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This study examined if an association exists between seasonal ozone air pollution in the Fort Worth area and patients admitted to local area hospitals with existing asthma, pneumonia, bronchitis and COPD. Ozone is a secondary pollutant formed in a complex reaction between oxides of nitrogen and volatile organic compounds, in the presence of sunlight and heat. The EPA has classified the Dallas – Fort Worth area as a non-attainment area by for ozone. The study did not find any apparent association between seasonal ozone AQI and the emergency respiratory admissions. The available hospital data significantly limited analyzing the connection between emergency hospitalization and daily fluctuations of ozone. Further studies are needed to address this complex relationship in a broader perspective.

ASSOCIATION BETWEEN EMERGENCY HOSPITAL ADMISSIONS

OF THE ADULT POPULATION WITH PREEXISTING

RESPIRATORY CONDITIONS AND

OZONE AIR QUALITY INDEX

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ASSOCIATION BETWEEN EMERGENCY HOSPITAL ADMISSIONS OF THE ADULT POPULATION WITH PREEXISTING RESPIRATORY CONDITIONS AND OZONE AIR QUALITY INDEX

THESIS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In the last two decades, air pollution has been consistently reported by many organizations and researchers as a cause of significant concern for the health of the public. Maintaining good air quality is important and has numerous public health benefits. A population's sensitive subgroups are particularly susceptible to this environmental determinant. These subgroups include adults 65 and older, children, as well as people with chronic lung diseases such as chronic bronchitis, emphysema and asthma, cardiovascular disease and diabetes (American Lung Association [ALA], 2006a).

The most prominent environmental hazards of ambient air pollutants are ozone and particulate matter. Susceptibility to these pollutants depends not only on the degree of concentration, but also on a person's preexisting health condition, age, lifestyle and genetics. Statistics demonstrate that the average American inhales approximately 12,870 liters of air per day; one of the many reasons why good air quality is so important (ALA, 2002). In a recent survey the Yale Center for Environmental Law and Policy found that 59% of Americans polled stated the environmental conditions as "fair" or "poor." Only 3% of the Americans graded the nation's environment as "excellent". However, 67 % expressed the concern that government should improve environmental quality (Yale University, 2004).

Ozone can be categorized as either "Good" or "Bad". "Good" ozone is found in the high strata of Earth's atmosphere (stratosphere) and "Bad" ozone is found in the troposphere at ground level (United States Environmental Protection Agency [U.S. EPA], 1999, p.1). Ground level ozone is formed as a product of a complex chemical process and environmental factors where the leading components include volatile organic compounds, nitrogen oxides, high temperature and sunlight (Clear the Air, 1999).

However, other factors such as wind direction, local geographic characteristics (large metropolitan areas) and natural sources of emissions (soil, plants) may influence the formation of ozone. Once ozone is formed, it can migrate over long distances from the area of origin. Since ozone is a photochemical oxidant, its concentration varies with the season and it's usually higher during the summer. Additionally the concentration tends to be elevated in the early afternoon hours (World Health Organization [WHO], 2003).

Several studies have identified the impact of ozone aggravation on cardiovascular diseases, and the potential association with premature mortality (Parodi, Vercelli, Garrone, Fontana, & Izzotti, 2005; Ruidavets et al., 2005; Zhang et al., 2006). The effects are more likely to be observed in the respiratory system, since this air pollutant enters through the lungs. Health effects from long-term exposure to ozone need further emphasis; so far research suggests that it may permanently damage the lung leading to diminished lung function and premature mortality (Galizia & Kinney, 1999; Kunzli et al., 1997; McDonnell, Abbey, Nishino, & Lebowitz, 1999).

Respiratory diseases can be exacerbated by numerous air pollutants which can act as disease triggers, or intensify preexisting respiratory conditions.

The most common air pollutants that affect respiratory health are ozone, particulate matter (PM_{10} / $PM_{2.5}$), carbon monoxide, sulfur dioxide and nitrogen dioxide.

The susceptible population at greater risk from exposure to these pollutants varies from the pollutant:

Ozone—Active children and adults, people with respiratory diseases, asthma, and people sensitive to ozone from unknown causes (U.S. EPA, 2003).

Particle matters—Active children, older people and adults with preexisting cardiovascular and respiratory diseases (i.e. coronary artery disease, congestive heart failure, asthma, COPD) (U.S. EPA, 2003).

Carbon monoxide—People with a medical history of cardiovascular conditions (i.e. angina); people with progressed status of cardiovascular and respiratory systems (such as diagnosis of congestive heart failure, cerebrovascular disease etc); young children as a sensitive part of the population are susceptible as well to carbon monoxide (U.S. EPA, 2003).

Sulfur dioxide—People with asthma who spend considerable time outdoors. In addition people with other chronic respiratory or cardiovascular diseases, elderly and children might develop various diseases of respiratory system (U.S. EPA, 2003).

The major irritant effects caused by these pollutants are concentrated in specific segments of the respiratory system:

Ozone (O_3) — Irritates the lung and causes acute respiratory conditions; reduces the ability of the lung to function normally by 15 – 20 % in some cases; increases the vulnerability of the organism to respiratory diseases like pneumonia and bronchitis; exacerbates asthma symptoms and causes inflammation of respiratory airways. Ten to twenty percent of respiratory hospital visits in northeast of United States are connected to summertime ozone pollution (U.S. EPA, 2006a).

Particulate Matter (PM_x) — Aggravates preexisting respiratory illnesses by increasing the number and severity of asthma attacks especially in children; increases premature mortality due to diseases of cardiovascular and respiratory system; raises the probability for heart attacks and hospital visits for cardiovascular diseases. Overall long-term exposure to particulate pollution has been linked to underdeveloped lung capacity and damage of the airways. These conditions have been associated with lung cancer and premature mortality (ALA, 2006a).

Carbon Monoxide (CO) — Constitutes a barrier to supplying specific body organs with oxygen. People with diseases of cardiovascular and respiratory system are at particular risk (U.S. EPA, 2003).

Sulfur dioxide (SO_2) — Increases respiratory symptoms (difficulty in breathing and wheezing caused by airways constriction). When extended exposure occurs, some people may develop respiratory diseases (U.S. EPA, 2003).

Nitrogen dioxide (NO_2) — One of the contributors of ground-level ozone formation. In combination with other environmental contaminants, can cause various respiratory symptoms (U.S. EPA, 1998).

These respiratory health effects also represent a financial burden to state and society.

During the year 2000, Chronic Obstructive Pulmonary Disease (COPD) accounted for approximately 720, 000 hospital admissions and 1.5 million visits to emergency departments (National Heart, Blood and Lung Institute [NHLBI], 2002 as cited in EPA, 2004). During the same year, the United States registered about 160 million tons of polluted air discharged into the environment (ALA, 2002). The yearly cost of treating respiratory conditions related to outdoor air pollution is approximately $50 billion (Tarrant County Public Health, 2006).

Aside from human health, ozone also damages parks, forests and other natural recreation sources. Almost 500 million dollars in financial harm from decreased crop production in the United States is due to ozone (ALA, 2002).

The history of federal acts that set the foundation for environmental regulations is marked by the Clean Air Acts. The first is the Air Pollution Control Act, passed by Congress in 1955. This environmental act recognized the need for further research in understanding causes and effects of air pollution. The Clean Air Act of 1963 set standards for controlling air pollution and addressed the need for research on ways and means to reduce it. The Clear Air Act amendments of 1970 represented a very ambitious plan to control pollution on the federal and state level. Four important regulatory programs were established by this Act: National Ambient Air Quality Standards, Natural Emission Standards for Hazardous Air Pollutants, State Implementation Plans and New Source Performance Standards. This Act was later enhanced with Amendments in 1977.

The Amendments of 1990 incorporated further regulations on the Clear Air Act of 1970, which addressed new issues and overall improved the existing act (U.S. EPA, 2006b).

Ozone standards have also reflected some revisions over time. The 1-hr ozone was considered as baseline of estimating the national standard for ozone.

In 1997, EPA substituted the 1-hr standard by implementing the 8-hr ozone standard (Texas Commission on Environmental Quality [TCEQ], 2006a). The Environmental Protection Agency classifies the standard as not met "if the level of 8-hr ozone 3-year average of the annual 4th highest daily maximum 8-hours ozone concentration is greater than 0.08 parts per million (ppm) (U.S. EPA, 2006c, p.1). Several researchers have estimated that the health benefits from attaining the 8-hr ozone standard in a three-year period (2000 to 2002) accounts for several billion dollars in decreased costs from reduction of emergency visits and hospitalizations, premature mortality and other factors (Hubbell, Hallberg, McCubbin, & Post, 2005).

Ozone is one of the most concerning pollutants to date, even though it has been on a decline nationwide since 1980. The national air quality trends for 2005 show an overall decrease of the 8-hr standard ozone levels by 8 % compared to 1990 and 20% compared to 1980 (U.S. EPA, 2006d).

However, according to the annual ALA report, almost half of the U.S. population lives in counties with concerning ozone pollution. About 15% of the population resides in counties with unhealthful levels of ozone and particulate matter (ALA, 2006a).

In a report issued by the organization "Clear the Air", Texas has the largest number of adverse health effect cases caused by ozone for the period April – October

1997. The classification of health effects was based on respiratory and cardiovascular hospital admissions, total respiratory ER visits, asthma ER visits, minor symptoms, and shortness of breath and asthma attacks. However, the report is limited since it analyzed only 37 states in the US (Clean the Air, 1999).

Ozone is of particular interest in this study since the Dallas – Fort Worth metropolitan area has been repeatedly ranked by ALA (ALA, 2003; 2004; 2005; 2006a) as one of the 25 most ozone-polluted cities in United States. The ALA gave Tarrant County air quality a grade of "F". This score means that the area has experienced at least 10 days a year with an Air Quality Index (AQI) color of "orange" (ALA, 2005); analogous to an AQI value between 101– 150: "Unhealthy for Sensitive Groups" (U.S.EPA, 2003). This "F" grade can also be assigned if there are 9 days with elevated pollution levels with at least one day ranging from "red" to "purple" in color (ALA, 2005); corresponding to an AQI of 151-200: "Unhealthy" for the population or 201-300: "Very Unhealthy" (U.S. EPA, 2003).

The U.S. Environmental Protection Agency in its city-by-city statistics convincingly demonstrates that Fort Worth – Arlington has a history of ozone peek periods.

In 1994 Fort Worth had 31 days with an AQI greater than 100. For the year 2004, Fort Worth had only 11 days with an AQI above 100. From 1994 – 2005, the number of days with an AQI greater than 100 shows some fluctuation, with the highest peak in 1994. The lowest number of days with an AQI greater than 100 was reported in 2004 (See Figure 1) (U.S. EPA, 2006e).

Ozone is considered to be produced by three main sources in the Dallas – Fort Worth Metroplex:

a) Mobile (transportation means: car, trucks, trains etc) produces approximately 56% of anthropogenic emission of ozone (Tarrant County Public Health, 2006).

b) Area (such as engines, solvent and paints) generate up to 32% of total ozone concentration (Tarrant County Public Health, 2006).

c) Stationary (industry related) constitutes almost 12 % of the total sources that leads to generation of ozone (Tarrant County Public Health, 2006).

However the relationship between the sources that contribute to air pollution may change in 2007. Based on estimates of the City of Fort Worth's Environmental Management Department, the sources of air pollutants for the area will be:

a) 51% from road vehicles

b) 34% from local sources such as landfills, wild fires etc.

c) 8% from biologic factors such as trees, plants

d) 7% from point causes mainly represented by industrial and non-industrial action

(City of Fort Worth Environmental Management Department, 2006a)

The American Lung Association has estimated that almost 150 million people in the United States live in counties with ozone or particulates at levels of concern. About 140 million live in counties that fall in the "F" category, for high ozone levels. The ALA estimates that in the Dallas – Fort Worth metropolitan area approximately 487,000 people aged 65 and older and 1,652,700 children of age 18 or younger, are at risk from ozone exposure. This region is ranked eighth on the list of the 25 most ozone polluted cities in United States. Tarrant County includes almost 131,000 persons of age 65 and over and 447, 000 children at risk of ozone-related pollution effects (ALA, 2006a). Demographics data about the adult population living in Fort Worth area are provided in Table 1.

Tarrant County has a decade long history of seriously high levels of ozone. Based on the 1990 EPA Amendments, four counties in the Dallas- Forth Worth Metroplex were categorized as non-attainment areas for the 1 hour-ozone standard (125 part per billion or higher). Tarrant County was one of the counties identified (TCEQ, 2006b). Monitors located in Grapevine, Dallas and Eagle Mountain measured ozone levels that exceeded the national standard during 2004 (City of Fort Worth Environmental Management Department, 2005).

In 2000, the Texas Commission of Environmental Quality (TCEQ) through State Implementation Plan Revision identified as source of local pollution the Houston – Galveston – Brazoria area. In 2004, the Environmental Protection Agency added 5 other counties to the ozone non-attainment area. New strategies for Dallas – Fort Worth region attempting to bring the area in the attainment status for 8-hr ozone by June 2010 will be revised in November, 2006 (TCEQ, 2006b).

The high levels of ozone in the metroplex have repeatedly been the focus of the local daily media (Streater, 2006; Streater & Shurley, 2006). In a broader perspective, numerous refereed journal articles and other research have shown an association between emergency department visits or hospital admissions associated with elevated concentration of ozone pollution (Medina-Ramon, Zanobetti, & Schwartz, 2006; Petroeschevsky, Simpson, Thalib, & Rutherford, 2001). Other scientific literature has supported the association between air pollution and health effects on the elderly population (Delfino, Murphy- Moulton, Burnett, Brook, & Becklake, 1997; Martins, Latorre, Saldiva, & Braga, 2002). However, some epidemiologic studies have not shown an association between ozone and selected respiratory admissions (Atkinson et al., 1999; Masjedi et al., 2003).

This study will observe the association between the seasonal fluctuations of ozone air quality and emergency department hospital admissions for respiratory causes in adults 18 years and over in Fort Worth/Arlington area hospitals. The Fort Worth - Arlington area includes the Cities of Fort Worth and Arlington, and the towns of Dalworthington Gardens and Pantego. The respiratory diseases analyzed in this study were identified based on International Classification of Disease, 9th Revision (ICD-9-CM) with the following codes:Asthma (ICD-9 code 493); COPD (ICD-9 code 494.1 to 496); Emphysema (ICD-9 code 492); Pneumonia (ICD-9 code 486); Chronic Bronchitis (ICD-9 code 491) (Hart, Hopkins, & Ford, 2005). These codes also included the codes of sub-categories within each disease[1].

Only data from acute care hospitals were used in this study. Children age 0-17 are not included in the analysis.

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[1] Even though ICD-10 has superseded ICD-9 for disease and mortality classification, ICD-9 has been used by the hospitals in the database of Texas Hospital Inpatient Hospital Discharge Public Database to identify patients various conditions and diseases.

Additionally, this study will not consider those residents of Fort Worth who sought medical attention from hospitals outside the region. Moreover, data from residents of nursing facilities, long term acute care or other long term care facilities were not used in this study since these residents most likely spend a limited amount of time outdoors. The effects of ozone on premature mortality were not evaluated.

This research makes use of secondary hospital data; therefore the analysis is limited to emergency hospital admissions of people 18 and older seeking emergency hospital care. The study does not include individuals who were evaluated at a physician's office or specialty clinic.

Primary emergency room visit data were not available for use in this study. Consequently the acute effects of ozone were assessed using admissions from emergency department using the code for "emergency-urgent".

A significant limitation of the study is the absence of patients' date of admission, which minimizes the possibility for an accurate estimation of the connection between the daily fluctuations of ozone and emergency hospital admissions. As randomly occurs in these types of environmental studies, confounding factors such as smoking, and duration of exposure to indoor air pollution are difficult to estimate. Although these elements do not constitute the direct subject of the research and therefore are not evaluated, their potential effects in biasing the findings have not been ignored.

The study will analyze whether the health of the adult population in this area is affected by the ozone concentration.

The main hypotheses of the study are:

a) There is an association between the seasonal levels of ambient ozone and emergency hospital admissions for respiratory diseases in the adult population of Fort Worth area.

b) Exposure to ozone during the warm season exacerbates human health conditions in especially those with existing respiratory diseases.

c) Identification of short-term effects of ozone is expected to be related to emergency admissions of the older adult population.

Hospitalization rates provide a sensitive tool for detecting any association between acute respiratory symptoms caused by ozone to the selected population.

This study represents important research in evaluating the short-term effects of ozone on lung health at the local level in the adults with existing respiratory conditions.

Definition of Terms

ICD-9- CM (International Classification of Diseases, 9th Edition Coding Manual): The standard diagnostic system of diseases and hospital procedures classification (National Center for Health Statistics [NCHS], 2005).

Asthma: A chronic condition affecting the lungs by causing narrowed and inflamed airways (National Cancer Institute [NCI], a).

Chronic Obstructive Pulmonary Disease (COPD): A condition of the lungs characterized by airflow obstruction. This condition not only advances with time but is also associated with an irregular reaction of the lungs to inflammatory factors. The process is partially reversible (WHO, 2006).

Emphysema: A condition in which anomalous inflated alveoli cause difficulty in breathing (National Cancer Institute [NCI], b).

Pneumonia: A respiratory disease in which the lung becomes inflamed in the presence of an infection (U.S. National Library of Medicine, 2006a).

Bronchitis: Inflammation of the bronchial airways. The disease is classified either as acute or chronic bronchitis. The chronic state of bronchitis is characterized by a length period of respiratory symptoms of 3 months or more (U.S. National Library of Medicine, 2006b).

Young adult: People of age 18- 39 years[2]

Middle age adult: People of age 40-64 years[2]

Older adults: People of age 65 and over[2]

Ground Ozone (O_3): Reactive photochemical formed at the ground level by volatile organic compounds and oxides of nitrogen, in the presence of sunlight and heat (U.S. EPA, 2006a).

Particulate Matter (PM_x): A mixture of different solid and liquid components such as dust particles and liquid droplets suspended in the air. PM_x is produced by motor combustion and other industrial or natural activities. Particulate matter is categorized as ultrafine particles (diameter of 0.1 microns or smaller); fine

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[2] The definitions are by the author in order to distinguish different age-groups of the study population.

particles (diameter of 2.5 microns or smaller- referred to as $PM_{2.5}$) or coarse particles (diameter less than 10 microns- referred to as PM_{10}) (U.S. EPA, 2006f).

Carbon monoxide (CO): A harmful gas with no detectible odor, originating from incomplete combustion of fuels containing carbon (U.S. EPA, 2006a).

Nitrogen oxide (NO_2): An irritant gas, predecessor of acid rain and some air pollutants. This gas is largely found in metropolitan areas with congested traffic (U.S. EPA, 2006a).

Sulfur dioxide (SO_2): A toxic substance with a characteristic odor, produced by industrial (fuel burning) and natural sources (eruption of volcanoes) (Agency for Toxic Substances & Disease Registry [ATSDR], 1999).

Nonattainment area: Any area where pollutant concentration surpassed the national ambient air quality standards (National Ambient Air Quality Standards). Also any area that depreciates the air quality of a surrounding location is classified with the nonattainment status (U.S. EPA, 2006a).

Attainment area: Any geographic area that is below these federal limits for air pollution (U.S. EPA, 2006a).

National Ambient Air Quality Standards (NAAQS): A set of standards promulgated by the EPA to assure safe and healthy air quality for the nation. It includes the Primary and Secondary EPA standards for regulated pollutants. Primary standards focus on protecting the general health of the public with emphasis on sensitive populations. The secondary standards regulate the boundaries of these pollutants in order to protect the public wellbeing, the environment and other interests (U.S EPA, 2006g). These standards are provided in Table 3.

Principal Pollutants: Pollutants recognized by U.S. Environmental Protection Agency as the criteria pollutants that define the quality of air (U.S. EPA, 2006a).

Air Quality Index (AQI) – The system devised by the EPA to inform the general public of air quality in an easily understandable format for the five criterion pollutants: ozone, particle pollution, carbon monoxide, sulfur dioxide and nitrogen dioxide. The scale of AQI ranges from 0 – 500, however levels above 300 are usually not listed. Environmental Protection Agency under the Clean Air Act has set an AQI of 100 as the counterpart of the National Ambient Air Quality Standards (NAAQS). See Table 4 (U.S. EPA, 2003).

Ozone Air Quality Index: The AQI that corresponds to specific concentrations of ambient ozone. For Air Quality Index scale (both 1 hour and 8 hour ozone values) see Table 2.

CHAPTER II

LITERATURE REVIEW

Numerous epidemiological studies have shown an association between air pollution and adverse health effects. The studies, for the most part, conducted in United States, Canada, South America and Europe, have suggested a link between fluctuations of pollutant concentrations and hospital admissions for various respiratory and cardiovascular conditions. Generally the short-term effects of anthropogenic atmospheric pollutants such as ozone were the pollutants of interest.

One of the major precepts of public health is that by protecting the most sensitive groups of the population — the young, the elderly and the infirmed — the rest of the population will generally be protected. This study will focus exclusively on the adult population; therefore this literature review will not include children. Although similar research has been reported in the last decades; only studies published during the 10 year period of 1996 – 2006 were used in this review.

A large number of epidemiological studies have analyzed the health outcomes of short and long-term exposure to ozone therefore many of the key points and findings of these studies are summarized in Appendix A, B and C.

This literature review describes selected research focusing on major studies of large populations with respiratory and cardiovascular diseases affected by air pollution. This selective review is restricted to epidemiological studies that analyze the health effects of ozone in combination with other pollutants. The researchers have generally considered the complex nature of effects of air pollution recognizing the potential interaction between several air pollutants on overall health effects.

The review has not considered the studies that primarily focus on population exposure to one of six criteria pollutants beside ozone. Many studies have focused on the summer months, illustrating the characteristic seasonality of ozone and health outcomes during this peak season. Generally these studies recognized the contribution of elevated concentration of ozone on hospital admissions for selected respiratory diseases.

Two large multi-center studies conducted in Europe and the US are of particular interest in this review. The first study, the Air Pollution and Health: a European Approach (APHEA) was a large-scale study conducted in five European cities, to determine the connection between hospital admissions for respiratory diseases and air pollution. Even though the analysis for different cities showed some inconsistency for specific pollutants, only ozone appeared to be constant among the regions (Spix et al., 1998). The original APHEA study, conducted by Sunyer et al. (1997), focused on hospital admissions for asthma in four European cities.

Key findings from these studies are summarized in Appendix A. A panel of studies focusing on cardio-respiratory effects of pollution and early mortality linked to air quality are provided in Appendix B and C.

In the United States, Medina-Ramon et al. (2006) conducted a case-crossover research in 36 large cities. The authors reported the effects of ozone and particulate matter on hospital admissions for patients diagnosed with pneumonia and COPD. The majority of the cities in this study showed a significant association between the range of pollutants and respiratory admissions.

One of the largest studies that reported a direct association between ozone and premature mortality was conducted by Bell, McDermott, Zeger, Samet, and Dominici (2004). Data collected in 95 US urban communities confirmed a significant association between changes in ozone concentrations and average mortality in the study communities. These findings are of particular importance since the sample size accounts for almost 40% of the United States population.

Hoek, Brunekreef, Goldbohm, Fischer, and van den Brandt (2002) conducted a 9 year cohort study in the Netherlands from 1986 to 1994, analyzing life expectancy in people of age 55 to 69 years old affected by air pollutants released in congested traffic areas. The authors suggested that long-term exposure to air pollutants is related to premature death for cardiopulmonary illnesses. Gehring and colleagues (2006) studied air pollution from traffic and other sources in connection with the mortality in women. The research concluded that people living in areas surrounded by major roads had higher rates of cardiopulmonary death and this was associated with long time exposure to air pollution.

Short-term effects of ozone have been linked to acute coronary dysfunction in healthy adults (Ruidavets et al., 2005). Patients with no previous history of heart conditions had a higher probability of developing acute myocardial function due to acute exposure to ozone.

Particulate matter and other principal pollutants have been associated with stroke related hospitalizations and mortality risk (Hong, Lee, Kim, & Kwon, 2002; Maheswaran et al., 2005). The research indicated that outdoor air pollution may increase the incidence of the disease and influence stroke-related mortality.

Respiratory effects linked to ozone pollution were of interest by several authors (Kinney & Lippmann, 1999; Yang et al., 2003). The series of studies suggested that respiratory responses to air pollutants result in pulmonary inflammation and decreased lung function. Regarding the respiratory exacerbation, children and older adults are a susceptible population to air pollution.

The response of the respiratory system to air quality problems and the adverse effects of pollutants on cardiovascular diseases have captivated the interest of many researchers. Particulate matter and ozone has been associated with hospital admissions for cardiac and pulmonary diseases (Koken et al., 2003).

Air pollution, predominantly ultrafine particles ($< 2.5\ \mu m$) has shown a positive association with coronary death, specifically for the people over 65 (Forastiere et al., 2005).

Other studies have broadened our understanding of how air pollution exacerbates the symptoms and the degree of severity of the diseases of the respiratory system.

Asthma is a disease commonly triggered from biological inflammatory agents or other physiological and environmental factors. Sunyer, Basagana, Belmonte, & Anto

(2002) conducted a study on the deterioration of health status and the possible risk for early death caused by air pollution in people with asthma. The researchers reported that nitrogen dioxide and ozone levels during the warm season are associated with risk of premature deaths in patients with a history of asthma. Migliaretti, Cadum, Migliore, & Cavallo (2005) conducted a two-year study in Turin, Italy investigating the connection between contaminated air in high traffic areas and hospital admissions for asthma in all age categories. As in previous studies, nitrogen dioxide and particulate matter played a significant role in urgent hospital admissions for asthma. Similar conclusions have been reported from a group of researchers leaded by Boutin- Forzano et al. (2004). The authors emphasize the role of ozone in emergency visits for asthma. The findings strengthened the evidence of the association between gaseous pollutants and increased risk of emergency department admissions in people with preexisting asthma conditions. The importance of reducing the concentrations of anthropogenic pollution is also underlined in the Journal of American Medical Association (JAMA) by Thurston & Bates (2003).

The authors highlighted the adverse effects of environmental pollutants on asthma exacerbation by summarizing findings of previous research. The authors call for greater attention of state regulatory agencies toward further initiatives that would lead to a better quality of air for all.

Although the available research provides wide evidence of outdoor pollution and health effects, the personal exposure to indoor levels of ozone, even though in low concentrations, has only been marginally considered.

Levy, Carrothers, Tuomisto, Hammitt, & Evans (2001) assessed the financial and public health benefits of reducing ozone concentrations. The financial advantage of decreasing the ozone concentration is $10 per person per microgram/ cubic meter in reduction of annual health costs related to ozone exposure.

Bell, Davis, Gouveia, Borja-Aburto, & Cifuentes (2006) analyzed three industrial cities of Latin America concerning the cost of reducing emissions of fuels and the health benefits and controlling pollution. The researchers extrapolated the economic impact of pollution on people's health for the next 20 years (2000 – 2020) using a model that predicted annual pollution levels. They estimated the approximate cost to be 21 – 165 billion dollars; a value that could have found a better use in other environmental areas if ozone and particulate matter emissions were controlled. Additional research conducted in France quantified the importance of reducing the concentration of pollutants (Eilstein et al., 2004). The authors estimated that every year almost 2, 800 premature deaths and a considerable number of hospitalizations could be avoided by decreasing the levels of pollution to 10 $\mu g/ m^3$.

This literature review serves as a window to expand the understanding of the complex nature of the association of air pollutants and respiratory health. Additionally, future research will strengthen the knowledge about the interactive process between these dynamic factors.

CHAPTER III

METHODS

Environmental Data

Texas Commission on Environmental Quality (TCEQ) collects and reports pollutant and meteorological data for the state of Texas. Air parameters in the Fort Worth – Arlington area are measured at six fixed monitoring sites which operate under the supervision of Dallas – Fort Worth regional office. Ambient air pollutants and meteorological data were obtained for 2004 for the Fort Worth – Arlington area. During this year, there were seven active sites; one (C308) was deactivated in September 2005. A map of the locations of these monitoring sites is presented in Figure 2.

The criteria air pollutant ozone was measured by most of the sites. Records were available for both 1 hour and 8 hour values. For the purpose of the study the 8 hour ozone levels were used since this standard has been substituted for the old 1 hour standard after the EPA's 1997 revision. The 8 hour standard was adopted to enhance the protection of general public and people who spend considerable time working or staying outdoors (ALA, 2002). The 2004 calendar year was chosen to assess the relationship between quarterly concentrations of ozone and respiratory diseases hospitalizations since it represents the latest data available for hospital admissions. Although the air pollution season for this region generally occurs from 1 May – 31 October, the highest values for ozone were during the months of June through September 2004, which coincide with the third quarter of the year. Overall, the second and the third quarter had the highest average, maximum and minimum values for ozone using the Air Quality Index (see Figure 4). The seasonal value for ozone AQI is calculated as the average AQI of the respective days within the quarter. Figure 3 summarizes the days by Air Quality Index for the period January – December 2004.

The Chi-square test for independence was used to determine the presence of an association between the quarterly concentrations of ozone and hospital admissions for the selected respiratory diseases. Since the admission date of the patients in local hospitals was not reported and the observed trend of hospitalization rates was dissimilar to the expected; further investigation concerning the influence of other pollutants or weather factors on the emergency admissions was not adjusted for.

Chi-Square test, frequencies and descriptive statistics were used to identify any possible connection between the variables under study. All the calculations were derived by using the Statistical Packages for the Social Sciences (SPSS®).

Hospital Data

Emergency hospital admissions for selected respiratory conditions were obtained from Texas Department of State Health Services: Texas Hospital Inpatient Discharge Public Data File, 2004. Texas Department of State Health Services (TDSHS) and Texas Health Care Information Collection (THCIC) are the agencies which collect the data from state licensed hospitals.

The 2004 calendar year was used for this study, since it is the most recent year with available quarterly hospital data. Data elements in this data set include demographic variables, source and type of admission, admission diagnosis, hospital and resident Zone Improvement Plan (Zip Code).

Quarterly counts of adult patient's emergency admissions are identified by the diagnostic codes: Asthma (ICD-9 code 493); COPD (ICD-9 code 496); Emphysema (ICD-9 code 492); Pneumonia (ICD-9 codes 494.1 and 486); Chronic Bronchitis (ICD-9 code 491).

Emergency hospital admissions for selected respiratory diseases were available for each quarter of the year. These quarters are January through March for the first quarter; April to June for the second quarter; July to September for the third quarter and October to December for the fourth quarter. In this study, the season of winter will usually refer to the first quarter of the year. Even though from the astronomic perspective winter begins on the 21st of December (winter solstice) and ends by March 21st (vernal equinox), the decision of considering the first quarter (January 1st- March 31st) as winter is also supported by outdoor temperature (see Figure 5). The same logic is followed for the seasonal classification of the yearly quarters. As shown in Figure 5, the first quarter had the lowest average and maximum temperatures. The third quarter (summer) recorded not only the highest values of AQI for ozone but also the maximum, minimum and average temperatures for the year. The second quarter is identified as spring and the fourth as winter.

The principal diagnosis for the patient was the decision of a health care professional. Therefore, the analysis is based on principal rather than admitting diagnosis of disease.

Seven hospitals in Fort Worth that provide acute care as well as three acute care hospitals in Arlington were used in this study. Cities of Pantego and Dalworthington Gardens, although considered a part of Arlington, do not have any acute care hospital serving their area; however residents of these cities generally seek medical care at one of the Arlington hospitals. Hospitals providing pediatric care were excluded from the research analysis.

Study Population

The population for this study is subjects 18 years and over admitted by the emergency departments of acute care hospitals of Fort Worth and Arlington with the respiratory diagnosis of interest. Therefore this sample population consisted of adult residents of the Fort Worth – Arlington geographic area.

Due to the system of data organization, Zone Improvement Plans (ZIP Codes) were used to identify the residents in the selected area. Patients who were hospitalized multiple times during the study period are considered as new cases given that the database did not include any information that would identify the patient and each admission as significant.

Residents of nursing facilities, long term acute care or other long term care facilities were not selected as part of the study, since their active time spent in outdoor activities is considered limited. Persons who reside in law enforcement institutions such as prisons or other detention centers are also excluded from the study.

CHAPTER IV

RESULTS

The population analyzed during the 366 days of study period consisted of 3,113 patients hospitalized in the acute care hospitals of the region. Emergency hospitalizations for the selected respiratory diseases represented 7.5% of the total number of hospitalizations of persons 18 and older during the study period. The average age of the individuals admitted by all hospitals under the selected criteria varied between 60 to 64 years old. Interestingly, winter had the highest number of emergency respiratory hospitalizations. Similarly, the second largest numbers of admissions were observed in autumn. Moreover, summer which had the highest ozone values for the year had the lowest number of respiratory hospitalizations admissions which were the lowest of any other season of the year. Based on chi-square, the study population had an overall lower observed sample size than the expected value of the second and third quarter of the year.

The only exception to this general trend was for patients 65 and older. This age-group had a higher observed admission than the expected number of hospitalizations during the same period and an approximately equal number of observed and expected cases during winter. Figure 6 illustrates the seasonal patterns of respiratory admissions and the ozone Air Quality Index.

The seasonal variation of respiratory admissions differs from the hospitalization of adults diagnosed with non-respiratory diseases. The overall hospitalizations from April through June had an equal distribution of respiratory and non-respiratory diseases. The third quarter (summer), which represents the period of the year when there should be an increase of respiratory hospitalizations due to ozone by our evidence, shows a significant decline in the hospitalizations compared to the non-respiratory group. However, the V-shape pattern of emergency hospitalizations for the Fort Worth area is analogous to the national trend for emergency visits in United States for 2004, see Figures 7 and 8.

Respiratory admissions were higher in the older population, which represented 57% of the total sample. Quarterly, respiratory emergency hospitalizations of patients 65 and older remained high throughout the year. As expected, patients aged 18-39 years old represented only 8% of the study population. Hospitalization data for Texas in 2001 provide comparable findings for this age-group. People of 18-44 years of age registered the lowest number of emergency hospital admissions (Texas Health Care Information Council [THCIC], 2003).

Within the same age group, patients over 65 years of age diagnosed with the selected respiratory diseases accounted for 11% of the total adult hospitalizations in the Fort Worth area. This percentage is the largest observed among the 3 adult age groups in this study. The analyses also reveal notable variability among age-group hospitalizations; with a steeper contrast in the second quarter and a moderate one in the fourth quarter of the year (see Figure 9).

Female hospitalizations accounted for sixty percent of the study population. This percentage is comparable to the total hospitalizations that occurred in Texas during 2001. Among the total number of patients discharged from the hospital, 62% were women (THCIC, 2003).

Chi-square was used in this study due to the limitations of the hospital data in conjunction with quarterly AQI ozone levels. Tests for independence of proportion were also conducted for the fourth quarter of the year for respiratory disease admissions compared to the non-respiratory group. As a result, various analyses of the data show some variation of observed versus expected cases in selected age categories. The group aged 18-39 years frequently had the lowest number of hospital admissions for respiratory diseases. However, in this group, the expected values are not substantially different from the observed (see Table 5). Patients in the 40-64 age group showed a small difference between observed cases of emergency hospitalization and expected cases. No significant difference could be found between respiratory admissions and non-respiratory admissions for the same time period (see Table 6).

The respiratory hospital admission rates are within the expected value. By considering the expected rate of respiratory admissions compared to the non-respiratory admission rates, the resulting value provides a practical approach to this consideration.

The 65+ population represents the age- group with the highest differences in the observed compared to expected. The emergency admissions in the winter and summer occurred at unusually high rates from the predicted rate (see Table 7).

All the results of the hospitalization rate during summer show an overall sharp decline for the year. A chi- square table for the total study population is in Table 8. The statistical values for respiratory admissions only as well as versus non-respiratory admissions are provided in Tables 9 and 10. The tests indicate that the proportion of respiratory admissions compared to non-respiratory admissions was significantly different from chance over the four seasons for the 40 – 64 and 65+ age groups. The frequency of respiratory admissions was greater than expected from January to June (winter and spring) and less than expected in the second half of the year (summer and autumn). The proportion of the respiratory admissions for young adults was not associated with any quarterly air pollution period (Table 10). Statistical tests for respiratory admissions showed that respiratory admissions differed from the expected values over the four seasons for age groups 40 – 64 years old and 65 and over. However there was no significant difference for the age group 18-39 (Table 9).

Distribution of admissions by race for all respiratory hospitalizations and selected diagnosis is illustrated in Figure 10. Seventy three percent of the emergency admissions are white. Among diseases with the highest percentage of admission, there is an interesting pattern of race distribution.

Chronic bronchitis is observed predominantly in the white population; asthma occurred mainly in the white populations although persons of other races have a higher proportion of distribution compared to other respiratory diseases. National prevalence and hospital discharge data confirm similar distributions of the diseases; however the white population shows a noticeably higher prevalence of the selected respiratory conditions[3] (see Figure 11).

Pneumonia was the respiratory condition having the largest number of hospitalizations for 2004, accounting for approximately 50 % of the respiratory diseases diagnosed. Not surprising, pneumonia appears to be one of the 20 most frequently diagnosed diseases in the emergency department's nationwide (National Center for Health Statistics (NCHS), 2006).

Chronic bronchitis and asthma were the second and third most prevalent hospitalization respectively (Figure 12). Almost 66% of chronic bronchitis diagnosis is in the 65+ age group and less than 1% is in the 18-39 age-group. Asthma was predominantly found in the young and middle-aged population. Chronic Obstructive Pulmonary Diseases accounted for approximately 2% of the admission diagnosis; yet a major proportion of the other diseases of interest in this study are co-conditions of COPD (i.e. asthma exacerbation with COPD, chronic bronchitis with COPD). Detailed data about the disease distribution are in Tables 11, 12 and 13.

Figure 13 illustrates admission frequencies by diagnosis and disease severity. Five respiratory diseases of interest for the study maintained a higher severity scale of diagnosis in the categories of moderate, major and extreme value of disease progression. This might have a reasonable effect on the limited sample size of the study.

Because of the large number of the population with a higher severity rating for respiratory admissions, it is plausible that people with less obvious severity of disease

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[3] Distribution of Pneumonia as a group is not represented in the table due to partial data that represent only various infective origins of the disease.

have received medical attention elsewhere (i.e. doctor's office, clinics) with no apparent reason to be hospitalized. Disease severity by age group is represented in Figure 14. The data show that the majority of the hospital admissions for all age-groups occurred under the moderate severity of principal diagnosis.

Detailed analysis of disease severity in percent for three major age groups is provided in Tables 14, 15 and 16. The effects of the severity of disease can be seen specifically in the older population. From April to September, a considerable percentage of the hospitalizations within the older age-group fall under the disease classification of major and extreme cases. This proportion represents the highest frequency identified between all age-groups. To fully understand this connection, chi-square analysis was conducted for the sample size of older population confined to the major and extreme cases of hospitalization. When we restrict the analysis to people 65 and older and severe cases (major and extreme), the difference between observed and expected proportions is significant over the four seasons (Table 17). Significance was also found from analysis of selected cases of disease severity for the spring and summer seasons for this age group (Table 18). However, a higher number of cases of observed admissions occurred during seasons with reasonably good air quality.

To compare the weekday ozone fluctuations and hospital admissions, we used non-parametric analysis. There was apparent significance found in this analysis. Simplified graphics of the respective patterns by quarter are presented in Figures 15, 16, 17 and 18.

Weekday frequencies for all respiratory and age group admissions are summarized in Tables 19, 20, 21 and 22. In the 1st quarter of the year, Mondays had the highest number of emergency admissions. The estimated admission rate for the older adults was also very high on Monday. These elevated admission frequencies during the first days of the week might be related to the peak AQI for ozone attained the day before (Sunday). However, this connection is weakened by the combined effect of lack of daily admissions and the exact ozone AQI value on the previous days.

By observing the rate of admissions by weekday and the respective AQI for ozone during the second quarter, a notable dissimilarity in the patterns of distribution throughout the week was observed (see Figure 16). However, even in this quarter we observed an interesting trend of hospitalizations and AQI for ozone. Particularly the overall admissions for all adults and for patients 65 and over provide the lowest number of hospitalizations by weekend. On the other hand, the maximum value of ozone concentrations for this quarter is mid-week. The third and fourth quarter do not offer a linear distribution for these variables.

In conclusion, due to the restricted data, precise inferences over the relationship between AQI for ozone and emergency hospitalization are not possible to explore without daily hospital admissions to increase accuracy.

CHAPTER V

DISCUSSION AND CONCLUSION

The available data for this study did not show any apparent association between seasonal ozone pollution and quarterly emergency hospital admissions in the Fort Worth area. Statistical analyses demonstrated significance in seasonal respiratory admissions over the four quarters of the year however, this association does not appear to be linked with levels of air pollution in respective seasons. The third quarter of the year (summer) had the lowest number of hospital admissions and the lowest proportion of observed cases compared to the expected outcome. This may indicate that the AQI ozone levels in this area during 2004 do not affect the older population group with existing respiratory diseases.

There was a significant difference in respiratory admissions for the age groups of 40 – 64 and 65+ over the year. The study found a significant difference in respiratory admissions for older adults identified with major and extreme severity of disease. Conversely in all the cases, a higher number of admissions occurred during the quarters with better air quality. Overall, the analyses show an inverse relation between air quality and hospital admission. In contrast, the results of the study do not support the majority of epidemiological research that addressed similar issues (Delfino et al., 1997; Martins et al., 2002; Spix et al. 1998). Other studies conducted under analogous conditions have not reported a significant association between hospital admissions and elevated ozone concentration (Hinhood et al., 2006; Masjedi et al., 2003).

However, on the local level, the results of this research are consistent with the conclusions of Espinosa's study (2005). The author compared the mortality rates in Tarrant and Bexar Counties in connection with ozone pollution. Even though the study population was considerably larger and the retrospective analysis of the data extended to a period of 4 years, ozone was not associated with mortality in any adult age-category. In fact, the author observed that more people died during days with good air quality. Furthermore, summer and spring had the lowest mortality in both Texas counties studied (Tarrant and Bexar). Although this study and Espinosa's used different assessment tools for measuring health effects of ozone (emergency admissions vs. mortality), very similar results were observed.

The seasonal variation in emergency hospital admissions for respiratory diseases is consistent with the overall national trend for emergency department visits reported by the NCHS (2006). The data summary for the adult population does not show the expected increase in emergency admissions during the warm seasons compared to the cool season. In contrast, winter and autumn have a higher average number of hospitalized patients than the rest of the year.

The report also shows that on a national level, emergency rooms have the highest number of visits for respiratory diseases in the cold seasons (winter and autumn) rather than the warm half of the year (spring and summer). Furthermore, emergency visits for respiratory conditions reported a lower percentage during 2004 compared to the previous year.

In addition, the report identified the population of 65+ as the leading group of patients with emergency visits compared to other population age-categories (NCHS, 2006). The national trends in emergency visits support the unusual seasonal pattern of emergency admissions in the Fort Worth area.

Although air pollution in the area has been above the national standards, 2004 reported concentrations of ozone lower than previous and successive years (see Figure 1). Accordingly, the number of days with Air Quality Index above 100 in 2004 was the lowest in the last 11 years: 1994 – 2005 (U.S. EPA, 2006e).

Some particular aspects related to Texas might be helpful in understanding the relatively small percentage of emergency admissions in comparison with the overall population demographics. The American College of Emergency Physicians gave Texas a "C" grade (American College of Emergency Physicians [ACEP], 2006). "Access to Emergency Care" mostly accounted for the State's overall national classification. As mentioned in the report, uninsured people constitute a significant part of the Texas population. Only a few other states have been given as low a grade for access to emergency room care.

Statistics demonstrate that Texas is the second state in the nation after California with a large number of illegal immigrants in 2005 (U.S. Department of Homeland Security [DHS], 2006). On the other hand, residents classified as "below the poverty level" in 2003 account for 16.2% of the overall population (U.S. Census Bureau, 2006).

Additionally, there are approximately 16 emergency department per1 million persons in the state of Texas (U.S. DHS, 2006). These social and demographic aspects might restrict emergency visits to only people who can afford hospital health care. Moreover, persons with serious disease conditions are likely to consider the hospital emergency rooms for medical evaluation.

On the other hand, personal exposure to ambient ozone may differ from the fixed monitoring sites. In some cases, the estimation of an individual's exposure to air pollution may lead a misclassification of the overall population dose. Liu, Delfino, & Koutrakis (1997) assessed the possible bias that affects the measure of population exposure to ozone. The author found that most of the subjects under study spent a limited amount of time outdoors during the peak hours of ozone concentration. These peak concentrations usually occurred around mid-day. Similarly, elevated outdoor temperature was classified as a second reason for the unintentional restricted exposure to ozone pollution. Generally, subjects avoided open-air activities when temperatures were higher than 70° F. By doing so, they also limited the extended time exposed to air pollutants. Considering a wide range of factors, the authors concluded that individual exposure to ozone is in far lower concentrations than the samples collected from local monitoring sites.

At the same time, exposure to air pollution is a combination of an individual's outdoor and indoor exposure. If during the peak hours of pollution people tend to avoid outdoor activities, the indoor ambient air would establish their exposure concentration. Lee et al. (2004) concluded that homes with air conditioners present limited indoor ozone concentration compared to the outdoor environment. Census Bureau surveys on the condition of housing in Fort Worth – Arlington concluded that almost 87% of houses in the region are equipped with a central air conditioning system (U.S. Census Bureau, 2004). This high percentage of residential conditioning air systems in the area and the diminished quantity of personal exposure versus the parameters measured in fixed stations, may reduce to some degree the exposure of the population to outdoor air pollution.

Older adults composed more than 55 % of this study population. The frequency of respiratory admissions for this age-group was greater than expected in the first and second quarter and slightly greater in the fourth one. However the biological aging process that leads to higher susceptibility of acquiring new respiratory infections or exacerbation of existing diseases in the older population, might be a confounders in the findings of this study.

One major factor that might have played a significant role in the findings of this present study is the lack of access to daily admissions for the population of interest. Suffering from accuracy, the investigation of possible effects of ozone over the moderate response of respiratory conditions was limited to seasonal rather than daily analysis. Thus the acute health exacerbations of peak ozone days are essentially diluted in quarterly averages of ozone AQI.

Additional implications for the present conclusions are related to the nature of the data. As largely recognized, emergency rooms serve as the first site of assessing a patient's status at the hospital level. In epidemiological studies, emergency department visits are usually considered as the direct approach of providing valuable available data in favor of an accurate evaluation of health consequences from air pollution.

Using emergency admissions that were validated by patients with aggravated disease status, may underestimate the assessment of any acute health effects exacerbated by ozone.

In fact, the admission data proved the severity of patients' health conditions. The status of disease severity is identified by the physician; consequently this classification is considered as accurate. Almost 77 % of patients admitted were regarded as "moderate" and "major" disease severity cases. Patients whom the severity of disease was confirmed as "major" and "extreme" represented 43% of the population age 65 and older. Thus, a wide range of people that manifest irritant effects from ozone or other pollutant exposure may not have been identified from hospital data.

At the same time, people with respiratory concerns may receive care in medical facilities other than the hospital, such as the family doctor or clinics. Usually this kind of service is not only easier to access but also less expensive for the patients. Data about these visits are difficult to estimate and most importantly not available for studies of this nature.

Another factor when considering the potential effects of ozone exposure on emergency hospitalization is the selected profile of the study population. Since we included only people older than 18 hospitalized with respiratory conditions, the findings of this study ignores children. In fact, some studies have reported a strong association of respiratory admissions linked to ozone in children and the older population (Yang et al., 2003).

Almost 50% of the hospital admissions for all age-categories in this study were diagnosed as pneumonia. The disease also accounted as the leading cause of hospitalizations from emergency rooms in Texas for 2001 (THCIC, 2003).
The epidemiologic cause of this disease is related to many meteorological, seasonal and individual factors. Researchers have reported that pneumonia related emergency department visits increased during the cold seasons (Lieberman & Friger, 1999; Marrie & Huang, 2005). Similar patterns were observed in the present statistical analysis. On the other hand, the lack of data on other upper respiratory infections such as cold and flu during the study period, creates ambiguity on detecting the origin of the high number of admissions for pneumonia. Consequently, the lack of daily data might lead to a biased interpretation of ozone effects for specific diseases.

Even if the Fort Worth – Arlington metropolitan area is a highly populated part of Tarrant County, the limited size of study population might have influenced the estimation of the environmental and health components under study.
Obviously a larger study sample would offer a more accurate approximation of the interaction between air pollution and respiratory health effects on preexisting conditions

The hospital admissions analyzed in this study tend to follow a cycle, with particularly higher admission rates at the beginning of the week and a lower rate by the weekend. This fluctuation was observed in the overall number of admissions as well as admissions for selected age-categories (65+). Other researchers have reported similar findings. A study conducted in Italy investigated the relationship of intended hospitalization rates throughout the year. The authors described the pattern of decreased hospitalization during the weekend or national holidays. The findings were for both planned and not planned hospitalizations; however, the difference was more significant for planned hospitalizations (Fusco, Saitto, Arca, Ancona, & Perucci, 2003).

This research also identified some seasonal fluctuation of diseases over the year (see Table 23). Asthma had a higher prevalence during the coldest months of the year (equivalence of first and fourth quarter). Even in the epidemiologic research, asthma is a disease with known seasonal patterns. Pendergraft, Stanford, Beasley, Stempel, & McLaughlin (2005) found that the climax period of asthma hospitalizations occurred throughout winter season.

Another study analyzed asthma periodicity in a broader perspective. The investigators found that particular age-groups manifested a dissimilar spectrum of disease seasonality. (Fleming, Cross, Sunderland, & Ross, 2000). Chronic Obstructive Pulmonary Disease (COPD) is a disease that also has some seasonality. In the current study, COPD had the highest rates of hospitalizations in the second half of the year. Otero, Blanco, Montero, Valino, & Verea (2002) identified a higher incidence of COPD and asthma in the emergency room visits during winter season.

Chronic bronchitis mostly impacted the older population. In this study, 66 % of the respiratory diseases were in patients 65 and older. This ratio is similar to that of chronic bronchitis in the Americans. American Lung Association reports that on the national level the disease is more prevalent in people 65 and older. The occurrence rate of the disease in this age group is approximately 62 per 1,000 persons (NCHC as cited in ALA, 2006b). Epidemiologic researchers have used the emergency room visits or hospitalization admission data to investigate the interaction of air pollution on health conditions. However, some effort has focused on the consistency of diagnostic coding among different medical centers. Delfino, Becklake, & Hanley (1993) studied if hospital data can be considered as a reliable estimation for measuring pollution effects on population hospitalization. According to the authors, there is a 75% possibility that diagnoses agreed for all respiratory diagnosis (except asthma which had an even higher percentage of agreement). Some of the suggested reasons that might interfere with the findings of epidemiological studies included issues in the type of hospital admissions and discrepancy in diagnosis accuracy.

The data available for this study did not facilitate the use of advance statistical analysis, to estimate any other relevant conclusions. Due to these limitations, the results of this study represent a general presentation of the complex nature of pollution effects on people.

Given the limitation of the available hospital data, the analysis for selected acute health effects in this study and the complex nature of the interaction between air pollution and physiological factors, it would not be accurate to conclude that the air pollution in the Fort Worth - Arlington area does not impact the health of the community.

Further studies should attempt to quantify the association between daily respiratory hospital admissions and mortality with short-term exposure to ozone pollution. Additionally, further research will need to address the differences in acute exacerbation of respiratory and cardiovascular diseases in years with higher air pollution levels (i.e. 2003, 2005).

Finally, this study offered an interesting approach to the overall estimation that pollution plays on the health effects of susceptible populations in this area. Despite the fact that the research did not found any significant association between the seasonal levels of pollution and emergency room admissions for respiratory diseases in the local communities, this conclusion constitutes positive results from the public health perspective since the majority of the local community do not appear to be affected by exposure to ozone.

Table 1. Total Population and Total Sample Size for Cities of Fort Worth and Arlington

Age- groups	Fort Worth Demographics*	Arlington Demographics**	Study Sample Size – Both cities
Total 20 -64 years old	278,922	215,580	1338
Total 65 years and over	51,254	21,446	1775

Source:

* U.S. Census Bureau (a)

** U.S. Census Bureau (b)

Table 2. Ozone Parameters and Air Quality Index

AQI	Category	1- hour ozone standard	8- hours ozone standard
0-50	Good	~ *	0-64 ppb
51-100	Moderate	~	65-84 ppb
101-150	**Unhealthy for Sensitive Groups**	**125-164 ppb**	**85-104 ppb**
151-200	Unhealthy	165-204 ppb	105-124 ppb
201-300	Very Unhealthy	205-404 ppb	125-374 ppb
301+	Hazardous	405 ppb +	~ **

Note: An AQI of 100 corresponds to an ozone level of 85 parts per billion (ppb).

* There is no AQI associated with hourly ozone averages less than 125 ppb

** There is not an available value for this category

Source: City of Fort Worth Environmental Management Department, 2006b

Table 3. National Ambient Air Quality Standards for Six Principal Pollutants

Pollutant	**Primary Standards - Averaging times**	**Secondary standards**
Carbon Monoxide	9 ppm* - 8 hour 35 ppm - 1 hour	None
Lead	1.5 µm/ m^3 - Quarterly Average	None
Nitrogen Dioxide	0.053 ppm – Annual	The same as primary standards
Particulate Matter (PM_{10})	50 µm/m^3 ** - Annual 150 µm/m^3- 24 hour	The same as primary standards
Particulate Matter ($PM_{2.5}$)	15 µm/m^3 - Annual 65 µm/m^3 -24-hour	The same as primary standards
Ozone	0.08 ppm - 8 hour	The same as primary standards
Sulfur Oxides	0.03 ppm -Annual	NA
	0.14 ppm- 24 hour	NA
	NA (ppm) - 3 hour	0.5 ppm

* ppm- parts per million by volume

**µm/m^3 – micrograms per cubic meter of air

Source: U.S. EPA, 2006g

Table 4. Interpretation of Air Quality Index and Ozone

AQI: Concern	Status of Air Quality	Caution measures
0-50 : Green	Good	None
51-100: Yellow	Moderate	Particularly sensitive population can consider reducing extended outdoor exposure.
101-150: Orange	Unhealthy for Sensitive Groups	People with existing lung problems, children and adults should limit prolonged activities outside.
151-200: Red	Unhealthy	Active children, adults and people with respiratory diseases strongly suggested avoiding outdoor exertion. Children in particular should avoid long exposure.
201-300: Purple	Very Unhealthy	Avoid all outdoor exposure for children, adults and people with lung conditions. The rest of the population, particularly children should avoid outdoor activities.
301-500 : Maroon	Hazardous	Everyone must avoid outdoor activities.

Source: U.S. EPA, 2003

Table 5. Chi-Square Analysis of Respiratory Diagnosis by Seasons 2004,

Age Group: 18-39 years old

Season	AQI for Ozone	Cases Observed	Cases Expected	Residual*
Winter	29	68	62	+ 6
Spring	40	53	62	- 9
Summer	62	56	62	- 6
Autumn	25	71	62	+9

Note: Analysis conducted in reference to respiratory admissions only.

Season	AQI for Ozone	Cases Observed	Cases Expected	Residual*
Winter	29	68	57	+ 9
Spring	40	53	60	- 7
Summer	62	56	66	- 10
Autumn	25	71	65	+ 6

Note: Analysis conducted in reference to non-respiratory admissions.

* Residual stands for the statistically calculated number of people above or below the expected value. The sign (+) indicates that the number of observed cases is higher than expected by the respective value in the table. The sign (–) indicates than the number of observed cases is lower than expected by the respective value in the table.

Table 6. Chi-Square Analysis of Respiratory Diagnosis by Seasons 2004,

Age Group: 40-64 years old

Season	AQI for Ozone	Cases		Residual*
		Observed	Expected	
Winter	29	313	272.5	+ 40.5
Spring	40	227	272.5	- 45.5
Summer	62	207	272.5	- 65.5
Autumn	25	343	272.5	+ 70.5

Note: Analysis conducted in reference to respiratory admissions only.

Season	AQI for Ozone	Cases		Residual*
		Observed	Expected	
Winter	29	313	263	+ 50
Spring	40	227	260	- 33
Summer	62	207	279	- 72
Autumn	25	343	289	+ 54

Note: Analysis conducted in reference to non-respiratory admissions.

* Residual stands for the statistically calculated number of people above or below the expected value. The sign (+) indicates that the number of observed cases is higher than expected by the respective value in the table. The sign (–) indicates than the number of observed cases is lower than expected by the respective value in the table.

Table 7. Chi-Square Analysis of Respiratory Diagnosis by Seasons 2004,

Age Group: 65 years and older

Season	AQI for Ozone	Cases Observed	Cases Expected	Residual*
Winter	29	542	443.8	+ 98.3
Spring	40	473	443.8	+ 29.3
Summer	62	315	443.8	- 128.8
Autumn	25	445	443.8	+ 1.3

Note: Analysis conducted in reference to respiratory admissions only.

Season	AQI for Ozone	Cases Observed	Cases Expected	Residual*
Winter	29	542	449	+ 93
Spring	40	473	438	+ 35
Summer	62	315	422	- 107
Autumn	25	445	466	+ 21

Note: Analysis conducted in reference to non-respiratory admissions.

Residual stands for the statistically calculated number of people above or below the expected value. The sign (+) indicates that the number of observed cases is higher than expected by the respective value in the table. The sign (–) indicates than the number of observed cases is lower than expected by the respective value in the table.

Table 8. Chi-Square Analysis of Respiratory Diagnosis by Seasons 2004, All Study Population

Season	AQI for Ozone	Cases		Residual*
		Observed	Expected	
Winter	29	923	778.3	+ 144.8
Spring	40	753	778.3	- 25.3
Summer	62	578	778.3	- 200.3
Autumn	25	859	778.3	+ 80.8

Note: Analysis conducted in reference to respiratory admissions only.

* Residual stands for the statistically calculated number of people above or below the expected value. The sign (+) indicates that the number of observed cases is higher than expected by the respective value in the table. The sign (–) indicates than the number of observed cases is lower than expected by the respective value in the table.

Table 9. Chi-Square Test by Respiratory Diseases Only for Selected Age Groups and Total Study Population

Age Group	Pearson Chi-Square	df	P-Value
18-39	3.774	3	0.287
40-64	47.600	3	< 0.001
65 and older	61.041	3	< 0.001
Total Population	87.646	3	< 0.001

Table 10. Chi-Square Test by Selected Respiratory Diseases and Age Groups Compared to Non- Respiratory Diseases

Age Group	Pearson Chi-Square	df	P-Value
18-39	4.744	3	0.192
40-64	45.545	3	< 0.001
65 and older	56.613	3	< 0.001

Table 11. Percentage of Admissions by Specific Respiratory Diagnosis and Seasons for Age Group: 18-39 years old

	Season	Asthma %	Bronchitis %	COPD %	Emphysema %	Pneumonia %	Total No.	Total % within year
	Winter	63.2 %	--*	1.5 %	--*	35.3 %	68	27.4 %
	Spring	64.3 %	1.9 %	--*	--*	34 %	53	21.4 %
	Summer	50 %	1.8 %	3.6 %	--*	44.6 %	56	22.6 %
	Autumn	53.5 %	2.8 %	--*	1.4 %	42.3 %	71	28.6 %
Total	No.	143	3	4	1	97	248	100%
Total	% within disease	30.2 %	0.3 %	5.7 %	3.2 %	6.3 %		

* No admission cases were observed.

Table 12. Percentage of Admissions by Specific Respiratory Diagnosis and Seasons for Age Group: 40-64 years old

	Season	Asthma %	Bronchitis %	COPD %	Emphysema %	Pneumonia %	Total No.	Total % within year
	Winter	18.9 %	31.9 %	0.9 %	--*	48.2 %	313	28.7 %
	Spring	21.2 %	33 %	0.8 %	0.4 %	44.1 %	227	20.8 %
	Summer	23.2 %	29.5 %	2.9 %	1.9 %	42 %	207	19 %
	Autumn	19.3 %	28.3 %	2.6 %	1.8 %	48.1 %	343	31.5 %
Total	No.	221	333	21	10	505	1090	100 %
	% within disease	46.6 %	33.7 %	30.5 %	32.3 %	32.6 %		

* No admission cases were observed.

Table 13. Percentage of Admissions by Specific Respiratory Diagnosis and Seasons for Age Group: 65 years and older

	Season	Asthma %	Bronchitis %	COPD %	Emphysema %	Pneumonia %	Total No.	Total % within year
	Winter	6.7 %	36.4 %	1.7 %	0.6 %	54.8 %	542	30.5 %
	Spring	6.1 %	34 %	2.3 %	1.3 %	56.9 %	473	26.6 %
	Summer	5.6 %	40.9 %	3.8 %	1 %	48.6 %	315	17.7 %
	Autumn	6 %	37 %	2.6 %	1.8 %	52.1 %	445	25.1 %
Total	No.	110	650	44	20	951	1775	100 %
	% within disease	23.2 %	66 %	63.8 %	64.5 %	61.1 %		

Table 14. Percent of Severity of Respiratory Diagnosis by Seasons 2004,

Age Group: 18-39 years old

Season	Minor	Moderate	Major	Extreme
Winter	42.6 %	35.3 %	14.7 %	7.4 %
Spring	49.1 %	35.8 %	11.3 %	3.8 %
Summer	39.3 %	41.1 %	12.5 %	7.1 %
Autumn	32.4 %	39.5 %	21.1 %	7 %

Table 15. Percent of Severity of Respiratory Diagnosis by Seasons 2004,

Age Group: 40-64 years old

Season	Minor	Moderate	Major	Extreme
Winter	20.8 %	49.1 %	27.2 %	2.9 %
Spring	18.5 %	49.3 %	27.4 %	4.8 %
Summer	22.2 %	50.2 %	25.2 %	2.4 %
Autumn	16.9 %	42.6 %	35.3 %	5.2 %

Table 16. Percent of Severity of Respiratory Diagnosis by Seasons 2004,

Age Group: 65 years and older

Season	Minor	Moderate	Major	Extreme
Winter	12.5%	47.6 %	32.7 %	7.2 %
Spring	11 %	42.7 %	38.1 %	8.2 %
Summer	9.5 %	44.8 %	40 %	5.7 %
Autumn	13 %	47.4 %	32.6 %	7 %

Table 17. Chi-Square Test for Major and Extreme Severity of Respiratory Diseases in People 65+ by Season

	Observed Cases		Expected Cases	
Seasons	No.	Percent	No.	Residual
Winter	216	28.6 %	188.8	+ 27.3
Spring	219	29 %	188.8	+ 30.3
Summer	144	19.1 %	188.8	- 44.8
Autumn	176	23.3 %	188.8	- 12.8
Total	755	100.0 %	755	

Significance of test

Age Group	Pearson Chi-Square	df	P-Value
65 and older	20.253	3	< 0.001

Table 18. Chi-Square Test for Major and Extreme Severity of Respiratory Diseases in People 65+ by Seasons of Spring and Summer

	Cases		
Seasons	Observed	Expected	Residual
Spring	219	181.5	+ 37.5
Summer	144	181.5	- 37.5

Significance of test

Age Group	Pearson Chi-Square	df	P-Value
65 and older	15.496	1	< 0.001

Table 19. Admission Rate by Age Groups and Weekdays,

January-March 2004

			Age Groups		
Weekdays	AQI	Admissions	65+	40-64	18-39
Monday	27.7	147	100	38	9
Tuesday	30.6	122	63	53	6
Wednesday	30.4	137	74	52	11
Thursday	27.4	132	81	39	12
Friday	26.2	130	75	46	9
Saturday	27	121	74	39	8
Sunday	31.5	134	75	46	13

Table 20. Admission Rate by Age Groups and Weekdays,

April-June 2004

			Age Groups		
Weekdays	AQI	Admissions	65+	40-64	18-39
Monday	37.5	127	86	36	5
Tuesday	35.4	102	67	25	10
Wednesday	40.5	133	85	35	13
Thursday	46.5	107	70	32	5
Friday	44.4	107	60	42	5
Saturday	34.6	90	58	26	6
Sunday	39.3	87	47	31	9

Table 21. Admission Rate by Age Groups and Weekdays,

July- September 2004

			Age Groups		
Weekdays	AQI	Admissions	65+	40-64	18-39
Monday	71.5	95	60	29	6
Tuesday	67.3	75	43	23	9
Wednesday	61	77	40	33	4
Thursday	54.9	88	42	35	11
Friday	63.7	76	41	25	10
Saturday	58.7	86	41	37	8
Sunday	58.8	81	48	25	8

Table 22. Admission Rate by Age Groups and Weekdays,

October- December 2004

			Age Groups		
Weekdays	AQI	Admissions	65+	40-64	18-39
Monday	21.7	120	59	50	11
Tuesday	26.4	128	64	53	11
Wednesday	26.8	120	59	52	9
Thursday	25.1	121	64	46	11
Friday	27.3	126	70	47	9
Saturday	27	130	70	47	13
Sunday	23.5	114	59	48	7

Table 1. Total Population and Total Sample Size for Cities of Fort Worth and Arlington

Age- groups	Fort Worth Demographics*	Arlington Demographics**	Study Sample Size – Both cities
Total 20 -64 years old	278,922	215,580	1338
Total 65 years and over	51,254	21,446	1775

Source:

* U.S. Census Bureau (a)

** U.S. Census Bureau (b)

Figure 1. Distribution of Days with Air Quality Index over 100 in Fort Worth- Arlington Metropolitan Area, 1990- 2005

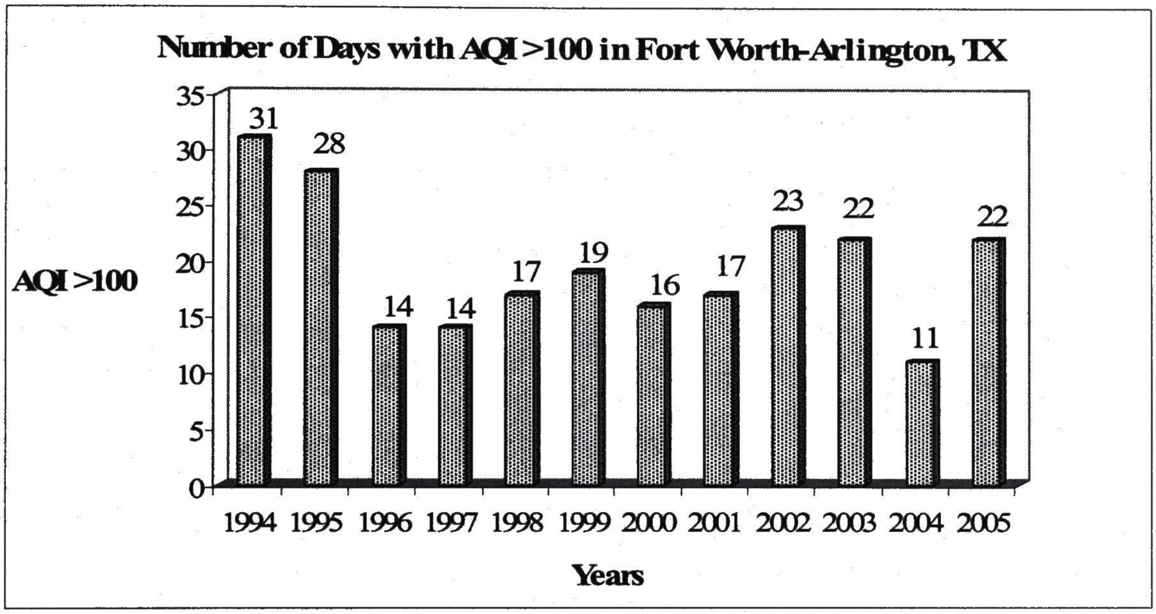
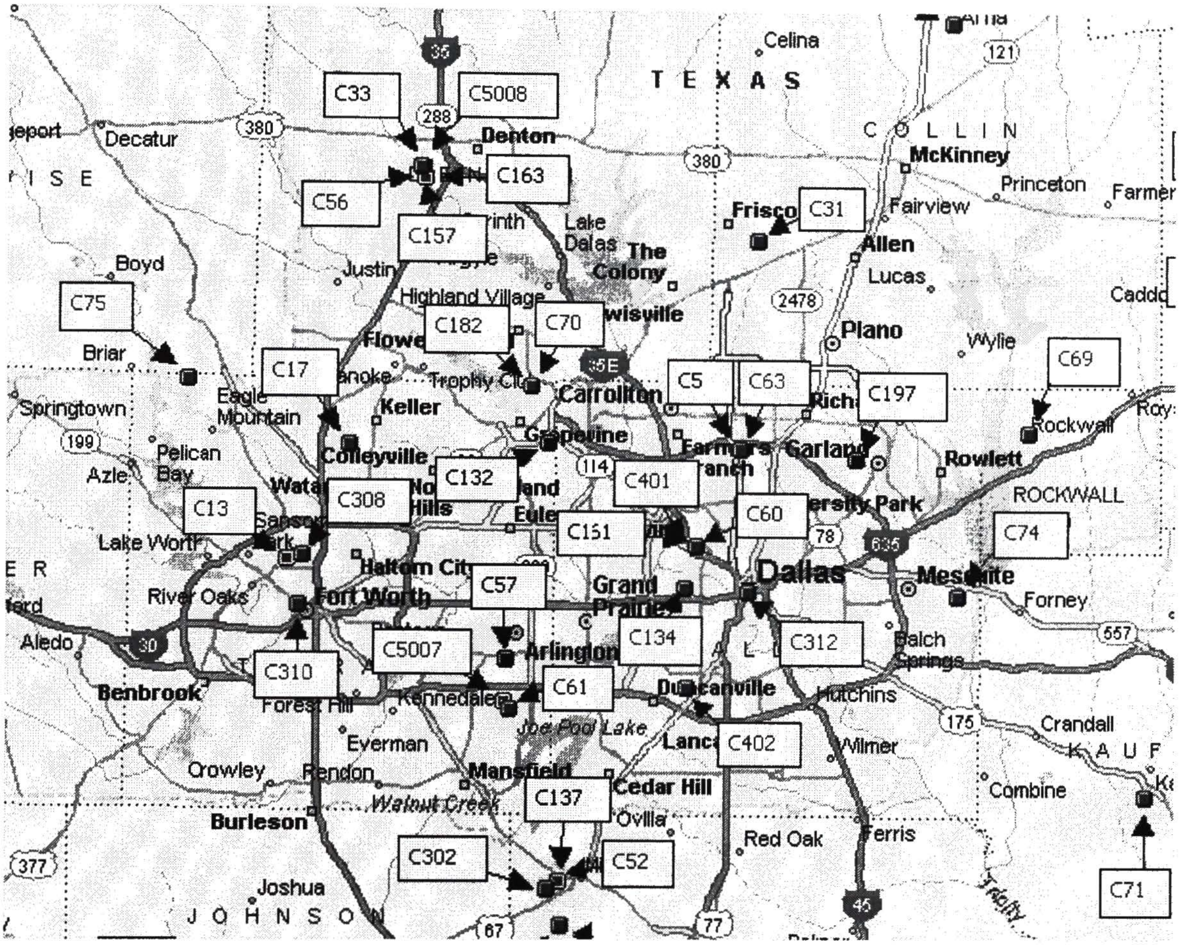


Figure 2. Map of Monitoring Site Relative Location in Fort Worth-Arlington Area



C61- Located in Arlington. Active since January, 2002.

C308- Located in Fort Worth, Diamond Hill. Activated in March, 2001; deactivated in September, 2005.

C75- Located in Eagle Mountain Lake. Active since June, 2000.

C13- Located in Ft. Worth Northwest. Active since August, 1997.

C70- Located in Grapevine Fairway. Active since August, 2000.

C310- Located at Haws Athletic Center in Fort Worth. Active since April, 2001.

C17- Located in Fort Worth. Active since July, 1997.

Source: Texas Commission on Environmental Quality (TCEQ), 2006c

Figure 3. Classification of Days by Air Quality Index and Quarter in 2004

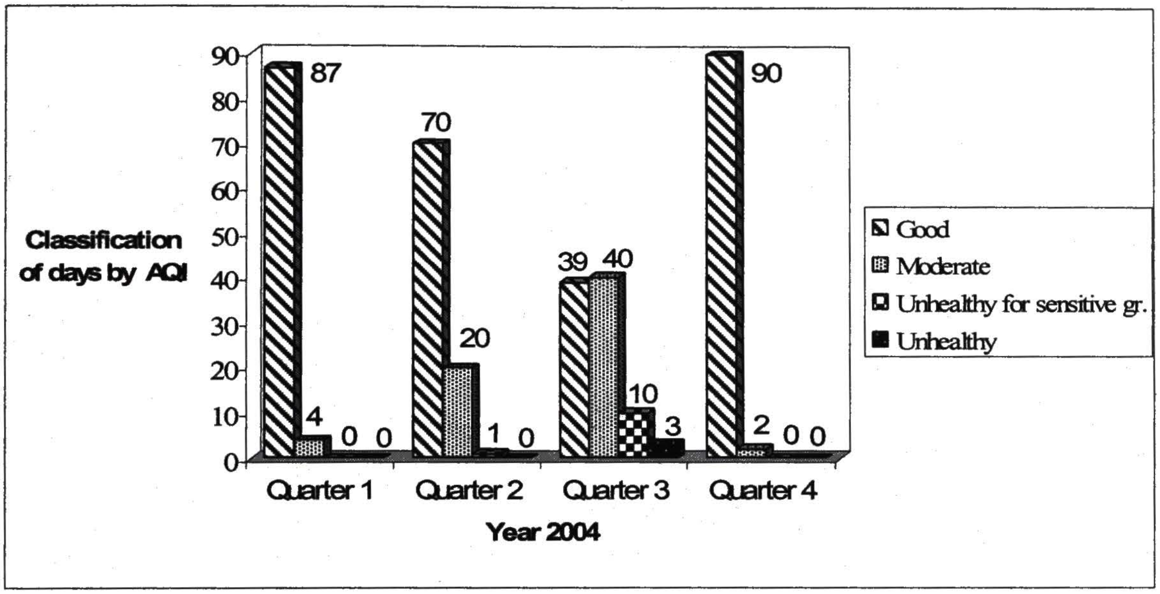


Figure 4. Average, Maximum and Minimum Values of AQI for Ozone by Quarters, 2004

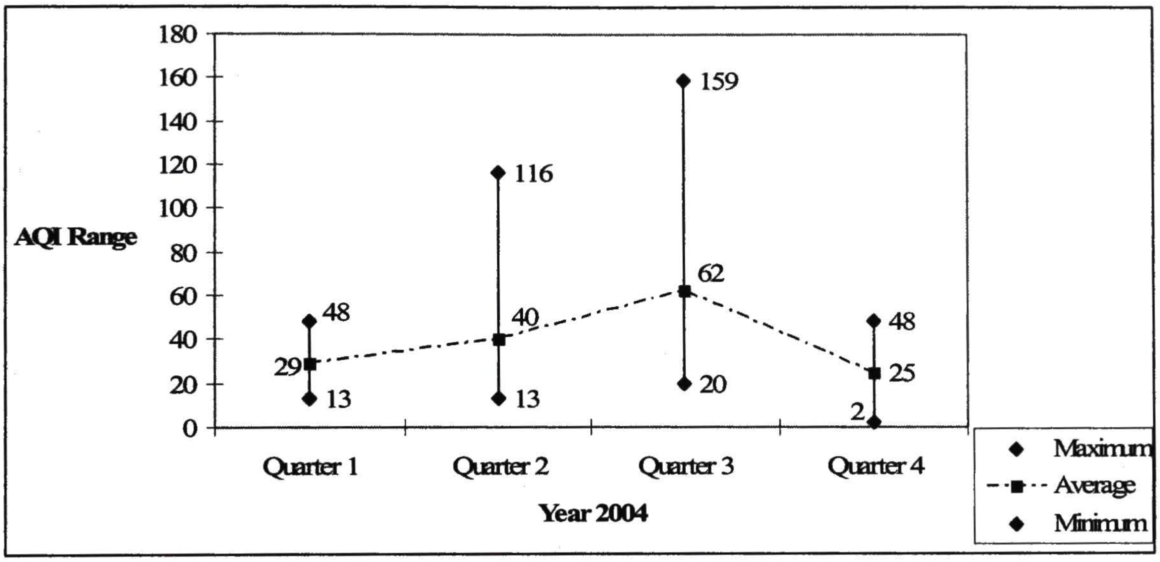


Figure 5. Average, Maximum and Minimum Outdoor Temperature by Quarters, 2004

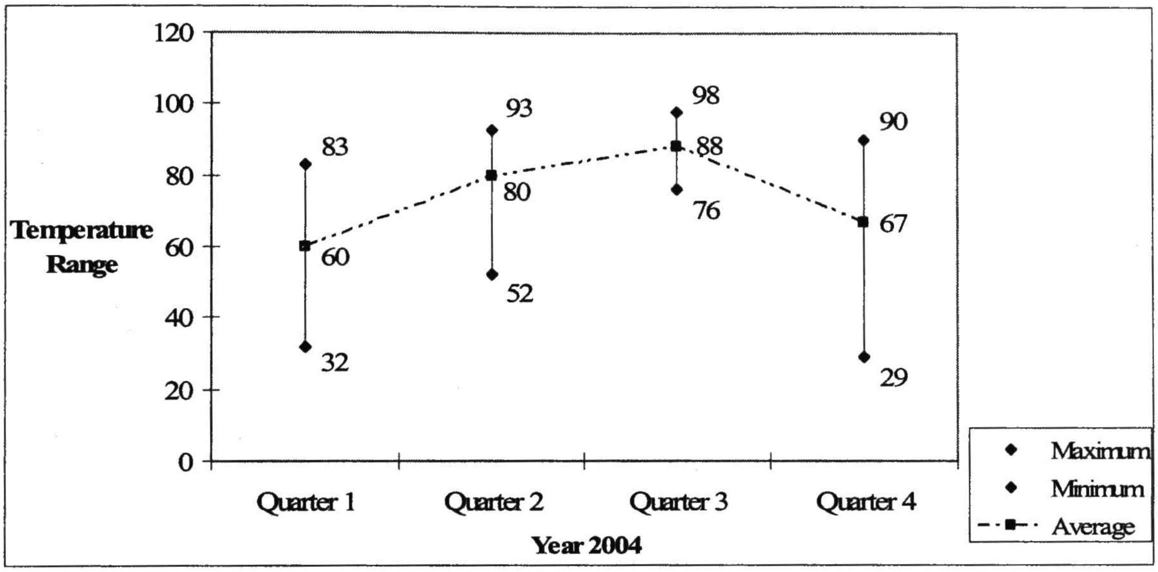


Figure 6. Proportion of Respiratory Admissions and Average AQI for Ozone per Quarter, 2004

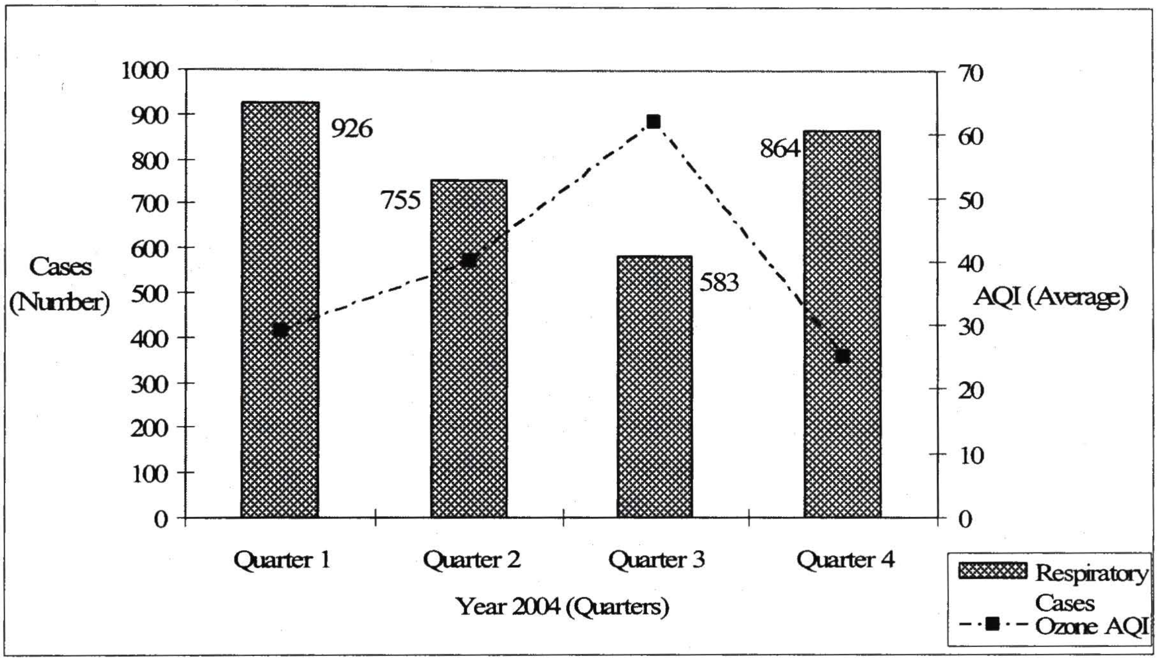


Figure 7. Variation of Hospitalization Rates (in Percent) by Selected Respiratory and Non-Respiratory Diagnosis: Fort Worth Area, 2004

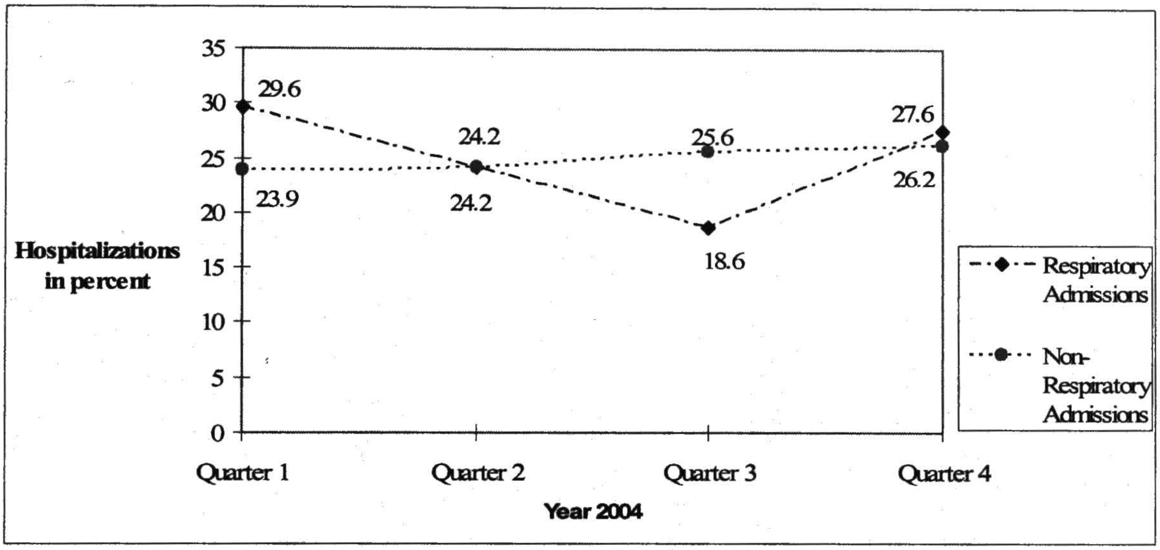
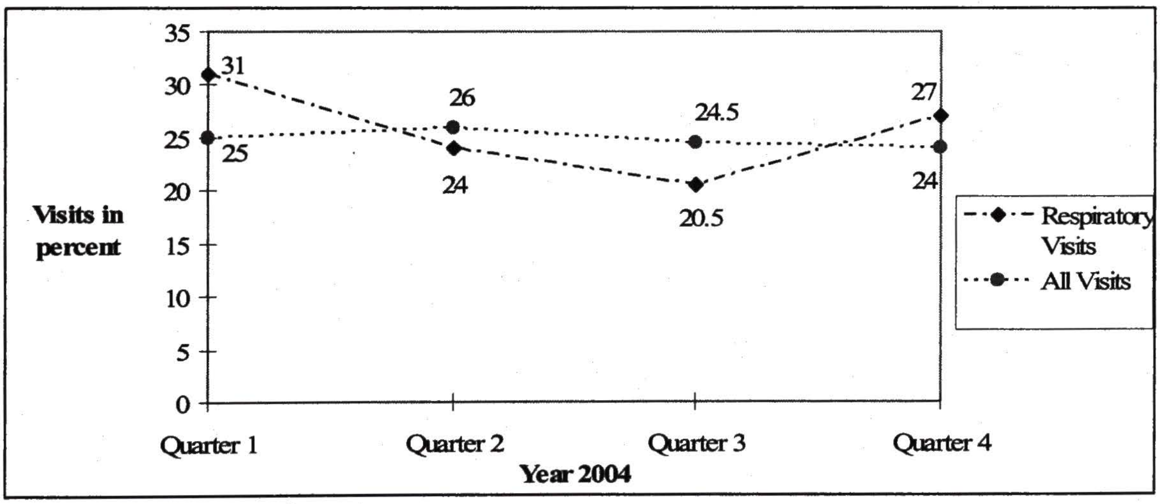


Figure 8. Approximated Rates of Emergency Department Visits for Respiratory and All Diseases, by Quarter: United States, 2004



Source: National Center for Health Statistics (NCHS), 2006

Figure 9. Percentage of Respiratory Admissions by Age Group and Quarters, 2004

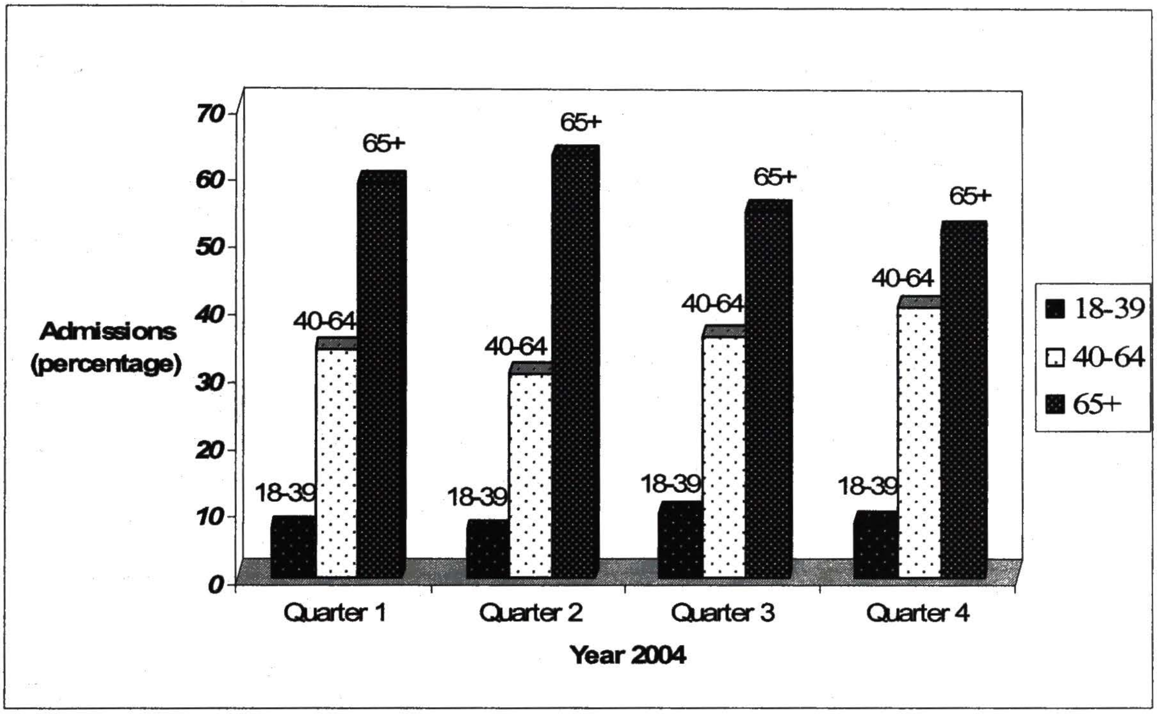


Figure 10. Percentage Distribution of Emergency Admissions for Total and Selected Respiratory Diseases, by Race in Fort Worth Area

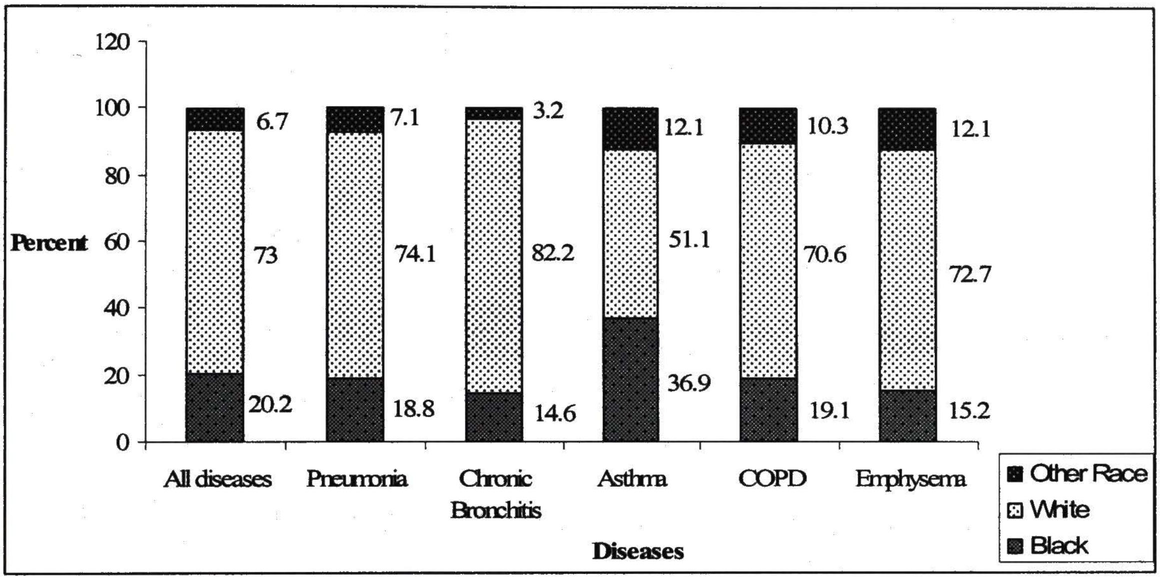
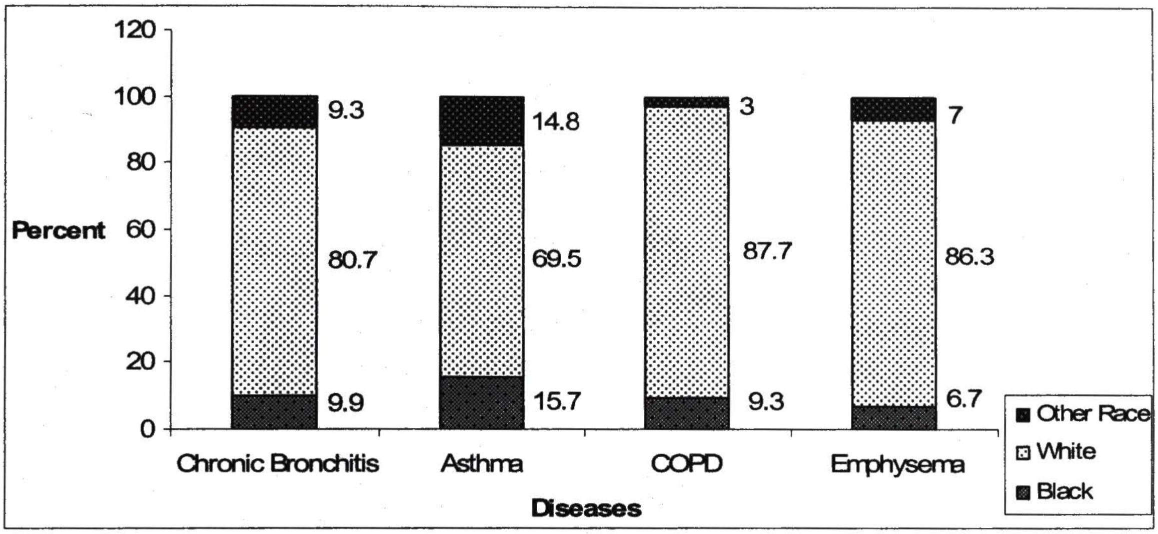


Figure 11. National Percentage Distribution of Selected Respiratory Disease by Race



Note: Percentage of Distribution to COPD refers to Hospital Discharges. Emphysema and Chronic Bronchitis percentages reflect distribution of the disease in the population. Asthma percentages reflect the lifetime prevalence of disease in the population.

Source:

Emphysema and Chronic Bronchitis Data- National Center for Health Statistics: National Health Interview Survey 2004 (as cited in American Lung Association, 2006b).

Asthma Data- National Center for Health Statistics: National Health Interview Survey 2004 (as cited in American Lung Association, 2006c).

COPD Data- National Center for Health Statistics: National Hospital Discharge Survey 1988-2004 (as cited in American Lung Association, 2006b).

Figure 12. Frequencies of Selected Respiratory Hospital Admissions for the Adult Population of Fort Worth Area, January- December 2004

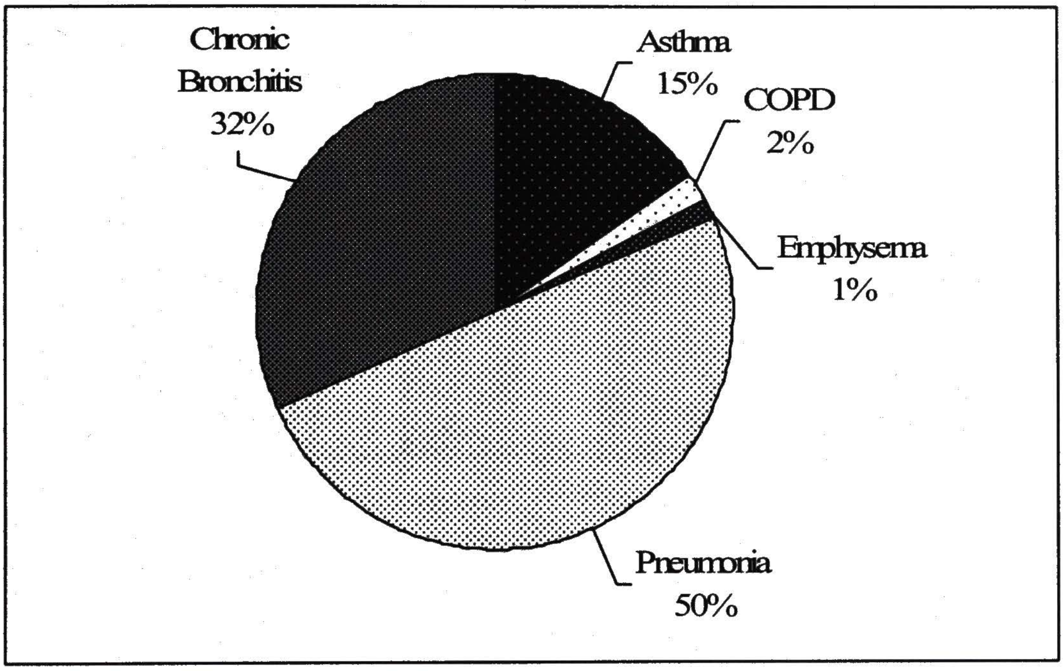


Figure 13. Severity of Diseases by Admission Diagnosis for Respiratory and Non-Respiratory Conditions

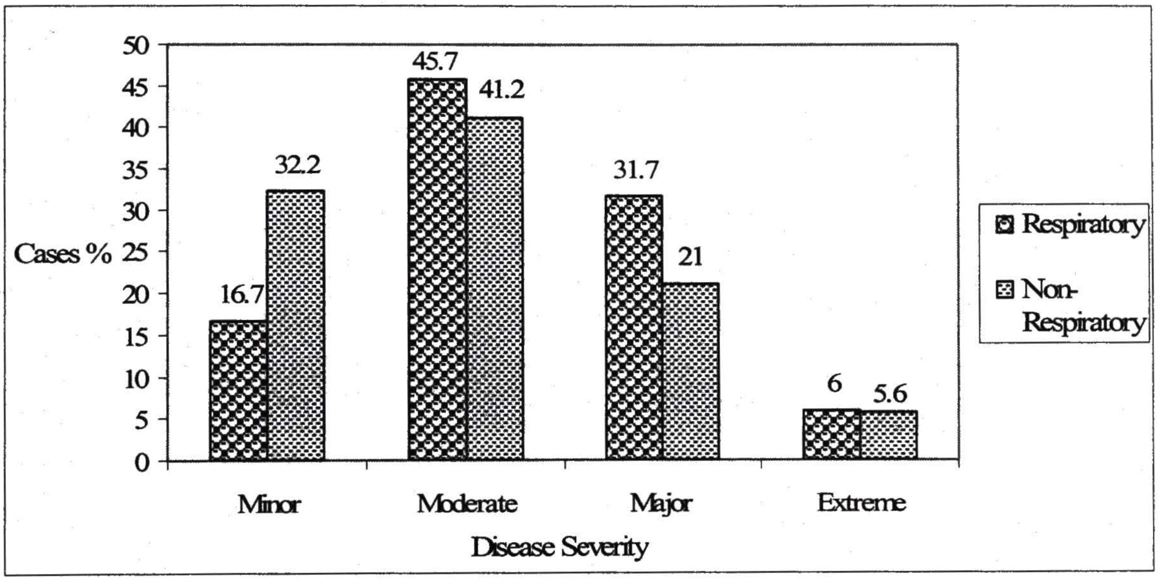


Figure 14. Disease Severity of Study Population by Age Group for Respiratory Diagnosis

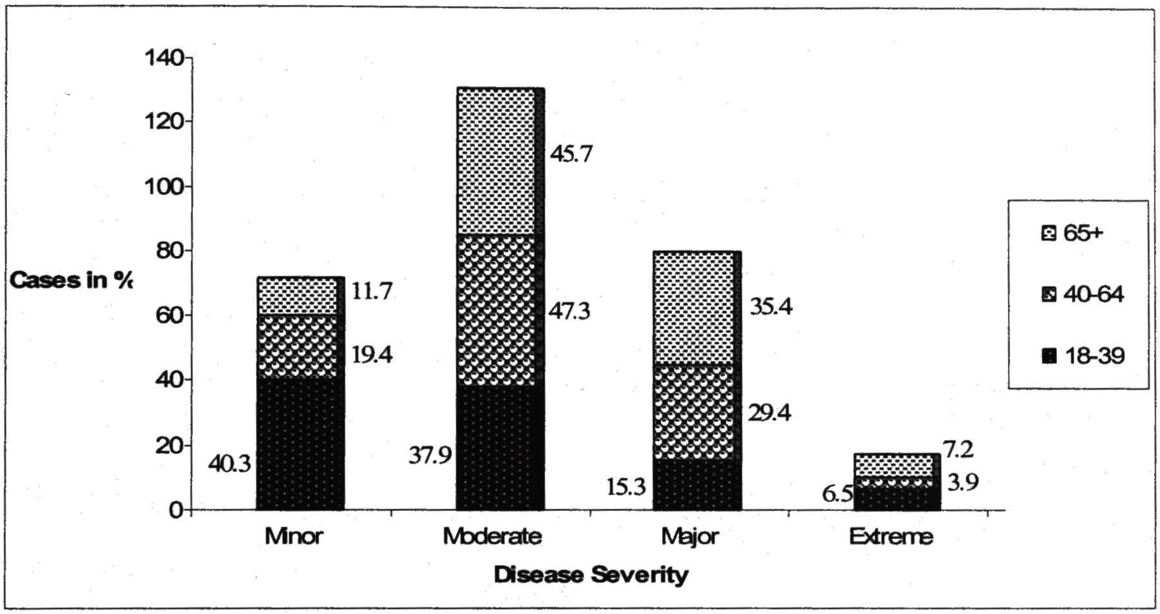


Figure 15. Fluctuations of Ozone AQI and Respiratory Admissions by Weekdays: January- March, 2004

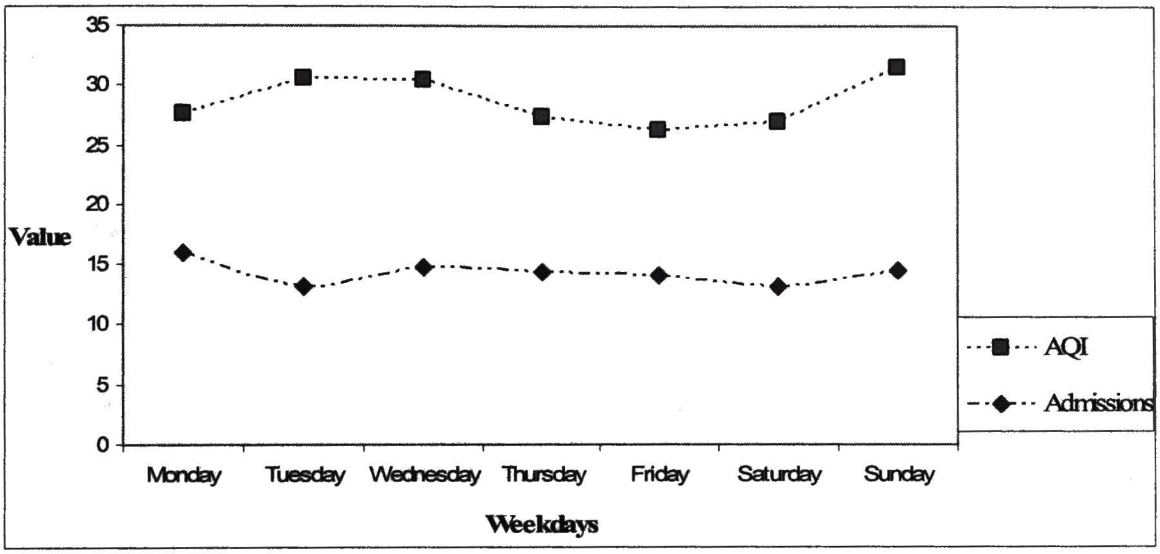


Figure 16. Fluctuations of Ozone AQI and Respiratory Admissions by Weekdays:

April- June, 2004

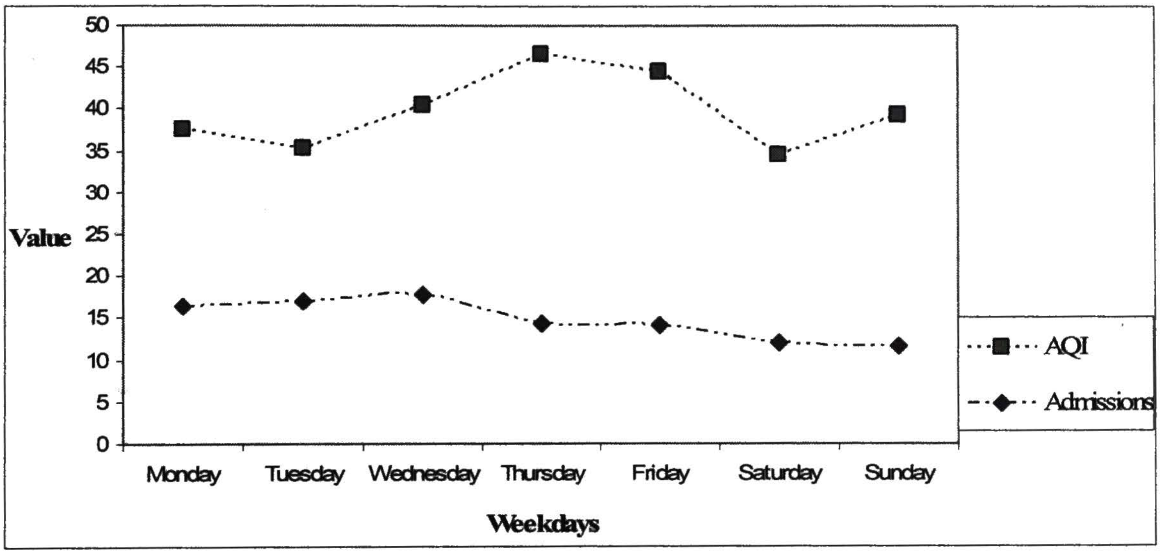


Figure 17. Fluctuations of Ozone AQI and Respiratory Admissions by Weekdays: July- September, 2004

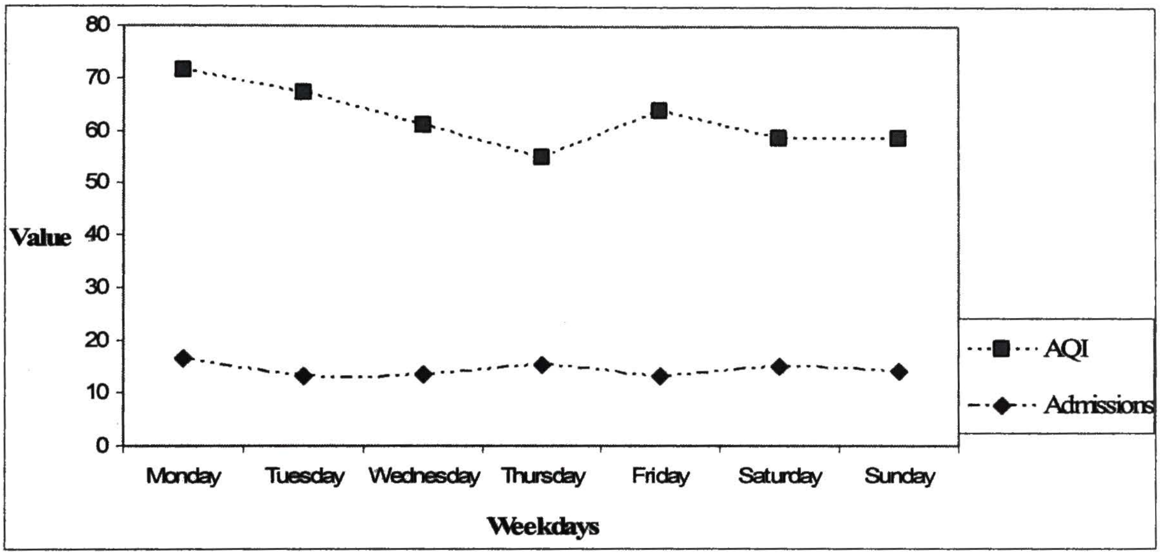
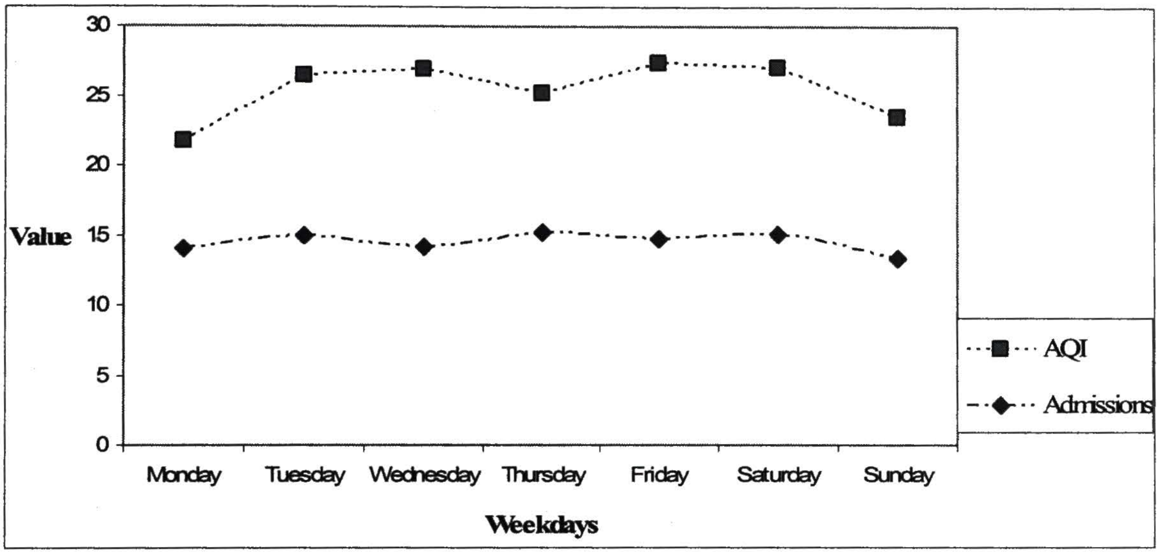


Figure 18. Fluctuations of Ozone AQI and Respiratory Admissions by Weekdays: October- December, 2004



APPENDIX A

SUMMARY OF STUDIES ON HEALTH EFFECTS OF AIR POLLUTION ON RESPIRATORY SYSTEM

Appendix A

Summary of Studies on Health Effects of Air Pollution on Respiratory System

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Girardot et al., 2006	2002- 2003 U.S.A	Adults of 18 to 82 years old with acute pulmonary conditions	15 min. average O_3, $PM_{2.5}$	None of these pollutants, found in levels below the standards, was associated with acute health effects in the study population.
Medina-Ramon et al., 2006	1986-1999 36 US cities	All age groups. Admissions with COPD and pneumonia	8 hour O_3, PM_{10}	In most of the cities under study, O_3 and PM_{10} are associated with hospital admissions for selected respiratory conditions.
Tsai et al., 2006	1996-2003 Kaohsiung, Taiwan	Admissions in all age groups for asthma	SO_2, NO_2, CO, O_3	Major association for asthma hospital admission and study pollutants except sulfur dioxide on days with high temperatures. On cold days, all pollutants are associated with number of admissions.
Chen et al., 2005	1995- 1999 Vancouver, Canada	Admissions of adults > 65 with acute respiratory symptoms	PM_{10}, $PM_{2.5}$ and PM_{10} - $PM_{2.5}$	No association between admissions and $PM_{2.5}$ concentrations. Significance found for particulates PM_{10} - $PM_{2.5}$ in specific days. Particulate pollutants affect people with preexisting respiratory conditions.
Luginaah et al., 2005	1995-2000 Ontario, Canada	Admissions for respiratory conditions in all age groups	SO_2, NO_2, CO, O_3, PM_{10}, COH, TRS.	No association between O_3 and respiratory admissions. Significant association between SO_2, NO_2, CO, PM_{10}, COH and hospitalizations.
Peel et al., 2005	1993- 2000 Atlanta	All visits for asthma, respiratory infections, COPD, pneumonia.	SO_2, NO_2, CO, 8 hour O_3, PM_{10}	Association between air pollutants and selected respiratory visits.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Wilson et al., 2005	1998-2000 in Portland, England 1996-2000 in Manchester, England	Visits in emergency rooms by all age groups for asthma and respiratory diseases	SO_2, 8 hour O_3 and weather variables	Increase of SO_2, O_3 associated with increase in emergency and asthma visits in Portland. No statistical association was concluded for the city of Manchester.
Yang et al., 2005	1994-1998 Vancouver, Canada	Hospitalization of older population with COPD	SO_2, NO_2, CO, O_3, PM_{10}	COPD hospitalization is associated with NO_2 and CO. The hospitalization for the selected population was not positively linked with levels of O_3 or SO_2.
Freitas et al., 2004	1993-1997 Sao Paulo, Brazil	Children < 15 years old and adults > 64 years old with respiratory conditions	CO, O_3, PM_{10}	Pollutants associated with hospital admission in children. Analogous findings of mortality in elderly in connection with CO and PM_{10}.
Galan et al., 2003	1995-1998 Madrid, Spain	Emergency room admissions for asthma	SO_2, NO_2, 8 hour O_3, PM_{10}	Positive association between ozone and emergency admission. Other pollutants also connected with asthma admissions.
Masjedi et al., 2003	1997- 1998 Tehran, Iran	Emergency admission of adult patients with asthma and COPD	SO2, NO_2, CO, O_3, PM_{10}, THC	Correlation between hospital admission in selected diagnosis and concentrations of NO_2 and SO_2. No association for other pollutants.
Sanchez-Carrillo et al., 2003	1996-1997 Mexico City	People 13> years old with respiratory and eye symptoms	8 hour O_3, PM_{10}, SO_2	Increase in O_3 affected the upper respiratory tract and ocular system. The nonsmoker population susceptible to low respiratory symptoms.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Yang et al., 2003	1986-1998 Vancouver, Canada	Admissions for respiratory conditions in people 3< and 65> years old	SO_2, NO_2, CO, daily average and 1-hr max. O_3	Ambient ozone associated with hospital admissions for respiratory conditions among children and elderly.
Desqueroux et al., 2002	1995- 1996 Paris, France	Adult people with severe status of asthma	SO_2, NO_2, 8 hour O_3, PM_{10}	Increased in O_3 & PM_{10} concentrations exacerbate the attacks and health of people suffering with asthma.
Martins et al., 2002	1996-1998 Sao Paolo, Brazil	Patients 64> years old presented at emergency departments with chronic lower respiratory conditions	SO_2, NO_2, CO, 1 hour O_3, PM_{10}	O_3 and SO_2 significantly associated with emergency room visits for these diseases.
Fusco et al., 2001	1995-1997 Rome, Italy	Hospital admissions for all age groups with total and acute respiratory infections (pneumonia, COPD, asthma)	SO_2, NO_2, CO, 8 hour O_3, particulate matter	O_3 significantly related with acute respiratory admission in children. Hospitalizations significantly associated with NO_2 and CO levels. The other pollutants did not affect the respiratory health of the population.
Schindler et al., 2001	Cross-sectional data. Eight regions in Switzerland	Adults (18-60 years old) with no smoking history. Analyzed pulmonary function of the population.	8 hour O_3, suspended particulates and NO_2	Concentration of pollutants was associates with decrease in lung function (measured in FVC, FEV and expiratory flow).

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Kinney & Lippmann, 2000	July-August 1990 Fort Dix, NJ Fort Benning, GA Fort Leonard Wood, MO Fort Still, OK	Sophomore cadets. Lung and respiratory function	Mean O_3, SO_2, PM_{10}	Exposure study pollutants showed a decline in respiratory health in subjects engaged in outdoor activities in relation with levels of O_3 and PM_{10}.
Moolgavkar, 2000	1987-1995 Three counties in U.S.	Admissions of all ages in one area; only 65 > years old in 2 areas. COPD	SO_2, NO_2, CO, O_3, PM_{10}, $PM_{2.5}$	Strong association of gases (with the exception of ozone) and COPD hospitalizations. In 2 out of 3 areas under study, O_3 associated with hospital admissions during April-September.
Atkinson et al., 1999	1992-1994 London, England.	Emergency visits patients with asthma, and other respiratory complaints in all age groups	SO_2, NO_2, CO, 8 hour O_3, PM_{10}, BS	Positive association of respiratory visits and SO_2, NO_2, PM_{10}. No association with O_3.
Galizia & Kinney, 1999	Multiple years. New Haven, Connecticat	Respiratory effects to long-term ozone exposure in students	O_3	Increased frequency of respiratory symptoms and decreased pulmonary function after long-term exposure to considerable levels of O_3 and other pollutants.
McDonnell et al., 1999	15 year period; Cohort study. Multiple counties in California.	Adults 27-82 years old with asthma	8 hour O_3	Male participants developed asthma associated with long-term ambient O_3 exposure. No significant results for females.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Zemp et al., 1999	Cross-sectional data. Eight regions in Switzerland	Adults 18-60 years old. Lung function and respiratory symptoms	NO_2, annual & daytime average and cumulative exposure O_3, PM_{10}	Positive association of NO_2 & PM_{10} and other particulates with respiratory symptoms. No association was found for yearly concentration of O_3 and symptoms.
Anderson et al., 1998	1987-1992 London, England.	Asthma admissions in all age groups	SO_2, NO_2, 1 and 8 hour max. average O_3, BS (black smoke)	Significant relationship of O_3 with hospital admission in patients 15-64 years old. Significant association found for: (a) NO_2 and hospital admission in children and older people; (b) SO_2 and children; (c) BS and older population.
Delfino et al., 1998	1989-1990 Montreal, Quebec.	Emergency respiratory visit for patients 2> years old. Main focus on older population.	1 and 8 hour max. O_3, $PM_{2.5}$	Significant correlation for respiratory visits of elderly with levels of O_3. Association between $PM_{2.5}$ and visits for respiratory conditions; however this relationship is prone to bias.
Hiltermann et al., 1998	1995 Holland	Nonsmoking asthmatic people	8 hour O_3, SO_2, NO_2, BS	Exacerbations of respiratory symptoms likely to be associated with levels of the selected pollutants.
Spix et al.,1998	1987-1991, England; 1977-1989, Holland; 1987-1992, France; 1980-1989, Italy.	Emergency admissions in selected respiratory causes (ICD9 460-519) for adults (15-64y) and elderly (65+y)	SO_2, NO_2, 1 hour and 8 hour O_3, particulate matters, black smoke (BS) and suspended particulates	Daily hospitalizations for respiratory conditions associated with high O_3 levels. Significant results for 65+ in warm periods. No consistent association with SO_2.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Tenias et al., 1998	1994-1995 Valencia, Spain.	Emergency visits in patients 14> years old with asthma	SO_2, NO_2, 1 hour O_3, BS	O_3 and NO_2 significantly associated with asthma emergency visits.
Burnett et al., 1997	1981-.1991 16 Canadian cities	Respiratory admissions	Daily average, 1 and 8 hour O_3, SO_2, NO_2, CO, COH	At low ambient concentration of ozone and other pollutants, an increase in respiratory admissions was observed.
Delfino et al., 1997	1992- 1993 Montreal, Canada.	Emergency room visits of people 64> years old with respiratory illnesses	1 hour O_3, PM_{10}, $PM_{2.5}$, sulfate fraction of $PM_{2.5}$ and aerosol strong acidity.	Emergency room visits increased with elevated mean levels of O_3 for part of the study period. Particle pollution did not cause the same effect on respiratory health.
Kunzli et al.,1997	Survey of several days. California, US	Freshmen: 17-21 years old. Small airway pulmonary function	1 hour conc. >60 ppb and 8 hour O_3	Decline in respiratory flow are predictors of possible pathological alteration in the lung due to long-term O_3 exposure.
Moolgavkar et al., 1997	1986- 1991 Minneapolis-St.Paul, MN; Birmingham, AL.	Hospital admissions of older patients with COPD and pneumonia	SO_2, NO_2, CO, O_3 , PM_{10} in MN and CO, O_3 , PM_{10} in AL.	O_3 is associated with respiratory admissions in Minneapolis. No significant association among pollutants and hospital admissions in Birmingham.
Sunyer et al., 1997	1986-1992 Barcelona; Helsinki; Paris; London.	Emergency admissions for asthma in children 15< and adults (15-64 year old)	SO_2, NO_2, 1 and 8 hours max. O_3, particles and black smoke	Admissions in adults were significantly associated with concentrations of NO_2. For adults, connection between asthma admissions and O_3 differed among cities. Admissions in children were significantly associated with SO_2.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Ponce de Leon et al., 1996	1987-1988 and 1991-1992 London, England.	Immediate admissions for respiratory diseases, all age groups	SO_2, NO_2, 1 and 8 hour O_3, Particulates (black smoke)	Minor but statistically significant association of ozone and respiratory hospitalization in London.
Schouten et al., 1996	1977-1989 Amsterdam & Rotterdam, The Netherlands.	Emergency admissions for all ages with respiratory diseases, COPD and asthma.	SO_2, NO_2, 8 hour O_3, and particulates (BS)	Significant association of ozone and emergency admissions in Rotterdam. Positive association found in Amsterdam.

APPENDIX B

SUMMARY OF STUDIES ON HEALTH EFFECTS OF AIR POLLUTION ON CARDIOVASCULAR AND RESPIRATORY DISEASES

Summary of Studies on Health Effects of Air Pollution on Cardiovascular- Respiratory Diseases

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Barnett et al., 2006	1998-2001 5 Cities in Australia; 2 in New Zealand.	Hospitalizations of adults 18-64 and > 64 years old. Arrhythmia, cardiac disease, cardiac failure, IHD, myocardial infarction, stroke.	NO_2, CO, 1, 4 and 8 hour O_3, PM_{10} , $PM_{2.5}$	Ozone was the only pollutant not significantly associated with 5 of 7 selected CVD. Some of the pollutants are positively associated with hospitalization for cardiovascular causes.
Hinwood et al., 2006	1992-1998 Perth, Australia	Hospitalizations of < 15 years old and > 64 years old. Respiratory, GI, CV diseases.	NO_2, CO, O_3, $PM_{2.5}$	Limited association between respiratory/ cardiovasculary hospitalizations and NO_2, CO, $PM_{2.5}$. No significance with ozone.
Lagorio et al., 2006	1999 Rome, Italy	Adults with heart and lung disease (COPD, asthma and ischemic heart disease)	SO_2, NO_2, CO, O_3, PM_{10}, $PM_{2.5}$	Exposure to air pollutants affects the lungs of people with respiratory and cardiovascular medical history. Asthmatics more sensitive to NO_2 levels.
Schwartz et al., 2005	Summer 1999	Subject 61- 89 years old. Heart rate functions.	SO_2, NO_2, Black Carbon, CO, 1 hour O_3, $PM_{2.5}$	Strong association between black carbon and heart function; weak association with ozone; no association for SO_2, NO_2.
Simpson et al., 2005	1996-1999 4 cities, Australia	Admissions in all age groups with cardiovascular and respiratory diseases	NO_2, O_3, and fine particles	Pollutants associated with respiratory and cardiovascular admissions in 3 of 4 cities studied.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Metzger et al., 2004	1993- 2000 Atlanta, Georgia	Emergency visits with cardiovascular conditions	SO_2, NO_2, CO, 8 hour O_3, PM_{10}, $PM_{2.5}$	Emergency visits for cardiovascular diseases are associated with levels of NO_2, CO,$PM_{2.5}$
Lee et al., 2003	1997- 1999 Seoul, Korea	Hospitalization of people 64> with ischemic heart diseases	SO_2, NO_2, CO, 1 hour O_3, PM_{10}, $PM_{2.5}$	Hospitalizations were associated with levels of air pollutants. Major significance was found for SO_2.
Petroeschevsky et al., 2001	1987-1994 Brisbane, Australia	Emergency admissions: for cardiovascular and respiratory diseases (including asthma).	SO_2, NO_2, 8 hour O_3 and particulate matters	O_3 and particular matters associated with hospital admissions for asthma and respiratory diseases.
Ye et al., 2001	1980-1995 Tokyo, Japan	Emergency transports to hospitals for 65 > years old with asthma, bronchitis, pneumonia & CVD.	SO_2, NO_2, CO, O_3, PM_{10}	NO_2, PM_{10} were the pollutants more significantly associated with asthma, chronic bronchitis, pneumonia and other CVD. The maximum temperature affected the cases of pneumonia.
Linn et al., 2000	1992-1995 Los Angeles, California	Admissions in people 30> years old with cardiovascular and pulmonary diseases	NO_2, CO, 1 hour O_3, PM_{10}	Hospital admissions for cardiovascular conditions were associated with concentrations of CO. No significance with O_3. Significance was found for respiratory admissions and NO_2, PM_{10}.

APPENDIX C

SUMMARY OF STUDIES ON AIR POLLUTION AND MORTALITY

Summary of Studies on Air Pollution and Mortality

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Zhang et al., 2006	2001-2004 Shanghai, China	Total, respiratory and cardiovascular mortality for all age groups.	8 hour O_3	Significant association on the cold months between overall and cardiovascular mortality and ozone concentration.
Bell et al., 2005	Meta- analysis study	Total, cardiovascular and respiratory mortality for all age groups	1 and 8 hour O_3	Strong association between ozone levels and premature mortality. Particular effect on cardiovascular and respiratory mortality and older population.
Parodi et al., 2005	1993- 1996	Total and cardiovascular mortality for all age groups.	24 and 8 hour O_3	Cardiovascular mortality in elderly associated with O_3. Overall effects stronger in hot season.
Biggeri et al., 2004	Meta-analysis study	Total, respiratory and cardiovascular mortality. Consideration to hospitalizations for respiratory, cardiac and cerebrovascular diseases.	NO_2, SO_2,O_3, CO, PM_{10}	Elevated levels of pollutants were associated with increase in mortality for all causes. The same conclusion for respiratory and cardiac hospitalization. Stronger effects on warm season.
O'Neill et al., 2004	1996-1998 Mexico City, Mexico.	Overall population mortality (exclude external causes).	24 hour O_3 , PM_{10}	Association of mortality among older population and ozone concentrations. Ozone related to overall population mortality.

Reference	Study Period Location	Population Health Condition	Pollutant (s)	Main Conclusions
Penttinen et al., 2004	1988-1996 Helsinki, Finland.	Daily mortality in population >15 years old	NO_2, SO_2,CO, PM_{10} , O_3 , TSP (suspended particulate matter)	Total and respiratory mortality related to ozone in warm and hot season. Significance found for PM_{10} and mortality for respiratory causes.
Fischer et al., 2003	1986-1995 The Netherlands	Population total and disease-specific mortality (excluded mortality for external causes and infants < 1 month old)	NO_2, SO_2,CO, 8 hour O_3 , PM_{10}	All pollutants significantly associated with mortality in older population.
Botter et al., 2002	1991-1993 Sao Paulo, Brazil	Population mortality in people > 65 years old	NO_2, SO_2,CO, 8 hour O_3 , particulates	SO_2 and weather variables have a positive effect on mortality.
Wong et al., 2001	1995-1997 Hong Kong, China	Daily mortality for respiratory, cardiovascular and nonaccidental causes in all age groups	NO_2, SO_2, 8 hour O_3 , PM_{10}	During the cold months, all pollutants are associated with daily mortality. No significant results obtained for the rest of the year.

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