hr	Spring	175.021	81.858	475.579	15.696	2763.464
	Summer	453.081	181.892	9183.385	162.672	327994.828
	Fall	27.922	38.913	32.210	-38.337	183.466
	Winter	110.777	28.236	202.759	74.080	426.558
NO_2 1hr	Spring	5.200	2.365	5.337	0.566	10.335
	Summer	5.897	2.947	6.075	0.122	12.381
	Fall	3.448	1.853	3.508	-0.185	7.338
	Winter	8.764	2.495	9.160	3.950	14.631
NO_3 (PM_{10})	Spring	78.429	36.115	119.085	7.943	344.665
	Summer	157.076	74.381	381.031	11.952	1966.884
	Fall	-18.589	13.693	-16.963	-36.509	8.599
	Winter	28.263	4.471	32.661	21.530	44.811
SO_4 (PM_{10})	Spring	399.134	181.219	5312.749	55.187	188691.057
	Summer	449.737	337.662	8878.032	-88.007	6720670.572
	Fall	-97.258	72.457	-62.189	-90.862	56.453
	Winter	219.283	29.744	796.057	400.209	1505.168
TC (PM_{10})	Spring	44.399	12.923	55.892	21.010	100.830

Table 4-24. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
	Summer	23.287	18.572	26.222	-12.291	81.646
	Fall	-0.495	5.942	-0.494	-11.433	11.796
	Winter	21.401	3.513	23.863	15.622	32.692

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-25. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, chronic respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	Season	β (x1000)	STD (x1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Spring	7.606	2.988	7.902	1.764	14.411
	Summer	4.441	2.751	4.541	-0.947	10.333
	Fall	2.483	1.261	2.514	0.011	5.081
	Winter	3.480	0.844	3.541	1.842	5.268
$PM_{2.5}$	Spring	10.187	4.885	10.724	0.615	21.850
	Summer	15.850	5.124	17.176	5.979	29.556
	Fall	4.995	1.624	5.121	1.828	8.521
	Winter	4.779	0.942	4.895	2.976	6.849
CF Mass	Spring	7.055	3.654	7.310	-0.106	15.276
	Summer	-0.557	4.482	-0.555	-8.918	8.576
	Fall	-0.308	2.199	-0.308	-4.513	4.083
	Winter	4.027	2.933	4.109	-1.708	10.270
Ozone 8hr	Spring	3.839	2.663	3.914	-1.370	9.481
	Summer	0.364	2.185	0.365	-3.843	4.756
	Fall	2.908	2.153	2.951	-1.302	7.387
	Winter	4.714	2.536	4.827	-0.257	10.169
CO 8hr	Spring	-91.698	84.602	-60.027	-92.386	109.850
	Summer	516.568	180.008	17415.591	414.238	596503.422
	Fall	42.788	39.660	53.401	-29.493	233.750
	Winter	136.720	30.250	292.437	116.909	610.004
NO_2 1hr	Spring	0.039	2.337	0.039	-4.441	4.728

Table 4-25. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by season, chronic respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutant	Season	β (x1000)	STD (x1000)	Percent change	Lower	Upper
	Summer	6.926	2.948	7.171	1.155	13.546
	Fall	3.698	1.827	3.767	0.116	7.551
	Winter	8.467	2.644	8.836	3.340	14.625
NO_3 (PM_{10})	Spring	35.153	36.213	42.123	-30.110	189.014
	Summer	7.672	89.275	7.974	-81.233	521.216
	Fall	3.510	13.011	3.572	-19.742	33.659
	Winter	17.928	4.633	19.635	9.251	31.007
SO_4 (PM_{10})	Spring	-30.646	182.511	-26.395	-97.942	2533.100
	Summer	25.263	365.214	28.741	-99.900	165279.560
	Fall	-47.957	72.746	-38.095	-85.124	157.605
	Winter	146.366	31.860	332.174	131.451	706.974
TC (PM_{10})	Spring	46.469	12.798	59.151	23.844	104.525
	Summer	29.896	18.196	34.845	-5.606	92.630
	Fall	10.481	5.830	11.050	-0.941	24.492
	Winter	13.590	3.645	14.557	6.659	23.039

Poisson regression models with smoothing splines (3 df) for date, temperature, and relative humidity and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Age Analyses

Tables 4-26 to 4-28 show the results for the four-day moving average for cardiovascular, acute respiratory and chronic respiratory emergency room visits, respectively, by age. Similar to the cardiovascular hospitalizations, the emergency room data are limited to those over 50 years of age. Increased visits were associated with $PM_{2.5}$, CO, and NO_2, while the coarse fraction was inversely associated (Table 4-26). Nearly all pollutants were associated with acute respiratory emergency room visits except for the coarse fraction mass and ozone (Table 4-27). These associations were generally for all age categories. Chronic respiratory emergency room visits were associated with most the pollutants except for the coarse fraction and ozone (Table 4-28).

Table 4-26. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, cardiovascular emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	50 +	0.027	0.669	0.027	-1.276	1.348
$PM_{2.5}$		1.351	0.817	1.360	-0.250	2.996
CF Mass		-2.654	1.396	-2.619	-5.247	0.083
Ozone 8hr		-2.476	0.962	-2.445	-4.267	-0.589
CO 8hr		22.537	20.303	25.279	-15.850	86.511
NO_2 1hr		0.116	0.924	0.116	-1.680	1.945
NO_3 (PM_{10})		5.682	5.508	5.846	-4.986	17.914
SO_4 (PM_{10})		43.439	32.088	54.402	-17.679	189.595
TC (PM_{10})		4.028	3.071	4.111	-1.971	10.569

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-27. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	< 20	3.633	0.868	3.700	1.951	5.479
	20-49	2.869	1.034	2.911	0.846	5.018
	50 +	3.518	0.867	3.581	1.836	5.356
$PM_{2.5}$	< 20	4.981	1.048	5.107	2.970	7.287
	20-49	4.947	1.198	5.071	2.632	7.568
	50 +	5.950	0.984	6.131	4.104	8.198
CF Mass	< 20	0.509	1.996	0.510	-3.347	4.521
	20-49	1.510	2.503	1.521	-3.339	6.625
	50 +	-2.370	2.149	-2.342	-6.370	1.860
Ozone 8hr	< 20	-1.636	1.516	-1.623	-4.503	1.344

Table 4-27. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
	20-49	0.204	1.815	0.204	-3.299	3.834
	50 +	-4.968	1.523	-4.847	-7.645	-1.964
CO 8hr	< 20	111.198	28.171	204.037	75.038	428.106
	20-49	89.200	33.401	144.000	26.787	369.573
	50 +	97.047	28.704	163.918	50.362	363.236
NO_2 1hr	< 20	8.741	1.435	9.135	6.109	12.248
	20-49	4.137	1.752	4.224	0.705	7.866
	50 +	6.092	1.498	6.282	3.207	9.448
NO_3 (PM_{10})	< 20	22.374	6.173	25.075	10.821	41.163
	20-49	-0.156	7.174	-0.156	-13.252	14.918
	50 +	22.472	5.572	25.198	12.245	39.645
SO_4 (PM_{10})	< 20	82.243	39.631	127.603	4.673	394.906
	20-49	20.628	44.864	22.909	-48.986	196.126
	50 +	226.819	35.336	866.185	383.362	1831.295
TC (PM_{10})	< 20	16.849	3.900	18.352	9.641	27.755
	20-49	11.769	4.540	12.490	2.913	22.958
	50 +	18.253	3.741	20.025	11.539	29.157

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-28. Percent change in rate per 10 unit increase in pollutant level for four-day moving average by age, chronic respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Age	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	< 20	5.588	1.169	5.747	3.352	8.198
	20-49	2.487	0.919	2.518	0.689	4.381
	50 +	3.711	0.841	3.780	2.084	5.505
$PM_{2.5}$	< 20	8.925	1.350	9.335	6.479	12.268
	20-49	4.619	1.084	4.727	2.526	6.975
	50 +	6.298	0.984	6.501	4.467	8.574
CF Mass	< 20	-0.790	2.720	-0.786	-5.937	4.646
	20-49	-0.516	2.138	-0.515	-4.597	3.742
	50 +	-0.782	2.076	-0.779	-4.734	3.341
Ozone 8hr	< 20	-5.742	1.979	-5.580	-9.173	-1.845
	20-49	-0.290	1.579	-0.290	-3.328	2.844
	50 +	-0.537	1.524	-0.535	-3.463	2.481
CO 8hr	< 20	196.415	37.636	612.885	240.920	1390.685
	20-49	101.794	29.416	176.750	55.488	392.583
	50 +	123.505	28.653	243.856	96.100	502.944
NO_2 1hr	< 20	8.586	1.821	8.965	5.144	12.925
	20-49	6.127	1.483	6.319	3.273	9.454
	50 +	6.850	1.377	7.090	4.237	10.020
NO_3 (PM_{10})	< 20	19.191	7.868	21.156	3.841	41.358
	20-49	-6.283	6.534	-6.090	-17.379	6.741
	50 +	14.186	5.657	15.242	3.148	28.754
SO_4 (PM_{10})	< 20	36.297	54.043	43.759	-50.156	314.625
	20-49	-69.586	40.939	-50.135	-77.648	11.243
	50 +	106.495	37.491	190.069	39.114	504.830
TC (PM_{10})	< 20	29.845	4.862	34.777	22.526	48.253
	20-49	11.190	4.045	11.840	3.316	21.067
	50 +	18.717	3.627	20.583	12.307	29.468

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Two Pollutant Analyses

Two pollutant models for emergency room visit data are presented in Tables 4-29 to 4-31. The relevant single pollutant models for comparison are in table 4-20 to 4-22.

For cardiovascular emergency room visits (Table 4-29), the primary pollutant effect that was robust with other pollutants in the model was ozone, and this was the inverse association noted earlier. The only other association noted in the single pollutant models was an inverse association observed with the coarse fraction and the effect estimate was reasonably stable with other pollutants in the model.

Acute respiratory emergency room visit results are shown in Tables 4-30. In general, the effect estimate for PM_{10}, and $PM_{2.5}$ were robust in the presence of other pollutants. The effect of CO was stable except when in a model with $PM_{2.5}$, when the CO effect estimate was negative (inversely related). The NO_2 estimate was generally lower when PM was also in the model.

Table 4-31 presents the data for chronic respiratory emergency room visit. The PM_{10}, $PM_{2.5}$, and NO_2 effect estimates were essentially unchanged when other pollutants were in the model. The CO effect estimate was considerably lower when $PM_{2.5}$ was also in the model.

Table 4-29. Two pollutant models for four day moving averages for cardiovascular emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutant	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	0.531	0.635	0.532	-0.712	1.792
Ozone 8hr	-2.823	0.913	-2.784	-4.507	-1.029
PM_{10}	-1.029	0.986	-1.023	-2.917	0.908
CO 8hr	48.122	29.713	61.805	-9.621	189.679
PM_{10}	0.277	0.855	0.277	-1.388	1.971
NO_2 1hr	-0.374	1.180	-0.374	-2.652	1.958
$PM_{2.5}$	1.463	0.797	1.473	-0.100	3.071
Ozone 8hr	-2.639	0.946	-2.605	-4.393	-0.783
$PM_{2.5}$	1.763	1.281	1.778	-0.746	4.367
CO 8hr	-8.227	32.057	-7.898	-50.865	72.643
$PM_{2.5}$	2.528	0.941	2.560	0.687	4.469
NO_2 1hr	-1.983	1.080	-1.964	-4.017	0.133
CF Mass	-1.878	1.380	-1.861	-4.480	0.830
Ozone 8hr	-2.104	0.962	-2.082	-3.912	-0.218
CF Mass	-3.624	1.380	-3.559	-6.132	-0.915
CO 8hr	35.576	20.272	42.726	-4.072	112.354
CF Mass	-3.429	1.477	-3.371	-6.128	-0.533
NO_2 1hr	0.583	0.995	0.585	-1.358	2.566
Ozone 8hr	-2.706	0.931	-2.670	-4.429	-0.878
CO 8hr	23.731	19.664	26.784	-13.765	86.399
Ozone 8hr	-2.926	0.921	-2.884	-4.621	-1.114
NO_2 1hr	0.677	0.886	0.679	-1.053	2.442
CO 8hr	60.282	28.505	82.726	4.511	219.475
NO_2 1hr	-2.332	1.299	-2.305	-4.762	0.215

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table 4-30. Two pollutant models for four day moving averages for acute respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	3.761	0.545	3.833	2.729	4.948
Ozone 8hr	-3.280	0.960	-3.227	-5.030	-1.389
PM_{10}	2.964	0.851	3.008	1.305	4.741
CO 8hr	28.411	27.697	32.858	-22.798	128.639
PM_{10}	2.142	0.731	2.165	0.713	3.639
NO_2 1hr	3.766	1.231	3.838	1.362	6.375
$PM_{2.5}$	5.190	0.662	5.328	3.971	6.702
Ozone 8hr	-2.115	0.998	-2.093	-3.989	-0.160
$PM_{2.5}$	5.418	1.051	5.567	3.414	7.765
CO 8hr	-12.668	29.503	-11.898	-50.586	57.079
$PM_{2.5}$	4.049	0.777	4.133	2.558	5.731
NO_2 1hr	3.051	1.133	3.098	0.834	5.413
CF Mass	1.710	1.331	1.724	-0.896	4.414
Ozone 8hr	-2.684	0.989	-2.649	-4.518	-0.742
CF Mass	-0.917	1.350	-0.913	-3.501	1.744
CO 8hr	94.672	18.658	157.724	78.788	271.511
CF Mass	-2.530	1.442	-2.498	-5.215	0.296
NO_2 1hr	6.736	1.042	6.968	4.805	9.176
Ozone 8hr	-2.360	0.991	-2.333	-4.212	-0.417
CO 8hr	101.494	18.446	175.919	92.204	296.096
Ozone 8hr	-4.984	0.959	-4.862	-6.634	-3.056
NO_2 1hr	8.223	0.926	8.571	6.619	10.558
CO 8hr	19.979	26.152	22.115	-26.859	103.882
NO_2 1hr	5.465	1.354	5.617	2.852	8.457

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Table 4-31. Two pollutant models for four day moving averages for chronic respiratory emergency room visits, Kaiser Permanente Central Valley Study, 1996-2000.

				95% CI	
Pollutant	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	3.910	0.560	3.988	2.852	5.136
Ozone 8hr	-2.585	1.002	-2.552	-4.447	-0.619
PM_{10}	2.455	0.886	2.485	0.720	4.281
CO 8hr	71.133	29.350	103.671	14.577	262.040
PM_{10}	2.213	0.757	2.238	0.732	3.767
NO_2 1hr	4.374	1.261	4.471	1.920	7.086
$PM_{2.5}$	6.145	0.684	6.338	4.922	7.774
Ozone 8hr	-1.079	1.043	-1.073	-3.075	0.970
$PM_{2.5}$	5.920	1.096	6.099	3.845	8.402
CO 8hr	13.883	31.207	14.892	-37.677	111.804
$PM_{2.5}$	4.934	0.810	5.058	3.404	6.739
NO_2 1hr	3.282	1.158	3.336	1.017	5.709
CF Mass	0.231	1.376	0.231	-2.437	2.972
Ozone 8hr	-1.648	1.040	-1.635	-3.620	0.391
CF Mass	-2.501	1.399	-2.470	-5.107	0.241
CO 8hr	138.821	19.822	300.768	171.748	491.042
CF Mass	-4.200	1.493	-4.113	-6.879	-1.266
NO_2 1hr	8.264	1.070	8.615	6.360	10.917
Ozone 8hr	-1.423	1.036	-1.413	-3.395	0.609
CO 8hr	129.806	19.366	266.217	150.551	435.282
Ozone 8hr	-3.530	0.998	-3.468	-5.339	-1.561
NO_2 1hr	7.820	0.936	8.134	6.168	10.137
CO 8hr	64.451	28.041	90.505	9.956	230.060
NO_2 1hr	4.784	1.404	4.900	2.053	7.827

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

SENSITIVITY ANALYSES

Several analyses were also undertaken to assess the sensitivity of the results to our model specifications. One such analysis was to assess the shape of the exposure-response curve. The models above are by definition assessing only a linear relationship. Clearly other types of response patterns are possible. For these analyses all exposure data for each pollutant were put into quartiles and modeled as dummy variables with the lowest quartile serving as the reference category. Thus, the percent change in the rate of hospitalization or emergency room admission for the second, third and highest quartile was estimated. We also analyzed the data stratified by center or community, and gender for each outcome and each type of admission.

Appendix D, Tables D-1 to D-3, contain the results for the quartile analyses for hospitalization data. Relatively few of the pollutants were associated with cardiovascular hospitalizations in a clear dose response fashion (Table D-1). The pollutant CO was the only one that showed a constant increase in the rate of admissions with an increase in exposure. The pattern for NO_2 was in a J-shape in that the response dropped going from the lowest to next lowest, but increased steadily with the highest quartile having the highest percent change increase in the rate. For acute respiratory hospitalizations, $PM_{2.5}$, CO, and TC (PM_{10}) demonstrated approximate dose response curves, with the dose-response curve for PM_{10}, and NO_2, being more of a J-shaped curve. The patterns were clearer for chronic respiratory disease in that $PM_{2.5}$, CO, NO_2, SO_4 (PM_{10}) and TC (PM_{10}) were all related in a dose response pattern (Table D-3). For PM_{10} and NO_3 (PM_{10}) the highest quartile had the highest percent increase. In addition, the inverse association with ozone was also related in a dose response in that the higher the pollutant level the lower the risk of hospitalization due to chronic respiratory disease, although the relationship was only significant in the highest ozone quartile.

We also conducted stratified analyses by center for hospitalization data and the results are presented in Appendix E in Tables E-1 to E-3. In general there were no important difference across center for cardiovascular hospitalizations except for CO where Fresno seemed to have a high, albeit not statistically significantly so, risk (Table E-1). There were interesting patterns in the acute respiratory hospitalization data (Table E-2). While most pollutant-outcome associations were similar across center, for the coarse fraction mass all centers had relatively high positive coefficients except for Sacramento where the coefficients were negative. SO_4 (PM_{10}) and TC (PM_{10}) coefficients were weakest for Sacramento and similarly high for the other centers. Table E-3 shows the chronic respiratory hospitalization results. The pattern for this outcome was quite similar to that of the acute respiratory hospitalizations.

We found no substantial differences in hospitalization results when the data were stratified by gender (Appendix F, Tables F-1 to F-3). This was the case for each of the hospitalization outcomes.

Appendix G contains the quartile analysis for the emergency room data. The pollutants $PM_{2.5}$, CO and SO_4 (PM_{10}) all showed a positive dose response pattern for cardiovascular emergency room visits (Table G-1). While there was no evidence of a dose response, the percent increase in the rate admission for the highest quartile for NO_3 (PM_{10}) was significantly elevated. In contrast, there was an inverse pattern for both the coarse fraction of PM and ozone with increasing pollutant level being associated with a decreasing rate of emergency room visits. The pattern was very similar for both the acute (Table G-2) and chronic (Table G-3) respiratory emergency room visit data. The patterns were clearer and stronger for the respiratory conditions results compared to the cardiovascular emergency room data.

Appendix H. has the analyses stratified by center for emergency room visits. No clear differences were observed across center for cardiovascular emergency room visit data except for $PM_{2.5}$ where strong positive associations were found for Sacramento while strong negative associations were found for Fresno. A somewhat similar although weaker pattern was observed between these two centers with the CO and some of the PM chemical component results. In contrast, the acute respiratory emergency room data generally showed similarity across Sacramento, Modesto and Fresno. The results from Stockton were usually inconsistent or showed no association when the results for the other sites were associated. The chronic respiratory emergency room data were most similar between Sacramento, Modesto and Fresno for most pollutants. As with the acute respiratory results, no consistency was observed between Stockton and the other centers. This latter pattern could be due to random variation due to the relatively small numbers of KPNC members, patterns in seeking care, or underlying patient profile patterns.

As with the hospitalization data, we found no convincing differences in emergency room visit results when the data were stratified by gender (Appendix I, Tables I-1 to I-3).

DISCUSSION

The results of this study support an association between ambient air pollution and cardiovascular, and chronic and acute respiratory hospitalizations and emergency room visits. The strength of the association varied by pollutant, outcome, type of admission, and to some extent, time of year, and age. The age structure of this population closely mimics that of the geographic area. As with other studies, cardiovascular disease occurs largely among older individuals and that is where we have observed associations in our data. Asthma, emphysema and chronic bronchitis are the primary diagnoses of our chronic respiratory outcome group. The pattern of associations observed with chronic respiratory outcomes is largely due to the pattern of chronic respiratory disease within this grouping. More specifically, the associations observed in the 50 years and older age group is almost all due the association with emphysema and chronic bronchitis (that is likely due to tobacco use). In the youngest group (e.g., those 20 years or younger) these associations are primarily due to asthma. For the middle group the diagnoses are mixed, however asthma also predominates in this group. Thus, while we did not analyze specific diagnoses due to the relatively small number of events, the associations we did observe suggest independent associations with more specific outcome categories, namely asthma and COPD. Nonetheless, additional data (e.g., years) in this study would likely make such analyses feasible by increasing the number of events by specific diagnostic categories.

In general we observed strong and consistent increases in the rate of hospitalization and/or emergency room visits for acute or chronic respiratory conditions associated with PM_{10} and $PM_{2.5}$. In addition, CO and NO_2 were often associated as well. Finally, we found the nitrate, sulfate and total carbon component of PM_{10} to be associated with respiratory admissions. These associations were generally consistent across types of analyses (e.g., lag versus moving average) or the type of stratification. Age was also observed to be an important factor in our analyses. Not surprisingly, only the older age category had significant associations between most of the pollutants and respiratory disease. In two pollutant models, the effect estimates for PM_{10} and $PM_{2.5}$ were robust when other pollutants were put into the model. This was generally true for acute and chronic respiratory admissions. Finally, some of our pollutant-outcome associations were in the opposite direction from what we expected, most notably ozone. The ozone-outcome associations were consistently in the inverse direction and across outcomes. While we do not know why this would be we believe that other factors, such as summer heat and air conditioning may have influenced the associations in a way we are unable to analytically control [23]. In addition, the coarse fraction of PM was often inversely associated. However, since we found poor correlations between the coarse fraction and other PM measures, and had a number of days with zero values, this likely represents measurement error in that it is a calculated metric using data from two different measurement sources. Thus, we believe that it is difficult to arrive at any conclusion regarding coarse fraction-outcome associations from this study. As noted in the exposure assignment section, misclassification of exposure may be part of the explanation.

The results for the PM chemical composition data provide an intriguing glimpse at pollutants that are increasingly of interest. Of particular note are the associations noted for the nitrate, sulfate and total carbon components of PM_{10}. Additional data, if possible, would be highly desirable.

As for the primary pollutants of interest, we often found associations for many of the pollutants were similar across hospitalization or emergency room visits. However, in analyses where not all pollutants were associated, an overview would suggest that various particle mass measures and CO and NO_2 predominated, particularly for the respiratory endpoints studied. The results for carbon monoxide present a different interpretation. Studies have found using monitoring data at the neighborhood level that CO is poorly spatially distributed compared to the other pollutants included in this study. In particular, CO concentrations decrease rapidly as the distance from major roadways increases [24-26]. This likely means that there is spatial heterogeneity within our exposure units that may violate our assumption of uniformity with exposure units. Thus, while we have included the CO results, we have serious questions about the interpretation of these data. It may be that our CO results suggest the source or marker of the pollution rather than being an exposure-outcome relationship. Given the pattern of our results, combustion products are suggested as the source. In the multipollutant models for the cardiovascular endpoints, we generally found that the estimate of effect associated with CO and NO_2 were robust with other pollutants in the model in the hospitalization results. There was little consistency observed for the cardiovascular emergency room visits. For the acute respiratory endpoints, $PM_{2.5}$, but not PM_{10} or the coarse fraction, was robust with other pollutants in the model. CO and NO_2 estimates were reduced when PM measures were introduced it the same model. Ozone was consistently inversely associated with acute respiratory admissions when any of the other pollutants were also in the analysis. The results for the chronic respiratory outcomes were similar to those of the acute respiratory admissions. If anything, the results were clearer in that the associations for PM_{10}, $PM_{2.5}$, and ozone were unaffected by other pollutants being in the model. NO_2 effect estimates were greatly reduced when PM_{10}, and $PM_{2.5}$ were in the same model.

These findings are consistent with prior studies of the acute health effects of ambient air pollution. Extensive reviews have been written that summarize this now large body of work [27-31]. Past studies have shown both gaseous pollutants and particulate matter to be associated with emergency room and hospitalization visits for cardiopulmonary conditions [2;32-40]. The association with ozone has been generally more variable in that many [32;33;38;41], but not all studies [34;42] have found an increased risk of respiratory or cardiovascular morbidity. Unfortunately, not all studies have reported ozone results. In contrast, the association between particulate matter (reported as either total suspended particles or TSP, PM_{10}, or $PM_{2.5}$) has consistently been associated with acute morbidity. Several of the studies looking at acute adverse health effects associated with ambient air pollution have been conducted in California [2;34-37;37;40;41;43-47]. Only a few of these studies were time-series studies of emergency room or hospitalizations, most were mortality studies. In this study we found inconsistent associations between the coarse fraction and our outcomes. This is in contrast to two other California studies that report on this particulate matter measure. One study [2] by our group in the Los Angeles Air Basin (LAAB) found more consistent associations between cardiovascular, chronic respiratory and acute respiratory hospitalizations and the coarse fraction than was found in this study. In contrast, Fairley [48] found $PM_{2.5}$ to be the robust air pollutant in multipollutant models for mortality, while Lipsett et al. [49] reported that PM associations were robust with NO_2 in the model for asthma hospitalizations. Both studies were conducted in Santa Clara County. Both this study and the LAAB study included two pollutant models with both the coarse fraction and $PM_{2.5}$ in the same analytic model. While most studies have not reported results from multipollutant models, some have. In these studies, the particulate matter results have generally remained robust when in the presence of other (gaseous) pollutants [6]. In another study in the Los Angeles area, ozone was found to be associated in single pollutant models, but not in models when particles were added [50]. In contrast, we found in the South Coast Air Basin that the effects on adverse outcomes, particularly for cardiovascular outcomes, were robust for particle measures when any gas pollutant was added to the analysis [6]. Indeed, we found that the results for the coarse fraction were robust in presence of $PM_{2.5}$ in the model. Studies in other areas have also found that PM associations are robust in multipollutant models [51]. A study in Canada with four ambient pollutants in a single model showed that all pollutants were associated with an increase in mortality [52]. A study by Ostro et al. [34;35] in the Coachella Valley found all-cause, cardiovascular, and respiratory mortality to be associated with particulate matter, although the most consistent findings were with the coarse fraction. While CO and NO_2 were also associated in this area, ozone was not [34]. There are likely to be slight differences in the composition of particulate matter in these three areas, however it is unlikely to fully explain this general trend. Alternative explanations may be based in population differences (e.g., age, gender, disease history, historical environmental exposures, or socioeconomic status), housing status (e.g., air conditioning), or other environmental conditions (e.g., wind or allergen patterns), among others.

Prior studies have found particulate matter to be associated with respiratory emergency room admissions [33;42;53-58]. One of these, conducted in Santa Clara County California, found the PM associated asthma admissions to vary by ambient temperature and no association with ozone [42]. We did not find evidence of a PM-temperature interaction in our data set. As in our study, many of the above mentioned studies have found carbon monoxide (CO) to be associated with short-term adverse outcomes [38;41;45;47]. As we have noted earlier, it remains unclear to us if this is a direct effect or a general marker for the adverse effects associated with combustion products.

STRENGTHS AND LIMITATIONS

Several features of this study make it different from most time-series studies that have been published in the past. First, the use of residential address to assign exposure has been a method used largely in our studies [2]. This approach to assign exposure represents what we believe is an improvement over typical single time-series studies that typically use large geographic boundaries such as county or city limits. Measurement error remains an issue for this study, as in all studies using ambient monitors. In single time-series studies, movement outside of the study area (e.g., the city or county being studied) is unlikely. However, individual or smaller group exposure will likely be misclassified if there is spatial variation in addition to the time variation.

In any study such as this multiple comparisons are a concern. When so many analyses are undertaken there are obviously going to be some statistically significant associations that are due to random variation or chance. While some may suggest that adjustments for multiple comparisons are needed, we believe this unnecessarily restricts the interpretation of the data. We have, however, focused our attention and interpretation largely on patterns of association in our data and not individual statistically significant results. Results that were internally consistent with other results, and were at or approached statistical significance were interpreted as being important findings. For example, we would focus on patterns within a set of analyses (e.g., all pollutants for cardiovascular hospitalizations), across types of analyses (e.g., associations seen in lag analyses reflected in four day moving average analyses), or across type of outcomes (e.g., hospitalizations compared to emergency room visits). In taking this approach we believe we have put emphasis on those associations that are important.

SECTION 5. SUMMARY AND CONCLUSIONS

In summary, we found consistent air pollution effects and acute and chronic respiratory hospitalizations and emergency room visits among Kaiser Permanente members living in the Central Valley of California. These associations were consistent across type of analysis and type of admission (hospitalization or emergency room visit). Of the pollutants studied we found consistent associations with PM_{10} and $PM_{2.5}$. To a lesser extent CO and NO_2 were associated with adverse outcomes in our study. In contrast we did not find convincing evidence of an association between the coarse fraction of PM and our outcomes. In addition, our results for cardiovascular admissions were less impressive and found inconsistent results at best with the pollutants studied. Finally, some of our pollutant-outcome associations were in the opposite direction from what we expected, most notably ozone.

SECTION 6. RECOMMENDATIONS

The exposure dataset collected by the California Air Resources Board has the potential to address significant remaining questions related to adverse health effects associated with exposure to ambient air pollution. A major need for epidemiologic studies is always to have improved exposure assessments. This study was able to take advantage of some improvements in the measurement of exposure data available from the California Air Resources Board. Nonetheless, additional exposure data are needed. First, the detailed data collection of the various PM chemical components continues to be an important addition and should be expanded. Second, the near daily nature of the complete dataset is another important improvement. Having daily data on all the pollutants of interest allows analyses that have been difficult in the past, such as moving average analyses with multiple pollutants. What can be improved is also just as clear. Our coarse fraction data suggests improvements in the measurement of both PM_{10} and $PM_{2.5}$ should be made to improve the analytic capabilities of studies such as this one. In addition, when studying areas of relatively small populations such as the Central Valley, the ability to have sufficient power to detect the relatively modest excess risks that are expected will demand long time-series, particularly if the issue of multipollutant studies are to be addressed. The exposure datasets for these types of studies demand continuous, and daily monitoring of all pollutants over extended (e.g., many years) time periods. Another aspect of this theme that deserves more attention is the health effects of rapid changes in exposure. Namely, while the moving average analyses showed adverse health effects, it may be that sudden changes (e.g., increases) in exposure level are associated with greater adverse health effects. For example, going from a good or mild air quality day to a much poorer air quality day may be associated with greater adverse health effects than the fourth consecutive poor air quality day.

Another area that was not addressed in this study is that of vulnerable populations. The Kaiser Permanente environment, indeed this dataset, can be used to study how socioeconomic status race/ethnicity, or disease history, among other interesting areas, can modify pollution-outcome associations. The ability to link information such as data derived from KPNC clinical sources and from external sources such as the U.S. Census among a diverse population is an unusual opportunity in this country. Despite KPNC being an “insured population”, the breadth of socioeconomic status within the health plan is quite broad and been used repeatedly to study how SES effects health. We recommend that CARB take advantage of existing datasets to extend them into areas of important research.

Finally, we have analyzed morbidity data in this study. Mortality is obviously of interest to provide a complete picture of the associations observed here. Again, datasets such as this can be efficiently extended to include mortality outcomes.

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SECTION 8. STATEMENT ON HUMAN SUBJECTS

This research was reviewed and approved by the Human Subjects Review Committee (HSRC) of the Kaiser Foundation Research Institute (Assurance of Compliance Number M1312). No breaches in human subject procedures occurred in the conduct of this study.

APPENDIX LISTING

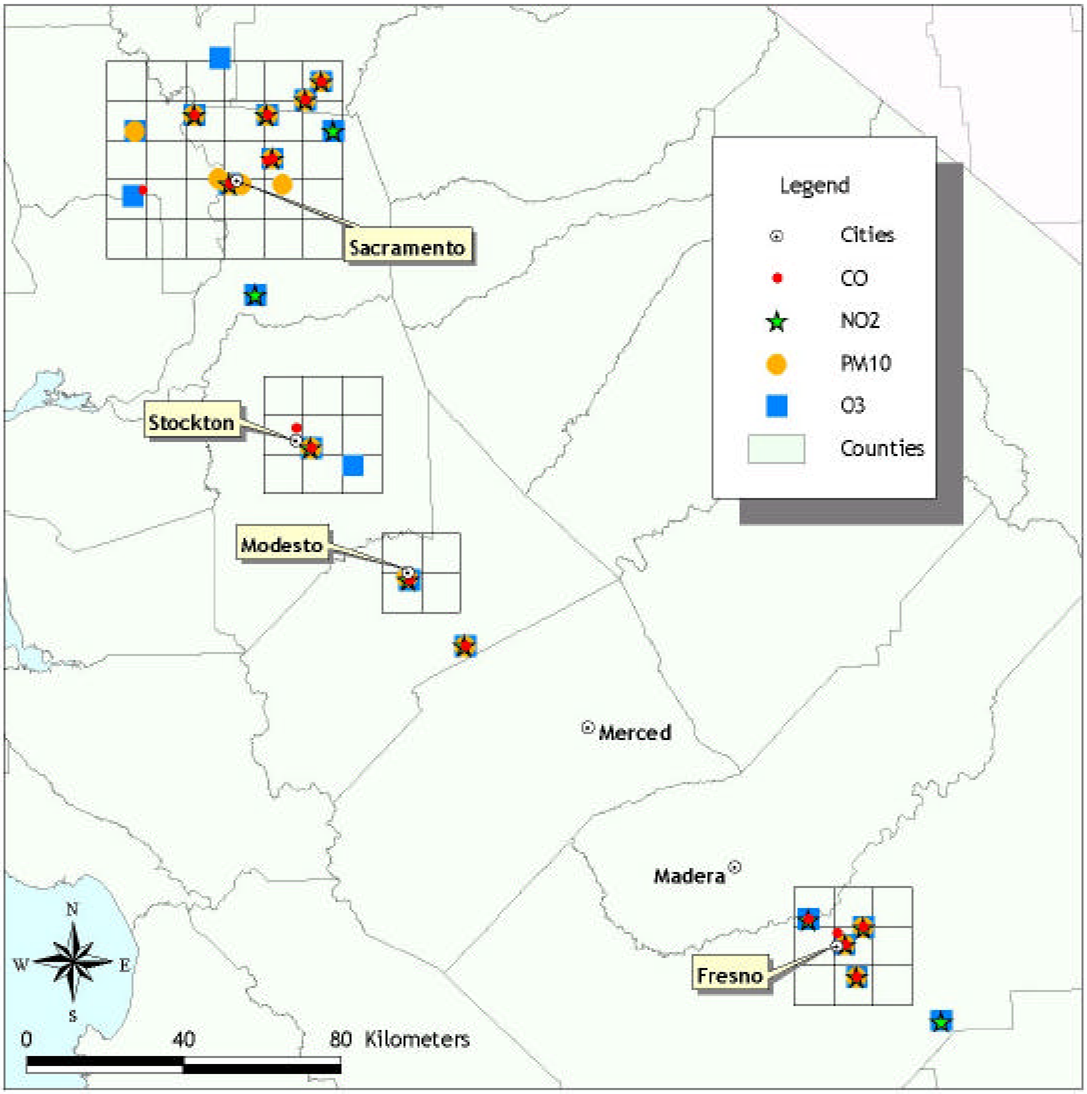
A. Map of Kaiser Permanente, Northern California Region Facilities
B. Location of Monitoring sites in Central Valley.
C. Air Pollutant monitoring sites.
D. Quartile Analysis Hospitalization Data
E. Center Analysis Hospitalization Data
F. Sex Analysis Hospitalization Data
G. Quartile Analysis Emergency Room Visits Data
H. Center Analysis Emergency Room Visits Data
I. Sex Analysis Emergency Room Visits Data

Appendix A. Map of Kaiser Permanente, Northern California Region facilities.

Population centers and Kaiser Permanente, Northern California facilities included in the study are underlined

Appendix B. Location of monitoring sites in Central Valley.

Including portions of the Sacramento Valley and San Joaquin Valley Air Basins



San Joaquin Valley Air Quality Monitors and Grids

Appendix C. Supplemental Information on the Air Quality Database

This appendix provides documentation of the data sources and methods used to assemble the 1996-2000 air quality and meteorological database for the ARB-sponsored Study on Particulate Matter and Morbidity in California's Central Valley. The database consists of the spatially mapped daily air quality and meteorological parameters listed in Table C-1. It includes ambient concentrations of ozone, nitric oxide, nitrogen dioxide, carbon monoxide, sulfur dioxide, PM_{10} mass, PM_{10} nitrate, PM_{10} sulfate, and PM_{10} carbon, $PM_{2.5}$ mass, selected trace elements in the fine and total size fractions, as well as ambient temperature and relative humidity. The geographic scope of the database includes the following five Central Valley communities: Sacramento, Stockton, Modesto, Fresno, and Bakersfield. The data were spatially interpolated to 10 x 10 km square grids shown in Figure C-1. The five grid domains are defined as:

1. Sacramento - A 60 x 50 km region extending from UTM 600, 4250 km to 660, 4300 km.
2. Stockton - A 30 x 30 km region extending from UTM 640, 4190 km to 670, 4220 km.
3. Modesto - A 20 x 20 km region extending from UTM 670, 4160 km to 690, 4180 km.
4. Fresno - A 30 x 30 km region extending from UTM 775, 4060 km to 805, 4190 km.
5. Bakersfield - A 30 x 30 km region extending from UTM 845, 3905 km to 875, 3935 km.

The database development process consisted 4 main steps:

1. Acquiring the hourly and daily data from AIRS, ARB CD, EPA, NWS, and CIMIS
2. Calculating the daily parameters from the hourly data (see Table C-1)
3. Developing regression equations to fill in missing PM data
4. Spatially mapping the parameters to the grids using inverse distance-squared weighting.

The availability of air quality monitoring data is summarized by monitoring station and year in Table C-2. The 1996-1999 air quality data were acquired from the ARB's Ambient Air Quality Data CD, Version 14. The 2000 air quality data were acquired from the EPA's AIRS database. EPA and the Desert Research Institute provided $PM_{2.5}$ TEOM data for the Fresno First Street station.

A substantial effort was made to develop methods to estimate missing PM_{10} and $PM_{2.5}$ concentrations because at most locations PM mass is only measured once every six day. There is fairly good coverage in these communities of continuously measured PM_{10} TEOM analyzers and Coefficient of Haze (COH) monitors. Our regression analyses indicate that daily PM_{10} and $PM_{2.5}$ mass can often be accurately estimated from collocated or nearby daily TEOM and COH data.

Regression equations were developed for PM_{10} mass using the 1995 through 1998 24-hr data for HiVOL PM_{10} mass and corresponding TEOM and COH data. Fresno regression equations regarding the TEOM PM_{10} use June 1997 through June 2000 data due to the availability of the Fresno 1st St. TEOM data. When the database included more than 100 days of data for a particular location, more accurate regression equations were obtained by separating the data into a warm and cool season (April –October and November-March). Regressions equations were developed for each HiVOL PM_{10} monitoring location in or near the five communities. Relationships were evaluated for both collocated continuous data and nearby continuous data. Also, because there are periods when either the daily TEOM or COH data are missing, single variable regression equations were developed as well as the multi-variate equations.

The equations for estimating PM_{10} mass are shown in Table C-3. The equations with both TEOM and COH variables are able to explain 52 to 95 percent of the variance in HiVOL PM_{10} mass concentrations. The R-squared values are above 0.75 in most locations. The results for single variable regressions indicate the TEOM data are a better surrogate for HiVOL PM_{10} mass than COH data, which is expected since the TEOM is designed to measure fine plus coarse mass while the COH monitor primarily responds to the elemental carbon portion of the fine particle mass.

Only equations with R-squared above 0.50 were accepted for use in estimating missing PM_{10} data. The missing PM_{10} concentrations were filled in using the season specific equation depending on both TEOM and COH when both TEOM and COH data were available. In cases where there were insufficient data to develop season specific equations, the estimates were made with a single equation for all seasons. The alternate equations listed in Table C-3 were used when either TEOM or COH were missing. The TEOM data were missing more frequently than the COH data. Overall, this procedure was able to provide reasonably accurate PM_{10} mass estimates on about 92 percent of the days with missing values.

Daily PM_{10} nitrate, sulfate, and total carbon were estimated from the daily PM_{10} mass. Tables C-4 through C-6 list the regression equations used. These component concentrations were usually derived from the estimated, rather than measured, PM_{10} mass concentrations. Thus, they are approximate and should be used with caution. Overall, we were able to fill in 74 percent of the missing carbon concentrations, 38 percent of the missing nitrate concentrations, and about 22 percent of the missing sulfate concentrations.

Missing Dichotomous sampler $PM_{2.5}$ (PM Fine) mass data were estimated by the same approach used for PM_{10} mass. Regression relationships between PM Fine, COH, TEOM PM_{10} and TEOM $PM_{2.5}$ were developed using 1995 through 1999 data. The Fresno regression equations were developed using the TEOM $PM_{2.5}$ data for June 1997 through June 2000. Table C-7 shows the regression equations for estimating PM Fine mass data. The equations are able to explain 53 to 76 percent of the variance in PM fine mass concentrations. Light scattering data (bscat) also proved to be a powerful predictor of PM fine mass. These data were not used, however, due to inconsistent data quality.

Data from California's Federal Reference Method (FRM) $PM_{2.5}$ monitoring network became available in 1999. This greatly increased the number of $PM_{2.5}$ monitoring sites in the San Joaquin Valley area. Regression equations for estimating the missing $PM_{2.5}$ were developed using TEOM and COH 1999 and 2000 data. The equations, shown in Table C-8, are able to explain 56 to 83 percent of the variance in $PM_{2.5}$ mass concentrations.

Only $PM_{2.5}$ is included in the final PM database. Thus, a relationship between PM Fine and FRM $PM_{2.5}$ was developed using 1999 and 2000 data. Linear regressions of all data, all data within San Joaquin Valley area, and seasonal (cool or warm) San Joaquin Valley area all yielded a 1.13 adjustment factor accounting for over 90% of the variance. The steps for estimating $PM_{2.5}$ mass data were as follows:

- Daily estimates were made for 1995 through 1998 PM Fine data.
- Daily estimates were made for 1999 and 2000 PM Fine data for sites not represented in the

FRM $PM_{2.5}$ network (Bakersfield Taft College and Modesto I St.).

- Resultant daily PM Fine data were adjusted to better estimate FRM $PM_{2.5}$.
- Daily estimates were made for 1999 and 2000 FRM $PM_{2.5}$ data.

We were able to fill in about 72 percent of the days with missing $PM_{2.5}$ values.
After the PM database was filled in, to the extent possible, these parameters were spatially interpolated using the same algorithm as was used for the gaseous species concentrations and meteorological parameters.

Table C-1. Daily air quality and meteorological parameters included in the Kaiser/ARB Study on Particulate Matter and Morbidity in California's Central Valley.

No.	Air Quality or Meteorological Parameter
1	Daily 24-hr average ozone (ppb)
2	Daily 6am-6pm average ozone (ppb)
3	Daily 10am-6pm average ozone (ppb)
4	Daily 8-hr maximum ozone (ppb)
5	Daily 1-hr maximum ozone (ppb)
6	Daily 24-hr Average NO (ppb)
7	Daily 8-hr Maximum NO (ppb)
8	Daily 1-hr Maximum NO (ppb)
9	Daily 24-hr average NO2 (ppb)
10	Daily 6am-6pm average NO2 (ppb)
11	Daily 10am-6pm average NO2 (ppb)
12	Daily 6am-10am average NO2 (ppb)
13	Daily 4pm-8pm average NO2 (ppb)
14	Daily 1-hr maximum NO2 (ppb)
15	Daily 24-hr Average CO (ppm)
16	Daily 8-hr Maximum CO (ppm)
17	Daily 1-hr Maximum CO (ppm)
18	Daily 24-hr Average SO2 (ppb)
19	Daily 8-hr Maximum SO2 (ppb)
20	Daily 1-hr Maximum SO2 (ppb)
21	Daily PM10 Mass (ug/m3)
22	Daily PM10 NO3 (ug/m3)
23	Daily PM10 SO4 (ug/m3)
24	Daily PM10 Carbon (ug/m3)
25	Daily PM2.5 Mass (ug/m3)
26	Daily PM10 Aluminum (ng/m3)
27	Daily PM10 Silicon (ng/m3)
28	Daily PM10 Phosphorous (ng/m3)
29	Daily PM10 Potassium (ng/m3)
30	Daily PM10 Calcium (ng/m3)
31	Daily PM10 Vanadium (ng/m3)

32	Daily PM10 Chromium (ng/m3)

Table C-1. Daily air quality and meteorological parameters included in the Kaiser/ARB Study on Particulate Matter and Morbidity in California's Central Valley. (continued)

No.	Air Quality or Meteorological Parameter
33	Daily Total Manganese (ng/m3)
34	Daily Total Iron (ng/m3)
35	Daily Total Cobalt (ng/m3)
36	Daily Total Nickel (ng/m3)
37	Daily Total Copper (ng/m3)
38	Daily Total Zinc (ng/m3)
39	Daily PM Fine Aluminum (ng/m3)
40	Daily PM Fine Silicon (ng/m3)
41	Daily PM Fine Phosphorous (ng/m3)
42	Daily PM Fine Potassium (ng/m3)
43	Daily PM Fine Calcium (ng/m3)
44	Daily PM Fine Vanadium (ng/m3)
45	Daily PM Fine Chromium (ng/m3)
46	Daily PM Fine Manganese (ng/m3)
47	Daily PM Fine Iron (ng/m3)
48	Daily PM Fine Cobalt (ng/m3)
49	Daily PM Fine Nickel (ng/m3)
50	Daily PM Fine Copper (ng/m3)
51	Daily PM Fine Zinc (ng/m3)
52	Daily 24-hr Minimum Temperature (degrees F)
53	Daily 1-hr Average Temperature (degrees F)
54	Daily 1-hr Maximum Temperature (degrees F)
55	Daily 24-hr Minimum Relative Humidity (%)
56	Daily 1-hr Average Relative Humidity (%)
57	Daily 1-hr Maximum Relative Humidity (%)

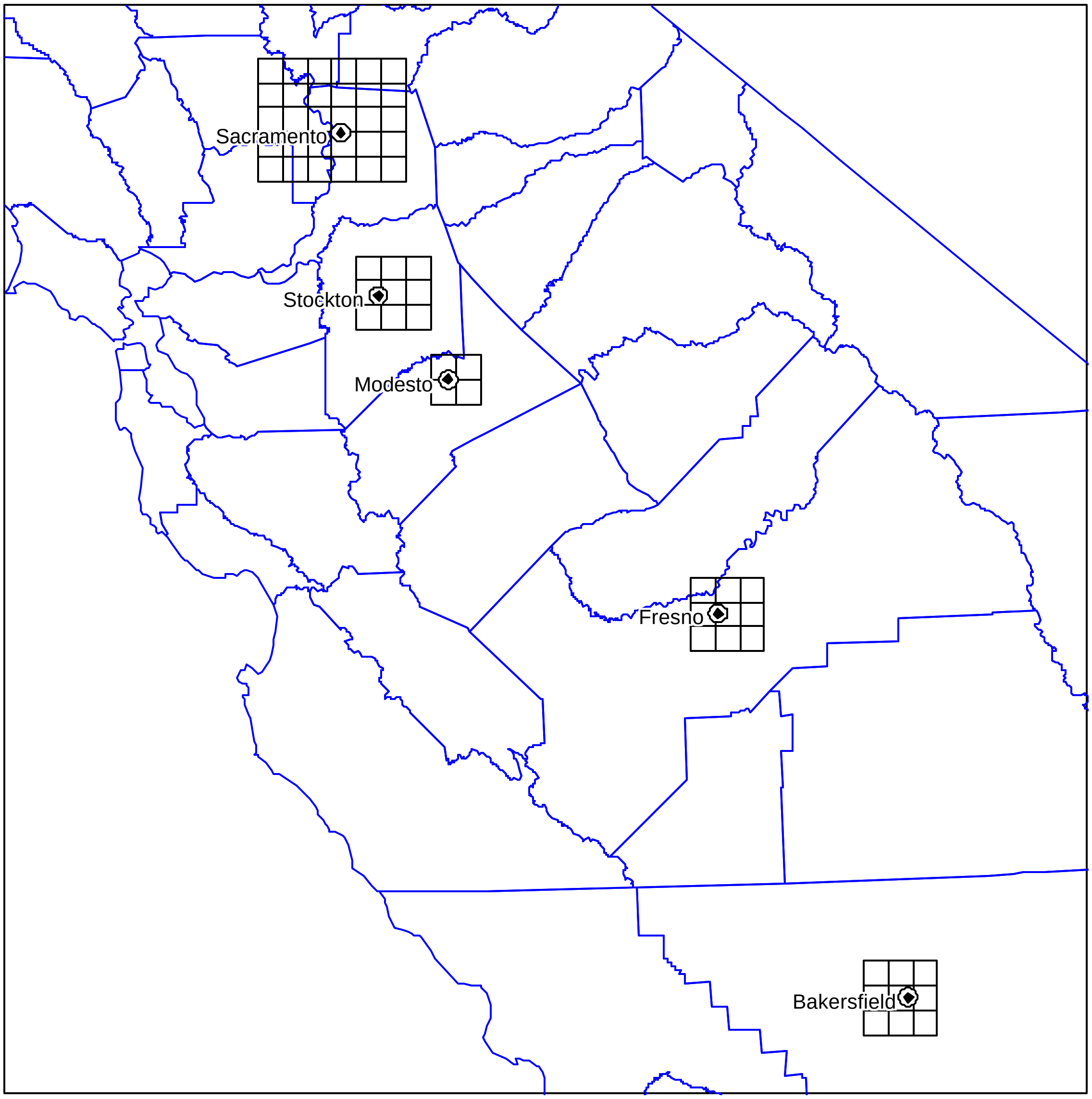


Figure C-1. The five communities for the Kaiser/ARB Study on PM and Morbidity in California's Central Valley.

Table C-2. Air quality data availability by site and years for Sacramento, Stockton, Modesto, and Fresno 1996-2000. X denotes data available for all years of the study.

Monitoring Site	ARB Code	AIRS Code	Ozone	NO/NO2	CO	SO2	HiVol PM10 Mass	HiVol PM10 SO4/ NO3	PM10 Total Carbon	Dichot PM10 Mass & Elements	TEOM PM10	TEOM PM2.5	Dichot PM2.5 Mass & Elements	FRM PM2.5	COH
Roseville-N Sunrise Blvd	2956	6061 0006	x	x	x		x	x	X					98-00	x
Rocklin-Rocklin Road	3008	6061 3001	x	96-96	96		x	x	X		97-00				x
North Highlands-Blackfoot Way	2123	6067 0002	x	x	x	x	x								
Sacramento-Health Dept Stockton Bl.	2346	6067 4001					x				X			99-00	
Folsom-City Corporation Yard	2472	6067 1001	96	96											
Sacramento-Del Paso Manor	2731	6067 0006	x	x	x	x	x				X			99-00	
Sacramento-El Camino and Watt	2840	6067 0007			x										
Elk Grove-Bruceville Road	2977	6067 0011	x	x											
Sacramento-T Street	3011	6067 0010	x	x	x		x	x	X	x	X		x	98-00	x
Sacramento-Earhart Drive	3019	6067 5002	96-97	96-97	96-97		96-97				96-97				
Sacramento-Branch Center	2703	6067 0283					x								
Folsom-Natoma Street	3187	6067 0012	x	x											
Sloughhouse	3209	6067 5003	97-99												

Monitoring Site	ARB Code	AIRS Code	Ozone	NO/NO2	CO	SO2	HiVol PM10 Mass	HiVol PM10 SO4/ NO3	PM10 Total Carbon	Dichot PM10 Mass & Elements	TEOM PM10	TEOM PM2.5	Dichot PM2.5 Mass & Elements	FRM PM2.5	COH
Sacramento-3801 Airport Road	3223	6067 0013	98-99	98-00	98-00		98-00				98-00				
Pleasant Grove-4 miles SW	2848	6101 0002	x												x
West Sacramento-15th Street	2079	6113 2001					x								
Davis-UCD Campus	2143	6113 0004	x	x	x										x

Table C-2. Air quality data availability by site and years for Sacramento, Stockton, Modesto, and Fresno 1996-2000. X denotes data available for all years of the study (continued).

Monitoring Site	ARB Code	AIRS Code	Ozone	NO/NO2	CO	SO2	HiVol PM10 Mass	HiVol PM10 SO4/ NO3	PM10 Total Carbon	Dichot PM10 Mass & Elements	TEOM PM10	TEOM PM2.5	Dichot PM2.5 Mass & Elements	FRM PM2.5	COH
Woodland-Sutter Street	2988	6113 0005	96-97				x		96-97						
Woodland-Gibson Road	3249	6113 1003	98-99				98-00							99-00	
Vacaville-Merchant street	2529	6095 3001					x								
Yuba City	2958	6101 0003	x	x	x		x	x	X		X			98-00	x
Fresno-Drummond Street	2013	6019 0007	x	x	x		x								
Fresno-Sierra Skypark #2	2844	6019 0242	x	x	x										
Fresno-1st Street	3009	6019 0008	x	x	x	97	x	x	X	x		x	x	99-00	x
Clovis-N Villa Avenue	3026	6019 5001	x	x	x		x	x						99-00	
Fresno-Fisher Street	3136	6019 0009			x										
Stockton-Hazelton Street	2094	6077 1002	x	x	x		x	x	X	x	X		x	99-00	x
Stockton-Claremont	2282	6077 0008			x										
Stockton-E Mariposa	2553	6077 0009	x												
Stockton-Wagner-Holt School	3195	6077 3010					x	x							
Modesto-14th Street	2833	6099	x	x	x		x	x	X	98-99	x		98-99	99-00	x

		0005													
Modesto-I Street	2861	6099 0002					x	x	X	x			x		
Modesto-Rover 14th Street	3216	6099 0010	98-98	98-98	98-98										

Table C-2. Air quality data availability by site and years for Sacramento, Stockton, Modesto, and Fresno 1996-2000. X denotes data available for all years of the study (continued).

Monitoring Site	ARB Code	AIRS Code	Ozone	NO/NO2	CO	SO2	HiVol PM10 Mass	HiVol PM10 SO4/ NO3	PM_{10} Total Carbon	Dichot PM10 Mass & Elements	TEOM PM10	TEOM PM2.5	Dichot PM2.5 Mass & Elements	FRM PM2.5	COH
Bakersfield-5558 California Ave	3146	6029 0014	x	x	x	x	x	x	x	x	x		x	99-00	x
Oildale-3311 Manor Street	2772	6029 0232	x	x		96-97	x	x							x
Edison	2312	6029 0007	x	x											
Bakersfield-Golden State Highway	3145	6029 0010	96-98	96-98	96-98		x	96	96					99-00	
Taft College	3024	6029 2004					x	x		x			x		
Maricopa-Stanislaus Street	2919	6029 0008	96-98												
Arvin-Bear Mountain Blvd	2941	6029 5001	x	x											
Shafter-Walker Street	2981	6029 6001	x												

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM data.

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Stockton – Hazelton St. (2094)	PM_{10}-Hivol = 1.527 + 25.599$[COH]_{2094}$ + 0.760$[TEOM]_{2094}$	Warm	0.948	68
	PM_{10}-Hivol = -4.566 + 50.844$[COH]_{2094}$ + 0.988$[TEOM]_{2094}$	Cool	0.902	43
	PM_{10}-Hivol = 1.240 + 0.909 $[TEOM]_{2094}$	Warm	0.917	70
	PM_{10}-Hivol = 1.015 + 1.446 $[TEOM]_{2094}$	Cool	0.818	46
	PM_{10}-Hivol = 14.902 + 76.759 $[COH]_{2094}$	Warm	0.510	127
	PM_{10}-Hivol = 1.629 + 110.875 $[COH]_{2094}$	Cool	0.751	88
Stockton – Wagner-Holt School (3195)	PM_{10}-Hivol = 1.712 + 75.444 $[COH]_{2094}$ + 0.300$[TEOM]_{2094}$	All	0.762	60
	PM_{10}-Hivol = -0.814+ 117.369 $[COH]_{2094}$	Cool	0.812	52
Modesto – 14^{th} Street (2833)	PM_{10}-Hivol = 2.909 + 61.342$[COH]_{2833}$ + 0.662$[TEOM]_{2833}$	All	0.816	61
	PM_{10}-Hivol = 10.529 + 1.117 $[TEOM]_{2833}$	All	0.577	62
	PM_{10}-Hivol = 11.692+ 87.234 $[COH]_{2833}$	All	0.673	61
Modesto - I Street (2861)	PM_{10}-Hivol = 2.737 + 22.625$[COH]_{2833}$ + 0.816$[TEOM]_{2833}$	Warm	0.914	130
	PM_{10}-Hivol = -2.910 + 52.404$[COH]_{2833}$ + 0. 815$[TEOM]_{2833}$	Cool	0.916	77
	PM_{10}-Hivol = 3.105 + 0.962 $[TEOM]_{2833}$	Warm	0.897	144
	PM_{10}-Hivol = 1.317 + 1.539 $[TEOM]_{2833}$	Cool	0.844	77
	PM_{10}-Hivol = 13.974 + 80.916 $[COH]_{2833}$	Warm	0.590	145
	PM_{10}-Hivol = -0.881+ 94.664 $[COH]_{2833}$	Cool	0.848	85

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM (continued).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	Samples
Fresno – Clovis St. (3026)	PM_{10}-Hivol = 8.401 + 12.848 $[COH]_{3009}$ + 0.936 $[TEOM]_{3009}$	Summer	0.903	68
	PM_{10}-Hivol = 6.585 + 14.681 $[COH]_{3009}$ + 1.131 $[TEOM]_{3009}$	Winter	0.831	59
	PM_{10}-Hivol = 7.228 + 1.045 $[TEOM]_{3009}$	Summer	0.881	73
	PM_{10}-Hivol = 9.312 + 1.315 $[TEOM]_{3009}$	Winter	0.815	61
	PM_{10}-Hivol = 20.218+ 97.558 $[COH]_{3009}$	Summer	0.568	132
	PM_{10}-Hivol = 13.130+ 60.735 $[COH]_{3009}$	Winter	0.519	98
Fresno – 1st St. (3009)	PM_{10}-Hivol = 5.745 + 11.302 $[COH]_{3009}$ + 0.994 $[TEOM]_{3009}$	Summer	0.916	68
	PM_{10}-Hivol = 2.337 + 35.563 $[COH]_{3009}$ + 1.048 $[TEOM]_{3009}$	Winter	0.930	62
	PM_{10}-Hivol = 5.016 + 1.100 $[TEOM]_{3009}$	Summer	0.832	74
	PM_{10}-Hivol = 7.076 + 1.544 $[TEOM]_{3009}$	Winter	0.867	64
	PM_{10}-Hivol = 20.50 + 98.304 $[COH]_{3009}$	Summer	0.601	133
	PM_{10}-Hivol = 8.928 + 74.735 $[COH]_{3009}$	Winter	0.719	105
Fresno – Drummond St. (2013)	PM_{10}-Hivol = 7.870 + 1.275 $[TEOM]_{3009}$	Summer	0.793	74
	PM_{10}-Hivol = 5.423 + 1.730 $[TEOM]_{3009}$	Winter	0.843	56
	PM_{10}-Hivol = 24.107 + 119.670 $[COH]_{3009}$	Summer	0.603	132
	PM_{10}-Hivol = 11.802 + 69.235 $[COH]_{3009}$	Winter	0.580	99
Bakersfield – California St. (3146)	PM_{10}-Hivol = 0.367 + 17.497$[COH]_{3146}$ + 0.910$[TEOM]_{3146}$	All	0.910	153
	PM_{10}-Hivol = -6.155 + 41.136$[COH]_{3146}$ + 1.153$[TEOM]_{3146}$	All	0.912	127
	PM_{10}-Hivol = 1.044 + 0.998 $[TEOM]_{3146}$	Warm	0.901	154
	PM_{10}-Hivol = 1.592 + 1.535 $[TEOM]_{3146}$	Cool	0.825	134

Location (ARB Site Code)	Regression Equation	Season	R-Squared	Samples
	PM_{10}-Hivol = 6.911 + 90.447 $[COH]_{3146}$	Cool	0.615	172

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM data (continued).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Bakersfield - Golden State Hwy (3145)	PM_{10}-Hivol = 4.304 + 14.656$[COH]_{3146}$ + 1.250$[TEOM]_{3146}$	Warm	0.739	87
	PM_{10}-Hivol = -4.046 + 29.284$[COH]_{3146}$ + 1.511$[TEOM]_{3146}$	Cool	0.844	53
	PM_{10}-Hivol = 5.152 + 1.312 $[TEOM]_{3146}$	Warm	0.735	88
	PM_{10}-Hivol = -0.797 + 1.846 $[TEOM]_{3146}$	Cool	0.802	57
	PM_{10}-Hivol = 9.847 + 100.567 $[COH]_{3146}$	Cool	0.592	80
Bakersfield – Oildale (2772)	PM_{10}-Hivol = -0.288 + 17.732$[COH]_{2772}$ + 1.035$[TEOM]_{3146}$	Warm	0.700	91
	PM_{10}-Hivol = -5.077 + 53.908$[COH]_{2772}$ + 1.065$[TEOM]_{3146}$	Cool	0.867	70
	PM_{10}-Hivol = -0.082 + 1.077 $[TEOM]_{3146}$	Warm	0.695	101
	PM_{10}-Hivol = -3.554 + 1.470 $[TEOM]_{3146}$	Cool	0.788	74
	PM_{10}-Hivol = 8.091 + 136.456 $[COH]_{2772}$	Cool	0.570	95
Bakersfield - Taft College (3024)	PM_{10}-Hivol = 3.479 + 34.351$[COH]_{2772}$ + 0.752$[TEOM]_{3146}$	Warm	0.653	85
	PM_{10}-Hivol = -2.730 + 26.140$[COH]_{2772}$ + 0.940$[TEOM]_{3146}$	Cool	0.772	66
	PM_{10}-Hivol = 1.365 + 0.930 $[TEOM]_{3146}$	Warm	0.618	94
	PM_{10}-Hivol = -3.089 + 1.167 $[TEOM]_{3146}$	Cool	0.761	69
	PM_{10}-Hivol = 9.056 + 93.048 $[COH]_{2772}$	Cool	0.523	89

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM data (continued).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Sacramento – T Street (3011)	PM_{10}-Hivol = 2.253 + 10.617$[COH]_{3011}$ + 0.962$[TEOM]_{3011}$	Warm	0.929	154
	PM_{10}-Hivol = 2.978 + 31.345$[COH]_{3011}$ + 0.817$[TEOM]_{3011}$	Cool	0.894	110
	PM_{10}-Hivol = 2.173 + 1.032 $[TEOM]_{3011}$	Warm	0.921	156
	PM_{10}-Hivol = 4.141 + 1.327 $[TEOM]_{3011}$	Cool	0.848	114
	PM_{10}-Hivol = 4.604 + 70.572 $[COH]_{3011}$	Cool	0.837	123
West Sacramento – 15th St. (2079)	PM_{10}-Hivol = 1.972+ 7.534$[COH]_{3011}$ + 0.928$[TEOM]_{2346}$	Warm	0.918	136
	PM_{10}-Hivol = -0.212 + 51.101 $[COH]_{3011}$ + 0.733 $[TEOM]_{2346}$	Cool	0.870	86
	PM_{10}-Hivol = 1.798+ 0.978 $[TEOM]_{2346}$	Warm	0.914	137
	PM_{10}-Hivol = -2.552 + 1.621 $[TEOM]_{2346}$	Cool	0.796	90
	PM_{10}-Hivol = 4.129 + 84.236 $[COH]_{3011}$	Cool	0.832	92
Sacramento – Health Dept (2346)	PM_{10}-Hivol = 3.202 + -2.130$[COH]_{3011}$ + 0.803 $[TEOM]_{2346}$	Warm	0.844	131
	PM_{10}-Hivol = 4.30 + 64.630$[COH]_{3011}$ + 0.257 $[TEOM]_{2346}$	Cool	0.830	89
	PM_{10}-Hivol = 3.260 + 0.788 $[TEOM]_{2346}$	Warm	0.843	131
	PM_{10}-Hivol = 1.203 + 1.393 $[TEOM]_{2346}$	Cool	0.693	93
	PM_{10}-Hivol = 5.699 + 76.506 $[COH]_{3011}$	Cool	0.825	95

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM data (continued).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Sacramento – Del Paso Manor (2731)	PM_{10}-Hivol = -0.333 + 15.278[COH]$_{2848}$ + 0.799[TEOM]$_{2731}$	Warm	0.788	96
	PM_{10}-Hivol = 2.195 + 42.015[COH]$_{2848}$ + 0.831[TEOM]$_{2731}$	Cool	0.672	82
	PM_{10}-Hivol = 0.335 + 0.866 [TEOM]$_{2731}$	Warm	0.751	100
	PM_{10}-Hivol = -0.918 + 1.501 [TEOM]$_{2731}$	Cool	0.592	86
	PM_{10}-Hivol = 9.831 + 73.739 [COH]$_{2848}$	Cool	0.607	94
Sacramento – Branch Center (2703)	PM_{10}-Hivol = 3.471 + 41.140[COH]$_{3011}$ + 0.710[TEOM]$_{2731}$	Warm	0.60	112
	PM_{10}-Hivol = 0.661 + 37.497[COH]$_{3011}$ + 0.723[TEOM]$_{2731}$	Cool	0.772	77
	PM_{10}-Hivol = -0.421 + 1.363 [TEOM]$_{2731}$	Cool	0.717	80
	PM_{10}-Hivol = 6.174 + 66.345 [COH]$_{3011}$	Cool	0.702	87
Roseville (2956)	PM_{10}-Hivol = -0.126 + 20.090 [COH]$_{2956}$ + 0.883[TEOM]$_{3008}$	All	0.815	82
	PM_{10}-Hivol = 2.408 + 1.072 [TEOM]$_{3008}$	All	0.705	82
	PM_{10}-Hivol = 7.633 + 41.622 [COH]$_{2956}$	Cool	0.636	107
Rocklin (3008)	PM_{10}-Hivol = -0.684 + 24.017 [COH]$_{3008}$ + 0.842[TEOM]$_{3008}$	All	0.862	80
	PM_{10}-Hivol = 0.478 + 1.030 [TEOM]$_{3008}$	All	0.771	82
	PM_{10}-Hivol = 11.971 + 78.352 [COH]$_{3008}$	Warm	0.517	146
	PM_{10}-Hivol = 4.832 + 55.761 [COH]$_{3008}$	Cool	0.727	104

Table C-3. Regression equations used to estimate daily PM_{10} mass concentrations from daily COH and TEOM data (continued).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
North Highlands (2123)	PM_{10}-Hivol = 3.703 + 11.766$[COH]_{2848}$ + 0.790$[TEOM]_{2731}$	Warm	0.687	108
	PM_{10}-Hivol = 3.627 + 17.944$[COH]_{2848}$ + 0.948$[TEOM]_{2731}$	Cool	0.716	82
	PM_{10}-Hivol = 4.083 + 0.844 $[TEOM]_{2731}$	Warm	0.684	114
	PM_{10}-Hivol = 2.175 + 1.252 $[TEOM]_{2731}$	Cool	0.689	86
	PM_{10}-Hivol = 12.613 + 54.741 $[COH]_{2848}$	Cool	0.584	93
Earhart (3019)	PM_{10}-Hivol = 3.820 + 54.617 $[COH]_{2848}$ + 0.522 $[TEOM]_{3019}$	All	0.804	98
	PM_{10}-Hivol = 6.962 + 0.671 $[TEOM]_{3019}$	Warm	0.777	69
	PM_{10}-Hivol = 7.182 + 157.732 $[COH]_{2848}$	Warm	0.565	89
	PM_{10}-Hivol = 5.0 + 83.382 $[COH]_{2848}$	Cool	0.686	51
Vacaville – Merchant St. (2529)	PM_{10}-Hivol = 4.118 + 34.454$[COH]_{2143}$ + 0.407$[TEOM]_{2346}$	Warm	0.652	132
	PM_{10}-Hivol = 7.759 + 70.206$[COH]_{2143}$ + 0.158$[TEOM]_{2346}$	Cool	0.568	87
	PM_{10}-Hivol = 4.282 + 0.513 $[TEOM]_{2346}$	Warm	0.604	136
	PM_{10}-Hivol = 8.946 + 82.872 $[COH]_{2143}$	Cool	0.562	94
Woodland – Sutter St. (2988)	PM_{10}-Hivol = -1.506 + 30.802$[COH]_{2143}$ + 1.370 $[TEOM]_{2958}$	Warm	0.673	125
	PM_{10}-Hivol = 3.603 + 80.415 [COH] + 0.736$[TEOM]_{2958}$	Cool	0.825	90
	PM_{10}-Hivol = -1.702 + 1.484 $[TEOM]_{2958}$	Warm	0.684	130
	PM_{10}-Hivol = 2.531 + 1.488 $[TEOM]_{2958}$	Cool	0.727	94
	PM_{10}-Hivol = 7.730 + 135.329 $[COH]_{2143}$	Cool	0.713	91
Yuba City (2958)	PM_{10}-Hivol = 5.662 + 12.337$[COH]_{2958}$ + 1.021$[TEOM]_{2958}$	Warm	0.769	146
	PM_{10}-Hivol = 7.069 + 3.763$[COH]_{2958}$ + 1.142 $[TEOM]_{2958}$	Cool	0.524	99
	PM_{10}-Hivol = 5.810 + 1.047 $[TEOM]_{2958}$	Warm	0.768	147

1) $[TEOM]_j$ and $[COH]_k$ refers to the 24-hr average TEOM concentration from station number j and 24-hr average COH reading from station number k.

Table C-4. Regression equations used to estimate daily PM_{10} nitrate (NO_3 in $\mu g/m^3$) concentrations from daily PM_{10} concentrations ($\mu g/m^3$).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Sacramento T Street (3011)	Nitrate = 0.1565 PM_{10}	Cool	0.6357	124
Roseville (2956)	Nitrate = 0.1126 PM_{10}	Cool	0.5059	105
Taft College (3024)	Nitrate = 0.2317 PM_{10}	Cool	0.7289	95
Oildale (2772)	Nitrate = 0.2265 PM_{10}	Cool	0.6189	102
Bakersfield California Ave (3146)	Nitrate = 0.2195 PM_{10}	Cool	0.7066	182
Modesto I Street (2861)	Nitrate = 0.2278 PM_{10}	Cool	0.772	107
Modesto 14th Street (2833)	Nitrate = 0.1773 PM_{10}	All year	0.6114	39
Clovis (3026)	Nitrate = 0.2153 PM_{10}	Cool	0.7298	98
Fresno 1st St (3009)	Nitrate = 0.1947 PM_{10}	Cool	0.7119	105
Stockton Wagner School (3195)	Nitrate = 0.1994 PM_{10}	Cool	0.7004	56
Stockton Hazelton St (2094)	Nitrate = 0.2097 PM_{10}	Cool	0.7117	94

Table C-5. Regression equations used to estimate daily PM_{10} sulfate (SO_4 in $\mu g/m^3$) concentrations from daily PM_{10} concentrations ($\mu g/m^3$).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Taft College (3024)	Sulfate = 0.5613 + 0.0375 PM_{10}	Cool	0.5421	95
Modesto I Street (2861)	Sulfate = 0.6375+ 0.0293 PM_{10}	Cool	0.508	107
Modesto 14th Street (2833)	Sulfate = 0.4459 +0.0396 PM_{10}	All year	0.5879	39
Stockton Wagner School (3195)	Sulfate = 0.4778 +0.0219 PM_{10}	Cool	0.575	56
Clovis (3026)	Sulfate = 0.178+ 0.03 PM_{10}	Cool	0.664	98
Fresno 1st St (3009)	Sulfate = 0.4936 +0.0218 PM_{10}	Cool	0.5239	105

Table C-6. Regression equations used to estimate daily PM_{10} carbon (TC in $\mu g/m^3$) concentrations from daily PM_{10} concentrations ($\mu g/m^3$).

Location (ARB Site Code)	Regression Equation	Season	R-Squared	No. Samples
Sacramento T Street (3011)	Carbon = 0.1554 PM_{10}	Warm	0.6434	112
	Carbon = 0.2648 PM_{10}	Cool	0.8596	131
Yuba City (2958)	Carbon = 0.1593 PM_{10}	Warn	0.5634	111
	Carbon = 0.5459 + 0.2362 PM_{10}	Cool	0.8247	98
Roseville (2956)	Carbon = 0.6851 + 0.1855 PM_{10}	All year	0.5069	64
Bakersfield California Ave (3146)	Carbon = 0.1822 + 0.1332 PM_{10}	Warm	0.7252	156
	Carbon = 1.9709 + 0.1613 PM_{10}	Cool	0.7567	172
Modesto I Street (2861)	Carbon = 0.1406 PM_{10}	Warm	0.803	116
	Carbon = 0.7017 + 0.1778 PM_{10}	Cool	0.8509	100
Modesto 14 Street (2833)	Carbon = 0.1981 PM_{10}	All year	0.7456	59
Fresno 1st St (3009)	Carbon = 0.442 +0.129 PM_{10}	Warm	0.712	101
	Carbon = 1.2195 + 0.2453 PM_{10}	Cool	0.7407	100
Stockton Hazelton St (2094)	Carbon = 0.2408 + 0.1351 PM_{10}	Warm	0.6808	100
	Carbon = 1.2883 + 0.1689 PM_{10}	Cool	0.8382	90

Table C-7. Regression equations used to estimate daily PM fine ($\mu g/m^3$) concentrations from COH and TEOM data.

Location	Regression Equation	Season	R-Squared	No. Samples
Stockton – Hazelton St. (2094)	PM fine = 3.957 + 20.275$[COH]_{2094}$ + 0.059$[TEOM]_{2094}$	Warm	0.554	71
	PM fine= -0.947 + 73.383 $[COH]_{2094}$	Cool	0.644	102
Modesto – 14th Street (2833)	PM fine= 0.929+ 80.649 $[COH]_{2833}$	All year	0.669	76
Modesto - I Street (2861)	PM fine= 4.798 + 23.638 $[COH]_{2833}$	Warm	0.560	137
	PM fine= 5.061+ 43.964 $[COH]_{2833}$	Cool	0.617	81
Fresno – 1st St. (3009)	PM fine= 4.733 + 36.166 $[COH]_{3009}$	Warm	0.645	135
	PM fine= 6.730 + 49.809 $[COH]_{3009}$	Cool	0.717	109
	PM fine= 0.707 + 1.294 $[TEOM\text{-}PM_{2.5}]_{3009}$	Warm	0.748	78
	PM fine= 5.038 + 1.882 $[TEOM\text{-}PM_{2.5}]_{3009}$	Cool	0.756	56
Bakersfield - California St. (3146)	PM fine= 2.398 + 24.521$[COH]_{3146}$ + 0.086$[TEOM]_{3146}$	Warm	0.509	154
	PM fine= -0.842 + 64.642 $[COH]_{3146}$	Cool	0.696	164
Bakersfield - Taft College (3024)	PM fine= 1.372 + 47.365$[COH]_{2772}$ + 0.124$[TEOM]_{3146}$	Cool	0.647	66
	PM fine= 2.748 + 57.429 $[COH]_{2772}$	Cool	0.532	86
Sacramento – T Street (3011)	PM fine= 5.544 + 27.673 $[COH]_{3011}$	Warm	0.603	158
	PM fine= 4.299 + 46.927 $[COH]_{3011}$	Cool	0.726	130

Table C-8. Regression equations used to estimate daily FRM $PM_{2.5}$ ($\mu g/m^3$) concentrations from COH and TEOM data.

Location	Regression Equation	Season	R-Squared	Samples
Stockton – Hazelton St. (2094)	$PM_{2.5}$-FRM = 4.648 + 48.388 $[COH]_{2094}$	Warm	0.811	123
Modesto – 14th Street (2833)	$PM_{2.5}$-FRM = 5.068+ 54.156 $[COH]_{2833}$	Warm	0.809	136
	$PM_{2.5}$-FRM = 3.722+ 85.676 $[COH]_{2833}$	Cool	0.826	96
Fresno – Clovis St. (3026)	$PM_{2.5}$-FRM =6.211 +55.317 $[COH]_{3009}$	Warm	0.772	66
	$PM_{2.5}$-FRM =7.276 +57.277 $[COH]_{3009}$	Cool	0.707	63
	$PM_{2.5}$-FRM = 2.555 + 1.460 $[TEOM\text{-}PM_{2.5}]_{3009}$	Warm	0.829	62
	$PM_{2.5}$-FRM = 1.324 + 2.232 $[TEOM\text{-}PM_{2.5}]_{3009}$	Cool	0.795	50
Fresno – 1st St. (3009)	$PM_{2.5}$-FRM = 5.589 + 59.703 $[COH]_{3009}$	Warm	0.781	289
	$PM_{2.5}$-FRM = 5.661 + 82.742 $[COH]_{3009}$	Cool	0.793	156
	$PM_{2.5}$-FRM = 2.139 + 1.611 $[TEOM\text{-}PM_{2.5}]_{3009}$	Warm	0.803	241
	$PM_{2.5}$-FRM = 20.974 + 1.508 $[TEOM\text{-}PM_{2.5}]_{3009}$	Cool	0.789	121
Bakersfield - California St. (3146)	$PM_{2.5}$-FRM = 3.210 + 20.405$[COH]_{3146}$ + 0.129$[TEOM]_{3146}$	Warm	0.564	312
	$PM_{2.5}$-FRM = -0.551 + 92.119 $[COH]_{3146}$	Cool	0.738	175
Bakersfield – Golden State Hwy (3145)	$PM_{2.5}$-FRM = -0.912 + 91.945 $[COH]_{3146}$	Cool	0.683	80
Sacramento – T Street (3011)	$PM_{2.5}$-FRM = -1.102 + 20.512$[COH]_{3011}$ + 0.410$[TEOM]_{3011}$	Warm	0.810	365
	$PM_{2.5}$-FRM = -2.482 + 8.688$[COH]_{3011}$ + 1.216$[TEOM]_{3011}$	Cool	0.579	197

Location	Regression Equation	Season	R-Squared	Samples
	$PM_{2.5}$-FRM = 5.401 + 62.828 $[COH]_{3011}$	Warm	0.625	365

Table C-8. Regression equations used to estimate daily FRM $PM_{2.5}$ ($\mu g/m^3$) concentrations from COH and TEOM data (continued).

Location	Regression Equation	Season	R-Squared	No. Samples
Sacramento – Health Dept. (2346)	$PM_{2.5}$-FRM = -0.499 + 43.148$[COH]_{3011}$ + 0.328$[TEOM]_{2731}$	Warm	0.815	127
	$PM_{2.5}$-FRM = -2.933 + 30.387$[COH]_{3011}$ + 1.029$[TEOM]_{2731}$	Cool	0.667	150
	$PM_{2.5}$-FRM = 6.286+ 72.266 $[COH]_{3011}$	Warm	0.731	131
Sacramento – Del Paso Manor (2731)	$PM_{2.5}$-FRM = -3.462 + 14.738$[COH]_{3011}$ + 0.514$[TEOM]_{2731}$	Warm	0.764	78
	$PM_{2.5}$-FRM = -6.088+ 45.847$[COH]_{3011}$ + 1.206$[TEOM]_{2731}$	Cool	0.622	51
	$PM_{2.5}$-FRM = 6.718+ 63.930 $[COH]_{3011}$	Warm	0.559	80
Roseville (2956)	$PM_{2.5}$-FRM = 2.704 + 33.677$[COH]_{3008}$ + 0.074$[TEOM]_{3008}$	Warm	0.738	62
	$PM_{2.5}$-FRM = -8.445+ 58.854$[COH]_{3008}$ + 0.633$[TEOM]_{3008}$	Cool	0.750	44
	$PM_{2.5}$-FRM = 3.351+ 40.985 $[COH]_{3008}$	Warm	0.712	65
	$PM_{2.5}$-FRM = -2.939+ 79.209 $[COH]_{3008}$	Cool	0.718	47
Yuba City (2958)	$PM_{2.5}$-FRM = -0.927 + 39.453$[COH]_{2848}$ + 0.321$[TEOM]_{2958}$	Warm	0.784	65
	$PM_{2.5}$-FRM = 1.053 + 34.883$[COH]_{2848}$ + 0.514$[TEOM]_{2958}$	Cool	0.565	48
	$PM_{2.5}$-FRM = 0.542+ 82.540 $[COH]_{2958}$	Cool	0.573	49

Appendix D. Quartile Analyses for Hospitalization Data

Percent change in rate of cardiovascular, acute respiratory and chronic respiratory hospitalization per 10 unit increase of pollutant by quartile for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Table D-1. Percent change in rate of cardiovascular hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	1	0.000		1.000		
	2	-20.161	8.562	-18.259	-30.888	-3.322
	3	-9.473	9.213	-9.038	-24.065	8.964
	4	-0.679	10.645	-0.677	-19.381	22.366
$PM_{2.5}$	1	0.000		1.000		
	2	10.652	8.734	11.240	-6.263	32.010
	3	20.302	9.421	22.510	1.853	47.356
	4	15.549	10.904	16.823	-5.657	44.660
CF Mass	1	0.000		1.000		
	2	-29.969	10.024	-25.895	-39.113	-9.808
	3	-39.674	11.800	-32.749	-46.635	-15.249
	4	-35.392	13.514	-29.807	-46.140	-8.520
Ozone 8hr	1	0.000		1.000		
	2	10.567	10.214	11.145	-9.020	35.780
	3	-11.205	13.006	-10.600	-30.717	15.357
	4	-14.743	17.152	-13.708	-38.345	20.775
CO 8hr	1	0.000		1.000		
	2	20.638	9.308	22.922	2.423	47.525
	3	25.016	9.693	28.423	6.203	55.293
	4	32.118	10.971	37.876	11.199	70.952
NO_2 1hr	1	0.000		1.000		
	2	-10.321	8.558	-9.806	-23.734	6.666
	3	7.617	9.250	7.915	-9.979	29.365
	4	19.166	10.130	21.126	-0.686	47.728

Table D-1. Percent change in rate of cardiovascular hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
NO_3 (PM_{10})	1	0.000		1.000		
	2	-9.188	12.545	-8.778	-28.663	16.650
	3	-18.847	14.948	-17.178	-38.212	11.017
	4	2.295	17.814	2.321	-27.834	45.077
SO_4 (PM_{10})	1	0.000		1.000		
	2	-1.690	12.377	-1.676	-22.856	25.319
	3	-10.018	15.651	-9.533	-33.432	22.947
	4	-15.623	17.202	-14.464	-38.945	19.833
TC (PM_{10})	1	0.000		1.000		
	2	5.135	8.618	5.269	-11.091	24.640
	3	-3.655	9.015	-3.589	-19.203	15.043
	4	-2.585	10.448	-2.552	-20.596	19.593

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table D-2. Percent change in rate of acute respiratory hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	1	0.000		1.000		
	2	-3.568	13.348	-3.505	-25.717	25.350
	3	6.332	14.419	6.536	-19.691	41.330
	4	22.924	16.722	25.764	-9.381	74.541
$PM_{2.5}$	1	0.000		1.000		
	2	14.968	14.115	16.146	-11.925	53.163
	3	26.916	15.131	30.887	-2.703	76.072
	4	23.070	16.700	25.948	-9.211	74.722
CF Mass	1	0.000		1.000		
	2	-63.007	15.407	-46.744	-60.625	-27.970
	3	-31.232	18.480	-26.825	-49.060	5.116
	4	-8.760	21.588	-8.387	-39.993	39.867
Ozone 8hr	1	0.000		1.000		
	2	-48.918	14.842	-38.687	-54.163	-17.986
	3	-79.321	19.983	-54.761	-69.422	-33.071
	4	-64.858	27.533	-47.721	-69.524	-10.320
CO 8hr	1	0.000		1.000		
	2	51.436	15.429	67.256	23.608	126.319
	3	50.024	15.888	64.912	20.784	125.161
	4	50.987	17.631	66.507	17.856	135.242
NO_2 1hr	1	0.000		1.000		
	2	-26.292	13.409	-23.120	-40.888	-0.010
	3	3.670	14.452	3.738	-21.852	37.707
	4	27.780	16.517	32.022	-4.490	82.492
NO_3 (PM_{10})	1	0.000		1.000		
	2	-26.362	18.151	-23.173	-46.172	9.651
	3	-32.028	21.708	-27.405	-52.562	11.092
	4	7.106	26.345	7.364	-35.937	79.932
SO_4 (PM_{10})	1	0.000		1.000		
	2	-9.595	17.723	-9.149	-35.810	28.586
	3	-41.690	22.991	-34.091	-58.001	3.429
	4	18.422	25.234	20.229	-26.681	97.151
TC (PM_{10})	1	0.000		1.000		

Table D-2. Percent change in rate of acute respiratory hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
	2	28.692	13.624	33.232	2.010	74.011
	3	18.069	14.243	19.805	-9.378	58.386
	4	32.957	16.157	39.038	1.299	90.836

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in μg/m^3, and gas pollutants in ppb.

Table D-3. Percent change in rate of chronic respiratory hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	1	0.000		1.000		
	2	26.979	17.810	30.969	-7.622	85.682
	3	8.035	19.419	8.366	-25.938	58.560
	4	87.328	21.009	139.475	58.644	261.490
$PM_{2.5}$	1	0.000		1.000		
	2	15.474	19.101	16.736	-19.719	69.743
	3	32.122	19.945	37.881	-6.733	103.836
	4	74.291	21.675	110.204	37.448	221.472
CF Mass	1	0.000		1.000		
	2	-5.707	19.908	-5.547	-36.062	39.533
	3	4.269	24.085	4.361	-34.909	67.324
	4	22.392	27.987	25.097	-27.720	116.510
Ozone 8hr	1	0.000		1.000		
	2	-17.226	19.813	-15.824	-42.912	24.119
	3	-30.609	26.365	-26.368	-56.081	23.449
	4	-96.989	36.815	-62.087	-81.575	-21.989
CO 8hr	1	0.000		1.000		
	2	33.236	20.779	39.426	-7.217	109.517
	3	56.118	21.119	75.273	15.864	165.144
	4	89.885	23.133	145.677	56.118	286.612
NO_2 1hr	1	0.000		1.000		
	2	29.864	17.855	34.803	-5.003	91.287
	3	42.457	19.226	52.894	4.890	122.866
	4	36.041	21.865	43.392	-6.587	120.111
NO_3 (PM_{10})	1	0.000		1.000		
	2	-5.246	24.419	-5.110	-41.202	53.136
	3	51.803	27.773	67.872	-2.598	189.327
	4	115.554	33.006	217.575	66.299	506.461
SO_4 (PM_{10})	1	0.000		1.000		
	2	3.882	23.922	3.958	-34.952	66.145
	3	26.293	29.447	30.073	-26.965	131.656
	4	103.158	30.785	180.550	53.449	412.926
TC (PM_{10})	1	0.000		1.000		

Table D-3. Percent change in rate of chronic respiratory hospitalizations per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI	
					Lower	Upper
	2	27.104	18.447	31.132	-8.654	88.248
	3	37.620	19.067	45.674	0.250	111.681
	4	95.399	20.775	159.604	72.773	290.075

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in μg/m^3, and gas pollutants in ppb.

Appendix E. Center Analyses for Hospitalization Data

Regression coefficients (B x 1,000) between air pollutants and cardiovascular, acute respiratory and chronic respiratory hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

Table E-1. Regression coefficients (β x 1,000) between air pollutants and cardiovascular hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
PM_{10}	0	0.896	0.310	2.859	0.042	-0.692	0.681	0.282	0.885
	1	0.628	0.538	0.534	0.694	-1.324	0.455	0.901	0.398
	2	-0.817	0.160	-0.090	0.982	1.428	0.481	-0.011	0.900
	3	-1.051	0.085	-0.801	0.591	-0.829	0.628	-0.907	0.326
	4	-1.310	0.036	-0.577	0.701	-1.479	0.415	-0.038	0.740
	5	-1.266	0.042	0.466	0.744	-1.169	0.509	-0.097	0.787
$PM_{2.5}$	0	0.935	0.356	2.601	0.173	-3.290	0.279	0.822	0.624
	1	1.071	0.288	1.129	0.563	-1.940	0.529	2.641	0.030
	2	-0.558	0.404	0.795	0.717	1.922	0.546	1.620	0.216
	3	-0.412	0.517	-0.067	0.901	-2.358	0.459	0.378	0.726
	4	-0.831	0.248	0.116	0.936	-3.330	0.297	1.944	0.120
	5	-0.498	0.447	1.166	0.569	-0.962	0.778	2.035	0.098
CF Mass	0	0.809	0.641	3.475	0.194	1.647	0.698	-1.595	0.485
	1	-0.575	0.589	0.287	0.874	-2.192	0.480	-4.597	0.037
	2	-1.272	0.274	-0.764	0.869	0.194	0.926	-5.002	0.024
	3	-2.380	0.043	-4.366	0.138	-0.262	0.885	-4.594	0.035
	4	-2.646	0.022	-2.576	0.403	-1.046	0.689	-5.200	0.016
	5	-2.670	0.022	-1.271	0.743	-1.831	0.507	-5.676	0.010
Ozone 8hr	0	-0.318	0.811	3.898	0.170	-0.698	0.811	-2.662	0.164
	1	-0.772	0.411	3.761	0.126	2.665	0.494	-2.852	0.124
	2	-0.035	0.864	-1.453	0.524	0.518	0.962	-1.963	0.306
	3	-0.758	0.390	-2.553	0.244	0.326	0.941	-0.128	0.921
	4	-1.346	0.075	-3.510	0.099	-0.697	0.764	0.101	0.788
	5	-0.760	0.398	-2.954	0.156	1.333	0.696	-0.237	0.853

Table E-1. Regression coefficients (β x 1,000) between air pollutants and cardiovascular hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
CO 8hr	0	44.004	0.027	50.675	0.164	-45.260	0.370	11.793	0.869
	1	28.640	0.199	31.670	0.391	35.065	0.536	80.072	0.055
	2	4.548	0.703	30.856	0.411	60.436	0.266	46.910	0.279
	3	-3.753	0.708	64.195	0.082	-7.145	0.870	19.133	0.787
	4	1.880	0.758	10.100	0.799	-50.271	0.347	-11.639	0.719
	5	-20.102	0.180	2.930	0.955	-43.732	0.404	40.289	0.447
NO_2 1hr	0	2.033	0.025	4.245	0.034	1.277	0.784	0.761	0.663
	1	1.541	0.105	3.101	0.122	1.333	0.748	1.873	0.470
	2	0.736	0.592	1.862	0.371	0.608	0.896	-0.083	0.864
	3	-0.324	0.541	1.020	0.638	0.954	0.894	-0.135	0.854
	4	-0.429	0.459	0.334	0.919	-1.333	0.561	0.633	0.743
	5	-0.900	0.170	-0.689	0.699	-3.007	0.245	2.116	0.273
NO_3 (PM_{10})	0	2.396	0.746	15.248	0.013	-6.960	0.403	5.880	0.369
	1	2.118	0.884	4.187	0.491	-5.025	0.549	6.362	0.310
	2	-4.711	0.396	-0.570	0.972	5.049	0.635	7.120	0.277
	3	-3.280	0.555	-1.787	0.775	-6.285	0.452	2.295	0.813
	4	-9.407	0.116	-4.114	0.530	-6.840	0.434	-0.795	0.869
	5	-10.963	0.069	-0.447	0.972	-4.245	0.597	3.341	0.936
SO_4 (PM_{10})	0	44.211	0.039	47.283	0.179	-26.313	0.552	18.585	0.671
	1	-33.907	0.180	13.076	0.674	-19.919	0.646	28.013	0.484
	2	-31.937	0.187	3.612	0.876	26.820	0.660	-4.628	0.862
	3	-22.911	0.338	-47.507	0.222	-12.573	0.756	-42.821	0.293
	4	-13.867	0.521	-1.267	0.952	-51.852	0.280	-24.405	0.582
	5	-43.439	0.050	12.739	0.679	0.477	0.985	-14.212	0.681
TC (PM_{10})	0	3.286	0.548	18.246	0.025	-4.384	0.641	3.639	0.454
	1	1.152	0.702	6.166	0.459	-8.247	0.399	7.215	0.089
	2	-3.019	0.262	1.569	0.872	7.798	0.472	3.491	0.485
	3	-6.160	0.038	-0.154	0.929	-7.234	0.457	-0.345	0.873
	4	-6.626	0.030	-1.893	0.798	-7.499	0.453	3.317	0.559
	5	-8.703	0.005	6.732	0.445	-8.013	0.419	4.751	0.291

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.
Particulate matter (PM) and PM chemistry pollutants in μg/m^3, and gas pollutants in ppb.

Table E-2. Regression coefficients (β x 1,000) between air pollutants and acute respiratory hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
PM_{10}	0	1.701	0.083	-1.304	0.577	3.870	0.136	2.667	0.148
	1	1.689	0.089	1.228	0.573	2.761	0.305	2.853	0.121
	2	1.001	0.258	2.139	0.356	1.949	0.479	4.234	0.015
	3	0.585	0.424	4.069	0.073	5.044	0.056	5.137	0.003
	4	0.982	0.197	4.262	0.065	4.987	0.051	4.172	0.018
	5	0.370	0.501	7.144	0.001	4.398	0.088	5.129	0.003
$PM_{2.5}$	0	3.378	0.024	-6.182	0.035	5.576	0.203	3.705	0.085
	1	4.678	0.001	-0.545	0.753	6.532	0.148	3.747	0.086
	2	3.676	0.023	2.782	0.373	4.366	0.376	4.223	0.042
	3	3.318	0.049	3.759	0.212	8.706	0.055	5.528	0.006
	4	3.203	0.063	5.652	0.056	6.909	0.127	3.716	0.085
	5	3.525	0.013	5.421	0.064	5.725	0.235	4.982	0.015
CF Mass	0	-1.748	0.648	5.965	0.207	5.818	0.209	-3.229	0.429
	1	-4.442	0.229	3.498	0.444	0.485	0.975	0.306	0.975
	2	-4.131	0.557	2.874	0.503	1.297	0.703	4.145	0.183
	3	-4.765	0.429	5.516	0.198	4.979	0.240	2.897	0.324
	4	-2.760	0.198	3.068	0.450	4.984	0.227	4.139	0.180
	5	-4.559	0.521	12.411	0.002	5.412	0.195	4.213	0.161
Ozone 8hr	0	-1.072	0.354	-4.964	0.307	7.703	0.217	-0.895	0.868
	1	-3.070	0.033	-6.194	0.169	-2.710	0.678	0.217	0.905
	2	-3.108	0.049	-5.961	0.170	-0.547	0.873	1.674	0.512
	3	-1.563	0.411	-3.451	0.474	-2.595	0.780	-1.315	0.802
	4	-1.541	0.251	-4.784	0.301	1.957	0.533	1.213	0.520
	5	-2.873	0.340	-5.380	0.235	1.789	0.533	-3.015	0.396
CO 8hr	0	49.835	0.134	-31.535	0.553	152.128	0.030	85.891	0.263
	1	44.141	0.247	-73.363	0.195	62.176	0.437	15.151	0.802
	2	55.342	0.116	9.144	0.889	47.444	0.612	140.528	0.052
	3	60.926	0.067	90.702	0.143	133.609	0.079	151.878	0.039
	4	42.489	0.275	150.813	0.010	52.106	0.566	79.521	0.317
	5	21.312	0.631	136.904	0.020	104.736	0.173	137.297	0.062

Table E-2. Regression coefficients (β x 1,000) between air pollutants and acute respiratory hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
NO_2 1hr	0	3.310	0.160	0.293	0.866	7.093	0.100	0.498	0.896
	1	2.900	0.266	0.618	0.896	2.098	0.650	0.783	0.944
	2	1.665	0.604	1.761	0.713	-3.961	0.346	6.077	0.058
	3	1.094	0.661	2.498	0.534	0.300	0.977	4.356	0.184
	4	-0.255	0.275	4.427	0.218	4.577	0.274	1.603	0.647
	5	-0.610	0.222	1.923	0.622	5.110	0.210	3.481	0.278
NO_3 (PM_{10})	0	-2.331	0.922	-13.221	0.235	18.751	0.136	15.422	0.150
	1	12.163	0.141	7.309	0.441	11.440	0.389	13.391	0.216
	2	8.054	0.377	1.714	0.783	14.080	0.272	20.074	0.038
	3	6.121	0.549	17.253	0.072	23.170	0.074	23.667	0.018
	4	4.309	0.836	18.789	0.059	24.512	0.049	15.155	0.168
	5	14.557	0.103	23.185	0.017	21.254	0.086	26.368	0.005
SO_4 (PM_{10})	0	-15.862	0.857	40.564	0.441	110.013	0.111	130.384	0.086
	1	40.707	0.154	-12.296	0.866	106.174	0.130	79.633	0.391
	2	44.748	0.126	49.613	0.361	42.655	0.537	125.733	0.117
	3	-43.287	0.184	91.458	0.103	77.123	0.280	191.201	0.011
	4	23.536	0.547	95.475	0.096	116.892	0.089	123.882	0.141
	5	21.208	0.557	168.906	0.003	106.892	0.113	177.696	0.017
TC (PM_{10})	0	7.793	0.165	-12.985	0.309	16.759	0.253	12.461	0.103
	1	8.952	0.117	2.399	0.803	16.182	0.284	11.268	0.148
	2	7.038	0.209	5.661	0.704	15.515	0.315	16.507	0.021
	3	6.315	0.239	19.742	0.147	28.329	0.054	20.970	0.002
	4	6.559	0.192	23.550	0.091	30.489	0.029	16.753	0.022
	5	5.099	0.292	41.046	0.002	24.038	0.095	19.894	0.005

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table E-3. Regression coefficients (β x 1,000) between air pollutants and chronic respiratory hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
PM_{10}	0	2.094	0.143	-1.824	0.463	7.641	0.022	7.940	0.000
	1	2.830	0.042	2.157	0.473	5.834	0.100	7.826	0.000
	2	1.989	0.137	4.556	0.103	4.214	0.267	8.824	0.000
	3	3.098	0.015	1.446	0.652	7.364	0.026	9.534	0.000
	4	0.261	0.780	3.816	0.173	3.559	0.355	10.076	0.000
	5	2.906	0.019	5.122	0.062	-1.386	0.540	10.507	0.000
$PM_{2.5}$	0	2.832	0.115	-1.908	0.501	15.069	0.001	8.153	0.001
	1	5.749	0.001	4.374	0.252	9.615	0.068	9.142	0.000
	2	3.741	0.046	3.881	0.331	4.302	0.606	10.022	0.000
	3	7.067	0.000	3.510	0.384	11.094	0.038	9.463	0.000
	4	2.715	0.162	4.100	0.280	6.432	0.318	11.718	0.000
	5	6.953	0.000	4.758	0.203	1.546	0.771	11.838	0.000
CF Mass	0	1.156	0.591	2.542	0.642	6.148	0.379	8.796	0.040
	1	-3.330	0.355	0.097	0.957	6.775	0.316	2.136	0.630
	2	-2.428	0.710	8.991	0.076	8.552	0.154	4.881	0.234
	3	-4.958	0.169	-1.122	0.889	8.896	0.135	9.260	0.019
	4	-4.376	0.304	8.537	0.075	2.336	0.748	3.609	0.382
	5	-4.137	0.405	9.061	0.059	-7.826	0.161	5.188	0.190
Ozone 8hr	0	-3.964	0.045	-11.310	0.061	-1.603	0.813	7.734	0.100
	1	-2.883	0.158	-3.787	0.533	3.992	0.432	6.297	0.127
	2	-4.715	0.011	-3.104	0.607	5.409	0.275	-5.600	0.215
	3	-6.078	0.000	1.174	0.675	-7.164	0.357	-3.191	0.493
	4	-3.128	0.197	-1.505	0.955	-12.869	0.054	-7.707	0.050
	5	-2.194	0.694	3.625	0.281	-8.219	0.238	-5.123	0.200
CO 8hr	0	56.389	0.216	-15.387	0.760	199.079	0.029	226.794	0.011
	1	76.697	0.069	61.615	0.438	85.283	0.484	263.109	0.002
	2	85.027	0.039	129.827	0.068	90.518	0.444	232.338	0.007
	3	104.158	0.008	83.275	0.268	173.034	0.059	294.149	0.000
	4	35.502	0.602	87.979	0.232	164.685	0.073	322.248	0.000
	5	82.429	0.045	98.988	0.169	60.610	0.698	353.802	0.000

Table E-3. Regression coefficients (β x 1,000) between air pollutants and chronic respiratory hospitalizations by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p	β (x 1000)	p
NO_2 1hr	0	2.888	0.428	-3.208	0.374	14.357	0.006	7.752	0.062
	1	2.084	0.845	1.581	0.752	5.666	0.338	5.372	0.210
	2	1.962	0.630	0.595	0.919	8.107	0.144	1.071	0.879
	3	1.563	0.720	0.607	0.902	5.189	0.371	2.442	0.564
	4	0.375	0.748	1.727	0.683	4.729	0.423	1.389	0.751
	5	1.607	0.471	3.574	0.367	-2.572	0.564	3.476	0.377
NO_3 (PM_{10})	0	4.128	0.661	-18.983	0.109	28.813	0.081	28.791	0.016
	1	29.832	0.005	6.274	0.660	25.477	0.138	30.273	0.011
	2	18.272	0.132	16.543	0.178	24.086	0.162	41.974	0.000
	3	27.273	0.013	3.633	0.832	31.916	0.047	42.375	0.000
	4	2.863	0.739	21.047	0.078	14.975	0.433	48.691	0.000
	5	30.206	0.006	10.613	0.395	5.552	0.895	51.531	0.000
SO_4 (PM_{10})	0	10.666	0.720	-25.261	0.721	180.499	0.051	204.769	0.046
	1	-18.678	0.683	28.802	0.702	179.194	0.057	241.037	0.015
	2	28.386	0.367	141.421	0.045	80.065	0.489	318.080	0.000
	3	42.810	0.261	66.819	0.355	157.109	0.094	359.250	0.000
	4	27.208	0.497	103.642	0.137	80.965	0.455	379.536	0.000
	5	53.953	0.190	80.183	0.253	-55.052	0.419	414.562	0.000
TC (PM_{10})	0	8.501	0.292	-18.337	0.209	41.279	0.021	32.799	0.000
	1	20.653	0.003	10.810	0.555	27.889	0.157	28.248	0.001
	2	12.508	0.081	18.055	0.284	23.724	0.242	34.120	0.000
	3	21.896	0.001	6.635	0.753	37.908	0.035	36.226	0.000
	4	6.750	0.361	24.858	0.120	16.378	0.462	37.467	0.000
	5	17.675	0.006	31.034	0.051	-3.954	0.699	44.202	0.000

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Appendix F. Gender Analyses for Hospitalization Data

Percent change in rate of cardiovascular, acute respiratory and chronic respiratory hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Table F-1. Percent change in rate of cardiovascular hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	Male	0.232	0.649	0.233	-1.034	1.515
	Female	-0.413	0.768	-0.412	-1.900	1.098
$PM_{2.5}$	Male	1.377	0.805	1.387	-0.200	2.999
	Female	0.908	0.946	0.912	-0.941	2.800
CF Mass	Male	-2.433	1.361	-2.404	-4.972	0.234
	Female	-3.616	1.612	-3.551	-6.550	-0.456
Ozone 8hr	Male	-0.548	1.004	-0.547	-2.485	1.430
	Female	-0.994	1.205	-0.989	-3.301	1.378
CO 8hr	Male	61.625	19.939	85.198	25.290	173.751
	Female	25.025	24.119	28.435	-19.946	106.056
NO_2 1hr	Male	2.915	0.917	2.958	1.124	4.825
	Female	0.318	1.104	0.318	-1.830	2.513
NO_3 (PM_{10})	Male	1.411	4.589	1.421	-7.304	10.966
	Female	5.087	5.249	5.218	-5.069	16.621
SO_4 (PM_{10})	Male	-28.740	27.164	-24.979	-55.949	27.764
	Female	1.499	32.092	1.510	-45.883	90.407
TC (PM_{10})	Male	2.604	3.022	2.638	-3.264	8.901
	Female	-0.645	3.555	-0.643	-7.331	6.528

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table F-2. Percent change in rate of acute respiratory hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Male	2.458	1.005	2.488	0.489	4.528
	Female	1.971	1.073	1.991	-0.131	4.158
$PM_{2.5}$	Male	4.308	1.212	4.403	1.951	6.913
	Female	3.113	1.281	3.162	0.605	5.785
CF Mass	Male	0.487	2.273	0.488	-3.891	5.066
	Female	-0.929	2.481	-0.925	-5.628	4.013
Ozone 8hr	Male	0.550	1.649	0.552	-2.646	3.854
	Female	-5.519	1.796	-5.370	-8.642	-1.979
CO 8hr	Male	65.654	31.041	92.810	4.931	254.289
	Female	90.881	33.258	148.137	29.298	376.202
NO_2 1hr	Male	6.252	1.559	6.451	3.247	9.755
	Female	0.041	1.742	0.041	-3.318	3.516
NO_3 (PM_{10})	Male	8.402	6.900	8.765	-4.994	24.517
	Female	13.864	7.143	14.872	-0.136	32.134
SO_4 (PM_{10})	Male	49.119	40.136	63.427	-25.582	258.895
	Female	18.819	43.556	20.706	-48.599	183.458
TC (PM_{10})	Male	9.243	4.689	9.684	0.053	20.241
	Female	9.962	4.905	10.475	0.349	21.624

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in μg/m^3, and gas pollutants in ppb.

Table F-3. Percent change in rate of chronic respiratory hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Male	5.181	1.461	5.317	2.344	8.377
	Female	5.417	1.162	5.566	3.188	7.999
$PM_{2.5}$	Male	6.927	1.759	7.173	3.540	10.933
	Female	7.168	1.408	7.431	4.507	10.436
CF Mass	Male	5.016	3.363	5.144	-1.563	12.308
	Female	3.332	2.743	3.388	-2.023	9.098
Ozone 8hr	Male	-6.456	2.599	-6.252	-10.908	-1.354
	Female	-5.299	2.129	-5.161	-9.037	-1.119
CO 8hr	Male	159.719	45.597	393.913	102.077	1107.213
	Female	133.623	37.788	280.467	81.410	697.946
NO_2 1hr	Male	5.894	2.438	6.072	1.122	11.263
	Female	3.912	1.974	3.990	0.044	8.091
NO_3 (PM_{10})	Male	32.403	9.395	38.269	15.014	66.225
	Female	31.454	7.610	36.964	17.985	58.995
SO_4 (PM_{10})	Male	164.329	57.663	417.215	67.045	1501.434
	Female	197.076	47.376	617.610	183.543	1716.177
TC (PM_{10})	Male	28.242	6.644	32.634	16.439	51.082
	Female	26.529	5.224	30.381	17.692	44.439

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Appendix G. Quartile Analyses for Emergency Room Visit Data

Percent change in rate of cardiovascular, acute respiratory and chronic respiratory emergency room visits per 10 unit increase of pollutant by quartile for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Table G-1. Percent change in rate of cardiovascular emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	1	0.000				
	2	-2.964	9.811	-2.921	-19.904	17.663
	3	1.794	10.693	1.810	-17.439	25.547
	4	3.391	13.019	3.449	-19.850	33.520
$PM_{2.5}$	1	0.000				
	2	0.689	10.054	0.692	-17.318	22.624
	3	4.331	11.071	4.426	-15.945	29.733
	4	42.110	12.822	52.363	18.505	95.894
CF Mass	1	0.000				
	2	-0.492	11.867	-0.490	-21.142	25.569
	3	-0.637	14.042	-0.635	-24.542	30.846
	4	-17.910	16.256	-16.398	-39.209	14.973
Ozone 8hr	1	0.000				
	2	-1.217	11.962	-1.209	-21.856	24.892
	3	-6.648	15.011	-6.432	-30.281	25.576
	4	-37.583	19.833	-31.328	-53.446	1.297
CO 8hr	1	0.000				
	2	3.201	10.811	3.253	-16.463	27.623
	3	13.786	11.155	14.781	-7.760	42.830
	4	13.353	12.817	14.285	-11.102	46.922
NO_2 1hr	1	0.000				
	2	-15.644	9.786	-14.482	-29.408	3.601
	3	-13.973	10.736	-13.041	-29.542	7.325
	4	-1.676	12.217	-1.662	-22.602	24.944

Table G-1. Percent change in rate of cardiovascular emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
NO_3 (PM_{10})	1	0.000				
	2	39.162	15.213	47.938	9.795	99.331
	3	2.341	19.752	2.368	-30.493	50.765
	4	77.101	25.595	116.195	30.911	257.039
SO_4 (PM_{10})	1	0.000				
	2	16.013	15.160	17.366	-12.804	57.975
	3	23.834	20.926	26.914	-15.785	91.264
	4	24.167	24.336	27.337	-20.969	105.167
TC (PM_{10})	1	0.000				
	2	7.028	9.907	7.281	-11.654	30.273
	3	-7.943	10.480	-7.635	-24.786	13.426
	4	24.072	12.364	27.216	-0.161	62.101

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table G-2. Percent change in rate of acute respiratory emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	1	0.000				
	2	9.378	10.205	9.832	-10.079	34.153
	3	14.549	10.952	15.661	-6.683	43.354
	4	26.314	12.345	30.100	2.140	65.714
$PM_{2.5}$	1	0.000				
	2	30.730	10.898	35.975	9.822	68.355
	3	52.430	11.414	68.928	35.067	111.279
	4	68.382	12.416	98.144	55.342	152.738
CF Mass	1	0.000				
	2	1.444	11.623	1.454	-19.214	27.411
	3	-13.680	14.215	-12.785	-33.993	15.236
	4	-10.691	16.630	-10.139	-35.135	24.489
Ozone 8hr	1	0.000				
	2	-32.708	11.292	-27.898	-42.213	-10.036
	3	-52.698	14.957	-40.961	-55.963	-20.849
	4	-73.548	20.875	-52.073	-68.166	-27.844
CO 8hr	1	0.000				
	2	38.707	12.058	47.266	16.269	86.526
	3	74.077	12.055	109.755	65.614	165.663
	4	92.242	13.226	151.537	94.099	225.974
NO_2 1hr	1	0.000				
	2	11.519	10.190	12.209	-8.106	37.015
	3	24.256	11.049	27.450	2.633	58.268
	4	52.634	12.653	69.273	32.093	116.918
NO_3 (PM_{10})	1	0.000				
	2	3.737	14.113	3.808	-21.277	36.886
	3	28.499	16.522	32.975	-3.809	83.825
	4	30.462	21.441	35.611	-10.919	106.445
SO_4 (PM_{10})	1	0.000				
	2	32.572	13.723	38.502	5.838	81.247
	3	20.987	18.046	23.352	-13.396	75.694
	4	56.217	19.894	75.447	18.796	159.113

Table G-2. Percent change in rate of acute respiratory emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
TC (PM_{10})	1	0.000				
	2	37.810	10.548	45.951	18.693	79.469
	3	45.846	10.947	58.164	27.622	96.014
	4	66.955	12.028	95.335	54.310	147.267

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.

Table G-3. Percent change in rate of chronic respiratory emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	1	0.000				
	2	3.365	10.661	3.423	-16.079	27.457
	3	23.653	11.703	26.685	0.719	59.345
	4	71.124	12.787	103.652	58.506	161.657
$PM_{2.5}$	1	0.000				
	2	32.621	11.300	38.571	11.041	72.927
	3	71.208	11.804	103.822	61.723	156.880
	4	101.157	13.007	174.990	113.109	254.840
CF Mass	1	0.000				
	2	5.979	12.308	6.161	-16.594	35.124
	3	-5.934	14.687	-5.762	-29.334	25.675
	4	-17.404	17.434	-15.974	-40.295	18.254
Ozone 8hr	1	0.000				
	2	-6.620	12.199	-6.405	-26.310	18.876
	3	6.544	15.458	6.763	-21.143	44.545
	4	-15.316	21.536	-14.201	-43.744	30.858
CO 8hr	1	0.000				
	2	32.991	12.068	39.085	9.787	76.200
	3	78.960	12.199	120.252	73.412	179.744
	4	102.370	13.476	178.348	113.736	262.490
NO_2 1hr	1	0.000				
	2	15.681	10.648	16.977	-5.058	44.126
	3	39.092	11.600	47.834	17.769	85.574
	4	79.977	12.985	122.502	72.507	186.986
NO_3 (PM_{10})	1	0.000				
	2	-6.991	15.465	-6.752	-31.134	26.264
	3	8.620	17.856	9.002	-23.186	54.678
	4	28.830	22.077	33.415	-13.446	105.648
SO_4 (PM_{10})	1	0.000				
	2	2.340	14.769	2.368	-23.361	36.735
	3	-9.328	19.280	-8.906	-37.573	32.925
	4	32.865	20.845	38.909	-7.680	109.007

Table G-3. Percent change in rate of chronic respiratory emergency room visits per quartile increase of pollutant for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Quartile	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
TC (PM_{10})	1	0.000				
	2	40.728	10.869	50.272	21.440	85.949
	3	45.577	11.562	57.738	25.753	97.859
	4	102.316	12.491	178.198	117.786	255.367

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Appendix H. Center Analyses for Emergency Room Visit Data

Regression coefficients (B x 1,000) between air pollutants and cardiovascular, acute respiratory and chronic respiratory emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

Table H-1. Regression coefficients (B x 1,000) between air pollutants and cardiovascular emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
PM_{10}	0	0.721	0.373	3.386	0.353	2.270	0.657	-1.289	0.270
	1	0.744	0.360	-0.331	0.913	-1.434	0.741	-1.323	0.238
	2	0.710	0.372	-0.452	0.906	2.945	0.546	-2.371	0.045
	3	0.620	0.427	-1.337	0.917	4.100	0.395	-3.651	0.003
	4	0.342	0.701	0.974	0.740	5.757	0.219	-2.851	0.022
	5	-0.080	0.838	-0.707	0.897	5.434	0.239	-1.757	0.146
$PM_{2.5}$	0	0.858	0.359	1.986	0.644	5.951	0.442	-1.107	0.400
	1	1.768	0.044	-4.690	0.511	2.717	0.759	-0.026	0.866
	2	2.329	0.008	0.796	0.818	4.413	0.560	-1.556	0.229
	3	2.101	0.019	-0.853	0.893	10.116	0.150	-3.275	0.022
	4	1.715	0.059	0.024	0.964	8.045	0.269	-0.999	0.426
	5	1.356	0.151	-0.712	0.906	9.435	0.164	-1.217	0.350
CF Mass	0	0.585	0.722	7.535	0.328	-0.559	0.940	-2.757	0.341
	1	-1.141	0.362	5.663	0.445	-7.997	0.376	-6.348	0.022
	2	-1.705	0.169	3.240	0.643	4.233	0.633	-5.381	0.043
	3	-1.279	0.296	-5.416	0.610	2.660	0.775	-5.167	0.047
	4	-2.122	0.080	4.377	0.532	6.305	0.468	-7.678	0.004
	5	-2.154	0.076	-2.853	0.821	5.090	0.550	-3.147	0.251
Ozone 8hr	0	0.248	0.861	-11.181	0.171	-17.307	0.089	-3.610	0.183
	1	-0.357	0.662	-18.487	0.013	-17.881	0.048	-4.294	0.088
	2	-0.867	0.257	-5.098	0.461	-12.573	0.124	-3.603	0.111
	3	-1.774	0.012	2.057	0.719	0.228	0.958	-2.862	0.183
	4	-1.553	0.027	-3.743	0.572	-6.443	0.389	-1.361	0.550
	5	-0.968	0.189	-5.843	0.363	-5.152	0.491	-1.247	0.584

Table H-1. Regression coefficients (B x 1,000) between air pollutants and cardiovascular emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
CO 8hr	0	9.479	0.962	-2.365	0.957	295.396	0.012	10.512	0.912
	1	24.943	0.254	52.736	0.582	-14.274	0.866	40.479	0.493
	2	24.541	0.279	20.606	0.808	-117.660	0.360	-39.196	0.388
	3	33.128	0.110	47.930	0.614	92.937	0.513	-92.747	0.060
	4	17.439	0.479	189.310	0.054	168.203	0.191	-95.213	0.057
	5	22.728	0.323	31.776	0.729	134.897	0.299	42.051	0.480
NO_2 1hr	0	1.568	0.126	-4.829	0.434	-5.062	0.526	1.994	0.391
	1	1.212	0.290	-1.369	0.828	-7.786	0.319	-1.427	0.467
	2	0.100	0.737	-1.748	0.788	-19.132	0.014	-3.834	0.069
	3	-0.106	0.757	-2.588	0.689	-7.069	0.364	-1.616	0.433
	4	-0.143	0.679	3.761	0.487	-4.275	0.600	-0.790	0.699
	5	-0.237	0.590	0.427	0.912	-6.890	0.380	2.598	0.245
NO_3 (PM_{10})	0	9.328	0.120	-0.880	0.919	14.140	0.535	-4.861	0.457
	1	7.671	0.221	1.107	0.891	16.290	0.490	-2.353	0.670
	2	14.494	0.018	-13.085	0.592	1.042	0.973	-7.290	0.254
	3	14.146	0.024	2.116	0.838	28.375	0.188	-18.212	0.010
	4	11.657	0.057	13.239	0.409	25.971	0.248	-11.798	0.083
	5	5.454	0.385	-9.827	0.727	23.336	0.276	-7.031	0.277
SO_4 (PM_{10})	0	28.323	0.173	-87.755	0.568	17.275	0.898	-32.951	0.505
	1	4.711	0.786	-95.404	0.521	-52.454	0.658	-87.871	0.079
	2	25.683	0.227	-32.628	0.906	100.133	0.415	-104.080	0.051
	3	4.596	0.810	24.027	0.730	99.268	0.429	-129.724	0.015
	4	-3.844	0.862	45.708	0.579	60.531	0.661	-119.677	0.030
	5	21.802	0.349	13.390	0.811	113.128	0.350	-117.553	0.029
TC (PM_{10})	0	3.439	0.372	24.074	0.272	9.356	0.755	-2.617	0.523
	1	5.241	0.151	0.715	0.936	-3.842	0.861	-0.093	0.872
	2	6.752	0.056	2.324	0.878	17.353	0.512	-6.387	0.143
	3	5.984	0.090	-4.721	0.952	19.237	0.468	-12.725	0.008
	4	4.338	0.235	9.521	0.644	31.633	0.216	-5.502	0.221
	5	0.740	0.901	8.920	0.665	35.297	0.152	-2.907	0.476

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.

Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table H-2. Regression coefficients (B x 1,000) between air pollutants and acute respiratory emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
PM_{10}	0	2.497	0.001	-1.213	0.655	6.645	0.072	3.653	0.001
	1	2.251	0.005	-1.748	0.521	7.163	0.049	4.310	0.000
	2	2.891	0.000	1.155	0.765	8.185	0.023	4.007	0.000
	3	2.719	0.000	3.839	0.225	7.650	0.035	4.412	0.000
	4	2.554	0.000	1.137	0.763	7.218	0.049	4.247	0.000
	5	1.706	0.009	-0.733	0.765	9.825	0.005	4.050	0.000
$PM_{2.5}$	0	3.920	0.000	-1.694	0.625	11.078	0.057	4.038	0.002
	1	3.979	0.000	-0.018	0.978	11.285	0.053	3.391	0.024
	2	5.007	0.000	2.715	0.524	12.780	0.025	4.232	0.001
	3	5.017	0.000	2.725	0.519	13.376	0.017	6.048	0.000
	4	5.921	0.000	2.005	0.669	11.429	0.047	4.492	0.001
	5	4.528	0.000	2.373	0.587	16.592	0.002	5.377	0.000
CF Mass	0	0.212	0.711	-0.104	0.973	8.732	0.212	2.154	0.385
	1	-1.331	0.593	-7.281	0.272	10.199	0.124	6.189	0.002
	2	-0.983	0.388	-0.499	0.924	10.828	0.093	2.521	0.193
	3	-1.715	0.270	9.715	0.115	6.450	0.326	-1.146	0.580
	4	-4.011	0.206	-0.745	0.892	9.267	0.153	3.722	0.044
	5	-4.108	0.210	-5.136	0.423	9.693	0.134	-0.299	0.967
Ozone 8hr	0	-2.774	0.012	-2.013	0.884	-0.047	0.952	-0.347	0.841
	1	-1.768	0.201	-7.007	0.292	-8.308	0.345	-3.600	0.222
	2	-2.954	0.016	-5.262	0.394	-9.815	0.206	-4.744	0.082
	3	-3.276	0.009	4.836	0.286	-3.586	0.761	-6.835	0.005
	4	-4.258	0.000	-4.229	0.469	4.366	0.366	-6.794	0.005
	5	-4.389	0.000	0.607	0.837	-5.141	0.568	-7.354	0.002
CO 8hr	0	64.385	0.009	-43.632	0.551	238.598	0.013	85.731	0.283
	1	59.173	0.028	25.024	0.812	62.958	0.719	123.903	0.058
	2	79.906	0.001	136.232	0.076	161.721	0.130	94.966	0.229
	3	96.698	0.000	100.221	0.212	194.149	0.057	167.804	0.001
	4	92.394	0.000	82.415	0.312	130.198	0.249	167.869	0.002
	5	98.926	0.000	-85.904	0.257	245.786	0.011	131.514	0.026

Table H-2. Regression coefficients (B x 1,000) between air pollutants and acute respiratory emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
NO_2 1hr	0	3.162	0.095	-2.696	0.554	13.107	0.034	5.127	0.088
	1	2.666	0.326	0.640	0.926	4.072	0.639	5.877	0.045
	2	3.312	0.012	1.544	0.764	4.038	0.628	3.948	0.259
	3	3.339	0.004	2.753	0.560	7.482	0.253	3.653	0.252
	4	1.896	0.171	-0.074	0.974	6.211	0.366	3.602	0.246
	5	1.287	0.500	0.012	0.988	17.529	0.002	4.200	0.114
NO_3 (PM_{10})	0	9.444	0.142	1.828	0.974	29.532	0.087	13.238	0.057
	1	18.735	0.004	-9.630	0.433	32.404	0.057	16.866	0.008
	2	13.037	0.049	1.002	0.942	37.788	0.024	19.544	0.001
	3	17.742	0.006	14.941	0.280	33.311	0.050	20.064	0.000
	4	23.867	0.000	-5.987	0.618	30.545	0.072	18.804	0.002
	5	19.498	0.002	10.235	0.462	42.194	0.010	19.524	0.002
SO_4 (PM_{10})	0	77.176	0.001	-3.936	0.940	168.704	0.094	100.573	0.046
	1	57.280	0.014	-93.129	0.269	205.923	0.035	101.434	0.046
	2	45.870	0.063	36.540	0.691	235.817	0.015	134.241	0.005
	3	38.812	0.090	50.761	0.566	227.486	0.020	167.695	0.000
	4	25.556	0.420	-21.328	0.790	252.063	0.008	121.789	0.008
	5	35.963	0.167	76.633	0.374	295.918	0.002	127.811	0.009
TC (PM_{10})	0	11.504	0.006	-8.527	0.582	33.892	0.096	12.808	0.010
	1	12.183	0.004	-5.406	0.696	35.135	0.083	15.855	0.001
	2	14.964	0.000	10.168	0.611	47.653	0.015	15.287	0.001
	3	14.763	0.000	22.317	0.220	42.166	0.033	18.012	0.000
	4	15.771	0.000	4.315	0.882	35.333	0.085	18.333	0.000
	5	11.627	0.001	-3.000	0.808	55.809	0.004	18.316	0.000

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table H-3. Regression coefficients (B x 1,000) between air pollutants and chronic respiratory emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
PM_{10}	0	3.757	0.000	4.865	0.139	2.088	0.622	2.046	0.101
	1	3.978	0.000	5.546	0.089	2.342	0.549	2.799	0.011
	2	4.147	0.000	-0.820	0.721	4.757	0.168	2.374	0.034
	3	3.306	0.000	-0.867	0.719	5.332	0.120	2.555	0.020
	4	2.930	0.000	-4.752	0.119	4.950	0.158	2.678	0.011
	5	2.216	0.001	3.504	0.301	6.242	0.073	3.446	0.001
$PM_{2.5}$	0	4.646	0.000	7.952	0.069	0.425	0.916	2.238	0.125
	1	5.047	0.000	10.704	0.009	1.052	0.944	3.064	0.015
	2	5.399	0.000	3.596	0.545	5.981	0.279	2.655	0.047
	3	6.124	0.000	1.645	0.795	6.453	0.240	3.884	0.001
	4	5.528	0.000	-0.124	0.946	6.120	0.282	4.196	0.000
	5	4.287	0.000	9.756	0.023	9.458	0.086	4.621	0.000
CF Mass	0	4.106	0.003	4.429	0.455	5.308	0.480	0.605	0.898
	1	3.693	0.004	-1.058	0.981	7.313	0.282	0.888	0.692
	2	3.593	0.002	-12.061	0.109	10.011	0.123	1.221	0.500
	3	-0.898	0.388	-10.792	0.156	9.087	0.150	-1.697	0.392
	4	-0.774	0.354	-22.434	0.003	7.672	0.234	-1.990	0.331
	5	-0.130	0.558	-11.231	0.140	8.761	0.168	-0.557	0.854
Ozone 8hr	0	-4.394	0.000	2.977	0.608	-9.731	0.336	-1.556	0.436
	1	0.102	0.733	-9.908	0.125	-7.704	0.355	0.624	0.772
	2	-1.574	0.729	0.372	0.873	-4.109	0.596	0.990	0.508
	3	-2.468	0.078	-5.253	0.451	-0.477	0.934	-0.609	0.699
	4	-2.533	0.082	-13.404	0.017	8.926	0.095	-1.327	0.811
	5	-2.632	0.069	-3.896	0.670	6.089	0.248	-2.015	0.421
CO 8hr	0	67.162	0.004	29.300	0.833	72.224	0.537	14.406	0.583
	1	92.399	0.000	128.016	0.131	27.459	0.839	62.281	0.396
	2	93.907	0.000	156.599	0.054	47.266	0.656	50.214	0.736
	3	96.697	0.000	-38.938	0.536	84.578	0.400	93.026	0.069
	4	86.474	0.000	-23.672	0.675	23.620	0.845	78.444	0.181
	5	83.098	0.000	-15.579	0.753	233.265	0.010	113.838	0.017

Table H-3. Regression coefficients (B x 1,000) between air pollutants and chronic respiratory emergency room visits by lag and center, Kaiser Permanente Central Valley Study, 1996-2000.

		Sacramento		Stockton		Modesto		Fresno	
Pollutant	Lag	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ	β (x 1000)	ρ
NO_2 1hr	0	1.225	0.368	5.416	0.292	-1.849	0.818	-0.974	0.374
	1	2.967	0.021	9.996	0.034	-4.299	0.665	1.200	0.414
	2	2.916	0.013	2.257	0.703	2.210	0.552	1.643	0.599
	3	2.702	0.013	-11.377	0.016	0.513	0.826	3.123	0.293
	4	1.849	0.108	-6.823	0.137	6.963	0.133	2.164	0.791
	5	1.598	0.084	-1.936	0.642	8.291	0.083	3.573	0.149
NO_3 (PM_{10})	0	18.786	0.008	20.310	0.157	3.794	0.873	8.928	0.203
	1	27.160	0.000	14.716	0.316	9.173	0.645	10.292	0.123
	2	17.578	0.021	-12.234	0.331	21.388	0.187	10.482	0.071
	3	20.754	0.005	-3.523	0.730	15.970	0.332	15.180	0.006
	4	19.828	0.006	-15.196	0.257	22.752	0.171	11.665	0.039
	5	22.378	0.002	24.350	0.074	25.741	0.116	18.204	0.001
SO_4 (PM_{10})	0	29.280	0.236	67.863	0.437	5.186	0.935	92.109	0.064
	1	58.665	0.018	-4.258	0.935	56.587	0.608	89.676	0.078
	2	38.849	0.160	-118.919	0.180	132.475	0.160	88.058	0.070
	3	34.179	0.211	-126.856	0.157	152.612	0.100	117.517	0.012
	4	39.527	0.140	-123.445	0.167	155.023	0.102	96.885	0.038
	5	47.800	0.077	62.043	0.463	193.201	0.045	160.403	0.000
TC (PM_{10})	0	17.528	0.000	29.988	0.107	1.080	0.951	7.492	0.170
	1	18.917	0.000	38.673	0.033	6.032	0.794	10.149	0.029
	2	18.197	0.000	5.914	0.958	21.320	0.251	8.964	0.062
	3	18.487	0.000	-4.434	0.721	27.082	0.144	10.444	0.020
	4	15.969	0.000	-22.604	0.172	18.806	0.328	12.991	0.002
	5	12.270	0.001	29.788	0.117	32.619	0.084	14.665	0.000

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week.

Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Appendix I. Gender Analyses for Emergency Room Visit Data

Percent change in rate of cardiovascular, acute respiratory and chronic respiratory emergency room visits per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Table I-1. Percent change in rate of cardiovascular emergency room visits per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

					95% CI	
Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	Lower	Upper
PM_{10}	Male	0.821	0.858	0.825	-0.857	2.534
	Female	-0.881	0.921	-0.877	-2.650	0.928
$PM_{2.5}$	Male	2.046	1.048	2.067	-0.009	4.186
	Female	0.809	1.122	0.813	-1.379	3.054
CF Mass	Male	-1.008	1.804	-1.003	-4.442	2.560
	Female	-5.689	1.899	-5.530	-8.981	-1.948
Ozone 8hr	Male	-3.005	1.231	-2.961	-5.274	-0.591
	Female	-2.478	1.305	-2.448	-4.912	0.079
CO 8hr	Male	23.397	26.036	26.360	-24.145	110.491
	Female	20.681	27.533	22.975	-28.311	110.949
NO_2 1hr	Male	-0.098	1.187	-0.098	-2.395	2.254
	Female	-0.654	1.252	-0.652	-3.060	1.816
NO_3 (PM_{10})	Male	6.738	7.053	6.971	-6.841	22.830
	Female	4.609	7.515	4.717	-9.625	21.336
SO_4 (PM_{10})	Male	31.591	41.361	37.150	-39.029	208.509
	Female	52.204	43.107	68.547	-27.593	292.337
TC (PM_{10})	Male	7.312	3.937	7.586	-0.404	16.216
	Female	0.154	4.250	0.154	-7.851	8.855

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table I-2. Percent change in rate of acute respiratory hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Male	3.961	0.744	4.041	2.535	5.569
	Female	2.974	0.758	3.018	1.499	4.560
$PM_{2.5}$	Male	5.819	0.877	5.991	4.185	7.829
	Female	4.931	0.877	5.055	3.264	6.876
CF Mass	Male	1.396	1.752	1.406	-2.018	4.949
	Female	-1.579	1.848	-1.566	-5.067	2.064
Ozone 8hr	Male	-1.289	1.288	-1.281	-3.741	1.243
	Female	-3.800	1.328	-3.729	-6.202	-1.190
CO 8hr	Male	106.637	24.289	190.480	80.454	367.592
	Female	98.494	24.848	167.764	64.529	335.775
NO_2 1hr	Male	6.883	1.238	7.125	4.558	9.756
	Female	6.694	1.285	6.923	4.264	9.650
NO_3 (PM_{10})	Male	21.248	5.225	23.675	11.637	37.011
	Female	13.757	5.080	14.748	3.873	26.762
SO_4 (PM_{10})	Male	156.669	33.491	379.076	148.496	823.612
	Female	97.734	32.252	165.738	41.229	400.016
TC (PM_{10})	Male	19.027	3.285	20.958	13.416	29.001
	Female	13.583	3.328	14.548	7.315	22.269

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in $\mu g/m^3$, and gas pollutants in ppb.

Table I-3. Percent change in rate of chronic respiratory hospitalizations per 10 unit increase of pollutant by gender for four day moving average, Kaiser Permanente Central Valley Study, 1996-2000.

Pollutants	Gender	β (x 1000)	STD (x 1000)	Percent change	95% CI Lower	95% CI Upper
PM_{10}	Male	3.631	0.822	3.698	2.040	5.383
	Female	3.832	0.726	3.906	2.439	5.395
$PM_{2.5}$	Male	6.320	0.968	6.524	4.521	8.565
	Female	6.255	0.857	6.455	4.682	8.257
CF Mass	Male	-0.550	1.967	-0.548	-4.309	3.360
	Female	-1.206	1.741	-1.199	-4.513	2.230
Ozone 8hr	Male	-1.433	1.456	-1.423	-4.195	1.431
	Female	-1.778	1.298	-1.762	-4.230	0.770
CO 8hr	Male	143.183	27.270	318.635	145.306	614.435
	Female	123.475	24.440	243.750	112.917	454.979
NO_2 1hr	Male	6.275	1.363	6.476	3.669	9.358
	Female	7.775	1.216	8.085	5.539	10.693
NO_3 (PM_{10})	Male	8.375	5.648	8.736	-2.658	21.464
	Female	8.826	5.096	9.227	-1.156	20.701
SO_4 (PM_{10})	Male	27.641	37.244	31.838	-36.464	173.568
	Female	49.532	33.329	64.102	-14.609	215.367
TC (PM_{10})	Male	18.647	3.564	20.498	12.369	29.216
	Female	18.990	3.157	20.912	13.658	28.630

Poisson regression models with smoothing splines for date, temperature, and relative humidity, and indicator variables for day of week and center.
Particulate matter (PM) and PM chemistry pollutants in µg/m^3, and gas pollutants in ppb.