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An Analysis of Cardiovascular and Respiratory Admission Rates as a Function of Air Pollutants in the Baton Rouge Five-Parish Area

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AN ANALYSIS OF CARDIOVASCULAR AND RESPIRATORY ADMISSION RATES AS A FUNCTION OF AIR POLLUTANTS IN THE BATON ROUGE FIVE-PARISH AREA

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ABSTRACT

In past years, the Baton Rouge Air Quality Control Region has struggled with compliance of ozone standards. In June of 2003, the Baton Rouge Five-Parish Ozone Non-Attainment Area was classified as severe under the 1-hour ozone standard. In July of 2012, the EPA classified the area as marginal non-attainment for ozone. Although this is an improvement from its severe classification, studies have shown that health effects of air pollution can be detected at concentrations lower than the National Ambient Air Quality Standards. Additionally, clinical and epidemiological studies have shown that a majority of the criteria pollutants negatively affect cardiovascular and respiratory functions, with many epidemiological studies finding an increase in hospital admissions associated with increases in ambient air pollution. The intent of this study was to examine the relationship between air quality in the Baton Rouge Air Quality Control Region and cardiovascular and pulmonary hospital admission rates between the years 2000- 2011. A multivariate regression analysis was run to examine the relationship between daily averages of O_3 and $PM_{2.5}$ and total hospital admissions for diseases of the circulatory and respiratory systems for all zip codes in the five parish area. Lag 0 (same day) showed that increases in hospital admissions were significantly associated with a decrease in ozone ($p<.0001$) and an increase in particulate matter ($p=.0002$), while lags 1, 2, 10, and 20 showed no significant association between pollutant levels and hospital admissions. A second multivariate regression analysis examined the relationship between same-day air pollution and hospital admissions surrounding the Baton Rouge Capital air monitoring site, since this was the only monitoring site that collected data for each of the criteria pollutants. Out of the five pollutants examined (O_3, $PM_{2.5}$, CO, SO_2, and NO_2), increases in only O_3 and NO_2 were statistically significant ($p<.0001$) in association with the number of hospital admissions. Both showed that increases in pollution levels were significantly associated with increases in hospital admissions.

CHAPTER I: INTRODUCTION

In 1948, smog composed of sulfuric acid and nitrogen dioxide enveloped the town of Donora, Pennsylvania. A temperature inversion caused the deadly pollution to remain there for days. By the end of the event, nearly 40 people were dead, and many more were hospitalized for cardiovascular and respiratory illnesses (EPA 2012). Widely publicized events, such as the 1948 Donora Smog and the Great Smog of 1952 in London, led to a growing concern about air pollution both globally and within the United States. As a result, the 1950s marked the beginning of air pollution regulations and standards in the United States. These regulations and standards were designed to protect both the public health and welfare. Today, however, there are still many areas within the United States that are not in compliance with national standards. As a result, people living in non-compliant areas may be subject to increased health risks.

Air pollutants have been linked to a variety of negative health effects. A recent study estimated that each year, 470,000 premature respiratory deaths and 2.1 million cardiopulmonary disease-related deaths are associated with anthropogenic ozone and $PM_{2.5}$, respectively, worldwide (Silva, West, et al. 2013). Clinical research on human exposure to common air pollutants shows clear links between air pollution and cardiovascular and respiratory diseases (Allred, Bleecker, et al. 1989; Horstman, Ncdonnell, et al. 1989; Sheps, Herbst, et al. 1990). The majority of these trials, however, only examined one pollutant at a time and therefore failed to accurately depict the complex mix of pollutants found in the real world.

In recent years, there has been increasing interest in epidemiological studies for air pollution (Bell, Peng, et al. 2009; Chen, Goldberg, et al. 2013; Ensor, Raun, et al. 2013; Jerrett, Burnett, et al. 2013). Epidemiological studies provide a key to better understanding possible antagonistic or synergistic effects of pollutants. The majority of these studies focus on sensitive subpopulations, such as children, asthmatics, and the elderly. Multiple studies worldwide have reported increases in cardiovascular and respiratory hospital visits during times of poor air quality; however, the magnitude of association and timescale at which this occurs differs from study to study. The intent of the present study is to examine the air quality of the Baton Rouge Air Quality Control Region, which has been in non-attainment of ozone standards for the majority of the past decade, and to determine if levels of pollutants have an effect on hospital admissions for cardiovascular and respiratory diseases. The study spans the years 2000-2011 with a large region of both rural and urban areas.

CHAPTER II: LITERATURE REVIEW

Air Quality Regulations

A brief history of air quality regulations.

The Air Pollution Control Act of 1955 was the first federal legislation to address the issue of air pollution within the United States. While the Act provided funds for federal research in air pollution, it failed to address the issue of controlling air pollution (EPA 2012). Further legislation was necessary, resulting in the creation of the Clean Air Act.

The Clean Air Act of 1963 took steps in addressing air pollution control by authorizing the "Department of Health, Education, and Welfare (HEW) to establish air quality criteria through conferences involving polluters and representatives from state and federal government" (Ferrey 2010). In 1967 the Air Quality Act was passed, which required the HEW to designate air quality control regions (AQCRs), geographical regions in which air quality is monitored and controlled. While the Air Quality Act of 1967 succeeded in identifying problematic regions and pollutants, it failed in setting enforceable national air quality standards (Ferrey 2010).

The Clean Air Act Amendments of 1970.

The Clean Air Act Amendments of 1970 remains the basic structure for the current act, the 1990 Clean Air Act. Under the 1970 amendments, the federal role was charged with creating national standards for ambient air quality. These standards were called the National Ambient Air Quality Standards or NAAQS. The state's role was to enforce these standards through federally approved plans known as State Implementation Plans (SIPs).

State Implementation Plans are detailed plans submitted by each state regarding the implementation, maintenance, and enforcement of NAAQS for each criteria pollutant. After a plan is submitted, the Environmental Protection Agency (EPA) can accept or reject the plan. If approved, the state and local regulations in the plan become enforceable as federal law. It is important to note that methods of controlling air pollution can include technology or techniques to disperse pollutants to other regions (Ferrey 2010). Thus, states downwind from high emission areas may be negatively affected.

National Ambient Air Quality Standards.

The Clean Air Act instructed the Environmental Protection Agency to enact National Ambient Air Quality Standards (NAAQS) for six "criteria pollutants," called so because they are regulated by "human health-based and/or environmentally-based

criteria" (EPA 2012). These pollutants originally consisted of particulate matter, sulfur dioxide, ozone, nitrogen oxides, carbon monoxide, and hydrocarbons. In the 1970s, lead was added to the list of criteria pollutants after a ruling in *NRDC v. Train* when the court held that the EPA "is obligated to list a pollutant once such pollutant has been determined by the agency potentially to have an adverse effect on public health and welfare" (Ferrey 2010). Viewed as a precursor to ozone, hydrocarbons were removed from the list of criteria pollutants in the 1980s, resulting in the current criteria pollutants (see Table 1).

National Ambient Air Quality Standards (NAAQS) contain both primary and secondary standards. The primary standard is designed to protect the public health, including sensitive subpopulations. The secondary standard is designed to protect the public welfare, including damage to visibility, animals, crops, and vegetation.

NAAQS are often expressed in "parts per million" of a pollutant in a sample of air and provide both a maximum and average concentration standard of that pollutant. Typically standards cannot be exceeded more than once per year and must be reviewed (and, if necessary, revised) every five years (Ferrey 2010). If the level of a criteria pollutant repeatedly exceeds the NAAQS in a given area, then this area may be designated as "non-attainment" of that pollutant (EPA 2012). Table 1 lists the current criteria pollutants, their corresponding NAAQs, and the number of exceedances allowed.

Table 1: National Ambient Air Quality Standards

Pollutant [final rule cite]		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]		Primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead [73 FR 66964, Nov 12, 2008]		Primary and secondary	Rolling 3 month average	0.15 µg/m	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]		Primary	1-hour	100 ppb	98th percentile, averaged over 3 years
		Primary and secondary	Annual	53 ppb	Annual Mean
Ozone [73 FR 16436, Mar 27, 2008]		Primary and secondary	8-hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution Dec 14, 2012	$PM_{2.5}$	Primary	Annual	12 µg/m	Annual mean, averaged over 3 years
		Secondary	Annual	15 µg/m	Annual mean, averaged over 3 years
		Primary and secondary	24-hour	35 µg/m	98th percentile, averaged over 3 years
	PM_{10}	Primary and secondary	24-hour	150 µg/m	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]		Primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

Taken from http://www.epa.gov/air/criteria.html

Baton Rouge Air Quality Control Region.

The Baton Rouge Air Quality Control Region consists of the following parishes: Iberville, West Baton Rouge, East Baton Rouge, Ascension, and Livingston. Throughout these parishes, there are a number of State and Local Ambient Monitoring Stations (SLAMS), Photochemical Assessment Monitoring Stations (PAMS), and Special Purpose Monitoring Systems (SPMS) set up to measure ambient air concentrations of criteria pollutants (details are presented in the Materials and Methods section). Figure 1 shows the placement of the monitoring sites throughout the five-parish region.

Figure 1: Air monitoring sites located in the Baton Rouge Five-Parish Area

Image taken from LDEQ and edited to include Geismar air-monitoring station.

In past years, the Baton Rouge Air Quality Control Region has struggled with compliance of ozone standards. In June of 2003, the Baton Rouge Five-Parish Ozone Non-Attainment Area was classified as severe under the 1-hour ozone standard. [The classifications for ozone non-attainment, listed in increasing order of severity, are: marginal, moderate, serious, severe, and extreme (EPA 2012)]. In March of 2010, the EPA ruled that the Baton Rouge five-parish area had attained the 1-hour ozone standard; however, by July of 2012 the EPA designated the area as marginal non-attainment for ozone (LDEQ). Although this is still an improvement from its severe classification, studies have shown that health effects of ozone can be detected at concentrations as low as .06 ppm (Keller 1992). Therefore, compliance of NAAQS does not necessarily mean that levels are without adverse health effects.

Criteria Pollutant Toxicity

Many of the criteria pollutants have similar at-risk populations. In general, children, the elderly, and those with cardiopulmonary diseases are at higher risk for the following reasons: 1) The majority of air pollutants aggravate cardiac and pulmonary problems. Thus, individuals with certain cardiovascular and respiratory disease are more susceptible to increased effects. 2) Children spend more time outside than adults and tend to breathe more rapidly than adults, thus exposing them to higher concentrations of air pollutants. Children are also more likely to have asthma, which can be triggered by pollutants. 3) Older individuals tend to have higher incidences of diabetes and heart and lung diseases.

The primary purpose of this section is to provide basic information about the six criteria pollutants, including emission sources, health effects (focusing on cardiovascular and respiratory effects), and at-risk populations. Furthermore, this section will explain what happens when the pollutant enters the body (absorption, distribution, and metabolism), along with providing relevant epidemiological studies when possible.

Carbon monoxide.

Carbon monoxide (CO) is a colorless, odorless gas that forms as a result of incomplete combustion of hydrocarbons. Sources include unvented kerosene and gas space heaters, gas stoves, tobacco smoke, and exhaust from automobiles and lawnmowers. Because combustion in internal combustion engines (found in vehicles) are less effective than combustion at fossil fuel plants, the majority of CO emissions (both nationally and in the Baton Rouge five-parish area) comes from mobile sources. Thus, higher concentrations of CO are typically seen near busy roadways. Figure 2 shows the major sources of carbon monoxide emissions in the Baton Rouge Five-Parish area.

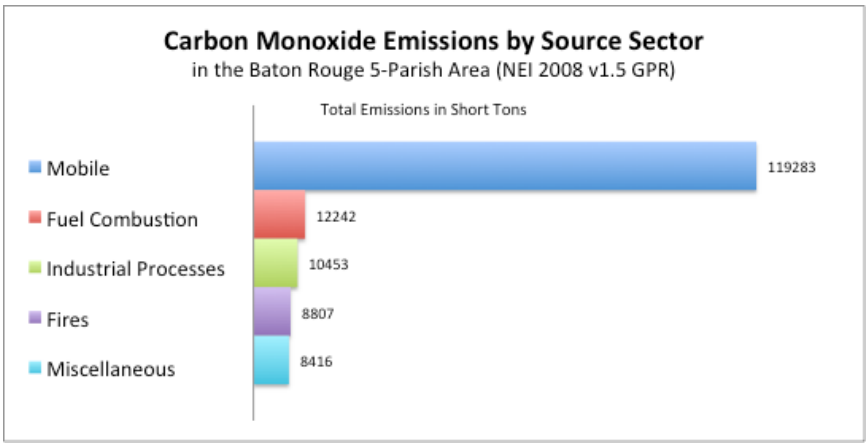

Figure 2: CO emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

Low levels of carbon monoxide can be found naturally within the body. Endogenous production of carbon monoxide is not associated with toxicity; rather, it has been found to play an important role in the regulation of many physiological functions (ATSDR 2012). If a threshold for carbon monoxide exists, it is likely that it would be at or near the endogenous production rate (ATSDR 2012).

Exogenous carbon monoxide, on the other hand, is toxic to the body. Carbon monoxide is classified as a chemical asphyxiant because it prevents the transport of oxygen throughout peripheral cells and tissues. Carbon monoxide affects cell metabolism through both hypoxic and non-hypoxic mechanisms of action, largely due to its ability to bind to heme (ATSDR 2012). Carbon monoxide's affinity to bind to hemoglobin is 210 times higher than oxygen's affinity for hemoglobin (Prockop and Chichkova 2007). When CO binds to hemoglobin it forms carboxyhemoglobin (COHb), blocking the transport and delivery of oxygen to vital tissues. Tissues with higher oxygen demands, including the brain and heart, are particularly at risk (ATSDR 2012). Tissue hypoxia can cause headaches, dizziness, weakness, nausea, disorientation, and fatigue (Bell, Peng, et al. 2009). When COHb levels near 40%, carbon monoxide poisoning can lead to loss of consciousness and fatal asphyxiation (Klaassen 2008). It is important to note that factors outside of exposure to ambient carbon monoxide pollution can increase COHb levels. Oxidative metabolism of exogenous precursors, including hydrocarbons such as dichloromethane, result in increased carbon monoxide production within the body (ATSDR 2012).

A number of factors, both behavioral and physiological, can increase the risk of effects from CO exposure. Cigarette smokers are at greater risk because their baseline COHb levels are already higher than those of nonsmokers. COHb levels in cigarette smokers can range from 3 to 8% versus the 0.3 to 1% in healthy, nonsmoking individuals (EPA 2010). The elderly are also at increased risk due to slower elimination of COHb and higher likelihood of having pre-existing conditions, such as cardiovascular disease (EPA 2010).

A variety of pre-existing medical conditions (including asthma, chronic obstructive pulmonary disease, emphysema, diabetes, and anemia) may increase risks associated with CO exposure. These risks are governed by the fact that each of these conditions affects oxygen gas exchange and oxygen utilization in the blood (EPA 2010). Although studies of the effects of CO exposure on these conditions are limited, it is reasonable to assume that CO exposure would exacerbate these pathological conditions. Other conditions, such as cardiovascular disease and coronary artery disease, have been studied more thoroughly for effects of carbon monoxide.

Studies have shown that cardiovascular disease (CVD) is exacerbated with COHb levels between 2 and 6% (ATSDR 2012). CVD reduces the individual's capacity for pumping blood from the heart to vital organs and tissue. The added stress of CO can further reduce oxygen supply to the heart, resulting in myocardial ischemia (the restriction of blood supply, and therefore oxygen, to the heart). Untreated, it can lead to angina (chest pain), arrhythmia (irregular heart beat), and myocardial infarction (heart

attack) (EPA 2012; Bell, Peng, et al. 2009; Prockop and Chichkova 2007). Exercise can also increase these risks due to increased oxygen demands on the body and increased minute ventilation (minute ventilation = respiratory rate x tidal volume), resulting in larger amounts of CO inhaled (EPA 2012).

Perhaps the most important determinant in increased vulnerability due to CO exposure is coronary artery disease (EPA 2010). A study assessing the effects of carbon monoxide exposure on individuals with coronary artery disease found that COHb levels as low as 2% exacerbated myocardial ischemia in individuals during exercise (Allred, Bleecker, et al. 1989). In a similar study, Sheps et al. found that individuals with coronary artery disease exposed to CO during exercise had significant increases in ventricular arrhythmias when COHb levels reached 6% (Sheps, Herbst, et al. 1990).

A recent study found that effects of CO exposure could be seen at levels lower than the National Ambient Air Quality Standards. In a six-year study in 126 urban counties throughout the United States, Bell et al. found that current ambient levels of carbon monoxide had a strong effect on emergency hospital admissions for cardiovascular disease (Bell, Peng, et al. 2009). The study used data from over 9.3 million Medicare enrollees (ages 65 and up) living in counties with populations of 200,000+ people and with CO data for at least 75% of the days examined in the study. Researchers tested for associations between CO and CVD admissions, using admissions for injuries and other external causes as a control for potential time-varying confounders. The model adjusted for $PM_{2.5}$, NO_2, and elemental carbon due to their associations with traffic and possible confounding effects. After adjusting for all other co-pollutants, the study found a statistically significant positive association between same-day daily 1-hour maximum CO levels and cardiovascular disease. (The control showed no statistically significant association.) When subset analyses were performed for levels less than the national CO standard (1-hour max of 35 ppm), a 1 ppm increase in CO was associated with a .55% increase in risk of CVD admissions. Thus, there was no indication of a threshold level where CO would not elicit a health response.

Lead.

Lead (Pb) is a heavy metal found naturally in the environment. Historically, lead has had a variety of uses ranging from use in pipes and paint to use in pesticides (ATSDR 2007). In the 1920s, lead started being used as an anti-knocking agent in fuel. During this time, vehicle exhaust was responsible for the largest releases of lead into the air. Due to health concerns the EPA began to limit and eventually ban (in 1996) the use of lead in gasoline, resulting in drastic decreases in national ambient levels (ATSDR 2007). Today, the highest concentrations of lead are found near lead smelters (EPA 2012). Nationally, mobile processes still account for the highest emission sources of lead (NEI 2008). In Baton Rouge, the highest emissions of lead come from industrial processes in East Baton Rouge Parish (see Figure 3).

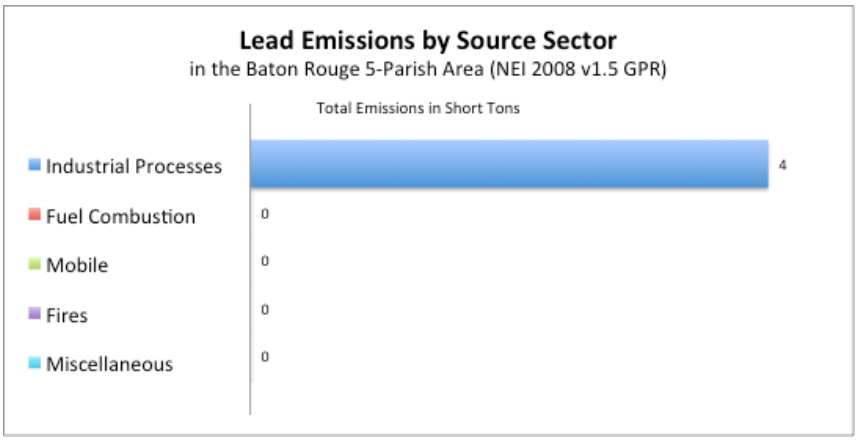

Figure 3: Pb emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

Lead (Pb) may be absorbed via inhalation or ingestion. Although ingestion of lead is far more common than inhalation, inhalation provides a far more efficient method of entering the blood stream (ATSDR 2007). When inhaled, lead is rapidly absorbed into the bloodstream, first moving to tissues and organs (such as the liver and kidneys) and eventually being stored in the bones and teeth. Lead can stay in the bones for decades and reenter the bloodstream during certain circumstances, such as pregnancy and senescence (ATSDR 2007).

In both children and adults, lead targets the nervous system by interfering with the release of neurotransmitters "by mimicking calcium action and/or disruption of calcium homeostasis" (ATSDR 2007). Children, who are more susceptible to lead poisoning, are also at greater risk for health effects. In children under the age of five, lead easily crosses the blood-brain barrier where it affects the central nervous system. In adults, the damage is primarily seen in the peripheral nervous system. Symptoms of lead poisoning include weakened muscles (e.g. foot drop), parasthesia (burning or tingling sensation of the skin), and anemia (decreased red blood cells or hemoglobin in the blood). High levels of lead exposure can cause severe damage to the brain and kidneys, death, and miscarriage in pregnant women (ATSDR 2007). Additionally, lead poisoning has been associated with an increased risk of hypertension in adults, decreased hemoglobin concentration, and decreased glomerular filtration rate (the rate of fluid filtered through the kidney) (ATSDR 2007). While the majority of lead found in an adult will be removed in a matter of weeks, only 32% of lead found in a child will be removed (ATSDR 2007). Therefore, children are especially at risk of accumulating lead if exposed for prolonged periods.

Nitrogen dioxide.

Nitrogen dioxide (NO_2) is a reddish-brown gas with a noxious odor. It is formed by the oxidation of nitric oxide (NO) in the atmosphere, which primarily comes from combustion emissions. The majority of NO_2 emissions are found near coal burning

power plants and areas with heavy motor vehicle use (ATSDR 2002). In most urban areas, the major source of NO_2 emissions comes from internal combustion engines in vehicles. In fact, the EPA notes that NO_2 concentrations are significantly higher near busy roadways than concentrations reported at monitors further away (EPA 2012). In Baton Rouge, the highest emissions of nitrogen oxides come from mobile sources (see Figure 4).

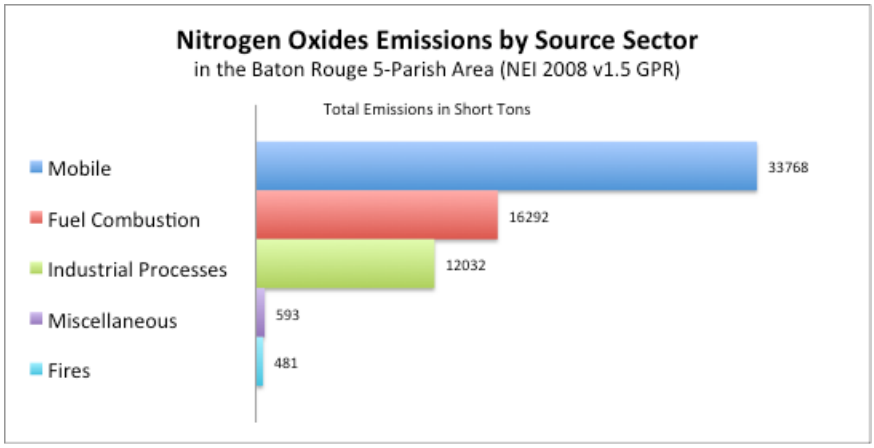

Figure 4: NO_x emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

NO_2 levels are of additional importance as they are a precursor for a number of other pollutants, including nitric acid, ozone, and particulate matter (WHO 2003). When NO_2 reacts with the hydroxyl radical in air, it forms nitric acid (HNO_3), which can penetrate deeply into sensitive parts of the lungs due to its low solubility. NO_2 irritates both the mucosa of conduit airways and the alveolar-capillary membrane deep in the lung at a cellular level. Low levels of exposure to nitrogen oxides can irritate the mucous membranes in the eyes, nose, and throat; whereas exposure to higher levels can cause shortness of breath, swelling in the upper respiratory tract, and pulmonary edema (build up of fluid in the lungs) with alveolar flooding (ATSDR 2002). Klaassen notes that in extremely high levels of NO_2 exposures nearing 75 to 100 ppm (significantly higher than the NAAQS limit of .1 ppm), individuals quickly experienced shortness of breath, delayed pulmonary edema, and pulmonary damage (Klaassen 2008). Additionally, toxicological studies have indicated that NO_2 exposure may increase susceptibility to viral and bacterial infections (Chauhan, Krishna, et al. 1998).

Numerous studies have linked exposure to NO_2 with increases in cardiovascular and respiratory admissions as well as with increases in cardiovascular mortality. A study in Rome, Italy examining the effect of air pollutants on respiratory illness found links between NO_2 and respiratory illnesses (Fusco, Forastiere, et al. 2001). In the study, total respiratory admissions were significantly associated with same-day levels of NO_2, specifically in regard to acute respiratory infections. Among children, both total respiratory admissions and asthma admissions were associated with NO_2 levels (Fusco, Forastiere, et al. 2001). In a study focusing on the relationship between NO_2 and heart

disease, Chen et al. found that cumulative exposures of NO_2 were associated with 12% and 15% increases in mortality from cardiovascular disease and ischemic heart disease, respectively, for each increase of 5 ppm of NO_2 (Chen, Goldberg, et al. 2013). A recent study showed strong associations between traffic-related pollutants and mortality. In this study, NO_2 was significantly associated with all-cause, cardiovascular disease, ischemic heart disease, and lung cancer mortality (Jerret, Burnett, et al. 2013).

Ozone.

Ozone (O_3) is a highly reactive molecule found in both the stratosphere and the troposphere. Ozone, while beneficial in the stratosphere in protecting against harmful ultraviolet rays, can cause adverse health effects when found in the troposphere. Ozone in the stratosphere is formed naturally, whereas tropospheric ozone is largely a result of anthropogenic sources.

Unlike other pollutants, which are often emitted directly into the air, ozone is formed from sunlight reacting with nitrogen oxides and volatile organic compounds (VOCs). In the troposphere, sunlight dissociates NO_2. This process leaves the atomic oxygen radical to react with O_2, thus forming O_3. The majority of ozone is formed from NO_2 during incomplete combustion processes. Due to the greater intensity of the sun as well as the larger concentration of NO_2 from morning traffic, ozone is often found in higher concentrations during midday (Klaassen 2008).

$NO_2 + h\nu$ (UV light) $\rightarrow O\bullet + NO\bullet$
$O\bullet + O_2 \rightarrow O_3$

Similar to NO_2, O_3 is a deep pulmonary irritant. As a potent oxidizer, O_3 breaks down elasticity of lungs, thus reducing lung function. Because ozone has limited solubility in water, the upper respiratory tract is not as effective in scrubbing ozone as it is for more water-soluble pollutants, such as sulfur dioxide (SO_2). Consequently, approximately 60% of inhaled ozone reaches the lower respiratory tract and dissolves in the thin layer of fluid lining the epithelium throughout the airways of the lung, with the majority of this deposition lying between the terminal bronchioles and the alveolar ducts (Klaassen 2008). This can result in the inflammation of airways, obstructive ventilator impairment, and bronchial hyperresponsiveness (Keller 1992).

Those who exercise outdoors are at higher risk of these symptoms, as increase in tidal volume increases ozone penetration. Individuals with pre-existing medical conditions (such as asthma, chronic bronchitis, and other respiratory diseases) could also be at higher risk to O_3 exposure due to impaired respiratory function. Additionally, it is well known that impaired respiratory function has negative impacts on cardiac diseases; therefore, increases in ozone may pose a risk for individuals with certain types of cardiovascular disease.

In studies of normal, healthy subjects exposed to ozone while exercising, subjects experienced a reduction in forced expiratory volumes (FEV1) after 2-3 hours of exposure

at .12- .4 ppm O_3 (Klaassen 2008) and experienced progressive lung function impairment between 4-6 hours of exposure to .12 ppm O_3 (Horstman, Ncdonnell, et al. 1989). [Forced expiratory volume is the volume of air that can forcibly be blown out in one second, after full inspiration.] In controlled human exposure studies, asthmatics (who already have decreased FEV1) have surprisingly shown no particular sensitivity to ozone (Balmes 1993); however, these studies may underestimate responses to ozone compared to epidemiological studies. A relatively recent epidemiologic study in southern California found that O_3 was associated with increases in hospital admissions for children with asthma (Moore, Neugebauer, et al. 2008).

Numerous studies have shown associations between ozone exposure and increased cardiovascular and respiratory mortality. The time frame at which this occurs has been debated. A study investigating the effect of long-term ozone exposure and mortality across the United States found that the risk of dying from respiratory causes were three times as great for those living in metropolitan areas with the highest ozone concentrations versus those living in areas with the lowest ozone concentrations (Jerrett, Burnett, et al. 2009). Another study investigating the relationship between cardiovascular and respiratory mortality and summertime ozone exposure in 21 European cities found that effects of ozone on cardiovascular mortality persist up to one week after exposure. Additionally, the same study found significant increases in respiratory mortality with lags up to twenty days (Samoli, Zanobetti, et al. 2009).

Particulate matter.

Particulate matter is a mixture of extremely small solid and liquid particles composed of a variety of chemicals. Whereas some particulate matter is a result of natural processes, such as wind erosion and volcanic ash, other comes from anthropogenic sources, such as the incomplete combustion of hydrocarbons during industrial processes. Major components of particulate matter include: nitrates, sulfates, metals, organic compounds, and silicates.

Particulate matter (PM) is often broken into two categories according to size. Particles with aerodynamic diameters greater than 2.5 and less than 10 micrometers are called coarse particulate matter, and particles with aerodynamic diameters less than 2.5 are called fine particulate matter. Fine particulate matter largely originates from anthropogenic sources. Figures 5 and 6 show the major sources for fine particulate matter and coarse particulate matter, respectively.

Inhalation of particulate matter can affect both the heart and the lung. Although there is some debate, many toxicologists believe that the size of the particle, rather than its chemical composition, is the main determinant for health effects. The magnitude of this effect, as well as the depth of penetration, depends on the size of the particle. The smaller the diameter, the deeper the particulate matter is able to penetrate. PM_{10} mostly impacts the nasal passages and throat, whereas $PM_{2.5}$ can penetrate deep into the bronchiole, and PM_1 can penetrate into the alveolar sacs.

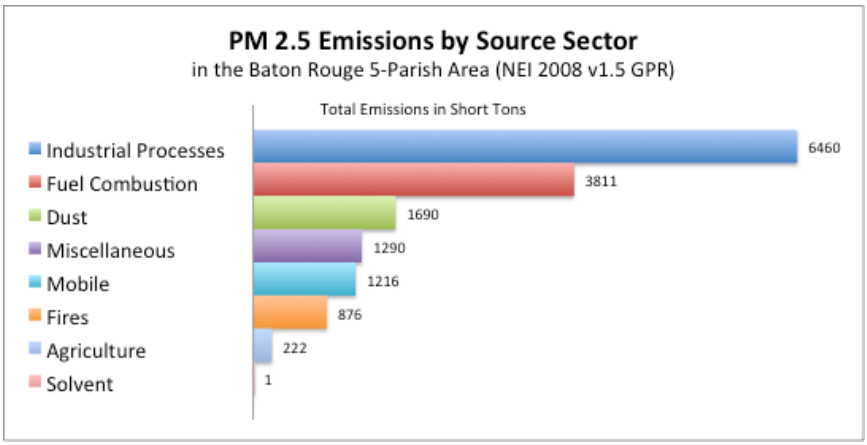

Figure 5: $PM_{2.5}$ emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

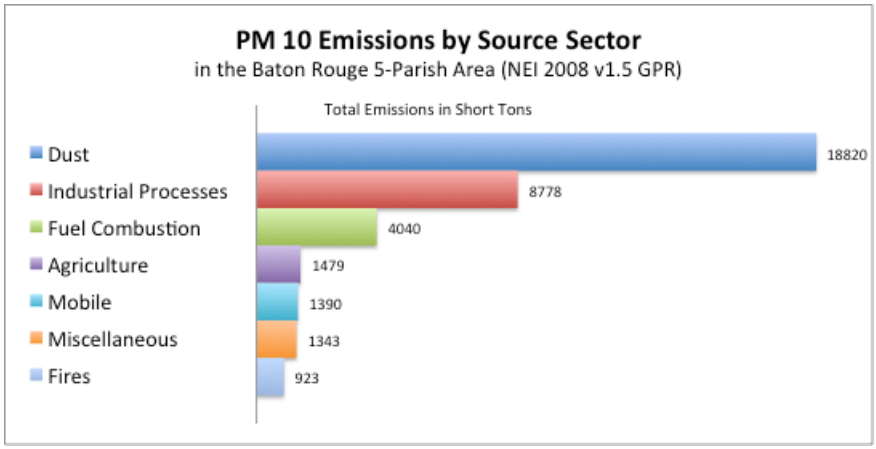

Figure 6: PM_{10} emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

Removal of PM from the body depends largely on the depth of penetration, with deeper penetration being much harder to remove. Large PM is deposited in the nasopharynx by impaction with nose hair and nasal turbinates and can be removed from the system fairly quickly through mucociliary transport. Small PM ($PM_{1\text{-}5}$) is deposited in the tracheobronchial via sedimentation, with $PM_{2.5}$ having a larger impact in the bronchioles. Here, particulate matter can be removed through the mucociliary escalator (where whip like movements of cilia transfer mucus to the pharynx and then to the digestive tract), but residence times are longer than for particulate matter deposited in upper airways. PM less than 1 μm is deposited in alveolar capillaries via diffusion, where it is able to enter the bloodstream and lymphatic system.

Particulate matter exposure can induce both cardiovascular and pulmonary health effects. Numerous studies have documented that exposure to $PM_{2.5}$ was associated with decreased FEV1, exacerbation of asthma symptoms, and increased hospital admissions and mortality for cardiovascular and respiratory illnesses. These risks may be increased for smokers and individuals whom exercise outdoors.

One of the most noted studies, with regards to long-term particulate matter exposure, has been the Harvard Six-Cities Study. The Harvard Six-Cities Study examined associations between mortality and air pollution in six cities for a total of 17 years with over 8,000 subjects between the ages of 25 and 74. The six cities were representative of the range of levels in particulate air pollution found throughout the United States. After controlling for potential confounders such as cigarette smoking, age, occupational exposure, education level, and increased body mass index (BMI), the study found that cardiopulmonary and lung cancer mortality was more strongly associated with levels of inhalable, fine, and sulfate particles than with levels of total suspended particles, SO_2, NO_2, or acidity of aerosols (Dockery, Pope, et al. 1993). This implies that exposure to ambient fine particulate matter may be a bigger determinant in cardiopulmonary mortality than other risk factors.

A recent case-crossover study in Houston examined the effects of daily air pollution and out-of-hospital cardiac arrests (OHCA) over a period of seven years. In case-crossover studies, individuals essentially act as their own controls, thereby reducing the influence of any confounding covariates. The analysis took into account possible confounding from any cardiac temporal pattern or meteorological events. The results found that in the two days prior to onset, OHCA was associated with a daily average increase of 6 $\mu g/m^3$ for $PM_{2.5}$. Further analysis showed that particular sensitivity was seen among men, African Americans, and individuals over 65 years of age. The study also found that apparent temperature was not a significant predictor for OHCA (Ensor, Raun, et al. 2013). In terms of duration of study, number of OHCA events, and number of air pollution monitors, this is the most comprehensive study to date.

While size seems to be the largest determinant in health effects from particulate matter, it is also important to note that many carcinogenic compounds can also attach to particulate matter, potentially leading to cancer. Pope et al. explains that the pathogenicity of cardiovascular end points may be mediated more by the particles themselves, whereas the pathogenicity of lung cancer may be mediated by carcinogenic compounds carried on particles (Pope, Burnett, et al. 2011).

Sulfur dioxide.

Sulfur dioxide (SO_2) is a highly reactive toxic gas with a strong, irritating odor. While sulfur dioxide can result from natural processes, such as volcanic eruptions, the majority of emissions comes from anthropogenic sources, namely industrial processes. Out of these industrial processes, the burning of fossil fuels at power plants accounts for 73% of SO_2 emissions nationwide (EPA 2012). Likewise, industrial processes account for the largest source of sulfur dioxide emissions in Baton Rouge (see Figure 7).

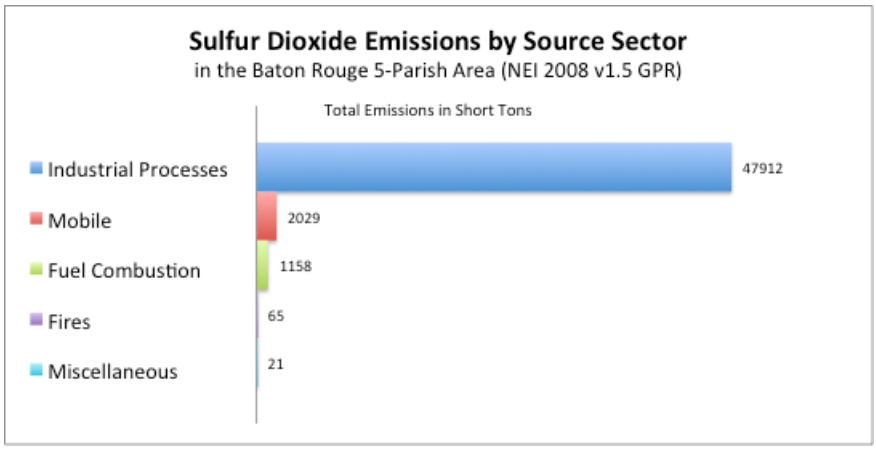

Figure 7: SO_2 emissions by source in the Baton Rouge Five-Parish Area

Data taken from National Emissions Inventory 2008

One major concern of SO_2 emissions is the creation of sulfuric acid (H_2SO_4), which not only causes damage to the environment in the form of acid rain and environmental acidification, but also causes a multitude of health effects. Unlike NO_2 and O_3, SO_2 is highly soluble. Because SO_2 is highly water-soluble, the mucosa in the upper respiratory tract is effective in scrubbing larger particles from inhaled air, leaving minimal amounts of SO_2 to penetrate to the lower respiratory tract; therefore, the majority of effects of SO_2 are seen in the upper respiratory tract. Smaller particles of SO_2 are able to penetrate deep into the lung in distal airways. When SO_2 comes into contact with surface lining in the lungs, sulfite is formed, which rapidly enters the bloodstream and can be excreted through the urine.

Exposure to SO_2 aggravates respiratory problems, but the exact mechanism remains unclear. It is believed that sulfite reacts with sensory receptors in airways, initiating bronchoconstriction (Klaassen 2008). Short-term exposure to high concentrations of SO_2 causes airway obstruction and burning of the nose and throat (Klaassen 2008). Concentrations nearing 100 ppm are considered an immediate danger to health and life (ATSDR 1998). Additionally, individuals with sulfur dioxide sensitivities may exhibit increased bronchoconstrictive responses (ATSDR 1998).

Few studies have shown clear associations between asthma and respiratory health effects from SO_2, but it is thought that asthmatics may be at higher risks. A study examining the relationship between SO_2 exposure and respiratory effects found that exposure to SO_2 was associated with increase respiratory admissions for children with asthma; however, these associations were negligible after controlling for CO and PM_{10} (Sunyer, Atkinson, et al. 2003).

CHAPTER III: MATERIALS AND METHODS

Site Selection

The 6,041 km^2 study area consisted of Iberville, West Baton Rouge, East Baton Rouge, Ascension, and Livingston parishes. This area was selected due to its 2003 classification of "severe" non-attainment under the 1-hour ozone standard and its 2010 designation of attainment under the 1-hour ozone standard, which allows for the examination of the effects of both high and low concentrations of ozone.

Additionally, this area offers an excellent opportunity to study the relationship between ambient ozone concentrations and hospitalizations for cardiovascular and respiratory illnesses in a large population that spans both urban and rural areas. Parishes differed vastly in population densities and number of air monitoring stations (see Table 2). Because denser populations are more likely to have higher volumes of traffic, individuals living there may be exposed to higher concentrations of traffic related pollutants, such as carbon monoxide, nitrogen dioxide, ozone, and particulate matter 2.5.

Table 2: Population density and number of air monitoring stations by parish

	Total Area (km2)	Land Area (km2)	Total Population (2010)	Pop. Density (per km2)	No. of Stations
East Baton Rouge	1,219	1,180	440,171	373	4
Ascension	784	755	107,215	142	1
Livingston	1,820	648	38,950	60	1
West Baton Rouge	527	495	23,788	48	1
Iberville	1,691	1,603	33,387	21	4
Totals	6,041	4,681	643,511		

Source: American FactFinder, Demographic Profile 2010

Air Quality Data

Ambient air quality measurements for the six criteria pollutants were obtained from a network of stations monitored by the Louisiana Department of Environmental Quality (LDEQ). The data was obtained for air quality monitoring sites within Iberville, West Baton Rouge, East Baton Rouge, Ascension, and Livingston parishes for the periods of January 2000 to December 2011. These measurements were used to estimate the population's exposure to carbon monoxide, lead, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter. There were a total of eleven air-monitoring stations throughout area. The largest concentration of monitoring stations was found near the most densely populated parish (East Baton Rouge) and the intersection of I-10 and I-12, where large amounts of traffic occur.

Each station monitored for different pollutants. Table 3 shows the list of air monitoring stations in the Baton Rouge AQCR, their locations, and which pollutants they monitored. Note that LDEQ reports that the French Settlement site monitors for $PM_{2.5}$;

however, air quality measurements collected for the French Settlement site contained no data for $PM_{2.5}$ throughout the duration of the study.

Table 3: Air monitoring sites in the Baton Rouge AQCR and pollutants monitored

Site Name & Abbreviation Address AQS Code	Parish	MSA	O3	NOx	SO2	CO	PM10 (BAM)	PM2.5 (FRM)	PM2.5 (BAM)	PM2.5 (TEOM)	VOC	MET	Other
Baton Rouge- Capitol (BC) 1061- A Leesville Ave 220330009	East Baton Rouge	Baton Rouge	SLAMS	SLAMS	SLAMS (trace level)	SLAMS (trace level)	SLAMS	SLAMS (COL)	SLAMS		PAMS	PAMS	PM2.5 speciation (STN), Trace Noy
Baker LSP (BE) 1400 West Irene Road Zachary, LA 220330003	East Baton Rouge	Baton Rouge	NAMS					SPMS					Lead/TSP (SLAMS)
Baton Rouge- LSU (BR) East End Aster Lane 220330003	East Baton Rouge	Baton Rouge	SLAMS	SLAMS							SPMS	SPMS	
Bayou Plaquemine (BP) 65180 Belleview Road 220470009	Iberville	Baton Rouge	PAMS	PAMS				SPMS		PAMS	PAMS	PAMS	NOy (PAMS)
Carville (CV) Highway 141, River Rd. 220470012	Iberville	Baton Rouge	SLAMS	SPMS							SPMS	SPMS	
Dutchtown (DT) 11153 King Road 220050004	Ascension	Baton Rouge	PAMS	PAMS							PAMS	PAMS	
French Settlement (FS) 16627 Perrilloux Lane 220630002	Livingston	Baton Rouge	SPMS	SLAMS						SPMS	SPMS	SPMS	
Geismar (GM) Highway 75 220470005	Iberville	Baton Rouge						SPMS					
Grosse Tete 19145 Sydney Rd. 220470007	Iberville	Baton Rouge	SPMS	SPMS							SPMS	SPMS	
Port Allen (PA) 1005 Northwest Drive 221210001	West Baton Rouge	Baton Rouge	SLAMS	SLAMS	SLAMS			SLAMS	SPMS		SPMS	SPMS	
Pride (PE) 11245 Port Hudson Pride Road 220330013	East Baton Rouge	Baton Rouge	PAMS	PAMS							PAMS	PAMS	

PAMS - Photochemical assessment monitoring stations
SLAMS - State and local air monitoring stations
SPMS - Special purpose monitoring stations
STN - Special trends network
COL - Site has co-located sensors for this parameter
FRM - Federal reference method
BAM - Met One BAM 1020 Continuous Particulate Monitor (both PM10 and PM2.5) designated by USEPA as a federal equivalent method (FEM)
TEOM - Thermo Scientific Continuous Particulate TEOM Monitor, Series 1400a
Celiometer - Measures mixing height
BAM Coarse - Substracts PM2.5 from PM10

Modified from LDEQ LouisianaAmbientAirMonitoringSites_September2011.pdf

Over the course of the study, there were periods in which measurements for any given monitor were not available due to power outages, equipment failures, equipment maintenance, etc. Days with incomplete data were not used in the study. It is also important to note that, of the data collected, there is a chance of erroneous data due to equipment malfunction and human error during the collection process.

Hospital Data

Since the study involved the use of data from human subjects, approval or exemption from the Institutional Review Board (IRB) was required before obtaining hospital data. An application for exemption from Institutional Oversight was submitted to the Louisiana State University Institutional Review Board on 30 April 2012. Exemption was granted 22 May 2012. See Appendix A for exemption approval.

Hospital data was obtained through the research director at a large hospital in Southeastern Louisiana. Each individual on the study was required to submit proof of the National Institutes of Health's "Protecting Human Research Participants" certification and agree to data use terms set out by the hospital. A copy of the Data Use Agreement has not been included in order to protect the privacy of the hospital.

The International Statistical Classification of Disease and Health Related Problems (ICD) is a health care classification system that classifies diseases by codes, with similar diseases being grouped together in major categories. Codes are generally updated every ten years. Although the most recent revision is the 10th revision (which has the benefit of increased specificity of information conveyed by the code), the hospital that provided data was still utilizing the 9th revision. Data was obtained for all patients admitted between 1 January 2000 and 31 December 2011 under International Statistical Classification of Disease and Health Related Problems, Ninth Revision (ICD-9) codes 390-519. ICD-9 codes 390-459 are for diseases of the circulatory system; codes 460-519 are for diseases of the respiratory system. Table 4 presents a break down of ICD-9 and ICD-10 codes by major categories. These codes were chosen based on evidence suggesting that air pollution has adverse health effects on both the heart and the lungs (as discussed in the Literature Review).

Table 4: ICD-9 and ICD-10 codes for diseases of the circulatory and respiratory systems

ICD-9 Code	ICD-10 Code	Major Category
390-392	I00-I02	Acute rheumatic fever
393-398	I05-I09	Chronic rheumatic heart disease
401-405	I10-I15	Hypertensive disease
410-414	I20-I25	Ischemic heart disease
415-417	I26-I28	Diseases of pulmonary circulation
420-429	I30-I52	Other forms of heart disease
430-438	I60-I69	Cerebrovascular disease
440-448	I70-I79	Disease of arteries, arterioles, and capillaries
451-459	I80-I89	Disease of veins and lymphatics, and other diseases of the circulatory system
460-466	J00-J06	Acute respiratory infections
470-478	J30-J39	Other diseases of the upper respiratory tract
480-488	J09-J18	Influenza and pneumonia
490-496	J40-J47	Chronic obstructive pulmonary disease and allied conditions
500-508	J60-J70	Pneumoconioses and other lung diseases due to external agents
510-519	J95-J99	Other diseases of the respiratory system

Data was obtained for gender, age, date admitted, zip code of residence, and reason for admission. In accordance with the HIPAA Privacy Rule, the data set did not

contain any information that could identify the individual. Appendix B contains terms set out by the HIPAA Privacy Rule.

Statistical Analysis

Statistics were analyzed using SAS software, Version 9.3 from the Louisiana State University Health Sciences Center, School of Public Health. The statistical analysis is broken down into two groups based on geographical region. The sections below give the details for each analysis.

CHAPTER IV: RESULTS

Analysis of Respiratory and Cardiovascular Hospital Admissions as a Function of O_3 and $PM_{2.5}$ for the entire Baton Rouge AQCR

This first part of this study examined patients ages 18 and up, living in the following zip codes: *70346, 70449, 70462, 70710, 70711, 70714, 70719, 70721, 70722, 70725, 70726, 70729, 70733, 70734, 70737, 70739, 70740, 70754, 70764, 70767, 70769, 70770, 70774, 70776, 70778, 70780, 70785, 70788, 70791, 70801, 70802, 70803, 70805, 70806, 70807, 70808, 70809, 70810, 70811, 70812, 70814, 70815, 70816, 70817, 70818, 70819, 70820, 70836*. In order for a zip code to be included, at least 75% of its area needed to lie within the five parishes. Figure 8 shows the geographical boundaries for the zip codes within the five-parish area.

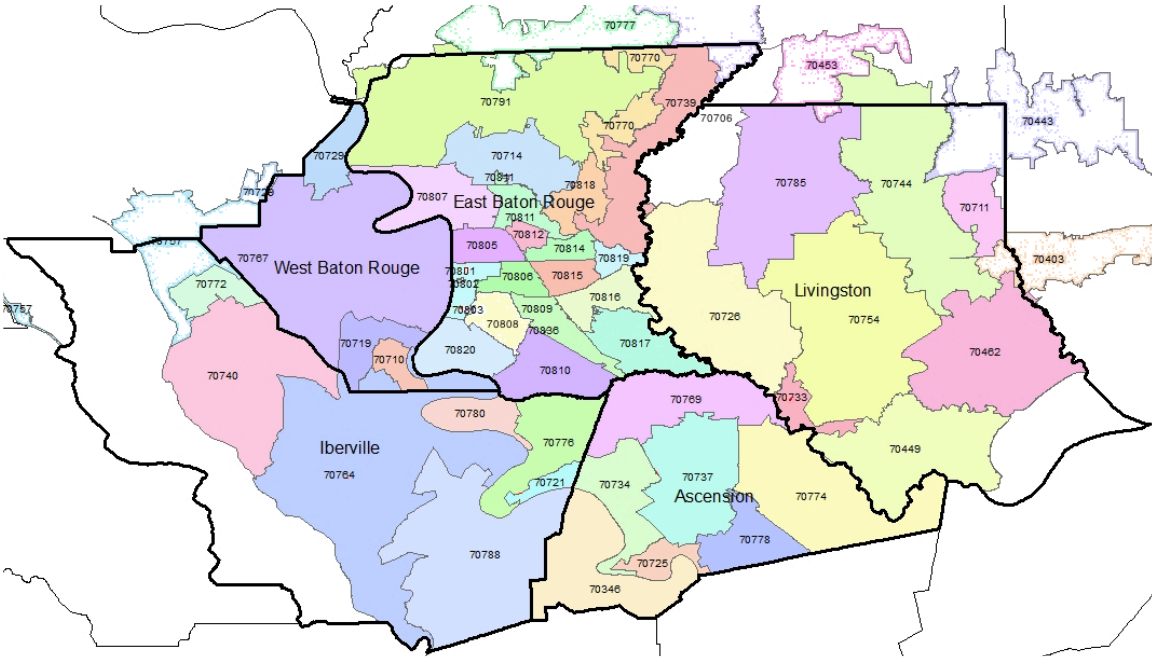

Figure 8: Zip codes within the Five-Parish Area

Colored regions represent zip codes included in data analysis.

As stated previously, any information that could possibly be used to identify the individual was not given in order to protect the privacy of individuals used in this study. Thus, billing zip codes were used to estimate the individual's location. This presented a number of issues.

Firstly, the accuracy in correlating admissions in a particular zip code encompassing a large land area to a particular monitoring site would be diminished. For example, were individuals living in zip code 70767 closer to the Grosse Tete or Port Allen monitoring site? Secondly, zip codes only determined that the individual most

likely lived in that area, not necessarily where the majority of exposure occurred. An individual living in one zip code could be working, and therefore exposed, in another zip code.

To resolve these issues, averages of air pollutants across all monitoring sites were used along with the total sum of hospital admissions for cardiovascular and respiratory diseases. This method helped control for the possibility that the source of exposure was in a different location than the zip code given. Additionally, an individual's precise location within the zip code was no longer important since the hospital admissions were summed. An added benefit to averaging across all monitoring sites is that it helps control for potential outliers. This method has been used in a number of studies examining air pollution exposure when precise data for the individual is not available (Ensor, Raun, et al. 2013; Matus, Yang, et al. 2007).

Because the study area spanned a large geographical region, correlations between admissions and peaks in air emissions were not examined. Although peaks in pollutant levels may be detrimental to health, they do not provide a good estimate of exposure over such a large area. Therefore, this study only examined daily averages for pollutants.

Ozone and $PM_{2.5}$ were the only two pollutants analyzed for this portion of the analysis. Firstly, these were the only two pollutants collected at a number of monitors that were well dispersed throughout the five parishes. (See Figures 9 and 10 for locations of monitoring sites for ozone and $PM_{2.5}$, respectively.) Secondly, there have been extensive studies showing that ozone and particulate matter exposure can induce cardiovascular and pulmonary health effects (Klaassen 2008). Lastly, studies have shown that effects of ozone exposure can be seen at levels below the current National Ambient Air Quality Standards (Keller 1992).

Figure 9: Distribution of ozone monitoring sites

Circled sites collected data for ozone.

Figure 10: Distribution of $PM_{2.5}$ monitoring sites

Boxed sites collected data for $PM_{2.5}$.

Correlations among monitoring sites.

Prior to averaging measurements across all air monitoring sites, correlation analyses needed to be run. Correlation analyses helped to determine the degree of association between air pollution levels at the various monitoring sites. High correlation between sites meant that pollution levels were more or less the same for any given site on a particular day.

For ozone, each site examined took daily measurements and was missing little to no data. Monitors for $PM_{2.5}$ took readings at different time scales: some daily, some every six days. At times, there were gaps in some of the data (e.g., the Baker site did not show any measurements for all of year 2000). This made the interpretation of results for $PM_{2.5}$ difficult, since assumptions made regarding missing data can be misrepresentative. However, in order to keep time scales consistent for the two pollutants, correlation analysis for $PM_{2.5}$ was done on a daily scale for all monitors that had recordings. Table 5 shows an excerpt of $PM_{2.5}$ data for the various sites.

Table 5: Temporal scale of $PM_{2.5}$ data (in $\mu m/m^3$) for different air monitoring sites

Date	BR Capital	Baker	Bayou Plaq.	Geismar	Port Allen
1/1/00	25.2		13.2	24.4	12.8
1/2/00	9.5				6.6
1/3/00	6.2				6.6
1/4/00	11.5				
1/5/00	10.6				
1/6/00	14.3				
1/7/00	12.2		10.2	16.2	11.4
1/8/00	17.2				11.7
1/9/00	7.4				5
1/10/00	12.5				9.7

The correlation matrices below show the Pearson's Correlation Coefficient (*r*) for the sites analyzed. The Pearson's Correlation Coefficient is a measure of the degree of association between two variables. In statistics, *r* values between 0.8-1.0 show a strong degree of association, whereas *r* values between 0.5-0.8 show only a moderate degree of association. However, in real world data, *r* values above 0.7 are often considered highly correlated.

Table 6: Pearson Correlation Coefficients for ozone monitoring sites

Bolded numbers show a strong degree of association.

Location	Baker	Bayou Plaq.	Capital	Carville	Dutchtown	French Sett.	Grosse Tete	LSU	Port Allen	Pride
Baker		**0.8231**	**0.9124**	**0.8334**	**0.8118**	**0.8366**	**0.8425**	**0.9291**	**0.9390**	**0.8857**
Bayou Plaq.	**0.8231**		**0.8076**	**0.8376**	**0.8281**	**0.8587**	**0.9220**	**0.8434**	**0.8102**	**0.8222**
Capital	**0.9124**	**0.8076**		**0.8912**	**0.8528**	**0.8146**	**0.8169**	**0.9426**	**0.9349**	**0.8115**
Carville	**0.8334**	**0.8376**	**0.8912**		**0.8493**	0.7998	**0.8320**	**0.8831**	**0.8735**	0.7722
Dutchtown	**0.8118**	**0.8281**	**0.8528**	**0.8493**		**0.8831**	**0.8370**	**0.8582**	**0.8238**	**0.8125**
French Sett.	**0.8366**	**0.8587**	**0.8146**	0.7998	**0.8831**		**0.8608**	**0.8463**	**0.8119**	**0.8825**
Grosse Tete	**0.8425**	**0.9220**	**0.8169**	**0.8320**	**0.8370**	**0.8608**		**0.8570**	**0.8357**	**0.8405**
LSU	**0.9291**	**0.8434**	**0.9426**	**0.8831**	**0.8582**	**0.8463**	**0.8570**		**0.9429**	**0.8388**
Port Allen	**0.9390**	**0.8102**	**0.9349**	**0.8735**	**0.8238**	**0.8119**	**0.8357**	**0.9429**		**0.8342**
Pride	**0.8857**	**0.8222**	**0.8115**	0.7722	**0.8125**	**0.8825**	**0.8405**	**0.8388**	**0.8342**	
Avg. Corr.	**0.8682**	**0.8392**	**0.8650**	**0.8414**	**0.8396**	**0.8438**	**0.8494**	**0.8824**	**0.8673**	**0.8333**
Avg. Corr. Across Sites=		**0.8530**	**(n= 40177)**							

Table 6 shows the Pearson Correlation Coefficients for the sites monitoring ozone. Correlation matrices for ozone show a high degree of association between ozone levels at all monitoring sites (significant to $p<0.0001$), with the exception of Carville/ Pride and Carville/French Settlement, which only showed moderate correlation. Capital and LSU sites showed the highest degree of correlation, which is expected due to their close proximity. Carville and Pride showed the lowest degree of correlation between the sites, which is also to be expected due to their distance from one another. Average correlation across all air monitoring sites showed a strong association ($r = 0.853$). Due to the strong correlation, it was assumed that sites, regardless of location, received similar levels of exposure. This supports the use of averages across all monitoring sites for ozone.

Table 7: Pearson Correlation Coefficients for $PM_{2.5}$ monitoring sites

Bolded numbers show a strong degree of association.

Location	Baker	Bayou Plaq.	Capital	Geismar	Port Allen
Baker		0.7647	**0.8826**	**0.8222**	**0.8612**
Bayou Plaq.	0.7647		0.7775	0.7717	0.7287
Capital	**0.8826**	0.7775		**0.8271**	**0.8542**
Geismar	**0.8222**	0.7717	**0.8271**		**0.8118**
Port Allen	**0.8612**	0.7287	**0.8542**	**0.8118**	
Avg. Corr.	**0.8327**	0.7606	**0.8354**	**0.8082**	**0.8140**
Avg. Corr. Across Sites=		**0.8102**	**(n=10946)**		

Table 7 shows the Pearson Correlation Coefficients for the sites monitoring $PM_{2.5}$. Individual correlations showed moderate to strong associations between sites for $PM_{2.5}$. Bayou Plaquemine showed the weakest associations, having only moderate correlations with all other monitoring sites. Baker and Capital sites showed the highest degree of association out of all the sites (r = 0.8826). Average correlation across all monitoring sites for $PM_{2.5}$ showed a strong degree of association (r = 0.8102). Since air monitoring sites showed an overall strong degree of correlation regardless of the time frame in which measurements were taken, daily averages were calculated across all five monitoring sites and used to estimate population exposure to $PM_{2.5}$.

Ozone trends.

Daily average concentrations for ozone throughout the study period showed a clear seasonal trend in levels of ozone (Figure 11). Ozone levels increased during spring and summer months and decreased during the fall and winter. This is expected due to the important role that sunlight plays in ozone formation. Figure 11 shows daily average ozone concentrations for the Baton Rouge Air Quality Control Region over the duration of the study. Figure 12 shows daily average ozone levels in year 2000 in order to give a clearer image of seasonal variation.

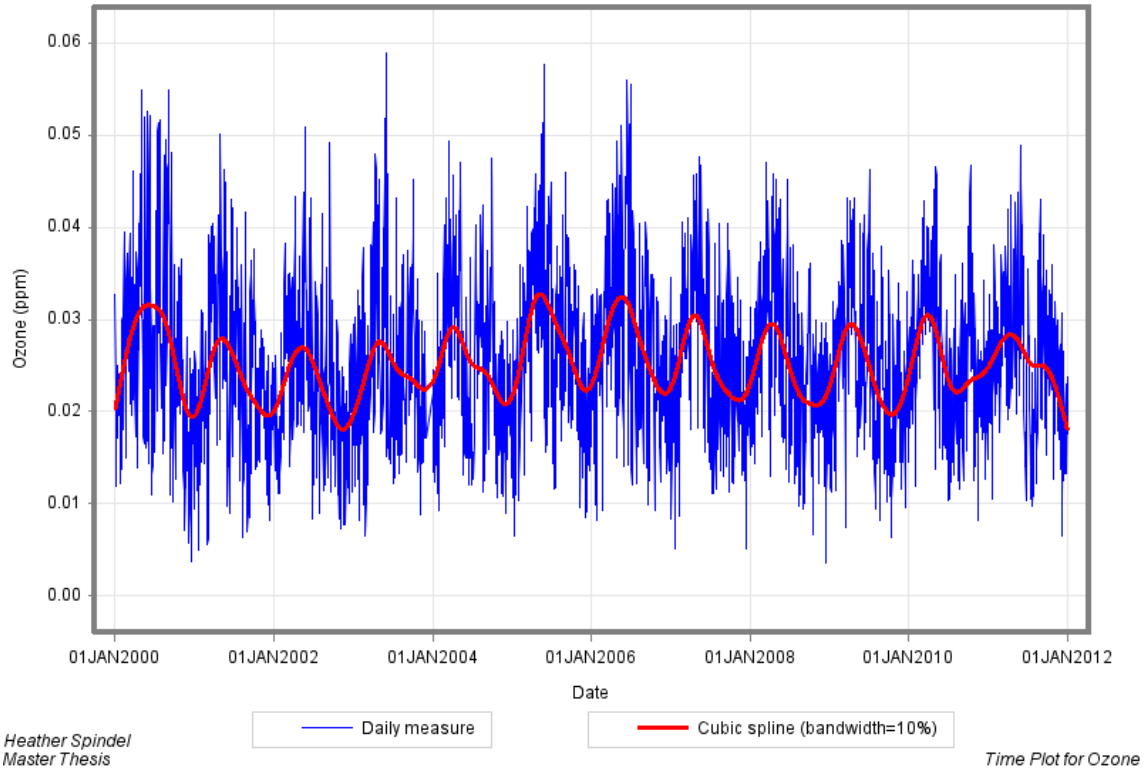

Figure 11: BR AQCR daily average concentrations for ozone, 2000-2011

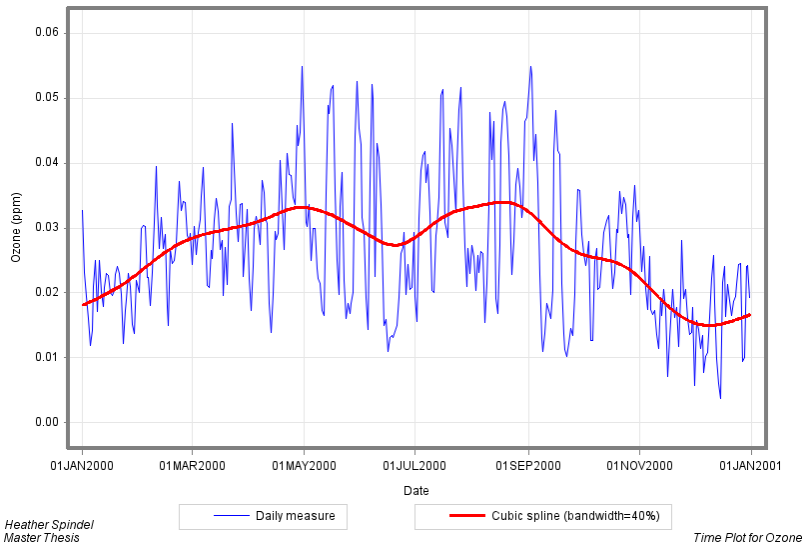

Figure 12: BR AQCR daily average concentrations for ozone, 2000

Particulate matter trends.

Daily average concentrations for $PM_{2.5}$ throughout the study period showed no clear trend. In general, levels of $PM_{2.5}$ were lower for winter months and peaked in summer months (Figure 13).

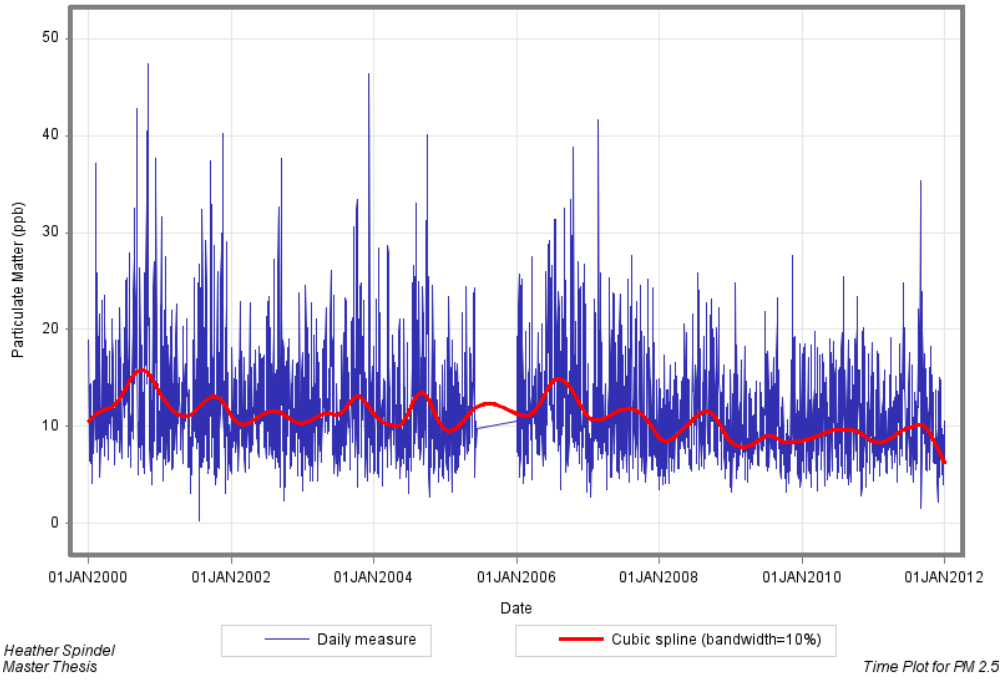

Figure 13: BR AQCR daily average concentrations for $PM_{2.5}$, 2000-2011

General statistics and trends for total hospital admissions.

A total of 290,798 admissions were used in the study. Of those admitted, gender was distributed fairly equally with 53.6% female and 46.4% male. The majority of hospital admissions were either Caucasian (63.5%) or Black (34.5%). Table 8 shows hospital admissions broken down into categories by age. See Appendix C for a breakdown of admissions by zip code.

Table 8: Hospital admissions by age

Age	Frequency	Percentage
18-45	59037	20.30%
46-60	72039	24.77%
61-75	87988	30.26%
>75	71734	24.67%

Circulatory diseases accounted for 71.4% of admissions, with respiratory diseases accounting for the remaining 28.6%. Of all major categories, the following diseases were the most frequent: hypertensive diseases (22.0%), other forms of heart disease (19.92%), and ischemic heart disease (10.45%). Table 9 shows the breakdown of hospital admissions for each ICD-9 code.

Table 9: Hospital admissions by ICD-9 codes

Major Category for ICD-9 Code	Percent
Acute rheumatic fever	0.003
Chronic rheumatic heart diseases	0.326
Hypertensive diseases	22.021
Ischemic heart disease	10.450
Diseases of pulmonary circulation	0.712
Other forms of heart disease	19.922
Cerebrovascular disease	7.124
Disease of arteries/ capillaries	5.069
Disease of veins	5.810
Acute upper respiratory infections	6.083
Other diseases of the upper respiratory tract	4.514
Influenza/pneumonia	4.412
Chronic obstructive pulmonary disease and allied conditions	8.278
Pneumoconioses and other lung diseases due to external agents	0.710
Other diseases of respiratory system	4.565

Table 10 shows the prevalence of diseases among different age groups. Cardiovascular diseases tended to increase with increasing age, whereas the majority of respiratory system diseases were fairly dispersed among all age groups. Acute upper respiratory infections and other diseases of the upper respiratory tract were noticeably higher for the 18-45 age group.

Table 10: Prevalence of diseases among age categories

Major Category for ICD-9 Code	18-45	46-60	61-75	>75
Acute rheumatic fever	0.01%	0.00%	0.00%	0.00%
Chronic rheumatic heart diseases	0.13%	0.22%	0.40%	0.51%
Hypertensive diseases	23.21%	28.60%	21.26%	15.37%
Ischemic heart disease	2.91%	12.78%	14.20%	9.73%
Diseases of pulmonary circulation	0.60%	0.68%	0.78%	0.76%
Other forms of heart disease	7.54%	14.93%	22.47%	31.99%
Cerebrovascular disease	2.63%	6.41%	8.60%	9.74%
Disease of arteries/capillaries	1.44%	4.89%	6.84%	6.06%
Disease of veins	7.01%	6.69%	5.00%	4.93%
Acute upper respiratory infections	20.83%	4.03%	1.64%	1.45%
Other diseases of the upper respiratory tract	10.63%	4.85%	2.97%	1.05%
Influenza/pneumonia	5.41%	3.41%	3.49%	5.71%
Chronic obstructive pulmonary disease and allied conditions	12.48%	7.56%	7.30%	6.74%
Pneumoconioses and other lung diseases due to external agents	0.30%	0.38%	0.57%	1.55%
Other diseases of the respiratory system	4.85%	4.58%	4.50%	4.40%

Figure 14 shows a time plot for all patients living in the Baton Rouge AQCR who were admitted for diseases of the circulatory and respiratory systems (ICD-9 Codes 390-478) during the period of 2000-2011. In general, higher admissions were seen in January and lower admissions were seen in June. Years 2000-2001 experienced noticeably higher admissions than following years; no explanation is presently available for this event.

One reason for increased admissions in winter months could be the increase in influenza in colder months. Additionally, cold temperatures may trigger other diseases. Studies have shown that incidence and mortality for coronary heart disease (which falls under the ischemic heart disease category for ICD-9 codes), cerebrovascular disease, and respiratory disease exhibit peaks during the winter and troughs during the summer (Pell and Cobbe 1999).

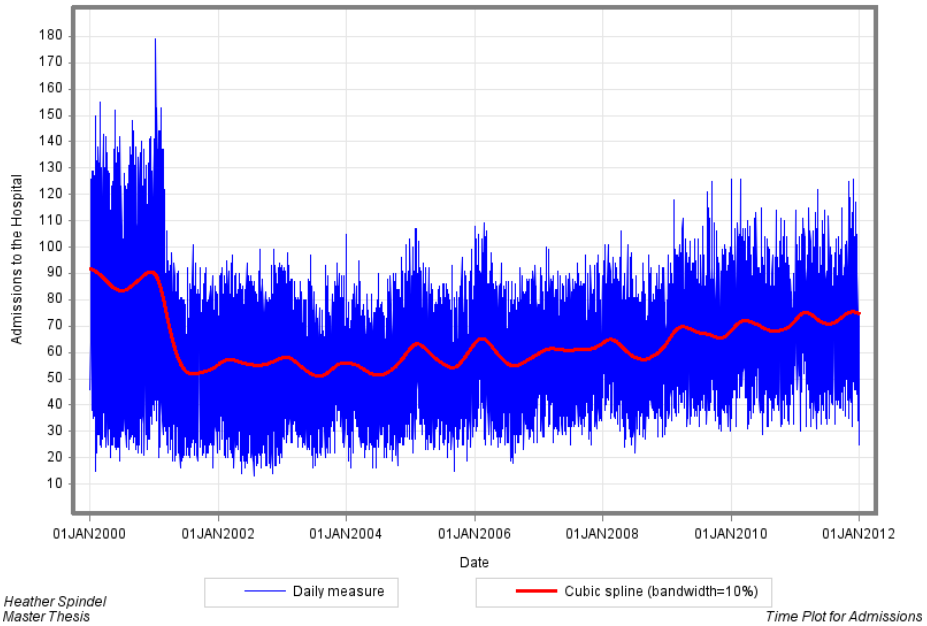

Figure 14: Cardiovascular and respiratory hospital admissions, 2000-2011

Multivariate regression analysis.

A multivariate regression analysis was run to examine the relationship between daily averages of O_3 and $PM_{2.5}$ and total hospital admissions for diseases of the circulatory and respiratory systems for all zip codes in the five parish area. Based on the high degrees of associations between air monitoring sites, the analysis assumed a homogenous mixture for $PM_{2.5}$ and ozone within the area.

Figure 14 shows a clear relationship between admissions and time. Modeling the total number of admissions using the month and the year, both variables were statistically significant ($p<.0001$). The r^2 value indicated that 85% of the variation could be explained by month and year. Therefore, both variables were used as covariates in the model with air quality data.

Five different time scales were examined for hospital admissions: admissions on the day of exposure to pollutants (Lag 0), admissions the day after exposure (Lag 1), admissions two days after exposure (Lag 2), admissions ten days after exposure (lag 10), and admissions twenty days after exposure (Lag 20). Tables 11-15 show multivariate regression models for Lags 0, 1, 2, 10, and 20. Lags 0 and 20 have a very high correlation ($p<.0001$) (see Table 16).

Ozone.

Table 10 shows that an increase in same day ozone yields a statistically significant decrease in hospital admissions ($p<.0001$). Lag 1 (Table 11) also shows that as ozone increases, hospital admissions decrease, but to a lesser extent (not significant, $p=.7699$). Lag 2 (Table 12) shows a positive, non-significant association between an increase in ozone and an increase in hospital admissions ($p=.0568$). This positive association peaks at Lag 10 (not significant, $p=.0047$) and returns to a negative association at Lag 20 (not significant, $p=.0011$) (see Tables 14 and 15). A high correlation was observed between Lag 0 and Lag 20 (Table 16).

Particulate Matter 2.5.

Lag 0 shows a near significant, positive association between an increase in $PM_{2.5}$ and an increase in hospital admissions ($p=.0002$). Lag 1 shows a non-significant, positive association between $PM_{2.5}$ and hospital admissions, but to a lesser extent ($p=.6211$). Lag 2 shows a non-significant, negative association ($p=.3238$). This negative association peaks at Lag 10 (not significant, $p=.1561$) and returns to a positive association at Lag 20 (not significant, $p=.0309$). Again, a high correlation was observed between Lag 0 and Lag 20.

Table 11: Multivariate Regression Model for Lag 0

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	86.2041429	2.82790127	30.48	<.0001
O3	-226.7758996	53.20414988	-4.26	<.0001
PM	0.2951830	0.07954815	3.71	0.0002
NewMonth	-2.2069069	0.57821357	-3.82	0.0001
NewMonth*NewMonth	0.2340009	0.04015320	5.83	<.0001
NewMonth*Year	-0.0451777	0.03155886	-1.43	0.1524
Year	-14.8951111	0.96728677	-15.40	<.0001
Year*Year	2.6123340	0.20409613	12.80	<.0001
Year*Year*Year	-0.1179311	0.01214304	-9.71	<.0001

Table 12: Multivariate Regression Model for Lag 1

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	81.07700774	2.83825396	28.57	<.0001
O3	-15.61835140	53.39892544	-0.29	0.7699
PM	0.03946760	0.07983937	0.49	0.6211
NewMonth	-1.02933342	0.58033035	-1.77	0.0762
NewMonth*NewMonth	0.15293053	0.04030019	3.79	0.0001
NewMonth*Year	-0.05713937	0.03167439	-1.80	0.0713
Year	-14.75499238	0.97082792	-15.20	<.0001
Year*Year	2.58148858	0.20484331	12.60	<.0001
Year*Year*Year	-0.11635988	0.01218750	-9.55	<.0001

Table 13: Multivariate Regression Model for Lag 2

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	77.7721275	2.83764228	27.41	<.0001
O3	101.7241210	53.38741736	1.91	0.0568
PM	-0.0787734	0.07982216	-0.99	0.3238
NewMonth	-0.3252506	0.58020528	-0.56	0.5751
NewMonth*NewMonth	0.1055016	0.04029151	2.62	0.0089
NewMonth*Year	-0.0680754	0.03166756	-2.15	0.0316
Year	-14.7132033	0.97061869	-15.16	<.0001
Year*Year	2.5765663	0.20479917	12.58	<.0001
Year*Year*Year	-0.1159876	0.01218487	-9.52	<.0001

Table 14: Multivariate Regression Model for Lag 10

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	74.5303166	2.82983382	26.34	<.0001
O3	150.7321991	53.24050897	2.83	0.0047
PM	-0.1129337	0.07960251	-1.42	0.1561
NewMonth	0.5089424	0.57860871	0.88	0.3791
NewMonth*NewMonth	0.0508530	0.04018064	1.27	0.2057
NewMonth*Year	-0.0827373	0.03158042	-2.62	0.0088
Year	-14.6665594	0.96794780	-15.15	<.0001
Year*Year	2.5822759	0.20423561	12.64	<.0001
Year*Year*Year	-0.1161295	0.01215134	-9.56	<.0001

Table 15: Multivariate Regression Model for Lag 20

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	83.2132632	2.82474405	29.46	<.0001
O3	-173.7566418	53.14475006	-3.27	0.0011
PM	0.1715958	0.07945934	2.16	0.0309
NewMonth	-0.7193718	0.57756802	-1.25	0.2130
NewMonth*NewMonth	0.1104505	0.04010837	2.75	0.0059
NewMonth*Year	-0.0299096	0.03152362	-0.95	0.3428
Year	-15.1075762	0.96620684	-15.64	<.0001
Year*Year	2.6575307	0.20386827	13.04	<.0001
Year*Year*Year	-0.1213409	0.01212948	-10.00	<.0001

Table 16: Correlation Coefficients for Lags 0, 1, 2, 10, and 20

Partial Correlation Coefficients from the Error SSCP Matrix / Prob > |r|					
DF = 4097	**Lag0**	**Lag1**	**Lag2**	**Lag10**	**Lag20**
Lag0	1.000000	0.313422	-0.256890	-0.279317	0.803968
		<.0001	<.0001	<.0001	<.0001
Lag1	0.313422	1.000000	0.313387	-0.266801	0.290080
	<.0001		<.0001	<.0001	<.0001
Lag2	-0.256890	0.313387	1.000000	0.292371	-0.262284
	<.0001	<.0001		<.0001	<.0001
Lag10	-0.279317	-0.266801	0.292371	1.000000	-0.285440
	<.0001	<.0001	<.0001		<.0001
Lag20	0.803968	0.290080	-0.262284	-0.285440	1.000000
	<.0001	<.0001	<.0001	<.0001	

Analysis of Respiratory and Cardiovascular Hospital Admissions as a Function of all Criteria Pollutants for the Baton Rouge Capital Region

The second part of this study consisted of a subset analysis of the area surrounding the Baton Rouge Capital air monitoring site, since this was the only monitoring site that collected data for each of the criteria pollutants. This data correlated with hospital admissions for zip codes in the nearest surrounding areas. Hospital admissions were used for the following zip codes: *70801, 70802, 70803, 70805, 70806, 70808* (see Figure 15). In order to a zip code to be used, over half of the zip code needed to fall within a five-mile radius of the Capital site. This resulted in a combined total of 65,020 hospital admissions for the entire study period. Days with incomplete air data were not used in the analysis.

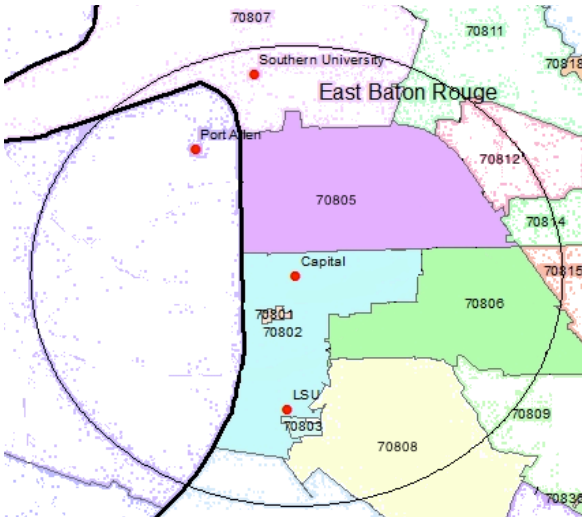

Figure 15: Zip codes surrounding the Capital air monitoring site

Colored regions represent zip codes included in data analysis.

Multivariate regression analysis.

Multivariate regression analysis was run to examine the relationship between daily averages of O_3, $PM_{2.5}$, CO, SO_2, and NO_2 and total hospital admissions for diseases of the circulatory and respiratory systems for the zip codes surrounding the Capital site.

Pearson Correlation Coefficients show only weak and negligible degrees of association between pollutants (see Table 17).

Table 17: Correlation Coefficients for Pollutants near Capital site

Pearson Correlation Coefficients					
	O3	**PM2 .5**	**CO**	**SO2**	**NO2**
O3	1.00000	0.34879	-0.04383	-0.01068	-0.04981
PM2.5	0.34879	1.00000	0.34607	0.17146	0.36474
CO	-0.04383	0.34607	1.00000	0.18051	0.34411
SO2	-0.01068	0.17146	0.18051	1.00000	0.36223
NO2	-0.04981	0.36474	0.34411	0.36223	1.00000

Again, both month and year were used as covariates in the analysis (statistically significant to $p<.0001$). After taking into account both year and month, only O_3 and NO_2 were statistically significant ($p<.0001$) in predicting the number of hospital admissions. The r^2 value indicated that the model 17% of the variation could be explained by the model (see Table 18).

Table 18: Multivariate Regression Model for Capital site

Simple Statistics			
	N	**Mean**	**Std Dev**
O3	4340	0.02355	0.00979
PM2.5	4049	12.23393	5.68753
CO	4339	0.47868	0.29154
SO2	4298	0.00286	0.00304
NO2	4365	0.01553	0.00929

R-Square
0.170953

Parameter	**DF**	**F Value**	**Pr > F**
Month	11	5.99	<.0001
Year	11	53.63	<.0001
O3	1	37.56	<.0001
PM2.5	1	0.00	0.9742
CO	1	1.99	0.1580
SO2	1	1.10	0.2950
NO2	1	132.28	<.0001

CHAPTER V: DISCUSSION

In recent years, studies have consistently shown associations between a decrease in air quality with an increase in cardiovascular and respiratory issues. Many of these studies focus on ozone and particulate matter. Ozone exposure has been linked to a reduction in forced expiratory volumes (Klaassen 2008), progressive lung function impairment (Horstman, Ncdonnell, et al. 1989), and increased cardiovascular and respiratory mortality (Samoli, Zanobetti, et al. 2009). Fine particulate matter exposure has been linked to decreased forced expiratory volumes, increased cardiopulmonary and lung cancer mortality (Dockery, Pope, et al. 1993), and increased out-of-hospital cardiac arrests (Ensor, Raun, et al. 2013).

This study included a large geographical region that encompassed multiple parishes and a large population. The sample period spanned 11 years, making it one of the most extensive studies of the region. The duration of study combined with the vast geographical area resulted in an extremely large sample size. Larger sample sizes provide a better estimate of the population and, therefore, provide more reliable results.

The first part of this study examined the general population of the Baton Rouge Air Quality Control Region for the period between 2000-2011. A total of 290,742 hospital admissions for cardiovascular and respiratory illnesses were used in the study. Of those admitted, gender was distributed fairly equally, with fairly equal distributions among Black and Caucasian races.

After controlling for the month and the year, the model showed that increases in hospital admissions were significantly associated with decreases in ozone and increases in particulate matter for the same day. This study expected to find that increases in ozone would result in increases in cardiovascular and respiratory health effects, and consequently, increases in hospital admissions. The findings for ozone contradict the general understanding that higher levels of ozone decrease lung function in healthy individuals and exacerbate symptoms for those with respiratory illnesses (Klaassen 2008; Moore, Neugebauer, et al. 2008). Furthermore, studies have shown that individuals exposed to long-term high levels of ozone had three times the risk of dying from respiratory causes than individuals exposed to lower levels of ozone (Jerrett, Burnett, et al. 2009). The findings for particulate matter, however, compliment those previously reported by Ensor, Raun, et al. that in the two days prior to onset, OHCA was associated with an increase in $PM_{2.5.}$

The model also shows a near significant, positive association between hospital admissions and ozone levels ten days after exposure. This was the peak for the positive association between ozone and hospital admissions for the lag times examined. Although the association was not statistically significant, analyses of lag times slightly before or after 10 days of exposure could produce significant results.

The second part of this study examined a subset population surrounding the Baton Rouge Capital air-monitoring site. This resulted in 65,020 hospital admissions being

used in the analysis. Again, after controlling for both month and year, the model showed that same day hospital admissions were associated with an increase in ozone and nitrogen dioxide (significant to $p<.0001$). This model may have more validity since the study area was smaller, and therefore, there should be a higher correlation between hospital admissions and the source of exposure. These findings correspond to similar studies, which have found increases in hospital admissions with increases in ozone levels (Moore, Neugebauer, et al. 2008) and increases in same-day nitrogen dioxide levels (Fusco, Forastiere, et al. 2001).

There may be synergistic effects of ozone and nitrogen dioxide. More and more, researchers are looking toward a multi-pollutant approach to air quality management (EPA 2012). Both nitrogen dioxide and ozone are highly insoluble, and thus have the ability to penetrate deep into the respiratory system. Past research has found that ozone and nitrogen dioxide may have a synergistic effect on rat lungs (Last, Gerriets, et al. 1983); however, no synergistic effect was found in human plasma cells (O'Neill, van der Vliet, et al. 1995).

Several factors may explain the contradicting results. The limited data received, due to privacy concerns, makes it impossible to control for potential confounders, such as cigarette smoking, occupational exposure, and increased body mass index (BMI). Certain occupations may expose individuals to higher levels of pollutants and toxic agents. One particular study found that construction workers are at increased risk of ischemic heart disease due to their increased exposure to particulate matter and diesel exhaust (Toren, Bergdahl, et al. 2007). As stated previously, cigarette smokers have elevated COHb levels as well as higher exposure to particulate matter and carcinogenic compounds. Increased BMI is associated with increased risks for cardiovascular disease as well as diabetes, both of which affect oxygen-gas exchange in the body. A study examining the association between air pollution and mortality found that increased mortality was associated with increased body-mass index (Dockery, Pope, et al. 1993). It is also unknown whether peaks in a pollutant may have a stronger effect than the average exposure level.

There may also be agricultural confounding. In Louisiana, sugar cane farmers burn the extra plant material, from which no sugar is produced, in order to allow for more efficient harvesting and larger sugar yields. Peak burning occurs from October through December, contributing to high levels of particulate matter, carbon monoxide, and nitrogen dioxide (Boopathy, Asrabadi, et al. 2002). The large increase in particulates may have an impact on both the environment and public health.

There is still much debate on the temporal correspondence between air pollutants and health effects. Samoli et al. found that the effects of ozone on cardiovascular mortality persist up to one week after exposure, with significant increases in respiratory mortality with lags up to twenty days (Samoli, Zanobetti, et al. 2009). A study in Houston found that in the two days prior to onset, OHCA was associated with a daily average increase of 6 $\mu g/m^3$ for $PM_{2.5}$ (Ensor, Raun, et al. 2013). A study in Rome found that total respiratory admissions were significantly associated with same-day levels of

NO_2 (Fusco, Forastiere, et al. 2001). Because the models examined levels of pollutants at the same time scale, there is a potential for confounding results. Furthermore, it is plausible that different medical outcomes may respond to exposure at different lag times. For example, asthma may have a quicker response to particulate matter than chronic obstructive pulmonary disease. Grouping all respiratory or cardiovascular admissions together may diminish possible associations.

There are limited studies examining air quality in Baton Rouge. Out of those studies, none examined the association between air quality and cardiovascular and respiratory morbidity. The results of this study can provide additional insights to possible health effects of air pollution in Baton Rouge. These results may be able to provide helpful insight into other cities of similar size and pollution levels. Understanding this role is crucial in protecting public heath, both locally and nationally.

In conclusion, there are indications that same-day nitrogen dioxide levels and same day particulate matter levels may play a role in increased hospital admissions for diseases of the circulatory and respiratory system. However, due to the limitations of this study, the impact of ozone on circulatory and respiratory health remains elusive. Further research is suggested to better define exposure periods with cardiovascular and respiratory endpoints. Ideally, future research in this area would consist of more precise geographical locations to account for exposure as well as more detailed information on hospital admissions to control for possible confounders.

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APPENDIX A

Application for Exemption from Institutional Oversight

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

-- Applicant,Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html

-- A Complete Application Includes All of the Following:
- **(A)** Two copies of this completed form and two copies of part B thru E.
- **(B)** A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
- **(C)** Copies of all instruments to be used.
  *If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
- **(D)** The consent form that you will use in the study (see part 3 for more information.)
- **(E)** Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
- **(F)** IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator: Vincent L. Wilson **Rank:** Professor

Dept: Environmental Sciences **Ph:** 225-578-1753 **E-mail:** monster77@aol.com

2) Co Investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space

Dr. Martin Hugh-Jones, Environmental Sciences, Emeritus Professor, mehj@vetmed.lsu.edu
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Gary Decossas, Environmental Sciences, undergraduate student, gdecos1@tigers.lsu.edu

IRB# E5980 LSU Proposal #

✓ Complete Application

○ Human Subjects Training

3) Project Title: An Analysis of Cardiovascular and Respiratory Admission Rates as a Function of Various Air Pollutants in the 5 Parishes Surrounding Baton Rouge

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 5/9/2015

4) Proposal? (yes or no) no **If Yes, LSU Proposal Number**

Also, if YES, either ○ **This application completely matches the scope of work in the grant**

OR ○ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) admits from selected ICD-9 codes

*Circle any **"vulnerable populations" to be used**: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature [signature] **Date** 5/5/12 (no per signatures)

** **I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ✓ Not Exempted ____ Category/Paragraph 4

Reviewer Mathews **Signature** [signature] **Date** 5/10/12

APPENDIX B

DATA USE AGREEMENT FOR LIMITED DATA SETS

For the purpose of this Agreement and consistent with the HIPAA Privacy Rule, "Minimum Necessary" is defined as that protected health information that is *"reasonably necessary to achieve the purpose of the disclosure"* and is disclosed to only *"Those persons or classes of persons, as appropriate, in its workforce who need access to protected health information to carry out their duties."*

Consistent with the HIPAA Privacy Rule, in no case will the limited data set include any of the following identifiers:

1. Names
2. All geographic subdivisions smaller than a State
3. All elements of dates (except year) for dates directly related to an individual including birth date, admission date, discharge date, date of death
4. Telephone numbers
5. Fax numbers
6. E-mail addresses
7. Social security numbers
8. Medical record numbers
9. Health plan beneficiary numbers
10. Account numbers
11. Certificate/License numbers
12. Vehicle identifiers & serial numbers, including license plate numbers
13. Device identifiers & serial numbers
14. Web Universal Resource Locators (URL's)
15. Internet Protocol (IP) address numbers
16. Biometric identifiers, including finger and voice prints
17. Full face photographic images and any comparable images
18. Any other unique identifying number, characteristic, code, or combination that allows identification of an individual.

APPENDIX C

PERCENTAGE OF ADMISSIONS BY ZIP CODE, 2000-2011

Zip Code	Percentage
70346	1.76204%
70449	0.44679%
70462	0.13276%
70710	0.29820%
70711	0.12451%
70714	3.09106%
70717	2.68417%
70719	0.84886%
70721	0.16716%
70722	0.45883%
70725	0.10318%
70726	7.35910%
70729	0.19880%
70733	0.31574%
70734	0.49322%
70737	3.82057%
70739	1.16117%
70740	0.24523%
70754	1.35034%
70764	2.78116%
70766	0.00034%
70767	3.15469%
70768	0.00034%
70769	3.62865%
70770	0.54550%
70774	1.16392%
70776	0.52899%
70778	0.18952%
70780	0.26037%
70785	1.75826%
70788	0.66691%

VITA

Heather Spindel was born in 1986 in New Orleans, Louisiana. After graduating from St. Mary's Dominican High School in 2005, she began studying environmental science at Tulane University. Heather graduated from Tulane University with a Bachelor of Science in Environmental Science in 2009. In 2010, Heather enrolled in the Environmental Science Master's program at Louisiana State University.