Examining the Association of Environmental Degradation and Poor Cardiovascular and/or Respiratory Health Outcomes in a Disadvantaged Community

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EXAMINING THE ASSOCIATION OF ENVIRONMENTAL DEGRADATION AND POOR CARDIOVASCULAR AND/OR RESPIRATORY HEALTH OUTCOMES IN A DISADVANTAGED COMMUNITY

by

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A Dissertation Submitted to the Faculty of Old Dominion University in Partial Fulfillment of the Requirement for the Degree of

DOCTOR OF PHILOSOPHY

HEALTH SERVICES RESEARCH

OLD DOMINION UNIVERSITY
August 2018

Approved by:
Anna Jeng (Director)
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ABSTRACT

EXAMINING THE ASSOCIATION OF ENVIRONMENTAL DEGRADATION AND POOR CARDIOVASCULAR AND/OR RESPIRATORY HEALTH OUTCOMES IN A DISADVANTAGED COMMUNITY

Khyati Niranjan Kantaria
Old Dominion University, 2018
Director: Dr. Anna Jeng

Air pollution is associated with poor cardiovascular and/or respiratory health outcomes. The poor air quality in certain communities due to the emission of toxic air pollutants from industries and major roadways has been a growing concern. The main objective of this study was to examine whether residential proximity to environmental air pollution sources, individual-level risk factors (age, gender, and body mass index (BMI)) and number of years at same residence are associated with observed poor cardiovascular and/or respiratory health outcomes in the residents of Southeast community in Newport News, Virginia. Logistic regression was conducted to assess this association using the self-reported demographic and health outcomes data from the surveys completed by the residents of the community. Exposure to air pollution was calculated as distance in miles between each geocoded residential address and source of air pollution using geographic information system (GIS) tools and then Lakes Environmental Screen View™, which as a user-friendly interface for US EPA SCREEN3 was used to model ground level concentration of pollutants released from Toxic Release Inventory (TRI ) reporting industries present in the community at each residential address. A significant negative correlation was observed between predicted concentration of pollutants from industries and distance of residence from the industries. Of 224 residents, 39.7% reported the presence of cardiovascular and/or respiratory health outcomes and 51.8% had BMI in the overweight or obese category. Results of logistic regression model reported no significant association with residential proximity to environmental
pollution sources. Some of the study limitations such as size of the study community as well as absence of real-time air monitoring stations could be contributing factors for the observing this lack of association. For individual-level factor, significant positive association was observed between obesity (OR = 3.03; 95% CI = (1.37 – 6.71); p = 0.01) and poor cardiovascular and/or respiratory health outcomes. And although, not statistically significant, higher prevalence rates of poor cardiovascular and/or respiratory health outcomes were observed in residents living at the same residence of ≥ 15 years compared to those living of < 15 years at same location.
Copyright, 2018, by Khyati Niranjan Kantaria, All Rights Reserved.
Dedicated to my son - Shivaay

and

To all my nieces and nephews - Jiya, Mahi, Amaira, and Anuj
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CHAPTER 1
INTRODUCTION

Background

Cardiovascular disease and chronic respiratory disease remains the number one cause and the third cause of death (Center for Disease Control and Prevention, 2016c), respectively in the United States. Cardiovascular disease includes conditions affecting the person’s heart and associated blood vessels, while respiratory disease commonly comprises conditions, causing breathing related problems like asthma and upper respiratory tract problems. Each year about 610,000 deaths are due to heart disease while 3,651 deaths are due to asthma. Both diseases are the leading cause of death in most of the racial/ethnic groups as such African-American and Hispanics. The common risk factors for both diseases include exposure to environmental air pollution due to emissions from industries and major roadways, and other individual-level factors like age, gender, race/ethnicity, body mass index (BMI), smoking and lack of physical activities (Center for Disease Control and Prevention, 2016a, Center for Disease Control and Prevention, 2016c).

Air pollution is associated with poor cardiovascular and respiratory health outcomes. (O’Neill et al., 2003). Outdoor air pollution was responsible for 72% of deaths due to heart disease and stroke, 14% of deaths due to lower respiratory infections and 14% of deaths due to the lung cancer in the year 2012 (World Health Organization, 2016). Air pollutants have also been consistently associated with high blood pressure (BP). Study by Delfino and Colleagues examined the association between BP and air pollution using ambulatory BP monitoring and outdoor air pollutant measurement in 64 elderly subjects in Los Angeles basin. Subjects were followed for 10 days with hourly waking ambulatory monitoring and positive association was
found between systolic and diastolic blood pressure and air pollutants (Delfino et al., 2010). Another study clinically examined the association between air pollution and blood pressure in non-smoking healthy adults. Responses during 2-hour exposure to concentrated particulate matter plus ozone were compared with particle free air and significant increase in diastolic pressure was observed with 2-hour exposure to concentrated particulate matter plus ozone (Urch et al., 2005).

Even a brief exposure to environmental air pollution for several days has been associated with an increase in respiratory and cardiovascular mortality (Samet, Dominici, Curriero, Coursac & Zeger, 2000; Peters, Dockery, Muller & Mittleman, 2001). Air pollution’s contribution to the risk of respiratory and cardiovascular diseases has been assessed since the 1970s. In the 1970s and 1980s, the methodology used in the studies usually compared the death counts for several days or weeks before, during and after episodes to evaluate the short-term changes in exposure to the air pollution. The deaths due to the cardiovascular disorders were more strongly associated with the short-term exposure to air pollution compared to the deaths due to respiratory disorders (Ciocco & Thjompson, 1961; Nemery, Hoet & Nemmar, 2001; Bell & Davis, 2001; Bell & Davis, 2004). Some of the other studies like the Harvard Six Cities study and American Cancer Society (ASC) study evaluated long-term exposure to particulate matter (PM) and they reported that long-term exposure to particulate matter (PM) was associated with respiratory illness in children and cardiopulmonary mortality in adults along with respiratory hospitalizations, lung functions and respiratory symptoms (Krewski et al., 2003).

There has been growing concern regarding the poor air quality and emission of toxic substances near industrial facilities and major roadways since the 1980s. The proximity of community to environmental air pollution sources has served as a proxy for exposure and
observed poor health outcomes in the individuals (Nweke et al, 2011; Chakraborty, Maantay & Brender, 2011). The concentrations of the toxic air pollutants from the vehicle emissions are elevated next to highways and major roadways. Individuals who live or spend time in locations adjacent to highways are more highly exposed to these pollutants. Living closer to highways is associated with childhood asthma, reduced lung function, poor cardiovascular health outcomes and mortality (Gauderman et al., 2005; Jerrett et al., 2009; McConnell et al., 2010; Gan et al., 2010). Also, recent studies have employed geographical information system (GIS) to study the proximity of the community to environmental air pollution sources as a proxy for exposure and adverse health impact. GIS allows to integrate multiple data sources, represent the data on graphs and apply various spatial techniques for proximity analysis (Chakraborty, Maantay & Brender, 2011).

**Purpose of Study**

The purpose of the study is to examine whether residential proximity to multiple environmental air pollution sources (industries and freeway) and individual-level risk factors (age, gender, and body mass index (BMI)) contribute to the observed poor cardiovascular and/or respiratory health outcomes in the residents of the Southeast Community in Newport News, Virginia.

**Problem Statement**

In certain communities, individuals are exposed more to the environmental air pollution due to emissions from the industries and vehicles on major roadways located nearby and therefore have increased the risk for poor cardiovascular and respiratory health outcomes. One such community is the Southeast community in Newport News, Virginia as shown Figure 1. The community is about 4 miles long and 2 miles wide. Its population is 11.2% White, 85.7%
African-American and rest American-Indians and Asians (U. S. Census Bureau, 2015a), with 57% of median household income below the state average, and 65.8% with high school education (U.S. Census Bureau, 2015a). According to the 2012 Virginia Health Equity Report, this community has been identified as one of the most vulnerable areas because of the high rates of poor cardiovascular and/or respiratory health outcomes observed in the residents (Virginia Health Department, 2016).

Figure 1. Study Community in Newport News, Virginia
Figure 2. Raster Map Showing Expected Count of Population Density of Residents in the Study Area
Residents in the community are disproportionately exposed to environmental air pollution due to the creation and use of Interstate 664, and the various industrial facilities operating in the area. Out of all known industrial facilities currently operating in the city of Newport News, 50% of them are located within the community. As seen from Figure 2, area with darker red scale represents region with higher expected count of residents compared to area with green scale which represents region with zero expected count of residents. Most of the residents were observed to be living in the area near industry and Interstate 664. Currently, environmental issues of concern are hazardous air pollutants, smog and particulate matter, diesel emissions and toxic chemical releases such as N-butyl alcohol, toluene, methanol and sulfuric acid. Respiratory problems like asthma, coughing, shortness of breath, bronchitis and heart problems like chest pain and heart murmurs are some of the health problems of concern in the community (United States Environmental Protection Agency, 2012)

**Significance of Study**

Environmental related factors such as residential proximity to air pollution sources like industries and traffic on major roadways running through the community have also been identified as major risk factors, along with commonly known risk factors like age, gender, and body mass index (BMI) for poor cardiovascular and/or respiratory health outcomes in an individual. Epidemiological studies conducted in the past have reported the link between poor cardiovascular and/or respiratory health outcomes and proximity to busy roads (Brunekreef et al., 1997; Wilhelm and Ritz, 2003; Garshick, Laden, Hart and Caron, 2003; Gauderman et al., 2007; Kim et al., 2008; McConnel et al, 2006) and polluting industrial facilities (Mohai & Bryant, 1992; Brown, 1995; Szasz & Meusar, 1997; Evans & Kantrowitz, 2002). However, these studies have either explored residential proximity to the industrial source or residential proximity to the
major roadways. The significance of the current study is that it will explore both the pollution sources present in the community – industries and major roadways and it will also utilize the predictive dispersion model along with various GIS tools to show the dispersion pattern of pollutants from the industries in an ideal condition over the study area. The study will also analyze individual-level risk factors to examine if they contribute to the observed poor cardiovascular and/or respiratory health outcomes in individuals along with the environmental air pollution sources.

**Theoretical Framework**

**Base Theoretical Framework.**

The presence of health disparities, particularly in some African-American communities have been documented across various cardiovascular and respiratory health outcomes. Factors contributing to the observed difference are multiple-factorial, including genetics, environmental factors and socioeconomic. The Stress-Exposure Disease Framework provides a basis for understanding the complicated relationship among essential determinants like residential based exposure to environmental pollution and risk for cardiovascular and respiratory disease, thus explaining why a certain individual is at an increased risk for poor health outcomes (Figure 2). The framework particularly hypothesizes that high correlation is observed between residential location and access to various community resources and exposure to environmental air pollution which results in the observed health outcomes in the individuals (Gee & Payne-Sturges, 2004; Payne-Sturges & Gee, 2006).
According to the framework, residential location affects individual’s exposure to various stressors, resources, and environmental pollution sources in the community. When the exposure to a stressor and environmental pollution sources combine to outweigh the community resources, it increases the individual’s vulnerability to respiratory and cardiovascular disease. The framework also identified 112 measures or indicators which can help track environmental health differences and study the health outcomes at the community level (Gee & Payne-Sturges, 2004).

All of the measures are organized into four main categories, such as social processes, physical environmental hazards, body burden indicators and health outcomes which are defined as below (Payne-Sturges & Gee, 2006):

- The social processes are defined as psychosocial factors that may directly or indirectly lead to illness. They include all the elements, which are operating at an interpersonal level as well as the
societal level, for example, socio-economic status, employment opportunities, recreational parks, and activities, etc.

- The physical environmental hazards or exposures are defined as condition or activities that identify the potential for or occurrence of exposure to an environmental contaminant or hazardous condition, for example, toxic chemical agents, physical agents, biochemical stressors, etc.
- Body burdens indicators are biological markers in tissue or fluid that identify the presence of the substance or combination of substance that impacts human health, for example, lead, cadmium, mercury, arsenic, cotinine, etc.
- The health outcomes are defined as disease or conditions that may be related to exposure to environmental hazard or pollutants.

**Modified Framework.**

As per the framework, these four categories are complementary to each other, and it is not necessary or sometimes even possible to study all categories for an issue. Following this reasoning, the framework below would be used in the current study which has been modified and adapted from Stress-Exposure Disease Framework. The modified framework shows that residential proximity to various environmental air pollution sources is responsible for the poor cardiovascular and respiratory health outcomes in an individual.

- Residential location is the place of residence of the individual.
- Environmental air pollution is a factor affecting the external environment of the community.

For this study, major environmental air pollution factors identified are industries and a major freeway.
• Health outcomes are observed changes in the health status of the individual. For this study, health outcomes identified are respiratory and/or cardiovascular health problems.

Figure 4. Modified Framework for the Study. Adapted from Gee & Payne-Sturges (2004)
CHAPTER II

LITERATURE REVIEW

The purpose of Chapter II is to review the literature related to the risk factors associated with poor cardiovascular and respiratory health outcomes. The risk factors are categorized into two main categories – environmental factors and individual-level factors. The environmental risk factors include exposure to air pollution from sources like industries and vehicle emissions due to residential proximity and the individual-level risk factors include age, gender, body mass index (BMI) and smoking. Also, the technology used to examine how the risk factors linked to the health outcomes are presented.

Introduction

In the year 2013, overall cardiovascular disease death rate was 222.9 per 100,000 Americans, and the death rates were 269.8 and 184.8 for men and women respectively (Mozaffarain et al., 2016). Where a person lives, works and plays can significantly influence his or her exposure to environmental air pollution (Bullard & Wright, 1992), along with the availability of other community factors, e.g., access to healthy food and recreational parks and can, therefore, affect the overall health of an individual. This may partially explain to a certain extent why certain individuals in the United States are healthier and why some are not (Center for Disease Control and Prevention, 2014). Although risk factors have been identified and studied, the lack of understanding of association between the area level and the individual-level risk factors hinder the ability to explain the exact role of community or neighborhood environment as a risk factor (Diez Roux et al., 1997; Sundquist, Malmstrom, Johansson, 1999; Yen and Kaplan, 1999). That further deters efficient resource allocation to the community impacted by health and social disparities.
Research on Residential Proximity to Air Pollution Sources

Most of the epidemiological studies, which have examined the association between residential proximity to busy roads, have focused mainly on poor respiratory health outcomes in children like childhood asthma and decreased lung function (van Vliet et al. 1997; English et al., 1999; Venn et al. 2000; Brauer et al. 2002; Nicolai et al. 2003; Zmirou et al. 2004; Gauderman et al. 2005). And the studies, which have examined the association between residential proximity to industrial sources, have mainly focused on race/ethnicity of the population living near the industrial source (Napton and Day, 1992; Greenberg, 1993; Zimmerman, 1993; Perlin, Sexton and Wong, 1999; Anderton, Anderson, Oakes and Fraser, 1994; Bowen, Salling, Haynes and Cyran, 1995). This section will provide a brief highlight on some of the studies which have examined associations between poor respiratory and cardiovascular health outcomes and residential proximity to busy roads and industrial sources respectively.

Residential Proximity to Major Roads

Environmental air pollutants like carbon monoxide, nitrogen oxides, sulfur dioxide, ozone, lead, particulate matter (PM), volatile organic compounds like benzene along with polyaromatic hydrocarbons are the primary pollutants released from the vehicular exhaust. Particulate matter in the air has been strongly associated with hospital admissions, and cardiopulmonary mortality (Brook et al., 2004; Boothe, 2008) and motor vehicles are the primary sources for these particulate matters. Cross-sectional and longitudinal epidemiological studies have consistently shown a significant association between residential proximity to highways with increased exposure to ozone and particulate matter and poor cardiovascular and respiratory health outcomes (Peters et al., 1999; Gauderman et al., 2000; Tager et al., 2005; Brugge et al., 2015). Some of the characteristics like duration of residence at the same home, prenatal history
and allergies (London et al., 2001; Penden 2000) are found to increase the risk for poor cardiovascular and respiratory health outcomes. The concentrations of essential pollutants from the traffic are frequently observed to be elevated next to major highways and freeways.

Many of the past studies have investigated whether living close to major roads and freeways increases the risk for poor cardiovascular and respiratory health outcomes, and have consistently reported that living close to major freeways with heavy traffic is significantly associated with childhood asthma, poor lung function, poor cardiovascular health and mortality (Gordian et al., 2006; McConnel et al., 2006; Gauderman et al., 2007; Kim et al., 2008). Most of these studies have used different metrics or combination of metrics like the distance of the residence from nearest major roads and freeways, variable radius buffers around the residence to explore traffic density and dispersion modeling for estimating the concentrations of the pollutants near residence as the exposure measure. For example, a case-control study (Lin, Munsie, Hwang, Fitzgerald and Cayo, 2002) conducted in Erie County, New York used variable radius buffer metric to investigate whether pediatric hospitalizations for asthma is related to the residence near roads with heavy traffic. This study used two radius buffers. One was of 500 m zone and the second one of 200 m zone drawn within the 500m zone for the residence. After adjusting for age and poverty, it was observed that the children hospitalized for asthma were more likely to live on the roads with heavy traffic passing by within 200m of their residence but no significant association was observed for asthma hospitalization in children living within 500m of heavy traffic roads. This suggests that exposure within 200m of heavy traffic roads contribute more to asthma compared to 500m. The Cincinnati Childhood Allergy and Air Pollution Study (Ryan et al., 2005) used both variable radius buffer and logistic regression to examine the association between exposure to traffic-related air pollution at varying distances and wheezing in
infants less than 1 year of age. The exposure was classified with distances of less than 100m, 150m, 200m, and 400m. Infants living within 100m of bus traffic had a significant increase in the risk of wheezing compared to infants unexposed to bus traffic. Several other studies have also reported similar findings of asthma risk being associated with the proximity to the traffic (Zhu et al., 2002; Gordian et al., 2006; McConnel et al., 2006).

Some studies have also used the combination of metrics (Gauderman et al., 2005) in analysis or utilized several parameters and compared them (Batterman et al., 2014). For example, the Children's Health Study conducted by Gauderman and colleagues (2005) recruited two cohorts of fourth-grade children between 1993-1996 to examine the association between a long-term effect of exposure to residential based traffic air pollution and respiratory health. Subjects in those cohorts were recruited from 12 southern Californian communities and were followed for up to 8 years. The exposure to pollution from the traffic was characterized by using metrics – proximity of the residence to the nearest freeway or nearest major non-freeway road and model-based estimates derived from the dispersion model. The hierarchical mixed-effects model was then used to examine the association between lung function and the exposure to traffic air pollution. Study results showed that the residential proximity to the freeway traffic was associated with significant adverse effects on lung function in the children when controlled for height, BMI, exercise, and tobacco smoking. The result was more prominent in the children living within 500m of the freeway compared to those who lived at least 1500m from the freeway (Gauderman et al., 2005). Another example is the Near-road Exposure and effects of Urban air pollutants Study (NEXUS) (Batterman et al., 2014) which examined how the exposure to air pollutants from nearby roadways is linked to respiratory health in children living in Detroit, Michigan. This study used several different metrics, including exposure due to proximity to
major roads, traffic volume, a mix of vehicle, traffic density and predicted the concentration of the pollutants from dispersion models. It compared the metrics, and several strengths and limitations were observed for each. The parameter of proximity to major roads was found easy to construct with minimal data requirements, but cutoff distances used were arbitrary and were sensitive to distance calculation. Next, the total traffic volume and the mix of vehicle metrics were easily constructed to select PM period of the day. However, it was difficult to estimate the needed traffic volume. The parameter of predicted concentrations of pollutants from dispersion models had several strengths, 1) it incorporated effects of emissions and meteorology; 2) it was derived for the specific period of the day, season or year but at the same time; finally, 3) comparisons of inter-studies were possible and meaningful.

Recently studies (Kim et al., 2004; McConnel et al., 2006; Gauderman et al., 2007; Kim et al., 2008) have employed geographical information system (GIS) tools for estimating the residential proximity to major roadways. For example, English and colleagues (1999) used GIS to explore whether residence of children in a low-income population in San Diego County near a busy road is associated with asthma. The authors used 550ft radius circular buffers around residence for the exposure because most of the dispersion models indicate that 80-90% of the pollutants decay between 492 – 656ft and compared cases of asthma with random control of non-respiratory diagnosis. Their study analysis showed no significant odds ratio for distribution of cases and controls with the traffic streets within the 550ft buffer. However, the cases who resided close to high traffic flows were more likely to have two or more medical visits for asthma compared to those who resided near low traffic flow. This may indicate that the exposure to high traffic may aggravate the asthmatic symptoms in the individuals who are already diagnosed with asthma (English et al., 1999). The East Bay Children's Respiratory Health Study (Kim et al.,
2004; Kim et al., 2008), conducted in the San Francisco Bay Area in 2001, also examined asthma, and other respiratory symptoms, in 1109 children living at varying distance from high-traffic roads. The study obtained the information on health outcomes, demographics and home environmental factors using parental questionnaire. The concentrations of various traffic pollutants like PM, black carbon, total nitrogen oxide and nitrogen dioxide were measured at the study sites, and GIS tools were used to assess the residential proximity to traffic. The associations between the pollutants and health outcomes were examined using hierarchical modeling strategy, and a significant association was observed between current asthma rates and residential proximity to traffic, with the highest risk observed in those living within 75m of a freeway. Those living at their current residence for at least one year had a significant increase in bronchitis symptoms. McConnell and colleagues (2006) conducted a new cohort study that recruited children from schools in 13 southern Californian communities. The residential distances to the middle of the nearest major roads were categorized as < 75 m, 75 – 150 m, 150 – 300 m and > 300 m. The study reported an increased risk for asthma among children within the 75 m compared to those living at least 300m from a major road. Also, the risk factor increased in residents who have been living at the same location for two years of age. Finally, significant increase (p = 0.02) was observed in risk for lifetime asthma among girls (OR = 2.51) compared to boys (OR = 0.94) (McConnel et al., 2006). Gauderman and colleagues (2007) later conducted a follow-up study, including 208 children that had lived at the same home and were randomly selected from the ten southern California communities from the original Children's Health Study (Gauderman et al., 2005). ArcGIS was used to calculate the distance of residence to nearest interstate freeways, U.S. highway or limited access highway. There was a strong association
between exposure to traffic-related air pollution at homes and lifetime history of asthma, current asthma medication uses and wheezing (Gauderman et al., 2007).

As seen earlier, most of the population-based studies have focused on children and examined the relationship between residence and traffic density on nearby roadways. Garshick and colleagues (2003) explored the relationship between adult respiratory disease and exposure to vehicular traffic. This study employed GIS tools to assess the relationship between respiratory symptoms of U.S male veterans from southern Massachusetts and residential proximity to major roadways. Men living within 50 m of a major highway experienced 30% excess wheezing problems compared to those living more than 400m away when adjusted for cigarette smoking, age and occupational exposure (Garshick, Laden, Hart, and Caron, 2003). The concentrations of the pollutants from the vehicular traffic are consistently found to be high near the roadways. However, accurate assessment for pollutant location and concentration is necessary to identify where the hazards are present and their effect. GIS tools can be used to estimate the residential distance to major roadways accurately with relatively little error.

**Residential Proximity to Industries**

The studies, which have explored the residential proximity to industrial pollutant sources, have mainly examined the race/ethnicity of the populations living nearby (Greenberg, 1993; Zimmerman, 1993; Perlin, Sexton and Wong, 1999). Some of them have found a positive correlation between race/ethnicity and residential proximity to polluting industries while some have reported no evidence of positive correlation (Napton and Day, 1992; Anderton, Anderson, Oakes and Fraser, 1994; Bowen, Salling, Haynes and Cyran, 1995). The data from the REACH U.S Risk Factor Survey showed that for 30 communities which were studied in the United States, minority communities when compared with the general population living in the same
county have greater risk factors for chronic diseases like cardiovascular and respiratory (Center for Disease Control and Prevention. 2015b) and it has been commonly observed that African-Americans and the Latinos are more likely to live in the areas with reduced air quality than are Whites (Anderton, Anderson, Oakes and Fraser, 1994).

A study by Perlin, Wong, and Sexton (2001) examined the interaction of socio-demographic variables in relation to residential proximity to industrial pollution sources and to determine whether certain populations were more likely than others to live closer to these sources in three areas: Kanawha Valley, WV; lower Mississippi River from Baton Rouge to New Orleans and Baltimore, MD. The study compared the socio-demographic characteristics of populations living up to 3 miles from industrial facilities. A consistent pattern was observed for all three regions namely Whites above poverty were located farthest from the nearest industrial facility, while the African-American were located closest to the nearest industrial facility (Perlin, Wong and Sexton, 2001). Peters et al. (2001) investigated the association between the chronic health of children and air pollution in Southern California. Specific residential, demographic and family characteristics were associated with higher respiratory disease prevalence rates in Southern California, which was independent of the outdoor air quality. The identified risk factors were being African-American or American-Indian ethnicity, smokers in the home and low socio-economic status (Peters, Dockery, Muller and Mittleman, 2001). Morello-Forsch, Pastor, and Sadd (2001) highlighted similar findings from their study focused on the hazardous air pollutants at county and census tract level. This study also found a strong association between the percentage of minorities and hazardous air pollutants concentration as well as pollutant related poor health outcomes.
One of the classic examples of this phenomenon found in the literature occurred in South Central Los Angeles. In the Los Angeles air basin, over 71% of African-Americans and 50% of Latinos lived in areas with the most polluted air while only 34% of Whites lived in these highly contaminated areas. The South Los Angeles neighborhood was in the "dirtiest" zip code in California. This 1-square mile area was saturated with abandoned toxic waste sites, freeways, smokestacks and wastewater pipes from the polluting industries. Some 18 industrial firms in 1989 discharged more than 33 million pounds of waste chemicals into the environment. The population living in the zip code area corresponding to this neighborhood was 59% African-American and 38% Latino (Bullard & Wright, 1992). There was another study conducted by Pastor, Sadd, and Hipp (2001) also in the Los Angeles area and examined the correspondence between polluting industrial facilities and disadvantaged communities. The study covered the time-period of 30 years and it explored the distribution of hazardous waste storage and disposal facilities and toxic air releases. It was found that toxic industrial facilities tend to be located in vulnerable communities rather than the other way around (Pastor, Sadd & Hipp, 2001). And similar results were observed in the study conducted by Saha and Mohai (2005) in the state of Michigan which covered 50-year time-period (Saha & Mohai, 2005).

Limitations of Previous Studies

To conclude, we saw that the residential proximity studies for polluting industrial sources described above have mostly examined racial and socioeconomic disparities of the study populations while residential proximity studies for polluting traffic sources have reviewed the distances of the study population from the source. Epidemiological studies which examine the health effects of environmental pollutants from various sources are needed in conjunction with these studies to make further inferences. However, the two bodies of research have not yet been
combined and some, of the reasons for it could be that data on environmental exposure broken by race and income, are still very limited for the number of settings like workplace, school, and neighborhood. And isolating the effects of environmental factors is very difficult as the population that is exposed are also affected by many other secondary factors like poor housing, lack of access to healthcare, insufficient nutritious food, etc. Also, there is lack of longitudinal data that would allow for examination of how changes in environmental exposure over time are linked to health outcomes as well as how such changes are moderated by race and income (Evans & Kantrowitz, 2002).

Research on Individual-Level Risk Factors

The poor cardiovascular and respiratory health outcomes observed in an individual are affected not only by the external environmental factors like exposure to air pollutants but also by factors which act at individual-level like age, gender, body mass index (BMI) and smoking. This section will provide a brief highlight on how these individual-level factors are associated with the adverse cardiovascular and respiratory health outcomes.

Age and Gender

We know cardiovascular disease or more commonly known as heart disease is the leading cause of death in both men and women in the United States but there is a significant difference in prevalence of heart disease when seen by age and gender. As per a study by Anderton, Anderson, Oakes, and Fraser (1994), the elderly population and children are more susceptible to adverse effects of the exposure to environmental pollution when compared to the general population (Anderton, Anderson, Oakes, and Fraser; 1994). Heart disease is the leading cause of death for men of the most racial group in the United States, which includes African-American, American Indians, Hispanics, and Whites. In the year 2007, age-adjusted deaths in
men due to cardiovascular disease was 300 per 100,000 compared to 212 per 100,000 in women. The prevalence of heart disease in women is also seen to vary per the racial/ethnic background. In women aged 20 years or older, the prevalence of cardiovascular disease was 47% among African-Americans, 34% among Whites and 31% among Mexicans Americans (Mosca, Barrett-Conner, and Wenger, 2011; Center for Disease Control and Prevention, 2016d). Figure 4 below shows that the prevalence of heart disease is higher and increases in men compared to women within each age group until after 75 years of age after which prevalence gap decreases.

![Figure 5. Prevalence of Heart Disease by Gender. Adapted from Mosca, Barrett-Conner and Wenger, 2011](image)

**Body Mass Index (BMI)**

Obesity is becoming a global epidemic and is found to be associated as an independent risk factor with numerous conditions like cardiovascular disease, hypertension, etc. While obesity requires technical equipment for its precise measurement, body mass index (BMI) is
frequently used as a surrogate measure of obesity in adults as well as children. In adults, overweight is defined as BMI of 25 to 29.9 kg/m$^2$ and obesity as BMI greater than 30 kg/m$^2$. Overweight and obese individuals are more likely to have respiratory symptoms like asthma and to wheeze compared to individuals with normal BMI. The frequency of self-reported symptoms of asthma and wheezing are observed to increase with an increase in the BMI. Beuther and Sutherland (2007) have demonstrated in their meta-analysis of the epidemiological studies that prevalence of asthma was higher by 38% in overweight patients and by 92% in obese patients. Another study by Schachter et al. (2001), also demonstrated that symptoms of asthma increased with the rise in BMI.

Individual's diet plays a significant role in preventing as well as developing cardiovascular related health problems. Overweight and obesity predispose individuals to increased risk for cardiovascular diseases like hypertension, coronary heart disease and heart failure and risk are shown to be elevated in individuals with central deposition of adipose tissues. A large study by US Department of Health and Human Services (2001) demonstrated that 10 kg increase in body weight is associated with 3 to 2.3 mmHg increase in blood pressure and this increase translated into an estimated 12% increase in coronary heart disease. Results from NHANES III study also showed that prevalence of hypertension increased with increase in BMI from 15% at BMI < 25 kg/m$^2$ to 42% as BMI of 30 kg/m$^2$ in men and from 15% kg/m$^2$ at BMI < 25 kg/m$^2$ to 38% at BMI of 30 kg/m$^2$ in women (Brown et al., 2000).

The prevalence of obesity is found to be significantly higher among African-American and Hispanic populations compared to White, and these associations are found to differ by gender (Chang and Lauderdale, 2005). Although the exact mechanism by which certain foods interact to increase the risk for cardiovascular disease is not very well understood, it is suggested
that diet low in fats and sodium, and high in fiber fruits and vegetables decreases the individual's risk for heart disease. In the year 2010, 58000 annual deaths due to cardiovascular disease were due to sodium intake of more than >2.0g/d, therefore representing 6.3% of all cardiovascular disease death (Morland, Wing, Roux and Poole, 2002). The studies examining obesity as the risk factor for cardiovascular illness usually measure obesity as mean body mass index (BMI) value, waist circumference or prevalence rates of obesity. The results so far from some of the studies have been conflicting with some reporting higher BMI rates in African-Americans and Mexican-Americans than Whites (Winkleby, Kraemer, Ahn and Varady, 1999; Harwell et al., 2001) while some have reported no significant difference (Finkelstein, Khavjov, Mobley, Haney, and Will, 2004).

**Smoking**

Cigarette smoking rates have declined in the United States, but still, it remains more common in men compared to women. Almost one-third of heart disease and respiratory deaths are attributed to smoking and exposure to secondhand smoke in spite that the percentage of adults who reported current cigarette use declined from 24.1% in 1998 to 16.9% in 2014 (Mozaffarain et al., 2016). One of the studies that have explored smoking as the risk factor for cardiovascular illness has reported that Mexican-Americans have a significantly lower prevalence of smoking than Whites and African-Americans (Kurian and Cardarelli, 2007). Another longitudinal study conducted by Greenlund and colleagues in five communities showed that White women had higher smoking prevalence than African-American in two sites while the other way round was reported for the remaining three places (Greenlund et al., 1998).
Research on Other Risk Factors

The literature shows that there are certain community or neighborhood levels factors like access to healthy food options and recreational spaces, where individual lives are indirectly associated with the poor cardiovascular and respiratory health outcomes. This section will briefly address these factors but they are not included in the study because of the limitations of the available data.

Limited Access to Healthy Food Options

Dietary choices made by individuals are influenced by a variety of factors like convenience and cost (Glanz, Basil, Maibach, Goldberg and Snyder, 1998). One of the neighborhood factors that are related to behavioral choices and obesity is the availability of local area food stores. Studies have shown that larger sized food stores such as supermarkets are more likely to stock healthy food and offer food at lower cost (Chung and Myers, 1999; Horowitz et al., 2004). They have also been associated with more fruits and vegetables and lower rates of obesity (Laraia et al, 2004). Cost of the food is found to be associated with the diet quality and one study showed that there is a correlation between diet quality and availability of healthy food (Fisher and Strogatz, 1999). Some of the studies conducted in the past showed that cost is the most significant predictor of the food choices made by people and therefore making healthy eating habits difficult to achieve. It is generally seen that healthier food costs more for people with low salary and hence they rely more on processed food (Morland, Wing, Roux and Poole, 2002). Many other studies also reported similar findings like residents in disadvantaged communities with low-income are forced to depend to small stores which have a limited selection of food and are high-priced (Curtis and McClellan, 1995). One study compared supermarkets, neighborhood grocery stores and convenience stores and health food stores in San
Diego, California. They found that supermarkets had twice the number of healthy food items when compared to neighborhood grocery stores (Sallis, Nader, Rupp, Atkins and Wilson, 1986).

The location of food stores in the United States has been explored by community's socio-economic status and racial and ethnic characteristics. For example, according to U.S. Department of Agriculture, in the year 2009, 40% of U.S. households did not have easy access to supermarkets. Individuals who live in communities which have a large grocery store or supermarkets have better access to fresh fruits and vegetables as well as other healthy foods and research suggests that this access to healthy food is often observed to be lower in people of rural, low income and disadvantaged communities (US Department of Agriculture, 2009; Powell et al., 2007). The results of the study by Morland showed that location of food stores is strongly associated with wealth and racial composition of the community. Fewer households in the disadvantaged community have access to transportation services and therefore have difficulty in obtaining healthy food. So, lack of transportation and supermarkets suggest that these communities might be at a disadvantage of achieving a healthy diet (Morland, Wing, Roux and Poole, 2002). Another study by Shaffer found that predominantly White versus predominantly Black zip codes in Los Angeles County have more supermarkets per household (Shaffer, 2002). Replacing the unhealthy high-calorie diet with the intake of fruit and vegetables can considerably reduce the risk for conditions like heart disease but they are found to be under-consumed in the United States, and most people do not consume the recommended amount of fruits and vegetables (Center for Disease Control and Prevention, 2011).

**Lack of Recreational Spaces**

Regular physical activity has been associated with reduced morbidity and mortality due to heart disease. According to Center for Disease Control and Prevention, adults require 150
minutes of physical activity per week (Center for Disease Control and Prevention, 2015c) Racial/ethnic minorities and low-income populations are less likely when compared to Whites to meet this recommended physical activity goal. The case involves a combination of factors like social, economic and environmental barriers (Taylor, Floyd, Whiitt-Glover and Brooks, 2007). These days, because of the increase in sedentary jobs and easy transportation, leisure time physical activities are essential to fulfilling the recommended physical activity goal. One of the places to achieve this is local parks in the neighborhood or community which are available to residents at low or no cost (Bedimo-Rung, Mowen and Cohen, 2005). Disparities have been observed regarding access to such local parks in low-income and racial minorities (Taylor, Floyd, Whiitt-Glover and Brooks, 2007). For example, a study by Moore and colleagues examined differences in availability of recreational resources in North Carolina, New York, and Maryland and it reported that minority neighborhoods had significantly less recreational facilities when compared to Whites (Moore, Diez Roux, Evenson, McGinn, Brines, 2008).

Use and Limitations of Geographical Information System (GIS) in Environmental Pollution Studies

The evidence so far from all the studies promoted researchers to further conduct quantitative analysis on the racial and socioeconomic disparities in the distribution of environmental pollutants. Some of the commonly used geographical information system (GIS) tools for quantitative analysis include unit hazard coincidence, buffer generation, and risk-based approach. Most of the quantitative analysis done so far in all the national level environmental justice studies have employed what is commonly known as the "unit hazard coincidence" approach (Anderton, Anderson, Oaks & Fraser, 1994; Anderton, Oaks & Egan, 1997; Daniels & Friedman, 1999; Davidson & Anderton, 2000). In this method, the researcher selects some
geographical unit, for example, a census tract or zip code area and determines which unit contains the source of interest and which do not. And then demographic characteristics of the area that includes the source is compared with that which do not provide the source (Mohai & Saha, 2006). This method of unit-hazard coincidence has several limitations such as, 1) most applications do not differentiate between spatial units that host one source and those which contain several sources; 2) it ignores the boundary effect that deals with the possibility that a facility could be located very close to edge of host unit and that non-host could equally be exposed and lastly it is assumed that exposure to hazards is distributed uniformly around host unit and restricted to only their boundaries and 3) pre-defined geographical units are very unlikely to represent the actual size or shape of the area exposed to the adverse health effects (Chakraborty, Maantay & Brender, 2011).

Another method commonly used is buffer generation. Buffers of various sizes have been used in the environmental studies to identify the populations at risk. Demographic characteristics of the population within a buffer is typically compared to the rest of the study to determine the disproportionate exposure. Radii of the buffers have ranged from 100 yards to 3 miles but most commonly used distances are 0.5-1.0 mile. While the buffer technique provides a more accurate representation of potential exposure to hazards, it has its own limitations. First, the radius of a buffer is chosen arbitrarily. The buffers have the same radii around all the hazards in the study. The properties of the toxic substances released at each individual facility or the environmental fate of the substances are rarely considered when determining the radii of the buffer. Next is the assumption that effects of the toxic pollutants are limited to the area in the buffer and that outside is unaffected (Chakraborty, Maantay & Brender, 2011).
Advances have been made in employing risk-based approaches in environmental studies. Rather than examining proximity to the source of environmental pollutant source, for example like distance to industrial facilities or hazardous waste sites, the risk-based approach uses the dispersion of pollution risk itself to see where the pollution burden falls. This method typically employs mathematical models which consider factors like quantity and type of toxic emission released, the timing of the release, exit velocities, wind speed directions, and other factors. Ringquist in a literature review found that studies that employ geographical information system (GIS) methods like distance based approaches tend to find greater racial and socioeconomic disparities in the distribution of the environmental pollutant source than those employing census tract or zip code areas (Ringquist, 2005).

Although the number of risk-based environmental studies have increased, they are more likely to complement rather than replace the proximity-based studies because the latter are more useful in examining where people are located in relation to physical structures that may generate environmental pollution concerns beyond health outcomes and also they represent what is known as "hard data" where physical presence of the noxious facilities are subjected to minimal ambiguity while risk-based analysis is often hampered with incomplete data and imperfect modeling assumptions (Mohai, Pellow & Roberts, 2009).

**Community Case Studies in San Francisco Bay Area**

The literature reviews on the residential proximity studies showed that most of the studies were conducted with populations in California. This section discusses some of the recently conducted community case studies in San Francisco Bay of California to get an idea on the type of environmental air pollution sources present in the community and their impact on the residents.
Crockett (Contra Costa County)

Crockett is in northern Contra Costa County where the Carquinez Bridge (Interstate 80) crossover Carquinez Strait and is home to approximately 3,151 people per 2010-2014 ASC 5-year. The community population is 79.8% White (U.S. Census Bureau, 2015a). For this community, the African-American and Hispanic population is significantly below state average and length of stay since moving in significantly above the state average (City Data, 2013). Crockett is home to major food processing industries, heavy-rail transfer facilities and many high-risk facilities which are sources for dioxin and mobile emission sources. Apart from these, there are also oil refineries and major oil storage facilities which are located within proximity to Crockett. California Air Resources Board (ARB) sponsored a study to investigate the relationship between air pollution and children's health because they are more vulnerable to environmental pollution and have higher exposure relative to their body size when compared to adults. In the long term, environmental air pollution can adversely affect children's lungs and heart. Air monitoring was conducted from 2001 to 2003 to examine the impact of exposure to industrial facilities and mobile source emission on children's health. Air monitoring stations were located at two schools which were an approximately one-half mile from Interstate 80. Some of the key pollutants measured were particulate matter, ozone, benzene and 1-3, butadiene which causes respiratory problems, asthma and cancer. The study results of the site were compared with two other closest air monitoring sites in San Pablo and Vallejo, and comparisons showed that air quality from all three sites was reasonably similar except for the levels of particulate matter which were found to be little higher in San Pablo. This suggested that it is identical regional rather than local conditions which are primary factors influencing the levels of air pollutants (California Protection Agency, n.a.).
**Fruitvale (Alameda County)**

Fruitvale is located between two major East Bay freeways – I-88 and I-580 which are significant sources of vehicular emission and is home to approximately 49,990 people according to 2010-2014 ASC 5-year. The community population is 38.8% White and 17% African-American (U.S. Census Bureau, 2015a). Fruitvale is also downwind to several industrial operations that are sources for toxic air pollutants. Similar to Crockett, air monitoring study was conducted in Fruitvale by California Air Resources Board (ARB) between 2001-2003 to investigate the impact of exposure to industrial facilities and mobile source emission on children's health. An air monitoring station was in a school which was a few miles south of downtown Oakland. More than 50 air pollutants were measured which included both toxic and six main pollutants. The study results from Fruitvale were compared to two other long-term monitoring sites in Oakland and Fremont, and it showed that average levels of criteria air pollutants were comparable with the data from other two sites but exceeded the state standard for particulate matter (California Protection Agency, n.a.).

**Richmond (Contra Costa County)**

Richmond is in San Francisco Bay Area in Contra Costa County, California. The community which is in the zip code 94801 is one of the poorest in the state and is home to approximately 29,269 people according to 2010-2014 ASC 5-year. The community population is 47.7% White and 18.2% African-American (U.S. Census Bureau, 2015a). As per one of the health studies conducted for the community, the prevalence of asthma among children in Richmond was 17%, and this was significantly high when compared to the national average (7%). And the prevalence of asthma among adults who have lived in Richmond more than 15 years was 34.9%. This was much higher than those who were recent residents (9.2%) and the
national average (8.7%). Other notable health problems related to environmental air pollution were headache, eye irritation, and skin irritation. One of the worst environmental polluting industries in the area is Chevron which is in the zip code 94801. The industry stores over 11 million pounds of toxic and explosive chemicals. Chevron had 304 accidents between 1989 and 1995 which included an explosion, toxic gas releases, and air contamination and the latest explosion occurred in 2012. In 1993, Chevron increased its chemical storage and number of toxic chemicals in Richmond Area. According, to the company, they were just trying to comply with mandates of the Clean Air Act and the entire process was part of developing cleaner-burning gas. Unfortunately, proposed changes increased the risk for the local community and increased pollution due to industry contributed to higher rates of asthma and respiratory allergies and heart disease in the residents (Cohen, Lopez, Malloy and Morello-Forsch, 2012).

**Summary**

Cardiovascular and respiratory disease are the leading causes of death in the United States. Recently, as seen above, factors which affect the external environment in which a person lives, works and play has been shown to increase the risk for poor cardiovascular and respiratory health outcomes, over and above other individual-level factors (age, gender, and BMI). Residential proximity to industries and highways increases exposure to toxic pollutants in the air like carbon monoxide, sulfur dioxide, ozone, particulate matter etc. Cross-sectional and longitudinal studies which have been conducted in the past have consistently shown that there is a significant association between increased exposure to toxic pollutants due to living close to industries and highways and poor cardiovascular and respiratory health outcomes. Apart from the external environment, literature also showed that there are individual-level factors like age, gender, and BMI which are associated with the poor cardiovascular and respiratory health
outcomes. It was seen that cardiovascular disease was the leading cause of death for both men and women and variations were seen per racial/ethnic background as well. A positive association was also observed between BMI and increased risk for the cardiovascular disease. At the community level, factors like limited access to healthy food options and lack of recreation spaces like parks for exercise were also observed to be associated with poor health outcomes in the residents of a community. The evidence collected from the previous studies have promoted the use of various geographical information system (GIS) tools like unit hazard coincidence, buffer generation and risk-based approaches for quantitative analysis on the distribution of environmental pollutants. GIS tools have been used in various community levels studies conducted across the United States.

This study will examine whether there is any significant association between poor cardiovascular and/or respiratory health outcomes observed in the residents of one particular community located in the southeast of Newport News, Virginia and residential proximity to various environmental air pollution sources as well as individual-level risk factors using various GIS and statistical tools.
CHAPTER III

METHODOLOGY

The focus of the study was to examine the association between residential based exposure to environmental pollution sources and the poor cardiovascular and/or respiratory health outcomes in the residents of a community. Specifically, the study examined whether the distance of residence from various environmental pollution sources and number of years at the same residence were linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the Southeast Community of Newport News, Virginia. Further, the study also examined whether any of the individual-level risk factors (age, gender and body mass index (BMI)) were linked with the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

Research Questions

Specific research questions that were addressed in the study are as follows:

1. Is the distance of residence from environmental pollution sources linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?
1a. Is the distance of residence from industrial pollutant source linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?
1b. Is the distance of residence from traffic pollutant source linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?
2. Are the number of years at the same residence linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?
3. Are the individual-level risk factors (age, gender and body mass index (BMI)) linked with the poor cardiovascular and/or respiratory health outcomes in the residents of the community and do
the association observed between poor health outcomes in the residents and exposure to environmental pollution vary according to demographic factors?

**Hypotheses**

The specific hypotheses that were evaluated and tested in the research study are as follows:

**Hypothesis 1a**

$H_0$: The distance of residence from industrial pollutant source is not linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

$H_{1a}$: The distance of residence from industrial pollutant source is linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

**Hypothesis 1b**

$H_0$: The distance of residence from traffic pollutant source is not linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

$H_{1b}$: The distance of residence from traffic pollutant source is linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

**Hypothesis 2**

$H_0$: Number of years at the same residence are not linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

$H_2$: Number of years at the same residence are linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community.

**Hypothesis 3**

$H_0$: Individual-level risk factors (age, gender and body mass index (BMI)) are not linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community and do
not affect the association observed between poor health outcomes in the residents and exposure to environmental pollution.

H3: Individual-level risk factors (age, gender and body mass index (BMI)) are linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community and do affect the association observed between poor health outcomes in the residents and exposure to environmental pollution.

**Research Design**

This was a retrospective cross-sectional study aiming to explore the poor cardiovascular and/or respiratory health outcomes in a population at a given time. This would allow for evaluation of multiple outcomes/factors and exposures at the same time.

**Study Setting and Study Sample**

The study area was in Southeast Community in Newport News, Virginia. This community is approximately 4 miles long, 2 miles wide and defined by zip code 23607. It is home to approximately 22,825 people according to the 2010-2014 ACS 5-year estimates and representing nearly 13% of the Newport News population (U.S. Census Bureau, 2015a). A total of 302 residents participated in the study. The demographics and health outcomes data were obtained using surveys after getting informed consent.

**Power Analysis and Sample Size Calculation**

A priori power analysis was conducted based on logistic regression to determine the minimum sample size required for this study using Gpower version 3.1.9.2 (Faul, Erdfelder, Buchner, and Lang, 2009). Specifically, the power analysis was conducted based on the hypothesis that participants with closer distance to environmental pollution sources (distance to traffic) are more likely to have poor health outcomes. According to Table 2 of Garshick, Laden,
Hart, and Caron (2003), for subjects with various self-reported poor respiratory symptoms within residence ≤ 50 meters to road, 35.66% (184/516) had developed persistent wheeze, 25.04% (127/507) had developed chronic cough, and 28.83% (145/503) had developed chronic phlegm. Additionally, the odds ratios were 1.33 (persistent wheeze), 1.42 (chronic cough), and 1.35 (chronic phlegm) when comparing subjects with residence ≤ 50 meters to the road to subjects with residence > 400 meters to the road. A more recent study observed a 2-fold increase in poorly controlled asthma (OR = 2.11) among asthmatic adults in the highest quintile of traffic density after adjusting for age, sex, race, and poverty (Meng, Wilhelm, Rull, English, & Ritz, 2007).

Thus, the power analysis made the following assumptions: 1) distance to traffic is a categorical variable with two levels (< 0.09 mile vs. ≥ 0.09 mile) based on size of the study community and study sample distribution and 40% of subjects living < 0.09 mile to traffic would have poor health outcomes (poor cardiovascular and/or respiratory health outcome); 2) a medium effect size (Haddock, Rindskopf, & Shadish, 1998); 3) a multiple correlation of 0.1 between the predictor of interest and the others in the model (Hsieh, 1989). For a two-sided test with a significance level of 0.05 and a power of 0.8 to show that participants with closer distance to environmental pollution sources (distance to traffic) are more likely to have two 2-fold increase in poor health outcomes (OR = 2.11 from Meng et al., 2007), the minimum sample size needed for the study was 268.

**Survey Collection**

The data on demographics and health outcomes was collected by conducting surveys among the residents of the community. A pilot test was conducted with a group of residents for testing and evaluating the survey question and based on the responses, survey questions were
modified and re-written to avoid biased answers. Most of the survey questions were in multiple-choice format, whereby the residents could choose a best fitting response to the questions. The survey questions also asked residents for their birthdate, height and weight which were later used to calculate variables like age and body mass index (BMI) respectively of the residents for the study. The surveys were later distributed among the participants who attended the series of three symposia – "Is My Neighborhood Killing me?" as well as at local events and fairs. It was convenience sampling as sample included the residents who were willing to complete the survey. The participants were first given brief description and purpose of the survey, and if they were willing to participate, informed consent was given followed by the main survey. The surveys were completed by the residents themselves and to protect the confidentiality they were coded by removing any identifying information.

**Independent and Dependent Variables**

**Dependent Variable**

1. Poor cardiovascular (chest pain, heart murmur, irregular heartbeat, heart disease and high blood pressure) and/or respiratory (shortness of breath, wheezing, coughing, hoarseness, asthma, bronchitis) health outcomes in residents of the community.

**Independent Variables**

1. Distance of residence from the industrial pollutant source

2. Distance of residence from the traffic pollutant source

3. Number of years at the same residence

4. Age

5. Gender

6. Body Mass Index (BMI)
**Control**

1. Smoking
2. Alcohol consumption

---

**Table 1**

*Definitions of Variables (Theoretical and Operational)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Theoretical</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Presence of the poor cardiovascular and/or respiratory health outcomes in residents of community</td>
<td>Cardiovascular illness is a condition that affects the heart and blood vessels (chest pain, heart murmur, irregular heartbeat, heart disease and high blood pressure). Respiratory illness is a condition that affects the tissues and organs of the upper respiratory tract (shortness of breath, wheezing, coughing, hoarseness, asthma, bronchitis).</td>
<td>Self-reported yes to any of the respiratory or cardiovascular illness mentioned in a survey by individual (Categorical).</td>
</tr>
<tr>
<td><strong>Independent Variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Distance of residence from the industrial pollutant source</td>
<td>Distance is the length of the path connecting industrial pollutant source and residential location.</td>
<td>Distance in miles between the industrial pollutant source and individual residential location (Continuous).</td>
</tr>
<tr>
<td>2. Distance of residence from the traffic pollutant source</td>
<td>Distance is the length of the path connecting traffic pollutant source and residential location.</td>
<td>Shortest distance in miles between the Interstate 664 and individual residential location (Continuous).</td>
</tr>
<tr>
<td>3. Number of years at the same residence</td>
<td>Number of years at the same residence is the total number of years lived at the same location (house).</td>
<td>Self-reported number of years lived at the same residential location by an individual (Continuous).</td>
</tr>
<tr>
<td>4. Age</td>
<td>Age is the length of time in completed years that a person has lived (U.S. Census Bureau, 2013).</td>
<td>Self-reported age recorded in the survey (Continuous).</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Theoretical</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Gender</td>
<td>Gender is a social construction whereby a society or culture assigns certain tendencies or behaviors the labels of masculine or feminine (U.S. Census Bureau, 2012).</td>
<td>Self-reported gender recorded in the survey (Continuous).</td>
</tr>
<tr>
<td>6. Body Mass Index (BMI)</td>
<td>BMI is individual’s weight in kilograms divided by square of height in meters (Center for Disease Control and Prevention, 2015a).</td>
<td>The ratio of individual’s self-reported weight in kilograms to the square of self-reported height in meters (Continuous).</td>
</tr>
</tbody>
</table>

Control Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Theoretical</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Smoking</td>
<td>Smoking is inhalation of smoke by burning tobacco enclosed in cigarettes.</td>
<td>Self-reported yes to the smoking-related question in the survey (Categorical).</td>
</tr>
<tr>
<td>2. Alcohol consumption</td>
<td>Alcohol consumption is an intake of beverage in containing any form of alcohol such as beer, wine, etc.</td>
<td>Self-reported yes to the drinking-related question in the survey (Categorical).</td>
</tr>
</tbody>
</table>

Data Sources

The secondary data sources that were used in the study are as follows:

1. TIGER/Line® Shapefiles

   Topologically Integrated Geographic Encoding and Referencing (TIGER) products are spatial extracts from the Census Bureau's MAF/TIGER database containing features such as roads, railroads, rivers as well as legal and statistical geographical areas. The Census Bureau offers several file types and online mapping application. These files are designed for use with Geographic Information System (GIS) and provide full details of data for boundaries, roads,
address information, water features, etc (U.S. Census Bureau, 2015b). In this study TIGER/Line® Shapefiles of 2014 were used and the specific layers that were used are census tract, roads, and address-range feature shapefiles.

2. Surveys collected by CARE coalition

The demographic data for the study was extracted from the surveys conducted by the CARE coalition in 2013-2014

3. Toxic Release Inventory (TRI) data

The TRI from the United States Environmental Protection Agency (EPA) contains data on toxic chemical release from the industrial sources that may pose a threat to human health and the environment. Facilities in different industry sectors annually report their chemical release to TRI (United States Environmental Protection Agency, 2016b). In this study, 2014 TRI database was used to identify industrial sources in the community which report to the TRI and the total amount of pollutants released by them in the air.

4. Risk-Screening Environmental Indicators (RSEI) Model data

RSEI is a geographically-based model that helps policymakers and communities to quickly analyze large amounts of data on releases of the toxic substances from facilities in an area. RSEI data was used to extract the stack information (stack is the chimney or funnel which discharges the pollutants in the air) of the industrial sources present in the community which were identified using from the EPA's TRI (United States Environmental Protection Agency, 2016a). This information was used in the study to model the dispersion of the predicted concentration of the pollutants released into the air over the study area.
Methods

1. Geographic scale and resolution of study

The geographic extent of this study was the Southeast community in Newport News, Virginia. It comprised approximately 10 square miles of land mass. This community was selected as the study area because of the number of air pollutants released into the air. TRI recorded 193.9 thousand pounds of toxic air emission for the year 2014 (United States Environmental Protection Agency, 2016c). The unit of analysis for demographic and socioeconomic data were the residents of the community.

2. Environmental pollutant sources for the study

Major environmental pollution sources for the study were commercial industrial facilities operating in the community which release toxic air pollutants into the air. The emissions from such sources are recorded by the TRI. Facilities within certain Standard Industrial Classification (SIC) codes (chemical, printing, electronic, plastics, refining, metal, paper industry, etc.) must report their emission and waste to TRI if they meet certain conditions like manufacturing more than 25,000 pounds per year or using more than 10,000 pounds per year of one or more of the 650 listed toxic chemicals. And because of the high threshold limits in the reporting regulations, TRI includes only the largest emitters of the toxic substances. In some communities, facilities which individually are below the reporting threshold for quantities of emission may contribute to much more on a cumulative basis to overall air emission. As these facilities are not listed in publicly available data, it is difficult to obtain their data. Therefore, for this study, only the facilities who report to the TRI were included and others were excluded. Another major contributor to air pollution was the particulate matter due to vehicles accessing the interstate highway 665, which runs through the middle of the community.
3. Cardiovascular and/or respiratory health outcomes for the study

The unit of analysis for the cardiovascular and/or respiratory health outcomes were the individual who self-reported yes to any of the cardiovascular (chest pain, heart murmur, irregular heartbeat, heart disease and high blood pressure) and/or respiratory conditions (shortness of breath, wheezing, coughing, hoarseness, asthma, bronchitis) mentioned in the survey.

4. Geo-coding the residential location

Geo-referencing was used to plot the locations of residents on a map using GCS_North_American_1983 geographic coordinate system in the Arcgis®. The street addresses were geo-coded and transformed into latitude and longitude. The latitude and longitude allow geo-referencing and plotting the residential location without knowing the participant's address. Some of the data with incomplete or missing values were excluded from the study as they could not be transformed into latitude and longitude. Geo-coding or geo-referencing also poses risk to participant privacy and confidentiality as tools which perform "reverse geocoding" can easily generate an approximate address based on latitude and longitudes plotted on the map. So in order to address the issue of privacy and confidentiality, a map with the location of the residents was not published in the study and only used for calculating the proximity distances to environmental air pollution sources.

5. Assessment of exposure to air pollutants from industrial sources and traffic sources

There are national air quality standards for most of the criteria air pollutants and their concentrations can be measured in the ambient air using air quality monitoring stations. Currently, there is no air quality monitoring station in southeast Newport News to monitor and record the pollutants being released. The Gaussian model was used to predict the concentrations of the air pollutants in the community, which are released from TRI facilities. The Gaussian
model assumes that air pollutant dispersion has a normal probability distribution. They are most often used for predicting the dispersion of continuous air pollution plume originating from ground level or elevated sources. EPA's SCREEN3 is a single source Gaussian plume model which provides maximum ground level concentrations for point, area, flare and volume sources, as well as concentrations in cavity zone and concentration due to inversion break up and shoreline fumigation. Lakes Environmental Screen View™ which is a user-friendly interface for the US EPA SCREEN3 was used to model the ground level concentration of pollutants released in air from TRI reporting facilities. RSEI and EPA TRI database was used to extract the data of the stack height, stack velocity, and stack diameter and quantities of the chemicals released from the stack for the industrial sources in the study respectively. These parameters entered into Screen View™ along with default full meteorology factors with all stability classes and wind speeds and automated distances. The interface was run for the simple terrain and for all industrial pollutant sources identified in the study to get the predicted concentration of pollutants at each residential location.

Exposure to air pollutants from the industries was defined by the distance between each geocoded residential address and industries. The distance (in miles) was calculated using the Point Distance tool available in the Proximity Toolset in ArcGIS. The Point Distance tool measures the distance from input point feature (residential location) to other point features (industry) within a specified radius. And individual distances between the residential and traffic pollutant source (Interstate 664) was calculated using the Measurement tools in ArcGIS. The shortest length of the straight line connecting the residential location and the closest point on the Interstate 664 was used for exposure measure. Figure 5 represents an example of how these distances were measured.
Using the tabular tools within the GIS, proximity distances to the industrial pollutant source and traffic pollutant source which were calculated using the Point Distance and Measurement tool respectively were combined with the base Care Coalition demographic data set along with the predicted ground level concentrations of pollutants from the industrial sources calculated at residential locations. The combined data sets were imported into Microsoft Excel.
(Excel 2013; Microsoft, Seattle, WA) and SPSS (IBM Corp., Armonk, NY) for statistical analysis.

Descriptive statistics was computed for the demographic, health status and environmental air pollution variables. To test the significant difference between the continuous predictors, T-test was used. Pearson’s correlation coefficient was used to test for correlation between distance of residence from industry and predicted concentration of pollutants from the industry. Prevalence rates for poor cardiovascular and/or respiratory health outcomes were calculated for residents living at same residence for ≤ 15 years and > 15 years and Chi-square test was used for computing the statistical significance between two groups. And multiple logistic regression for binary response variable (Agresti, 2002) was employed for testing the association between independent and dependent variables. The following assumptions for logistic regression were tested before proceeding with the analysis (Stolzfus, 2011) and standardized z-scores were used for detecting any outliers in the study. Any z-score greater than 3 or less than -3 was considered outlier.

1. Dichotomous dependent variable: Dependent variable should be measured on the dichotomous scale.

2. Independence of errors: All sample group outcomes are separate from each other which indicates that there should be no duplicate responses.

3. Linearity in the logit for any continuous independent variable: There should be a linear relationship between continuous independent variable and their logit transformed outcomes. Box-Tidwell test was used to test for this assumption. Natural log was calculated for the continuous predictor and interaction between the variable and natural log was included in the
logistic regression model. If the interaction was significant, it indicated violation of the assumption.

4. Absence of multicollinearity among independent variables: Variables which are highly correlated should not be included in the same model.

5. Dependent variable should have mutually exclusive and exhaustive categories.

The outcome variable was the poor cardiovascular and/or respiratory health outcomes and the predictors included distances from residence to environmental air pollution sources (distance from industry 1, distance from industry 2, and distance from traffic), demographic factors (age, gender, and BMI). The variables were included in the model in different blocks in the following order using ENTER method and SIMPLE contrast was used for categorical variable.

Block 1: Smoking, Drinking (Control variables)

Block 2: Age, Gender, BMI (Individual-level risk factors)

Block 3: Distance of residence from industry 1, Distance of residence from industry 2, Distance of residence from traffic (Environmental air pollution variables)

The interaction effects of demographic factors and, distances from residence to environmental air pollution sources were included in the model in order to determine if the association between distances from residence to environmental air pollution sources (i.e., distance from industry 1, distance from industry 2, distance from traffic) varied according to demographic factors. Wald chi-square test statistics (Agresti, 2002) was used to determine if a predictor was statistically significant. A p-value less than 0.05 indicated significance and odds ratio estimates for the predictors and the corresponding 95% confidence intervals were also computed. Note that if the confidence interval for the odds ratios of a predictor does not contain
1, then it implies that the effect was significant. Hosmer-Lemeshow goodness-of-fit test (Agresti, 2002) was being used to determine the adequacy of the fitted model (a p-value > 0.05 indicated adequate model fit). All data analyses were conducted using SPSS version 23 (IBM Corp., Armonk, NY).

**Validation and Generalization of the Study**

The model used in the study has been derived for the study site, so to address the generalization and validation of the framework, it was applied to another setting, similar in makeup, to examine if it still holds valid when applied to another location. For this study, the model was applied to Richmond, California. This site was selected because it lies between major freeway that is significant sources of traffic pollutant emission similar to Interstate 664 in the study site and is also downwind to several industrial operations which are sources for toxic air pollutants similar to study site.
CHAPTER IV

RESULTS

The retrospective cross-sectional study was conducted to examine if there is any significant association of exposure to environmental air pollution sources and demographics with the poor cardiovascular and respiratory health outcomes in the Southeast community residents. Generalizability of the study was addressed by comparing the results obtained from study community with results from another community where residents were exposed to similar environmental air pollution sources and experienced similar health outcomes.

Descriptive Statistics

A total of 302 residents completed the survey. 37 residents had incomplete addresses which could not be geocoded and plotted on the map, therefore they were excluded from the study as it was not plausible to calculate their distance of residence from environmental air pollution sources. Of the remaining 265 residents, whose addresses could be correctly geocoded and plotted on the map, 26 were from other communities and were not included in the study as the study focused on the Southeast community in Newport News, VA. Furthermore, 15 of remaining 239 residents had missing or implausible values for the demographic data and were excluded from the study. Thus, the final sample size was 224.

Demographics of the residents. Table 2 summarizes the data on demographics of the Southeast community residents. Most of the residents were in the 21 – 40 years of age range (48.7%), African-American (91.3%), female (53.1%) and did not smoke (64.2%) or drink (63%). Further, 72.5% residents reported living in the community for less than 15 years.
Table 2

*Demographics of the Residents*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>≤ 20 years</td>
<td>4.9</td>
</tr>
<tr>
<td>21 – 40 years</td>
<td>48.7</td>
</tr>
<tr>
<td>41 – 60 years</td>
<td>32.1</td>
</tr>
<tr>
<td>≥ 61 years</td>
<td>14.3</td>
</tr>
<tr>
<td>Length of residence in community</td>
<td></td>
</tr>
<tr>
<td>&lt; 15 years</td>
<td>72.5</td>
</tr>
<tr>
<td>≥ 15 years</td>
<td>27.5</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>53.1</td>
</tr>
<tr>
<td>Male</td>
<td>46.9</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>91.3</td>
</tr>
<tr>
<td>White</td>
<td>4.7</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>0.4</td>
</tr>
<tr>
<td>Other</td>
<td>3.6</td>
</tr>
<tr>
<td>Poor</td>
<td>2.2</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>33.0</td>
</tr>
<tr>
<td>No</td>
<td>64.2</td>
</tr>
<tr>
<td>Quit more than six months ago</td>
<td>2.8</td>
</tr>
<tr>
<td>Drinking status</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>34.3</td>
</tr>
<tr>
<td>No</td>
<td>63.0</td>
</tr>
<tr>
<td>Quit more than six months ago</td>
<td>2.8</td>
</tr>
</tbody>
</table>
Health Status of the residents. Table 3 summarizes the data on health status of the residents of the community. 48.2% of residents were in underweight/normal BMI category and most of the residents had at least good health (62.8%) and did not report any poor cardiovascular health outcome (78.8%) or poor respiratory health outcomes (74.2%).

Table 3

Health Status of the Residents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass Index (BMI)</strong></td>
<td></td>
</tr>
<tr>
<td>Underweight/normal (18.5 &lt; BMI ≤ 24.9)</td>
<td>48.2</td>
</tr>
<tr>
<td>Overweight (25.0 &lt; BMI &lt; 29.9)</td>
<td>29.0</td>
</tr>
<tr>
<td>Obese (BMI≥30)</td>
<td>22.8</td>
</tr>
<tr>
<td><strong>Overall health</strong></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>19.7</td>
</tr>
<tr>
<td>Very good</td>
<td>23.8</td>
</tr>
<tr>
<td>Good</td>
<td>39.0</td>
</tr>
<tr>
<td>Fair</td>
<td>15.2</td>
</tr>
<tr>
<td>Poor</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Poor respiratory health outcome</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25.8</td>
</tr>
<tr>
<td>No</td>
<td>74.2</td>
</tr>
<tr>
<td><strong>Poor cardiovascular health outcome</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>21.3</td>
</tr>
<tr>
<td>No</td>
<td>78.7</td>
</tr>
<tr>
<td><strong>Poor cardiovascular and/or respiratory health outcome</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>39.7</td>
</tr>
<tr>
<td>No</td>
<td>60.3</td>
</tr>
</tbody>
</table>
Individual poor cardiovascular and respiratory health outcomes reported by the residents are summarized in Table 4. High blood pressure and chest pain were the top two poor cardiovascular health outcomes reported by the residents. And for poor respiratory health outcomes, shortness of breath, wheezing and bronchitis were the top three outcomes reported by the residents.

Table 4

*Individual Cardiovascular and Respiratory Health Outcomes of the Residents*

<table>
<thead>
<tr>
<th>Health Status</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor respiratory health outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>17.7</td>
<td>82.3</td>
</tr>
<tr>
<td>Wheezing</td>
<td>13.8</td>
<td>86.2</td>
</tr>
<tr>
<td>Coughing</td>
<td>11.3</td>
<td>88.7</td>
</tr>
<tr>
<td>Hoarseness</td>
<td>2.2</td>
<td>97.8</td>
</tr>
<tr>
<td>Sleep apnea</td>
<td>7.8</td>
<td>92.2</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>13.2</td>
<td>86.8</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>4.0</td>
<td>96.0</td>
</tr>
<tr>
<td>Others</td>
<td>2.2</td>
<td>97.8</td>
</tr>
<tr>
<td>Poor cardiovascular health outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest pain</td>
<td>10.9</td>
<td>89.1</td>
</tr>
<tr>
<td>Heart murmurs</td>
<td>3.0</td>
<td>97.0</td>
</tr>
<tr>
<td>Irregular heartbeat</td>
<td>4.3</td>
<td>95.7</td>
</tr>
<tr>
<td>Heart disease</td>
<td>3.4</td>
<td>96.6</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>20.4</td>
<td>79.6</td>
</tr>
<tr>
<td>Others</td>
<td>2.2</td>
<td>97.8</td>
</tr>
</tbody>
</table>
For this study, the continuous predictors (distance of residence from industry 1, distance of residence from industry 2, distance of residence from traffic pollutant source, BMI) were recorded into categorical variables. Predicted concentration of the pollutants (mainly volatile organic compounds (VOCs) such as n-butyl alcohol, xylene, toluene, methanol, etc.) from industry 1 and industry 2 were plotted against the distance of residence from the industry (Graph 1 and Graph 2). A significant negative correlation was observed between the distance of residence from industry and the predicted concentration of pollutants from industry which indicated that as the distance of residence increased from industry, predicted concentration of pollutants decreased (Table 5).

Graph 1. Plot of Predicted Concentration of Pollutants from Industry 1 vs. Distance of Residence from Industry 1
Figure 7. Gradient Map of Predicted Concentration of Pollutants from Industry 1
Graph 2. Plot of Predicted Concentration of Pollutants from Industry 2 vs. Distance of Residence from Industry 2
Figure 8. Gradient map of Predicted Concentration of Pollutants from Industry 2
Table 5

**Correlation Between Distance of Residence from Industry and Predicted Concentration of Pollutants from the Industry**

<table>
<thead>
<tr>
<th>Distance of residence from industry</th>
<th>Pearson Correlation</th>
<th>Predicted concentration of pollutants from industry 1</th>
<th>Predicted concentration of pollutants from industry 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>industry 1</td>
<td></td>
<td>-0.825**</td>
<td>-0.344**</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>224</td>
<td>224</td>
</tr>
<tr>
<td>industry 2</td>
<td></td>
<td>-0.355**</td>
<td>-0.759**</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>224</td>
<td>224</td>
</tr>
</tbody>
</table>

Concentration gradient maps created for the predicted concentration of the pollutants from the industry (Figure 6 and Figure 7) were used for categorization of the distance of residence from the industry. Distance of residence was grouped into two categories based on predicted concentration of pollutants: <180 g/sec and ≥ 180 g/sec. Categorization for the distance of residence from traffic was based on the literature review (English et al., 1999) because gradient mapping of the predicted concentration of pollutants from traffic was not possible due to the absence of air monitoring stations in the area. The distance of residence from the traffic pollutant sources was grouped into two categories: <0.09 mile and ≥ 0.09 mile as most of the dispersion models used for traffic pollutant source in previous study (English et al., 1999) indicated that 80-90% of pollutants decay between 492 – 665 ft (0.09 – 0.1 mile). And for the categorization of BMI, standards established by the Center for Disease Control and Prevention (CDC) standards (Center for Disease Control and Prevention, 2015a) were used:
underweight/normal (18.5 kg/m² < BMI ≤ 24.9 kg/m²), overweight (25.0 kg/m² < BMI < 29.9 kg/m²) and obese (BMI ≥ 30 kg/m²)

A two-way frequency table shows the distribution of data based on the above categories of the continuous predictors (Table 6). As observed from the table, 34% of residents (n = 76) and 58% (n = 180) lived in the area which had predicted concentration of pollutants released from industry 1 and industry 2 > 180 g/sec respectively. For the traffic pollutant source, 99.55% of residents were observed to live in ≥ 0.09 mile distance from the traffic. One of the plausibility for this could be that categorization of the predictor was based on values derived from literature review and resolution scale of the study which has been further addressed in discussion section later. 48.2% and 52.01% of residents were within normal/underweight and overweight/obese BMI category respectively.

Table 6

Two-way Frequency Tables of Cases and Categorical Predictors

<table>
<thead>
<tr>
<th>Poor cardiovascular and/or respiratory health outcomes</th>
<th>Yes (n = 89)</th>
<th>No (n = 135)</th>
<th>Total (n = 224)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from industry 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 180 g/sec</td>
<td>29</td>
<td>47</td>
<td>76</td>
</tr>
<tr>
<td>≤ 180 g/sec</td>
<td>60</td>
<td>88</td>
<td>148</td>
</tr>
<tr>
<td>Distance from industry 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 180 g/sec</td>
<td>57</td>
<td>73</td>
<td>130</td>
</tr>
<tr>
<td>≤ 180 g/sec</td>
<td>32</td>
<td>62</td>
<td>94</td>
</tr>
<tr>
<td>Distance from traffic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 0.09 mile</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>≥ 0.09 mile</td>
<td>89</td>
<td>134</td>
<td>223</td>
</tr>
</tbody>
</table>
Table 6. (continued)

<table>
<thead>
<tr>
<th>Poor cardiovascular and/or respiratory health outcomes</th>
<th>Yes (n = 89)</th>
<th>No (n = 135)</th>
<th>Total (n = 224)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight/normal</td>
<td>38</td>
<td>70</td>
<td>108</td>
</tr>
<tr>
<td>Overweight</td>
<td>18</td>
<td>47</td>
<td>65</td>
</tr>
<tr>
<td>Obese</td>
<td>33</td>
<td>18</td>
<td>51</td>
</tr>
</tbody>
</table>

**Descriptive statistics of continuous predictors.** Table 7, Table 8 and Table 9 present the descriptive statistics of the continuous predictors in the study by poor respiratory health outcome, poor cardiovascular health outcomes and both poor cardiovascular and/or respiratory health outcomes, respectively. No statistically significant effect was observed for any of the predictors when the residents who reported poor respiratory outcomes were compared to those who did not report poor respiratory health outcome (Table 7). A significant effect was observed for age ($p = 0.009$) and BMI ($p = 0.03$) in residents who reported poor cardiovascular health outcomes compared to those who did not report poor cardiovascular health outcomes (Table 8). And significant effect was again observed for BMI ($p = 0.002$) when both poor cardiovascular and/or respiratory health outcomes were considered (Table 9).
### Table 7

**Descriptive Statistics of Continuous Predictors by Poor Respiratory Health Outcome**

<table>
<thead>
<tr>
<th></th>
<th>Yes (n = 55)</th>
<th>No (n = 158)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from industry 1 (mile)</td>
<td>1.48 (1.07)</td>
<td>1.42 (0.87)</td>
<td>0.64</td>
</tr>
<tr>
<td>Distance from industry 2 (mile)</td>
<td>1.03 (1.49)</td>
<td>0.99 (1.22)</td>
<td>0.86</td>
</tr>
<tr>
<td>Distance from traffic (mile)</td>
<td>0.58 (1.25)</td>
<td>0.57 (1.02)</td>
<td>0.96</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 1 (µg/m³)</td>
<td>165.91 (43.25)</td>
<td>168.23 (37.83)</td>
<td>0.70</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 2 (µg/m³)</td>
<td>180.51 (52.84)</td>
<td>181.70 (48.75)</td>
<td>0.87</td>
</tr>
<tr>
<td>Age (year)</td>
<td>44.31 (16.51)</td>
<td>40.28 (16.06)</td>
<td>0.11</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.24 (8.31)</td>
<td>25.87 (6.17)</td>
<td>0.05</td>
</tr>
</tbody>
</table>

N = 213 (data with only respiratory health outcome); SD = standard deviation; *Significant at p<0.05 level

### Table 8

**Descriptive Statistics of Continuous Predictors by Poor Cardiovascular Health Outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Yes (n = 47)</th>
<th>No (n = 174)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from industry 1 (mile)</td>
<td>1.46 (1.00)</td>
<td>1.38 (0.75)</td>
<td>0.54</td>
</tr>
<tr>
<td>Distance from industry 2 (mile)</td>
<td>0.94 (1.33)</td>
<td>0.97 (1.08)</td>
<td>0.86</td>
</tr>
<tr>
<td>Distance from traffic (mile)</td>
<td>0.54 (1.15)</td>
<td>0.54 (0.88)</td>
<td>0.96</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 1 (µg/m³)</td>
<td>165.60 (39.57)</td>
<td>169.98 (37.95)</td>
<td>0.48</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 2 (µg/m³)</td>
<td>190.70 (47.27)</td>
<td>178.67 (48.11)</td>
<td>0.12</td>
</tr>
<tr>
<td>Age (year)</td>
<td>47.06 (18.14)</td>
<td>39.30 (15.33)</td>
<td>0.009*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.67 (8.16)</td>
<td>25.83 (6.40)</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

N = 221 (data with only cardiovascular health outcome); SD = standard deviation; *Significant at p<0.05 level
Table 9

Descriptive Statistics of Continuous Predictors in the Study by Poor Cardiovascular and/or Respiratory Health Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Yes (n = 89)</th>
<th>No (n = 135)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Distance from industry 1 (mile)</td>
<td>1.41 (0.87)</td>
<td>1.43 (0.94)</td>
<td>0.84</td>
</tr>
<tr>
<td>Distance from industry 2 (mile)</td>
<td>0.91 (1.20)</td>
<td>1.06 (1.31)</td>
<td>0.35</td>
</tr>
<tr>
<td>Distance from traffic (mile)</td>
<td>0.50 (1.00)</td>
<td>0.61 (1.10)</td>
<td>0.46</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 1(µg/m³)</td>
<td>168.42 (39.52)</td>
<td>168.56 (39.26)</td>
<td>0.97</td>
</tr>
<tr>
<td>Concentration of pollutants from industry 2 (µg/m³)</td>
<td>186.69 (47.10)</td>
<td>176.97 (50.34)</td>
<td>0.14</td>
</tr>
<tr>
<td>Age (year)</td>
<td>44.45 (16.63)</td>
<td>38.51 (15.57)</td>
<td>0.07</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.34 (7.67)</td>
<td>25.26 (6.16)</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

N = 224(data with cardiovascular and/or respiratory health outcome); SD = standard deviation; *Significant at p<0.05 level

Logistic Regression

Standardized z-score test detected 6 outliers in study data with z-score greater than 3. These outliers could have resulted from error in the geocoding process and therefore they were dropped out during data cleaning and analyzing process. Further, the following assumptions were met which indicated that study data was good fit for the logistic regression model:

1. Dependent variable was poor cardiovascular and/or respiratory health outcome which was dichotomous (Yes or No).
2. All sample group outcomes were separate from each other with no duplicate responses.
3. Interaction between continuous predictor and its natural log was not significant which indicated that assumption of linearity was met.
4. Highly correlated variables were not included in same model (for example, weight and BMI).

5. Dependent variable had mutually exclusive and exhaustive categories.

An interaction between the demographic factors and distances from residence to environmental air pollution sources was examined before conducting the main effects model. The distance of residence from the traffic pollutant source was not included in any of the regression model since no residents with poor cardiovascular and/or respiratory health outcome lived in < 0.09 mile away from the traffic. Table 10 shows the results of the logistic regression with the interaction effects. None of the interactions among factors was statistically significant (p > 0.05) thus indicating that any association between poor cardiovascular and/or respiratory health outcomes and environmental air pollution (i.e., distance of residence from industry 1, distance of residence from industry 2, distance of residence from traffic) was independent of the individual-level risk factors (age, gender, and BMI).

Table 10

Results of Logistic Regression (with Interaction Effects)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.44</td>
<td>0.35</td>
<td>1.55</td>
<td>1</td>
<td>0.21</td>
<td>1.56</td>
<td>0.77</td>
</tr>
<tr>
<td>Drinking</td>
<td>0.47</td>
<td>0.35</td>
<td>1.79</td>
<td>1</td>
<td>0.18</td>
<td>1.60</td>
<td>0.80</td>
</tr>
<tr>
<td>Gender</td>
<td>-2.24</td>
<td>1.50</td>
<td>2.22</td>
<td>1</td>
<td>0.13</td>
<td>0.10</td>
<td>0.96</td>
</tr>
<tr>
<td>Age</td>
<td>0.02</td>
<td>0.03</td>
<td>0.61</td>
<td>1</td>
<td>0.43</td>
<td>1.02</td>
<td>0.00</td>
</tr>
<tr>
<td>BMI</td>
<td>6.99</td>
<td></td>
<td>2</td>
<td>0.03*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI(1)</td>
<td>-0.54</td>
<td>0.42</td>
<td>1.58</td>
<td>1</td>
<td>0.20</td>
<td>0.58</td>
<td>0.25</td>
</tr>
<tr>
<td>BMI(2)</td>
<td>0.76</td>
<td>0.66</td>
<td>1.30</td>
<td>1</td>
<td>0.25</td>
<td>2.14</td>
<td>0.57</td>
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<tr>
<td>Distance from</td>
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<td>0.56</td>
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<td>2.01</td>
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<tr>
<td>industry 1</td>
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</table>
Table 10 (continued)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
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<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI</th>
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<tbody>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Distance from industry 2</td>
<td>0.25</td>
<td>0.41</td>
<td>0.39</td>
<td>1</td>
<td>0.53</td>
<td>1.29</td>
<td>0.57</td>
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<td>2.91</td>
</tr>
<tr>
<td>Age by Distance from industry 1</td>
<td>0.01</td>
<td>0.02</td>
<td>0.31</td>
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<td>0.57</td>
<td>1.01</td>
<td>0.96</td>
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<tr>
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<tr>
<td>Age by Distance from industry 2</td>
<td>-0.02</td>
<td>0.02</td>
<td>1.68</td>
<td>1</td>
<td>0.19</td>
<td>0.97</td>
<td>0.93</td>
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<td>1.01</td>
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<td>Age by Distance from traffic</td>
<td>-0.01</td>
<td>0.03</td>
<td>0.14</td>
<td>1</td>
<td>0.70</td>
<td>0.98</td>
<td>0.92</td>
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<tr>
<td>Gender by Distance from industry 1</td>
<td>1.39</td>
<td>1.16</td>
<td>1.44</td>
<td>1</td>
<td>0.23</td>
<td>4.02</td>
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<td>39.16</td>
</tr>
<tr>
<td>Gender by Distance from industry 1</td>
<td>1.11</td>
<td>0.76</td>
<td>2.09</td>
<td>1</td>
<td>0.14</td>
<td>3.03</td>
<td>0.67</td>
</tr>
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<td>13.65</td>
</tr>
<tr>
<td>Gender by Distance from traffic</td>
<td>-1.25</td>
<td>1.35</td>
<td>0.85</td>
<td>1</td>
<td>0.35</td>
<td>0.28</td>
<td>0.02</td>
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<td>4.06</td>
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<tr>
<td>BMI by Distance from industry 1</td>
<td>0.01</td>
<td>0.03</td>
<td>0.08</td>
<td>1</td>
<td>0.77</td>
<td>1.01</td>
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<td>BMI by Distance from industry 1</td>
<td>0.03</td>
<td>0.03</td>
<td>0.87</td>
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<td>0.35</td>
<td>1.03</td>
<td>0.96</td>
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<td>1.10</td>
</tr>
<tr>
<td>BMI Distance from traffic</td>
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<td>0.05</td>
<td>0.01</td>
<td>1</td>
<td>0.92</td>
<td>0.99</td>
<td>0.89</td>
</tr>
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</tr>
<tr>
<td>Constant</td>
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<td>1.16</td>
<td>2.52</td>
<td>1</td>
<td>0.11</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

Note: B = parameter estimate; SE = standard deviation; Wald = Wald chi-square statistic; DF = degree of freedom; p = p-value.

As no interaction existed among the factors, only the main effects of the predictors were included in a logistic regression model to assess their association with poor respiratory health outcome, poor cardiovascular health outcome, and poor cardiovascular and/or respiratory health outcomes. The results of the Hosmer-Lemeshow goodness-of-fit for all the three models indicated that model fit was appropriate (p = 0.965; p = 0.99; p = 1.00 respectively).

There was no significant association observed between the environmental pollution sources (distances of residence from industry 1 and the distances of residence from industry 2) and poor respiratory health outcomes, poor cardiovascular health outcome and poor
cardiovascular and/or respiratory health outcomes. (Table 11, Table 12, Table 13). For the individual-level risk factors, significant positive association was observed between poor respiratory health outcome and the obese category of the BMI (OR = 2.36; 95% CI = (1.02 – 5.44); p = 0.04) (Table 11). Residents with BMI ≥ 30 kg/m² reported 2.36 times more poor respiratory health outcomes compared to residents with BMI ≤ 24.9 kg/m². Significant positive association was observed between age (OR = 1.02; 95% CI = (1.00 – 1.05); p = 0.02) and obese category of BMI (OR = 2.74; 95% CI = (1.09 – 6.85); p = 0.03) and poor cardiovascular health outcomes (Table 12). Older residents with BMI ≥ 30 kg/m² reported 1.02 times and 2.74 times more poor cardiovascular health outcomes respectively. When both cardiovascular and respiratory health outcomes were considered, significant positive association was observed with obese category of BMI (OR = 3.03; 95% CI = (1.37 – 6.71); p = 0.01) (Table 13). 3.03 times more poor cardiovascular and/or respiratory health outcomes were reported by resident with BMI ≥ 30 kg/m² compared to residents with BMI ≤ 24.9 kg/m².

Table 11

Results of Logistic Regression (without Interaction Effects) for Poor Respiratory Health Outcomes

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.35</td>
<td>0.38</td>
<td>0.84</td>
<td>1</td>
<td>0.35</td>
<td>1.42</td>
<td>0.66</td>
</tr>
<tr>
<td>Drinking</td>
<td>0.003</td>
<td>0.38</td>
<td>0.00</td>
<td>1</td>
<td>0.99</td>
<td>1.00</td>
<td>0.47</td>
</tr>
<tr>
<td>Age</td>
<td>0.01</td>
<td>0.01</td>
<td>1.10</td>
<td>1</td>
<td>0.29</td>
<td>1.01</td>
<td>0.99</td>
</tr>
<tr>
<td>Gender</td>
<td>0.45</td>
<td>0.34</td>
<td>1.72</td>
<td>1</td>
<td>0.19</td>
<td>1.58</td>
<td>0.79</td>
</tr>
<tr>
<td>BMI</td>
<td>11.24</td>
<td>2</td>
<td>0.00*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI(1)</td>
<td>0.81</td>
<td>0.46</td>
<td>3.11</td>
<td>1</td>
<td>0.07</td>
<td>0.44</td>
<td>0.18</td>
</tr>
<tr>
<td>BMI(2)</td>
<td>0.85</td>
<td>0.42</td>
<td>4.05</td>
<td>1</td>
<td>0.04*</td>
<td>2.36</td>
<td>1.02</td>
</tr>
</tbody>
</table>
| Distance of residence from industry 1 | 0.01 | 0.39 | 0.001 | 1 | 0.97 | 1.01 | 0.46 | 2.21
Table 11 (continued)

<table>
<thead>
<tr>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Distance of residence from industry 2</td>
<td>-0.10</td>
<td>0.39</td>
<td>0.06</td>
<td>1</td>
<td>0.79</td>
<td>9.00</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.53</td>
<td>0.53</td>
<td>8.18</td>
<td>1</td>
<td>0.00</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Note: B = parameter estimate; SE = standard deviation; Wald = Wald chi-square statistic; DF = degree of freedom; p = p-value; CI = confidence interval. *indicates significance at < 0.05 level. The probability of "cases = yes" was modeled. For BMI, "underweight and normal" was the reference group; for gender, the male was the reference group; for the distance from industry 1 and distance from industry 2, "≥1 mile" was the reference group and for the distance from traffic "≥0.09 mile" was the reference group.

Table 12

Results of Logistic Regression (without Interaction Effects) for Poor Cardiovascular Health Outcomes

<table>
<thead>
<tr>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.85</td>
<td>0.40</td>
<td>4.44</td>
<td>1</td>
<td>0.03*</td>
<td>2.35</td>
</tr>
<tr>
<td>Drinking</td>
<td>0.47</td>
<td>0.40</td>
<td>1.35</td>
<td>1</td>
<td>0.24</td>
<td>1.60</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.45</td>
<td>0.38</td>
<td>1.42</td>
<td>1</td>
<td>0.23</td>
<td>0.63</td>
</tr>
<tr>
<td>Age</td>
<td>0.02</td>
<td>0.01</td>
<td>5.02</td>
<td>1</td>
<td>0.02*</td>
<td>1.02</td>
</tr>
<tr>
<td>BMI</td>
<td>5.68</td>
<td>2</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (1)</td>
<td>0.01</td>
<td>0.45</td>
<td>0.00</td>
<td>1</td>
<td>0.98</td>
<td>1.01</td>
</tr>
<tr>
<td>BMI (2)</td>
<td>1.00</td>
<td>0.46</td>
<td>4.64</td>
<td>1</td>
<td>0.03*</td>
<td>2.74</td>
</tr>
<tr>
<td>Distance of residence from industry 1</td>
<td>-0.12</td>
<td>0.43</td>
<td>0.08</td>
<td>1</td>
<td>0.76</td>
<td>0.88</td>
</tr>
<tr>
<td>Distance of residence from industry 2</td>
<td>0.45</td>
<td>0.43</td>
<td>1.09</td>
<td>1</td>
<td>0.29</td>
<td>1.56</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.36</td>
<td>0.57</td>
<td>17.19</td>
<td>1</td>
<td>0.00</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: B = parameter estimate; SE = standard deviation; Wald = Wald chi-square statistic; DF = degree of freedom; p = p-value; CI = confidence interval. *indicates significance at < 0.05 level. The probability of "cases = yes" was modeled. For BMI, "underweight and normal" was the reference group; for gender, the male was the reference group; for the distance from industry 1 and distance from industry 2, "≥1 mile" was the reference group and for the distance from traffic "≥0.09 mile" was the reference group.
Table 13

Results of Logistic Regression (without Interaction Effects) for Poor Cardiovascular and/or Respiratory Health Outcomes

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>DF</th>
<th>p</th>
<th>Odds Ratio</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking</td>
<td>0.47</td>
<td>0.34</td>
<td>1.89</td>
<td>1</td>
<td>0.16</td>
<td>1.60</td>
<td>0.81</td>
<td>3.16</td>
</tr>
<tr>
<td>Drinking</td>
<td>0.48</td>
<td>0.34</td>
<td>1.98</td>
<td>1</td>
<td>0.15</td>
<td>1.61</td>
<td>0.82</td>
<td>3.16</td>
</tr>
<tr>
<td>Age</td>
<td>0.01</td>
<td>0.01</td>
<td>3.03</td>
<td>1</td>
<td>0.08</td>
<td>1.01</td>
<td>0.99</td>
<td>1.03</td>
</tr>
<tr>
<td>Gender</td>
<td>0.01</td>
<td>0.30</td>
<td>0.00</td>
<td>1</td>
<td>0.95</td>
<td>1.01</td>
<td>0.55</td>
<td>1.86</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td>13.08</td>
<td>2</td>
<td>0.00*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI(1)</td>
<td>0.44</td>
<td>0.36</td>
<td>1.47</td>
<td>1</td>
<td>0.22</td>
<td>0.64</td>
<td>0.31</td>
<td>1.31</td>
</tr>
<tr>
<td>BMI(2)</td>
<td>1.11</td>
<td>0.40</td>
<td>7.49</td>
<td>1</td>
<td>0.01*</td>
<td>3.03</td>
<td>1.37</td>
<td>6.71</td>
</tr>
<tr>
<td>Distance of residence from industry 1</td>
<td>0.15</td>
<td>0.34</td>
<td>0.20</td>
<td>1</td>
<td>0.65</td>
<td>1.16</td>
<td>0.59</td>
<td>2.30</td>
</tr>
<tr>
<td>Distance of residence from industry 2</td>
<td>0.41</td>
<td>0.34</td>
<td>1.44</td>
<td>1</td>
<td>0.23</td>
<td>1.50</td>
<td>0.77</td>
<td>2.94</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.92</td>
<td>0.45</td>
<td>4.08</td>
<td>1</td>
<td>0.04</td>
<td>0.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: B = parameter estimate; SE = standard deviation; Wald = Wald chi-square statistic; DF = degree of freedom; p = p-value; CI = confidence interval. *indicates significance at < 0.05 level. The probability of "cases = yes" was modeled. For BMI, "underweight and normal" was the reference group; for gender, the male was the reference group; for the distance from industry 1 and distance from industry 2,"≥1 mile" was the reference group and for the distance from traffic "≥0.09 mile" was the reference group.

The residents living in the community for 15 years or more were observed to have higher prevalence rates of poor respiratory health outcomes, poor cardiovascular health outcomes and poor cardiovascular and/or respiratory health outcomes compared to those who were living in the community for less than 15 years (Table 14).
Table 14

Results of Prevalence Rates (< 15 Years vs ≥ 15 Years at Same Residence)

<table>
<thead>
<tr>
<th>Number of years at same residence</th>
<th>Poor cardiovascular/and or respiratory health outcomes (%)</th>
<th>Poor respiratory health outcome (%)</th>
<th>Poor cardiovascular health outcome (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15 years</td>
<td>38.06</td>
<td>23.22</td>
<td>18.70</td>
</tr>
<tr>
<td>≥15 years</td>
<td>43.33</td>
<td>28.33</td>
<td>25.00</td>
</tr>
<tr>
<td>p</td>
<td>0.48</td>
<td>0.43</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*denominator = total population at that given time

Study Generalization

Richmond is located in the San Francisco Bay across from the Richmond – San Rafael Bridge in the Contra Costa county, California. The community which resides in North Richmond, particularly in the zip code 94801 is one of the poorest in the state, and it is home to approximately 29,269 people according to the 2010-2014 ACS 5-year estimates and representing nearly 27% of the Richmond City population (U.S. Census Bureau, 2015a). Richmond has a long history of industrial air pollution, and the residents have been burdened by the impacts of air pollution due to two major industries and a freeway present. Richmond Health Survey was conducted to document health outcomes of the residents of the community and their perception about the environmental air pollution sources present in the community. Residents from four neighborhoods which are in the zip code 94801 were invited to participate in the Richmond Health Survey. A total of 198 households were surveyed with an average of 3.65 residents per household. Therefore, total data was collected for 722 residents out of which 282 were children (less than 18 years of age) and those who smoked were ineligible for the study because of the
significant correlation of smoking with the health outcomes (CBE, 2009; Cohen, 2012). Table 16 summarizes the data on demographics of residents of the community who participated in the Richmond Health Survey.

Table 15

Demographics of the Residents of the Community in North Richmond

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>82.3</td>
</tr>
<tr>
<td>Male</td>
<td>17.7</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td>23.0</td>
</tr>
<tr>
<td>White</td>
<td>11.2</td>
</tr>
<tr>
<td>Hispanics/Latino</td>
<td>64.7</td>
</tr>
<tr>
<td>Other</td>
<td>1.1</td>
</tr>
</tbody>
</table>

79% of residents within one mile of industry were observed to be African-American. The majority of the residents responded with their health being good or fair (Table 17), and some of the major health concerns identified among residents were respiratory health issues particularly asthma and respiratory allergies. 93.4% of residents identified the link between air pollution in the community and poor health outcomes. An oil refinery was identified as the most common source of air pollution followed by traffic by the residents (CBE, 2009).
Table 16

*Overall Health Status of the Residents of the Community in North Richmond*

<table>
<thead>
<tr>
<th>Overall health</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>12</td>
</tr>
<tr>
<td>Good</td>
<td>38</td>
</tr>
<tr>
<td>Fair</td>
<td>39</td>
</tr>
<tr>
<td>Poor</td>
<td>11</td>
</tr>
</tbody>
</table>

The Richmond Health Survey reported separate data for chronic health outcomes, especially asthma and other respiratory allergies by adults (n = 440) and children (n = 282) as the prevalence of respiratory health outcomes varied based on age. The survey data showed that prevalence of asthma among adults was 9.1% and it was found to be correlated with the length of time the resident had lived in Richmond. It was observed that for life-long residents (number of years at same residence = 20 years), the rate of asthma was 45%. A statistically significant difference was observed between the asthma rates for those who lived in Richmond for five years or less and those who lived in Richmond for their entire life (CBE, 2009; Cohen 2012).

For study generalization, the current study was compared with the Richmond study. For the current study, majority of the population was observed to be African-American (91.3%) and females (53.1%) while, for Richmond study majority of the population was observed to be Hispanics/Latinos (64.7%) and females (82.3%). Majority of residents for both the studies reported their overall health status to be good. Both the study sites were observed to be impacted by similar environmental pollution sources such as TRI reporting industries and major freeway. Further majority of the population residing within 1 mile of these industries was observed to be African-American in both the studies. Poor respiratory health outcomes were the common
identified health problems for Newport News and Richmond study and for both the length of stay was observed to be correlated with the poor health outcomes and long-term residents were observed to have higher rates for poor health outcomes compared to short-term residents. When compared at state level, rates for individual-level risk factor such as obesity were found to be higher. Newport News City reported 34% for adult obesity compared to 28% for Virginia while Contra Costa County reported 24% for adult obesity compared to 23% for California (County Health Rankings & Roadmaps, 2018). Further at national level (428.4 per 100,000), Newport News City was found to have higher rates (433.8 per 100,000) for heart disease than Contra Coast County (341.2 per 100,000) (Center for Disease Control and Prevention, 2017).
CHAPTER V
DISCUSSION AND CONCLUSION

The primary purpose of this study was to examine the association between factors like residential based exposure to environmental air pollution sources, the number of years spent at the same residence and demographic factors with the poor cardiovascular and/or respiratory health outcomes observed in the residents of the Southeast Community of Newport News, Virginia. Chapter V will present discussion of results by each research question followed by limitations of the study and health policy implications. The chapter will conclude with a section on recommendations for future studies.

Discussion of Research Question 1

Is the distance of residence from environmental pollution sources linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?

1a. Is the distance of residence from industrial pollutant source linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?

1b. Is the distance of residence from traffic pollutant source linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?

The current study did not observe any significant association between the distance of residence from industrial pollutant source and poor cardiovascular and/or respiratory health outcomes in the current study which could be due to some of the plausibility as discussed below. The strength of the current study was that it looked at the association between the distance of residence from the two major TRI reporting industries present in the area and poor cardiovascular and/or respiratory health outcomes using GIS. Ground level concentrations of the pollutants from both the industries were modeled using Lakes Environmental Screen View™,
which uses the principles of Gaussian plume modeling and after that geostatistical analyst extension (kriging) within ArcGIS was used to develop a set of contour lines representing the predicted concentration of pollutants, mainly of volatile organic compounds (VOCs) for entire study area. Using built-in user-defined parameters, kriging interpolates lines which represent locations with same pollutant concentration magnitude. The distance of residence from both the industries was categorized based on the concentration gradient map rather than arbitrary buffers. Geographical information system (GIS) has been used at varying levels in environmental health studies. Its use ranges from simply geocoding addresses of the study population to using proximity to pollutant source as a surrogate measure for exposure to integrating environmental monitoring data for analysis of health outcomes (Comba et al., 2003; Floret et al., 2003; Nuckols, Ward and Jarup, 2004). The use of GIS in spatial statistics for linking exposure data with health outcomes data is a fairly new growing research field. Always there is a constant contact between the air pollutant and human respiratory system, thus leading to exposure and GIS tools are commonly used for assessing this exposure to air pollution. Exposure modeling is a logical construct which allows estimation of individual’s exposure to air pollutants from available input data. The main purpose of such exposure models is to develop a real-world scenario of human exposure to air pollutants over time and consequently assess the health outcomes. When compared to direct air pollution models, one of the advantage of exposure modeling as used in the current study is that they can be used to supplement the monitoring data when direct measurements are not available. Exposure modeling can also assist in predicting future exposures and complexity of the model can be altered as per needs. And expenses associated with the source-intensive monitoring programs can be significantly reduced with exposure modeling. Air dispersion models also known as air pollution dispersion models incorporate
emission data and basic meteorological data to predict the concentration of pollutants over space and time. Over the past decade, air dispersion models have been integrated with GIS to depict individual exposure to air pollutants more accurately by combining residence location and air pollutant concentration data (Zou et al., 2009).

Data from epidemiological studies indicate that respiratory and cardiovascular systems are primarily affected by toxic air pollutants (Cohen et al., 2005; Huang and Ghio, 2006; Kunzli and Tager, 2005; Sharma and Agrawal, 2005). The toxic air pollutants differ in their chemical composition, their ability to be transported over short or long distance, their persistence in the environment and their overall effect on the human health. Some of the factors that can lead to different health outcomes are a different composition of air pollutants, dose and time of exposure and humans being exposed to pollutant mixture rather than a single pollutant. Most of them share some similar properties and therefore are grouped into four main categories: gaseous pollutants, persistent organic pollutants, heavy metals and particulate matter. Particulate matter in the air has been found to be associated with the mortality and morbidity from cardiovascular disease. Some of the possible mechanism observed behind these associations are oxidative stress and inflammation and vasomotor dysfunctions.

VOCs are the common type of gaseous pollutants present in the air and the health effects of VOCs depend on the type of VOC, level of exposure and the length of exposure. Long-term exposure to VOCs can cause central nervous system, kidney, and liver damage while short-term exposure to VOCs can cause eye and respiratory tract irritation, headache, dizziness, visual disorders, fatigue, loss of coordination, nausea, allergic skin reaction and memory impairment (U. S. National Library of Medicine, 2017). Xylene which was one of the main VOC reported being released in the air by industry 1 is found to cause difficulty in breathing, problems in lungs
along with irritation to nose, eyes, throat and skin (Agency for Toxic Substances and Disease Registry, 2008). 42.4% of the total residents had reported to having poor health outcomes such as shortness of breath, wheezing and chest pain which are found to be associated with exposure to xylene as mentioned.

The transportation equipment manufacturing company (industry 1) was identified as the major source of pollution in the community followed by nonmetallic mineral product producer (industry 2). Gaseous pollutants, particularly the VOCs were the major class of pollutants released by the industries and present in the air over the community which are formed by the combustion process. 221,973 lbs of total toxic pollutants were released by industry 1, in which VOCs like n-butyl alcohol (70,807 lbs) and xylene (32,849 lbs) were the top two chemicals released in terms of quantity while industry 2 released 71,314 lbs of total toxic pollutants which had VOCs such as methanol (30,924 lbs) and toluene (40,390 lbs) (United States Environmental Protection Agency, 2017). Set of contour lines indicated the decrease in the predicted concentration of VOCs as the distance from both industries increased (Figure 9 and Figure 10). 33% and 64% of residents had reported having poor cardiovascular and/or respiratory health outcomes who lived in an area with > 180 g/sec predicted concentration of pollutants released from industry 1 and industry 2 respectively.
Figure 9. Contours of Predicted Concentration of Pollutants from Industry 1
Concentration gradients observed in the current study which is conducted at the zip code level could be substantially influenced by the resolution of the scale and could be one of the possible reasons for the observed lack of association. Air toxic and TRI studies conducted previously have taken advantages of spatial mapping to assess how the resolution of geographic levels affect the results. Summarizing all those studies Lopez (2002) explained the results of air
dispersion model studies often differ based on the geographic unit used in the analysis. For example, Dolinoy and Miranda conducted air dispersion modeling of releases from TRI reporting as well as non-TRI reporting facilities at four levels of geographic resolution in Durham County, North Carolina. Kriging results from the study showed that the range of concentration at census block level was greater than the range of concentrations observed at zip code level. Further, modeling exposure at census block revealed neighborhood level hot spots which were not apparent at zip code level (Dolinoy and Miranda, 2004).

Exposure to air pollution due to residential proximity to sources like major roads along with above mentioned TRI reporting industries is found to be associated with poor cardiovascular health outcomes such as stroke as well as poor respiratory health outcomes like asthma and self-reported outcomes such as wheezing (Oosterlee et al, 1996; Van Vliet et al, 1997; Venn et al, 2001). There is growing evidence that proximity to traffic is an accurate surrogate for exposure to traffic-related air pollution (Miyake, Yura, and Iki, 2002; Venn et al, 2005). Our study used the proximity to main road present in the community as a measure of exposure to traffic air pollutants. The present study utilized measures from the literature review to examine the association of distance of residence from traffic pollutant source and poor cardiovascular and/or respiratory health outcomes in residents due to the lack of the traffic pollutant data and the predicting model used for estimating traffic exposure. The dispersion models used in the previous studies (English et al., 1999) have indicated that 80-90% of traffic pollutants decay 492 – 665 ft (0.09 – 0.1 mile) from the source. So, a distance of residence was categorized based on this logic and it was observed that 99.55% of residents lived ≥ 0.09 mile of traffic pollutant source. The current study did not show any association with traffic pollutant source on the major freeway present in the community. Sample distribution might be one of the
main reasons for observed lack of association with traffic pollutant source as zero participants reported poor cardiovascular and/or respiratory health outcomes in > 0.09 mile. Further resolution of the scale used for study could be possibly attributed to sample distribution pattern. The current study was a community level study which spread across one zip code while most of the previous studies which have reported significant association have been conducted at larger scale such as census tract (Maheswaren and Elliot, 2003; Hu et al, 2008) or city level (Maantay 2007) or involved multiple communities (Kim et al, 2004; Gauderman et al, 2005). Maheswaren and Elliott (2003) involved census tract level data and proximity to main roads were used as a proxy for exposure and a 5% increase in stroke mortality was observed in areas within 200m, of the main road. Another census tract level study by Hu et al (2008) which was conducted in northwest Florida, determined the observed and expected stroke mortality due to residential proximity to air pollution sources like TRI sites, superfund sites and roads with high average vehicle count. And it was observed that mean age-adjusted stroke rate in the study was more than 8 times the expected rate and the census tract which showed higher levels of air pollution with air pollution density maps had a significantly high risk for stroke mortality. Also, previous studies have used air pollutants concentration data which have been collected over a period from air monitoring stations or other standardized sources for dispersion model (Gauderman et al 2005; Gauderman et al, 2007). The lack of monitoring stations near the study site which could record the real-time concentration of the pollutants released from the vehicles passing on Interstate 664 could explain lack of association observed in the current study.

Self-reported health responses could have further contributed to the results of the current study as it could lead to under-reporting of the poor cardiovascular and/or respiratory health outcomes as compared to hospital records or physician diagnosed outcomes. Most of the
previous studies (Lin et al., 2002; Samargiassi et al., 2009; Maantay, 2007) have utilized hospital records as a measure of health outcomes which provide more accurate and reliable responses compared to the self-reported health outcomes in the current study. Samargiassi et al. (2009) examined exposure due to residential proximity to point air pollution source in Montreal Island using American Meteorological Society – Environmental Protection Agency Regulation air dispersion model for children along with asthma data from hospital records, and found that short-term increases in air pollutants such as SO$_2$ were significantly associated with higher number of emergency department visits for asthma. Similarly, an asthma and air pollution study conducted by Maantay (2007) in Bronx, New York utilized hospital admission data for asthma and half a mile buffer system for mapping the area which would be most affected by TRI industries and it observed that people living within half a mile of a TRI industry were 66% more likely to be hospitalized for asthma.

The air dispersion model used in the current study can provide complete pollutant concentration gradients over space and time. The main advantage of such model is that more factors which affect the dispersion of pollutants are considered such as meteorological factors and road type. Additionally, they can be applied at different spatial scales which can further help improve resolution.

**Discussion of Research Question 2**

Are the number of years at the same residence linked to the poor cardiovascular and/or respiratory health outcomes in the residents of the community?

Hazardous chemicals escape into the environment due to many man-made activities and can cause an adverse effect on the health and as seen earlier respiratory and cardiovascular disease are associated with proximity to roads with heavy traffic or exposure to traffic-related air
pollution. Short-term and long-term exposure to air pollution has been linked to mortality and reduced life-expectancy (Kampa and Castanas, 2008). Studies like Harvard Six Cities and American Cancer Society (ACS) cohort have provided strong evidence of the occurrence of poor cardiovascular health outcomes due to long-term exposure to air pollution (Brook et al., 2004). Increased risk for poor cardiovascular and/or respiratory health outcomes such as asthma and wheezing are expected in the long-term residents based on the fact that they have been exposed to air pollutants for longer a period.

Most of the large-scale studies which have used census tract or county level data have not considered the number of years spent at the same residence as one of the predictor variables (Lin et al, 2002; Gordian, Haneuse, and Wakefield, 2006; Maantay, 2007; Batterman et al, 2014). One community-level study of individual-level data conducted in Richmond, California reported a significant association of adult asthma rates with being a long-term resident of 15 years or more. A significant difference was observed in the prevalence of asthma for residents who lived in Richmond for less than 15 years (9.2%) compared to residents who lived in Richmond for 15 years or more (34.9%) (Cohen et al., 2012).

The current study looked at prevalence rates of cardiovascular and/or respiratory health outcomes in adults and children. And although not statistically significant, higher prevalence rates for poor cardiovascular and/or respiratory health outcomes were observed in children as well as adults who have lived at the same residence for 15 years or more compared to those who lived for less than 15 years. Duration of residence at the same location also serves as a surrogate measure for the amount of toxic pollutants that the residents have been exposed to indicating that residents living at the same location for >15 years have been exposed to air pollutants for a longer period of time compared to residents living at the same location for < 15 years.
Discussion of Research Question 3

Are the individual-level risk factors (age, gender and body mass index (BMI)) linked with the poor cardiovascular and/or respiratory health outcomes in the residents of the community and do the association observed between poor health outcomes in the residents and exposure to environmental pollution vary according to demographic factors?

Along with increased air pollution, a sedentary lifestyle is another challenge which is brought about by industrialization and obesity is a major outcome of a sedentary lifestyle. Many studies have shown that obesity is a major risk factor for both respiratory and cardiovascular health outcomes (Carey, Cook & Strachan, 1999; Chinn, Cotes & Reed, 1996; Lui et al., 2015) along with other risk factors such as age, gender, and smoking. Body mass index (BMI) is a commonly used measure of obesity and it is defined as a person’s weight in kilograms divided by height in meters squared. An individual with BMI in range of 25.0-29.9 kg/m² and greater than 30.0 kg/m² are considered overweight and obese respectively (Center for Disease Control and Prevention, 2015a). Obesity has been identified as a significant risk factor for cardiovascular disease and recently its link with respiratory disease is also increasingly recognized (Poulain et al., 2006). The exact influence of obesity on respiratory disease is a complex process but it is believed that rising BMI is associated with a decrease in lung volume which results in a reduction of forced expiratory volume in one second, forced vital capacity and total lung capacity. Overweight and obese individuals are more likely to have poor respiratory health outcomes when compared to individuals with normal BMI (Poulain et al., 2006; Zammit et al., 2010) and studies have also shown an increase in self-reported wheezing in obese individuals when compared to individuals with normal BMI (Gibson, 2000; Babb et al, 2008). Current study showed similar significant positive association between obesity and poor respiratory health
outcome. Further, aging process also brings about many changes to the respiratory system of an individual and some of these changes include a decrease in volume of the thoracic cavity, reduced lung volume and change in muscles that help with respiration (Lowery et al., 2013) which puts older individuals at an increased risk for respiratory disease compared to younger individuals. No significant association was observed between age and poor respiratory health outcomes in the current study and one of the reason could be that approximately 67% of residents who reported poor respiratory health outcomes were less than 55 years of age.

The risk of developing cardiovascular disease is largely dependent on the presence of the traditional other risk factors (genetics, diabetes, cholesterol, age). Age is one of those traditional risk factors which is non-modifiable and with aging, there is the incremental addition of several other cardiovascular disease risk factors such as obesity, smoking. When age and other risk factors like obesity are jointly used to examine individual’s risk for cardiovascular disease, it has been hypothesized that the contribution of age reflects the duration of exposure to other risk factors. The longer an individual is exposed to modifiable risk factors, such as obesity, the greater the risk for cardiovascular disease, which means, at a younger age an individual with several cardiovascular risk factors will have lower risk for cardiovascular disease compared to an older individual with the same set of risk factors (Dhingara and Vasan, 2012; Cetin and Nasr, 2017). The current study had similar results showing a significant positive association between both obesity and age with poor cardiovascular health outcomes. And significant positive association was observed for obesity and when both poor cardiovascular and/or respiratory health outcomes were considered together,

Along with age and BMI, gender differences have been observed in the death rates and burden of cardiovascular and respiratory disease. In the year 2010, death rate attributable to
cardiovascular was 235.5 per 100,000. Higher deaths rates were observed in men (283.4) compared to women (197.3) (Go et al., 2014). Many cross-sectional epidemiological studies have shown an association between obesity and asthma (Beckett et al., 2000; Lauder et al., 2004; Ronmark et al., 2005). Lauder et al (2004), explored the association between BMI and asthma in men and women in New York. Results from the weighted logistic regression showed that prevalence of asthma was 4.6% among men and 8.1% among women. Further in women, the prevalence of asthma significantly increased in those with BMI 25 kg/m\(^2\) when compared to the reference group with BMI 22-24.9 kg/m\(^2\). For the current study, no significant association was observed for gender and one of the considerations could be that the present study did not stratify data by gender like previous studies mentioned above.

**Limitations of the Study**

The present study had a couple of limitations which could attribute to the results of the study and it is important to give considerations to these limitations while interpreting the results. First, the cardiovascular and respiratory health outcome was self-reported by the study participants and the study sample was small and confined to just one community. Therefore, results may be impacted due to under-reporting of the health outcomes as well as because of restricted sample size with study being retrospective in design. Second, the study does not consider the amount of time spent by residents at places other than their residences such as work or school or while commuting. This would leave out other air pollutant exposure routes to which residents could have been possibly exposed. Third, due to lack of personal monitoring stations, the study utilizes the surrogate exposure metrics to estimate the concentration to air pollutants from industries which do not take into account physical, chemical or toxicity properties of the pollutants, as it is cost-prohibitive with several technical challenges and time-consuming. And
the surrogate measures only considered exposure to industrial air pollutants and does not account for exposure to indoor sources or from vehicular exhaust or coal piers because of lack of data. And fourth, the study was not able to model the concentration of air pollutants released from the vehicle due to lack of air monitoring stations in the area to record daily concentrations of the air pollutants. The closest air monitoring station was at NASA Langley Research Center which is 10 miles away and therefore, it was not possible to perform spatial interpolation to get the concentrations of air pollutants from vehicles over the study area.

**Health Policy Implications**

Despite some of the limitations identified in the present study, some important findings could be gathered from the study which could contribute to the residentially based exposure studies for chronic diseases like cardiovascular and/or respiratory. Health policy implications from this study can be made at the specific community-level. Given that associations were found between poor cardiovascular and/or respiratory health outcomes and distance of residence from industry, age and BMI, an increased awareness about air pollutants released from the industry and their health impacts is important among the residents of the community. This would involve educating residents about air pollutants released into the air and their impact on health and planning community-level interventions targeted toward reducing weight and BMI. Further, the results of the study could further contribute to developing effective policies targeted towards reducing the number of toxic air pollutants released for promoting public health.

**Future Research**

The findings from the current study provide couple opportunities for the future research. A real-time measurement of the air pollutants is required to accurately map the concentrations over the study area. This could be achieved by placing air monitoring stations in the community
which could record the pollutants on daily basis. Future research would involve, collecting air pollutant data from industries and Interstate 664 for a longer period to explore if it varies due to seasons and then interpolating the data over the study area to accurately map the concentrations of pollutants to which residents are exposed to. The second recommendation for the future research would be to increase the resolution of scale to explore if any significant changes are observed in associations when study is conducted at larger scale such as census tract (Maheswaren and Elliot, 2003; Hu et al, 2008) or city level (Maantay 2007). And third recommendation would be to consider hot spot created by two industries and traffic and cumulative amount of air pollutants that residents are exposed to in this hot spot area.

**Conclusion**

The present study examined the association between poor cardiovascular and/or respiratory health outcomes and various factors such as residential based exposure to toxic air pollutant sources, the number of years lived at the same residence and demographic variables (age, BMI, and gender). Poor cardiovascular and/or respiratory health outcomes were statistically significantly associated with residential based exposure to toxic air pollutants released from industry present in the area and also with demographic factors (age and BMI). Although not significant, higher prevalence rates for poor cardiovascular and/or respiratory health outcomes were observed for residents living at the same residence for 15 years or more. This study identifies the need for data collections especially for toxic air pollutants which can contribute to more accurate interpolation mapping of the air pollutant concentration. Multi-level epidemiological framework examining the role of community-level factors as well as individual-level factors in the development of chronic diseases may be the next required step.
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APPENDIX

Survey

1. What is your gender?
   ○ Female
   ○ Male

2. What is your birthdate? _______________________
   MM/DD/YYYY

3. Your height and weight.
   Height: _____ ft _____ in.
   Weight: _____ lbs

3. What is your current marital status?
   ○ Single
   ○ Married
   ○ Divorced
   ○ Separated
   ○ Widowed

4. What is your race?
   ○ African-American
   ○ White
   ○ Asian
   ○ American Indian or Alaska Native
   ○ Other ____________________________

5. What is your street address?
   ________________________________, Newport News, Virginia ZIP ____________
6. How many years have you lived at this address?
_________________ Years

7. Which of the following describes your employment status?

○ Employed
○ Not Employed
○ Retired

8. Do you work at any of the following locations? (You can choose more than one answers)

○ Shipyard Name ______________________, ________________ years
○ Chemical Plant Name__________________________, ___________________years
○ Factory Name ____________________________, _____________________years
○ Other _________________________, _______________ years
○ None

9. How would you rate your overall health?

○ Excellent
○ Very Good
○ Good
○ Fair
○ Poor

10. Have you recently visited a doctor?

○ Yes
○ No

11. Do you have diabetes?
12. Do you have tuberculosis (TB)?

- Yes
- No

13. Do you have cancer? If “No” skip to question 14.

- Yes, what kind___________________________
- No

14. Do you have any breathing problems?

- No
- Yes

If “Yes”, choose the type of breathing problems. (choose all that apply)

- Shortness of breath how long? ________ years
- Wheezing how long? ________ years
- Coughing how long? ________ years
- Hoarseness how long? ________ years
- Sleep Apnea how long? ________ years
- Asthma how long? ________ years
- Pneumonia how long? ________ years
- Bronchitis how long? ________ years
- Other ________________ , how long? ________ years
15. Do you have any heart problems?

- No
- Yes

If “Yes”, choose the type of heart problems. (choose all that apply)

- Chest pain how long? _______ years
- Heart murmurs how long? _______ years
- Irregular heartbeat how long? _______ years
- Heart disease how long? _______ years
- High blood pressure how long? _______ years
- Other ____________________, how long? _______ years
- Past heart attack _______ years ago

16. Males only- Do you have any reproductive diseases or symptoms?

- No
- Yes

If “Yes”, choose the type of reproductive diseases or symptoms. (choose all that apply)

- Urethral stricture how long? _______ years
- Penile cancer how long? _______ years
- Testicle pain how long? _______ years
- Blood in urine how long? _______ years
- Erectile dysfunction how long? _______ years
- Other ____________________, how long? _______ years
- None
17. Females only- Do you have any reproductive diseases or symptoms?

- No
- Yes

If “Yes”, choose the type of reproductive diseases or symptoms. (choose all that apply)

- Blood in urine how long? _______ years
- Excessive urination how long? _______ years
- Prolapsed uterus how long? _______ years
- Endometriosis how long? _______ years
- Miscarriage how long? _______ years
- Pelvic inflammatory disease (PID) how long? _______ years
- Other _______________________, how long? _______ years
- None

V. ENVIRONMENT

18. Are you aware of any environmental pollution in your community?

- No
- Yes

If “Yes”, choose the type of environmental pollution (choose all that apply)

- Coal Dust
- Exhaust Emissions from vehicles on Interstate 664
- Emissions from industrial plants in this area
- Emissions from the shipyards
- Hazardous Waste from brownfields (abandoned waste and industrial sites)
- Other_____________________________

19. What do you think about air quality in your community?
20. What do you think about soil/dirt quality in your community?

- Excellent
- Very Good
- Good
- Fair
- Poor
- Very Poor

21. What do you think about the overall environment in your community?

- Excellent
- Very Good
- Good
- Fair
- Poor
- Very Poor

22. In your opinion, what are the top five environmental issues in your community?

1. ______________________________________________
2. ______________________________________________
3. ______________________________________________
4. ______________________________________________
5. ______________________________________________
23. In your opinion, what can the city/government do to improve the environmental quality in your community?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

VI. CIGARETTE AND ALCOHOL CONSUMPTION

24. Do you smoke?

○ Yes, ____________# cigarettes in a week for _____________ year(s).
○ No
○ Quit more than six months ago

25. Does anyone in your household currently smoke cigarettes?

○ Yes, someone does
○ No, no one does

26. Do you drink alcohol?

○ Yes, ____________# (beers, glasses of wine, mixed drinks)/week for __________ year(s).
○ No
○ Quit more than six months ago
VITA

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