The Association Between Lung Cancer and Air Pollution in Trinidad: A Mixed Methods Literature Review

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ABSTRACT

Environmental quality affects human health, and recent studies have demonstrated an association between lung cancer and air pollution. Yet cancer prevention policies and initiatives rarely emphasize air quality. I analyzed studies documenting association between lung cancer and PM 2.5, PM 10, PAHs, and NOx. I collected hazard risk ratios from each study and conducted a meta-analysis to derive a pooled hazard ratio for each pollutant. PAHs had a stronger association with lung cancer compared to the other compounds. I then sought to assess the air quality related lung cancer risk in areas of Trinidad by comparing the emissions sources and cancer rates across boroughs. Most industries that generate PAHs are located on the west coast of Trinidad. However, most people who have lung cancer are found on the east coast of Trinidad. Even though I could not conclude that there was an association between these pollutants and lung cancer in Trinidad, it does not mean that there is no association between lung cancer and air pollution. It is vital for researchers to fully comprehend how air pollution in Trinidad is not only affecting the prevalence and mortality of cancer, but other health problems as well.

KEYWORDS

environmental health, polycyclic aromatic hydrocarbons, particulate matter, nitrous oxides, meta-analysis

INTRODUCTION

Cancer is defined as the uncontrollable cell division occurring in a specific part of the body, such as the lungs, that leads to malignant tumors (Medicinet 2016). Exposure to air pollutants such as nitrogen dioxide, volatile organic compounds, heavy metals, and carbonyls associated with industrialization and urbanization have been linked with lung cancer in developing countries (Brook et al. 2007; Fiotakis et al. 2008). Recently, the International Agency for Research on Cancer (IARC) confirmed that particulate matter, derived from smoke, fires, industry, and power plants, is a carcinogen (IARC, in press; US EPA 2015; Cohen et al. 2013). Many oil refineries emit chemicals such as benzene and polycyclic aromatic hydrocarbons (Misrach & Orff 2012; Connoly & O'Rourke 2003), which are associated with lung cancer (Huff 2007, Battershill et al 2005, Ma et. al 2009) Yet, governments in small developing countries may not admit the links between the degradation of human health to industry, which may be important to the economy and provide revenue for the state, and there continues to be a lack of research on the health effects of air pollution in these contexts.

Trinidad and Tobago is one of the most developed countries in the Caribbean due to its oil, gas, and manufacturing industries (Commonwealth 2014). The main point sources of pollution in Trinidad and Tobago are manufacturing, transportation, fuel trade, electrical power generation, and oil refineries (EMA 2000). Trinidad is also subject to Saharan dust air masses that intermittently blow organochlorine and organophosphate pesticides (OCPPs), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyl (PCB) congeners into the country (Foreman et al. 2014). In 2015, Trinidad and Tobago passed the Air Pollution Rules, which required air pollutants emitted from factories to be reported. This is a step towards reducing air pollution caused by industry. Yet, few chemicals are regulated by this law, which requires air quality assessment before the permit to start production and manufacturing is given, but not after it is received. While the Air Pollution Rules are the first step Trinidad and Tobago has taken to monitor air quality. it is essential to go beyond this law by continuing to assess air quality, provide transparent data on air quality, and assess how air quality has impacted human health.

Trinidad and Tobago has one of the highest cancer rates in the Caribbean and in the Americas (PAHO 2013). From 1999 to 2002, cancer incidence rose by 11 percent and cancer mortality increased by 35 percent (Mohammed 2011). Yet, there is an insufficient amount of research and data on why this is so. Unfortunately, the most recent reports on cancer rates in Trinidad and Tobago only examined high cancer risk personal behavior and services provided for cancer treatment, ignoring environmental factors, which follows a pattern of cancer studies in Trinidad and Tobago, and in other parts of the world, that only focuses on screening, race, access to treatment, and socioeconomic factors. This highlights an important gap in the research, which has significant implications for public health policy, international funding agencies, and health care policy. It is important that Trinidad and Tobago and other developing nations promote and conduct research on air quality and associations between various health problems and pollutants. Since there is currently a lack of air quality data from Trinidad and Tobago, it could be difficult to determine which populations in the country are at risk of exposure to high levels of carcinogenic pollutants, which constrains the development of public health policies that can address ways to reduce the incidences of lung cancer in Trinidad.

Methodology

Lung cancer is caused by genetic mutation of lung cells (American Lung Association 2016), which are associated with risk factors, such as smoking, secondhand smoking, radon, radiation, diet, and carcinogenic substances found the environment (CDC 2015). Epidemiologists commonly test for the association between risk factors and cancer by using the following math equation to generate a risk ratio: $\frac{risk\ of\ event\ happening\ in\ experimental\ group}{risk\ of\ event\ happening\ in\ control\ group}$ (Green and Higgins 2011). Cancer studies prefer to look at hazard ratios because they can use these ratios to determine the rate at which an outcome is likely to occur, given the exposure. For this study, I collected hazard ratios from my literature review to create a pooled hazard ratio for each pollutant. The pooled hazard ratio is generated through a meta-analysis, which is a statistical analysis of pooled data gathered from studies to infer the significance of the data.

The current primary mode of preventing any cancer is through early screening and detection and minimizing exposure to risk factors. Trinidad has many policies and programs dedicated to early screening for cancer (PAHO and WHO 2013, PAHO and WHO 2013), but initiatives dedicated to protecting citizens from risk factors focus exclusively on diet and tobacco PAHO and WHO 2011). Yet Trinidad's health ministry has not conducted research on environmental risk factors, and particularly the air pollution, in areas with high rates of lung cancer, including Sangre Grande and Rio Claro-Mayaro, which are the two boroughs with the highest rates of lung cancer between both genders (Canreg 2003). In this study, I analyzed the amount of PAHs, NOx, and particulates found in this area and compared it to other boroughs in Trinidad to determine whether there is a correlation between these compounds and lung cancer. NOx are released from fuel combustion or agriculture (Brasseur 2007). Through incineration and generating fossil-fuel products, PAHs are formed (National Research Council (US) Committee on Pyrene and Selected Analogues 1983). PM 2.5 is made from combustion activities such as power plants, and burning organic matter (EPA 2016). PM 10 is generated through the same mechanisms that form PM 10, but usually takes the form of dust (CA EPA 2009).

Study Objectives

My main objective in this study was to identify spatial patterns of likely exposure to airborne pollutants associated with lung cancer risk in Trinidad. To do this, I conducted a literature review that examined relationships between cancer rates and air pollution to analyze this same relationship by borough in Trinidad. I analyzed four pollutants: NOx, PM 2.5, PM 10, and PAHs; then, I determined their how strongly the correlation of each pollutant to lung cancer by conducting a meta-analysis. I hypothesized that areas with higher sources of pollution would contain communities with high prevalence of lung cancer.

METHODS

Literature Search

I searched PubMed and Web of Knowledge to find cohort studies published between 1990 and 2015, using the search terms “air pollution OR nitrogen dioxide OR particulate matter OR exhaust OR traffic pollution AND cancer.” I reviewed abstracts to determine if the data in a given study was useable for my study. For polycyclic aromatic hydrocarbons, I expanded my date range from 1970 to 2015, using MEDLINE, OLDMEDLINE, NIOSHTIC-2, and CancerLit.

Study Inclusion and Exclusion Criteria

I chose studies that had been included in previous systematic reviews to ensure that all had the studies had the same study design, allowing me to perform the same analysis on each study. I included studies that did not focus on the Caribbean to understand the trends of air pollution and its effect on health. I included studies that focused on cancer incidence and mortality; to examine the prevalence of lung cancer in. I only reviewed cohort studies because they account for the fact that cancer attributed to air pollution requires exposure for long periods of time. I excluded studies published in articles, reviews, reports, editorials, comments, or case studies because these studies did not contain risk ratios. I also excluded studies that tested only for residential exposure, did not demonstrate a change in incidence or mortality rate due to cancer, or did not adjust for age and sex because I wanted all potential factors associated with lung cancer to be examined, so the only variable I could look at would be outdoor air pollution.

For PAHs, I also used studies exclusively from systematic reviews, and collected the calculated relative risk ratios. I excluded studies that were not in English, did not focus on an industries found in Trinidad, did not conclude that PAHs were the main cause of lung cancer, did not quantify exposure, or in which exposure occurred through means other than inhalation. I analyzed only articles containing the most recent follow-ups, which allowed me to analyze the most recent data.

Data Synthesis

I performed all data analyses in STATA, using the following function to generate my pooled hazard ratio (HR), which shows the rate of an outcome given the exposure, with a 95% confidence interval (CI): metan ln_hr lnlowconf lnhighconf, random eform label(namevar=citation). For studies that included the number zero in their confidence interval, I rounded the number to .0001to perform my analysis. I assigned a percent weight to each ratio used to denote level of precision. There was no variation among the outcomes from the studies I collected, so I applied a fixed effect model, which is appropriate for non-random variables.

Mapping

I used Google Earth to create a map of Trinidad and Tobago, and created a code for each air pollution category with an associated level of risk based on the pooled hazard ratio that I calculated from my meta-analysis. I located sources of pollution by doing an online search for the location of factories, power plants, oil refineries, and other industrial sites, and verified their locations on Google Earth. I then identified the location of hospitals by borough. For a defined residential area in Trinidad and Tobago, I coded the pooled hazard ratio that I generated for each type of pollutant and quantified each source of pollution by summing the code number of each pollutant associated with each site. I also generated a map using data from Trinidad and Tobago's Cancer Registry to visualize the prevalence of lung cancer in Trinidad by borough.

RESULTS

I selected 19 studies that met my inclusion requirements. I used hazard ratios from the following studies: Abbey et. al 1999, Armstrong et. al 1994, Armstrong et. al 2004, Beelen et. al 2008, Beeson et. al 1998, Berger et. al 1992, Carey et. al 2013, Cesaroni et. al 2013, Doll et. al 1972, Gustavsson et. al 1990, Katanoda et. al 2011, Milham et. al 1979, Moulin et. al 2000, Mur et. al 1987, Naess et. al 2006, Puett et. al 2014, Rockette et. al 1983, Romundstad et. al 2000, and Spinelli et. al 1991.

PM 2.5 was least correlated with lung cancer, having an pooled hazard ratio of 1.099 (Table 1) and the average confidence interval from 1.060 to 1.140 (Figure 1). The hazard ratios calculated by Cesaroni (2013) and Carey (2013) were assigned more weight in this analysis because they had a smaller standard error and a larger sample size. The overall data looked normal (Figure 1). However, the Katanoda (2011) data seemed skewed. The variables that were held fixed for this pollutant were age, sex, socioeconomic status, BMI, active smoking, passive smoking, education, occupational exposure, marital status, alcohol use, vegetable intake, fruit intake, energy intake, fatty acids intake, folate intake, fish consumption, and family history.

Table 1. Hazard Ratios of PM 2.5. I collected relative ratios from each literature review to determine the average hazard ratio.

Study	ES	[95% Conf.	Interval]	% Weight
(Cesaroni et. al 20	1.050	1.010	1.100	8.72
(Cesaroni et. al 20	1.020	0.980	1.070	8.66
(Beelen et. al 2008	1.060	0.820	1.380	1.61
(Beelen et. al 2008	0.870	0.520	1.470	0.46
(Carey et. al 2013)	1.140	1.070	1.220	7.48
(Carey et. al 2013)	1.080	1.030	1.140	8.30
(Carey et. al 2013)	1.020	0.970	1.070	8.39
(Carey et. al 2013)	1.040	0.990	1.090	8.44
(Puett et. al 2014)	1.050	0.900	1.230	3.48
(Puett et. al 2014)	1.060	0.910	1.250	3.40
(Puett et. al 2014)	1.240	0.740	2.050	0.48
(Puett et. al 2014)	1.250	0.750	2.070	0.48
(Katanoda et. al 201	1.270	1.190	1.360	7.42
(Katanoda et. al 201	1.240	1.120	1.370	5.60
(Katanoda et. al 201	1.230	1.090	1.380	4.82
(Katanoda et. al 201	1.230	1.080	1.390	4.49
(Naess et. al 2006)	1.070	0.980	1.170	6.22
(Naess et. al 2006)	1.070	0.970	1.180	5.74
(Naess et. al 2006)	1.080	0.980	1.190	5.78
D+L pooled ES	1.099	1.060	1.140	100.00

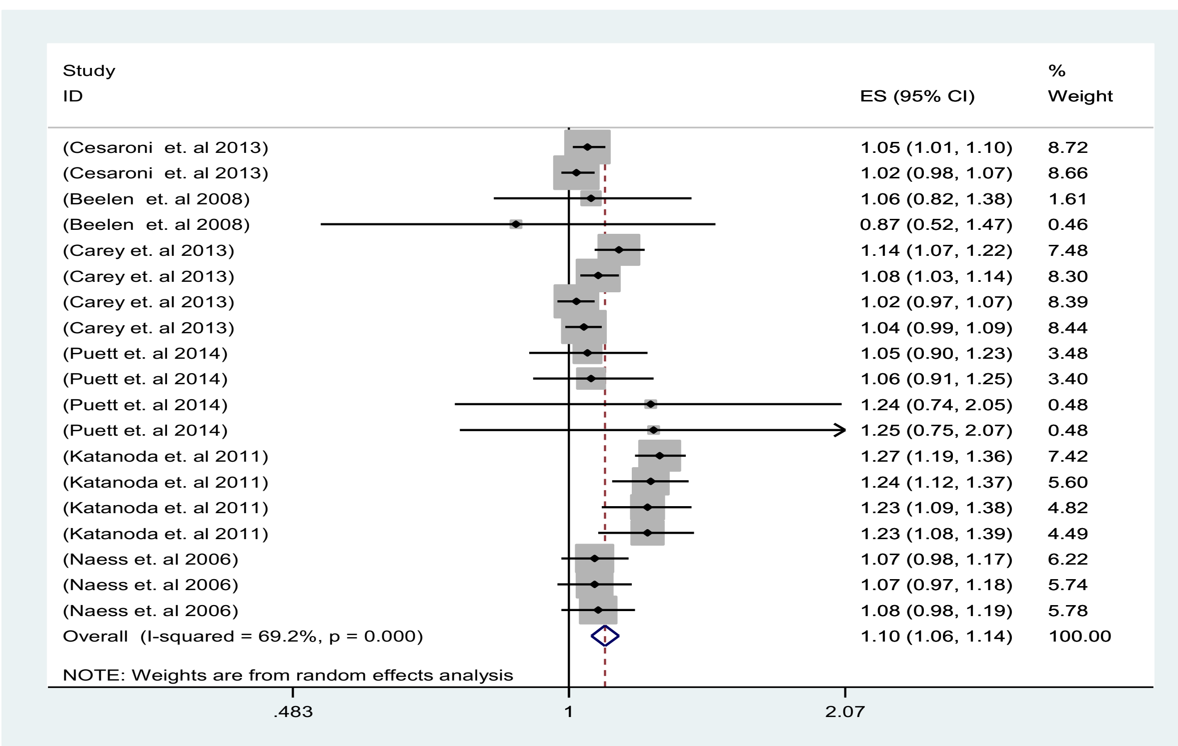


Figure 1. Hazard Ratios for PM 2.5. This graph shows the association between all hazard ratios generated from each study and their confidence interval.

NOx had a stronger association with lung cancer than did PM 2.5, with an pooled hazard ratio of 1.110, and a pooled confidence interval between 1.069 and 1.152 (Table 2). For this pollutant, Cesaroni (2013) was also precise, but Katonoda's data fit more with NOx. Therefore, Katonoda's study had a higher weight. In general, the graph is normal (Figure 2). The confounding factors mostly associated with NOx were the same for the previous pollutant.

Table 2. Hazard Ratios of NOx. I collected relative ratios from each literature review to determine the average hazard ratio.

Study	ES	[95% Conf.	Interval]	% Weight
(Cesaroni et. al 20	1.040	1.020	1.070	8.50
(Cesaroni et. al 20	1.030	1.000	1.050	8.48
(Beelen et. al 2008	0.910	0.720	1.150	1.98
(Beelen et. al 2008	0.800	0.520	1.230	0.70
(Beeson et. al 1998)	1.450	0.670	3.140	0.23
(Carey et. al 2013)	1.200	1.120	1.270	7.05
(Carey et. al 2013)	1.130	1.070	1.190	7.48
(Carey et. al 2013)	1.060	1.000	1.120	7.33
(Carey et. al 2013)	1.110	1.050	1.170	7.44
(Katanoda et. al 201	1.200	1.170	1.240	8.36
(Katanoda et. al 201	1.170	1.100	1.260	6.83
(Katanoda et. al 201	1.150	1.060	1.240	6.35
(Katanoda et. al 201	1.160	1.070	1.250	6.38
(Naess et. al 2006)	1.080	0.990	1.180	5.93
(Naess et. al 2006)	1.070	0.970	1.180	5.49
(Naess et. al 2006)	1.110	1.010	1.220	5.64
(Naess et. al 2006)	1.090	0.980	1.200	5.36
(Abbey et. al 1999)	1.820	0.930	3.570	0.30
(Abbey et. al 1999)	2.810	1.150	6.890	0.17
D+L pooled ES	1.110	1.069	1.152	100.00

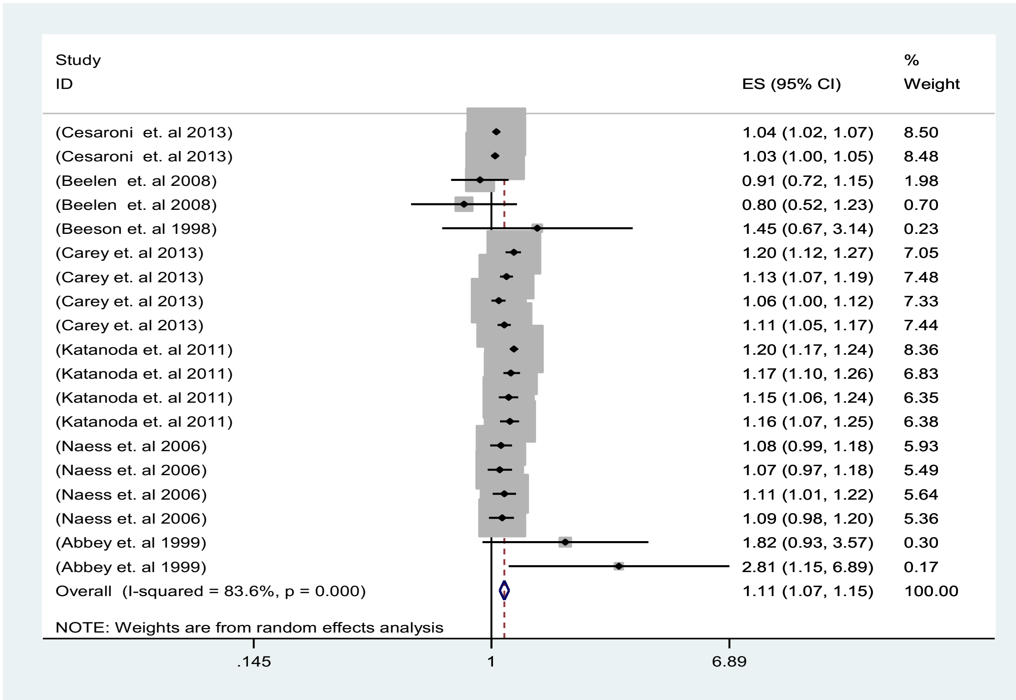


Figure 2. Hazard Ratios for NOx. This graph shows the association between all hazard ratios generated from each study and their confidence interval.

The pooled hazard ratio for PM 10 was 1.123. The confidence interval that was generated from this analysis is 1.060 to 1.190. The Carey (2013) studies were given more weight in this analysis. The plot for these studies was a little skewed for the Beeson and Abbey ratios. (Figure 3). This data mostly looked at variables that dealt with gender, but also focused on smoking, BMI, and income.

Table 3. Hazard Ratios of PM 10. I collected relative ratios from each literature review to determine the average hazard ratio.

Study	ES	[95% Conf.	Interval]	% Weight
(Beeson et. al 1998)	4.500	1.310	15.400	0.22
(Beeson et. al 1998)	4.960	1.540	16.000	0.24
(Beeson et. al 1998)	4.720	1.690	13.180	0.31
(Beeson et. al 1998)	3.430	1.710	6.880	0.65
(Beeson et. al 1998)	2.950	1.710	5.090	1.02
(Beeson et. al 1998)	5.210	1.940	13.990	0.33
(Carey et. al 2013)	1.120	1.050	1.200	9.21
(Carey et. al 2013)	1.070	1.020	1.130	9.69
(Carey et. al 2013)	1.010	0.960	1.060	9.74
(Carey et. al 2013)	1.030	0.980	1.080	9.76
(Puett et. al 2014)	1.060	0.980	1.160	8.58
(Puett et. al 2014)	1.040	0.950	1.140	8.33
(Puett et. al 2014)	1.120	0.850	1.460	3.20
(Puett et. al 2014)	1.110	0.850	1.460	3.20
(Naess et. al 2006)	1.070	0.980	1.170	8.43
(Naess et. al 2006)	1.070	0.970	1.180	8.07
(Naess et. al 2006)	1.100	1.000	1.210	8.17
(Naess et. al 2006)	1.080	0.980	1.200	7.95
(Abbey et. al 1999)	2.380	1.420	3.970	1.14
(Abbey et. al 1999)	3.360	1.570	7.190	0.55
(Abbey et. al 1999)	1.080	0.550	2.130	0.69
(Abbey et. al 1999)	1.330	0.600	2.960	0.50
D+L pooled ES	1.123	1.060	1.190	100.00

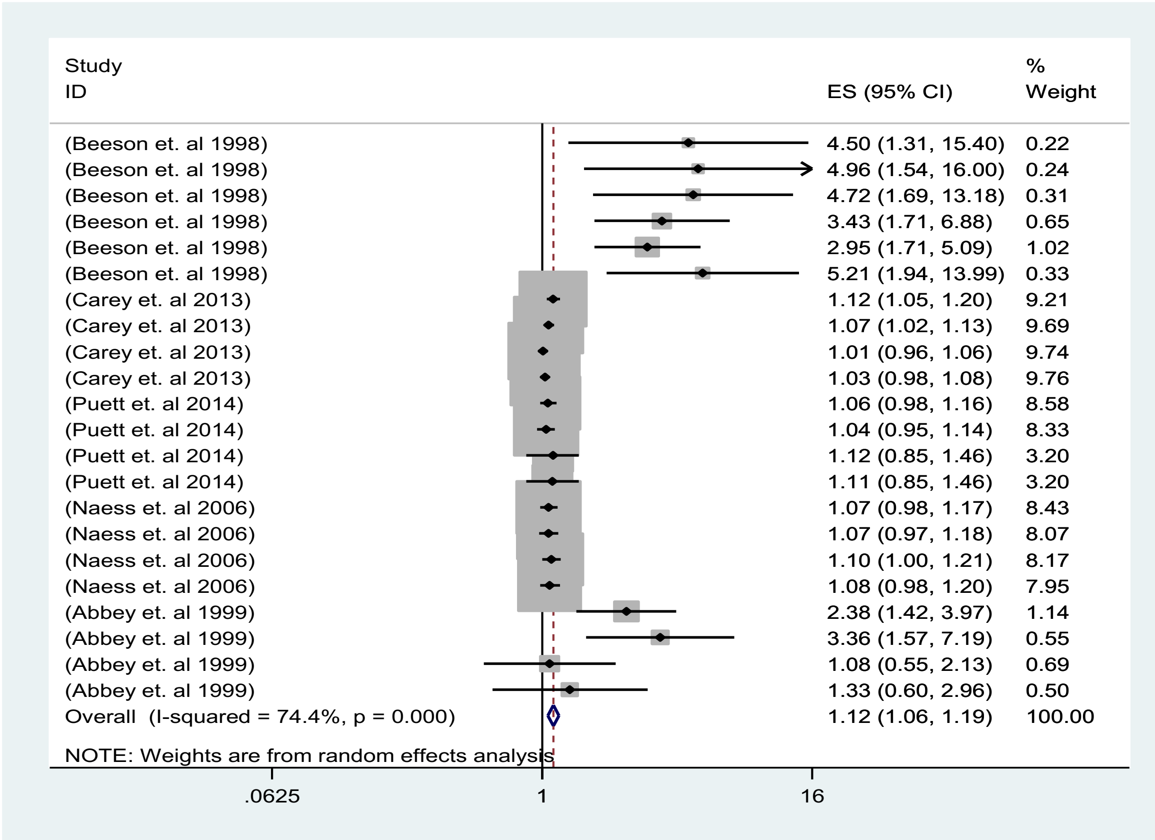


Figure 3. Hazard Ratios for PM 10. This graph shows the association between all hazard ratios generated from each study and their confidence interval.

PAHs had the greatest correlation with lung cancer, with an average relative ratio of 1.166, and a confidence interval of 1.060 to 1.190 (Table 4). Armstrong's (2004) study contained more precise data because it was given more weight in this analysis. This data had a lot of irregular points (Figure 4). The only variables considered in these studies were the types of industries that were releasing PAHs.

Table 4. Hazard Ratios of PAHs. I collected relative ratios from each literature review to determine the average hazard ratio.

Study	ES	[95% Conf.	Interval]	% Weight
(Berger et. al 1992)	1.150	1.110	1.210	28.12
(Doll et. al 1972)	4.010	1.160	13.870	0.16
(Doll et. al 1972)	5.820	1.060	32.000	0.09
(Armstrong et. al 19	1.220	1.090	1.370	12.50
(Milham et. al 1979)	0.190	0.040	1000.000	0.01
(Moulin et. al 2000)	1.110	0.460	2.660	0.32
(Mur et. al 1987)	0.690	0.310	1.540	0.39
(Rockette et. al 198	1.850	0.530	6.530	0.16
(Rockette et. al 198	0.060	0.040	9.580	0.03
(Romundstad et. al 2	0.990	0.790	1.220	4.64
(Spinelli et. al 199	1.310	0.720	2.390	0.69
(Armstrong et. al 20	1.150	1.110	1.200	29.23
(Armstrong et. al 20	1.160	1.050	1.280	14.91
(Armstrong et. al 20	1.290	1.110	1.490	8.76
D+L pooled ES	1.166	1.109	1.226	100.00

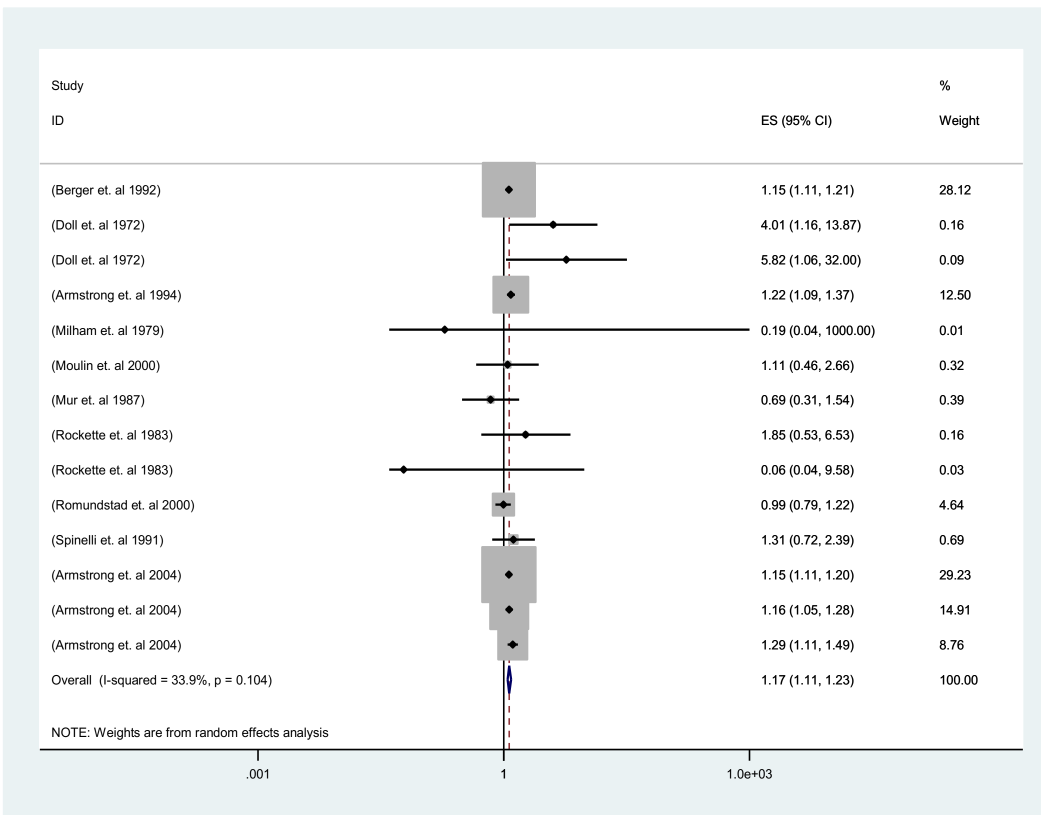
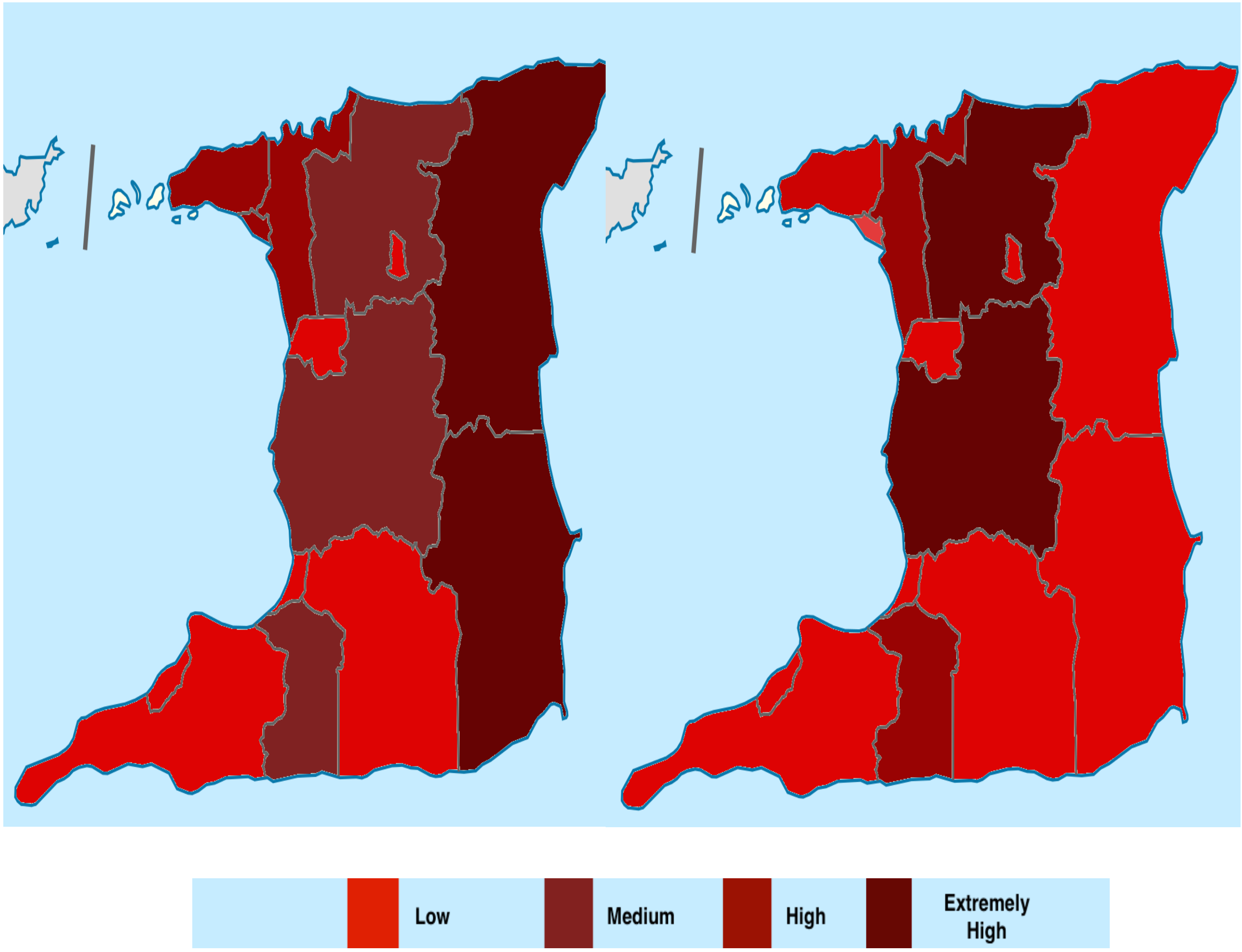


Figure 4. Hazard Ratios for PAHs. This graph shows the association between all hazard ratios generated from each study and their confidence interval.

The Couva-Tabaquite-Talparo and Tunapuna-Piarco boroughs have the highest rates of pollution, while San Fernando, Arima, and Port Fortin have the lowest rates of lung cancer. The highest levels of pollution associated with NOx, particulate matter, and PAHs are found on the west coast of Trinidad. The east coast, where which Sangre Grande and Rio Claro-Mayaro are located, does not contain many sources of pollution. The risk score calculated for both boroughs were 5.666 and 3.498, respectively.

Table 5. Risk Score by Borough. I recorded the number of sources that emitted a specific pollutant then multiplied that by the pooled hazard ratio to generate the risk score.

Borough	**NOx**	**PM 2.5**	**PM 10**	**PAH**	**Risk Score**
Port of Spain		2	1	10	*14.981*
San Fernando	1				*1.069*
Chaguanas	1			3	*4.567*
Arima		1	1		*2.222*
Point Fortin			1	1	*2.289*
Couva-Tabaquite-Talparo	3	4	9	19	*39.864*
Diego Martin	1	1		8	*11.496*
Penal-Debe	2	1		20	*26.557*
Princes Town			2	5	*8.076*
Rio Claro-Mayaro				3	*3.498*
San Juan-Laventille		2		19	*24.352*
Sangre Grande	1	1		3	*5.666*
Siparia		1	2	4	*8.009*
Tunapuna-Piarco	4	3	4	16	*30.721*



Map 1. Lung Cancer in Trinidad. This map shows the prevalence of lung cancer in Trinidad by borough.
Map 2. Air Pollution in Trinidad. This map shows the distribution of air pollutants in Trinidad by borough.

DISCUSSION

Understanding the affects of air pollution on public health is important in a world with ever-increasing rates of industrialization and urbanization. Over the past decade, Trinidad has experienced an increase of air pollution and non-communicable diseases, including cancer (Sheey and Sharma 2013). However, there is an inadequate amount of research on cancer, especially lung cancer, in Trinidad. Since there is an association between lung cancer and air pollution, and Trinidad is known to have a pollution problem, it is important to document the relationships between specific pollutants and lung cancer. I determined that PAHs, which are emitted by waste sites and oil refineries, are more likely to be associated with lung cancer than

PM 2.5, PM 10, and NOx. PAHs are most concentrated in Port of Spain, Point Fortin, San Juan-Laventille, and San Fernando, while the highest rates of lung cancer are found in the Sangre Grande and Rio Claro-Mayaro. Yet Couva-Tabaquite-Talparo and Tunapuna-Piarco have the highest rates of pollution. This apparent discrepancy highlights the complexity of relationships between environmental pollutants and cancer, and suggests the need to conduct further research on the association between of air pollution and lung cancer in Trinidad. Moreover, it is imperative to advocate for more research on the environmental causes of lung cancer, so Trinidad can identify actions to decrease the country's high incidence and mortality rates. Even though my findings suggest that PAHs, NOx, and particulate matter may not be associated with lung cancer in Trinidad, it is clear that many air pollutants are associated with lung cancer. (Gazdar 2007) Though my results are inconclusive, Trinidad must address the increasing prevalence and mortality rates of lung cancer, and its lack of air monitoring infrastructure.

Location of Pollutants in Trinidad

Exposure to carcinogens such as polycyclic aromatic compounds, outdoor air pollution, and diesel exhaust are associated with lung cancer (CDC in press). With no access to data on air pollution by borough in Trinidad, I looked at NOx, PM 2.5, PM 10, and PAHs because these are common chemicals released from anthropogenic activities. Most sources of these pollutants are associated with industries focused on manufacturing for export, and located on the west coast of Trinidad. A possible reason for this is that factories in Trinidad are more likely to be on the west coast because they want to be close to ports, so they can ship out their goods. This means that most of the air pollutants I tested for are found on the west side of Trinidad along the coast. Though, individuals with lung cancer live on the east coast of Trinidad, and according to my study, the east coast has some of the lowest levels of pollution. However, the types of pollution found in the east are predominantly PAHs, which was proven to have the strongest association to lung cancer in my study.

Lung Cancer in Trinidad

Despite the fact that lung cancer is the most prevalent cancer among both genders in Trinidad, there is an insufficient data regarding lung cancer in Trinidad. Behavioral factors, such as smoking tobacco, have been proven to be associated with lung cancer. While smoking rates have been decreasing in Trinidad and Tobago, 21% of the population still smoke tobacco (PAHO 2013). Diet is also linked to lung cancer, and rising obesity rates in recent years may be associated with the increase in non-communicable diseases in Trinidad (Sheey and Sharma 2013). In 2012, Trinidad and Tobago implemented. Yet, despite a 33% tax increase on cigarettes, a ban of smoking in public places an action plan to reduce obesity (PAHO 2013), cancer rates are still increasing in Trinidad (Mohammed 2011), suggesting that other courses of action must be taken to address lung cancer. There has been very little consideration of the effects of the environment on lung cancer by government agencies. There are many papers on screening and access to treatment (Bascombe et al 2015, Bhola et al 2010, Annandsingh et al 2013, Green and Ocho 2013, Patrick 2009) for Trinidadian citizens, but the literature on environmental hazards and lung cancer has been absent. Outdoor air pollution contains many chemicals that are known to be carcinogens, therefore, it is necessary to understand the correlation between lung cancer and air pollution.

Air Pollution in Trinidad

Trinidadians are conscious of environmental issues and have been vocal about their concerns (Numbeo 2016). Since the early 2000's, it has been known that Trinidad was suffering from a major air pollution problem (EMA 2000). It has taken the Environmental Management Authority (EMA) 15 years to address air pollution by releasing the Air Pollution Rules. This long period of inaction may have done great damage to communities in Trinidad. In December of 2013 alone, the Petrotrin oil refinery in Pointe-à-Pierre had 11 oil spills. Residents of nearby San Fernando had to evacuate their homes, and many still presented symptoms of benzene poisoning in October 2014 (Guardian 2014). Public health officials should address this issue and work in conjunction with government officials to enact policies that prevents this situation from happening again, since benzene has been proven to cause various types of cancer, such as lung cancer (Huff 2007). The effective regulation of point source emissions, such as active air monitoring and safe waste disposal, from factories is necessary to ensure the safety and well being of Trinidad.

Exposure to air pollution happens daily in communities at home and work. Oil and gas production generate much of the country's economic revenue and employment. Petrotrin, along with factories, are important to the economic development of Trinidad, but they may be harmful to the health of residents and workers. The main concern should not be the effect of one chemical on the human body, but how these chemicals act together to produce harmful health outcomes. Though researchers do not fully understand the synergistic effect of these chemicals on the human body (Acaro 2005, Samet 1995, Yang 1998), precautions still must be taken. A possible solution to this would be to abstain from chemicals that are not yet proven to be safe and use alternate chemicals that have been proven to be safe.

Lung Cancer and Air Pollution

There is no debate regarding the association between lung cancer and air pollution; it has been proven in several studies and stated by many health organizations that they are correlated, so it is possible that this would be true for Trinidad (Burnett 2002, Lewtas 2007). According to the IARC, one out of five cancers are caused by environmental and occupational factors (PAHO 20ll). However, with Trinidad's prevailing rates of cancer, there seems to be an underlying problem that has not been addressed by recent policies and programs addressing cancer on the island. Trinidad has combatted cancer by addressing all risk factors associated with lung cancer, except environmental exposure. Trinidad is not an outlier in this, as many countries take the same approach to dealing with lung cancer. This is strange because it is well known that lung cancer is caused by mutations within lung cells. Mutations are caused by some internal malfunctions, but they can also be caused by exogenous factor, like chemicals, such as air pollutants. By this logic, it makes sense to examine air pollution as a determinant of lung cancer.

Limitations and Future Directions

Assessing air pollution in Trinidad was very difficult because there is no publically accessible air quality data for the country. My assumptions about the air quality of Trinidad were based on literature from different countries in which researchers examined how PAHs, PM 2.5, PM 10 produced by human activities are associated with lung cancer. Not having access to air quality data prohibited me from examining other types of air pollutants in a borough that could also be associated with lung cancer. Another limitation is that I made assumptions about where each person with lung cancer lived based on the hospital at which they sought treatment. Lacking patients' historical addresses also limited me in my analysis because I could not control for the time lag associated with cancer. It would have also been helpful if I were able to collect the addresses of cases' previous jobs to see if there was also an association between occupational exposure to chemicals and lung cancer.

To continue this project, I would like to conduct a survey on small subset of lung cancer patients in Trinidad. My subject population will contain people from different demographics. My analysis would be based on a patient's work history, resident history, and when they developed lung cancer. This would allow me to evaluate the types of pollutants that each individual comes into contact with on a daily basis up until the point they developed lung cancer. This study was not able to inconclusively prove that NOx, particulate matter, and PAHs were associated with lung cancer in Trinidad. However, there are many other pollutants, such as radon and asbestos, which should be examined. To accurately state that there is no association between air pollution and lung cancer in Trinidad, more research needs to be conducted. This research needs to be more in depth and examine other pollutants associated with lung cancer, by looking at air monitoring data, and incorporates physical geographical data such as wind patterns.

Broader Implications

Environmental Implications

Trinidad and Tobago's EMA should produce more comprehensive air quality monitoring data that is reported more frequently. The latest report, which was released in 2000, is ambiguous and provides information on a range of pollutants usually found in the atmosphere. However, the government should provide a comprehensible report that addresses at what levels specific pollutants were found in Trinidad and the geographical dispersion of these pollutants. People have the right to know what toxins they come into contact with, and this can only be achieved if the government monitored air pollution and produce reports on this data that is publically accessible. Furthermore, it is surprising that few independent researchers have collected data on pollution in Trinidad, and, few of these studies address how human health is affected by air pollution. I believe this emphasizes the lack of knowledge between pollution and human health on this island.

It is essential to take into account the various ways air pollutants enter human bodies. Air pollution can enter the soil or water sources, leading to contamination in food sources. For example, water sources and food sources have known to be contaminated with PAHs in the Caroni Swamp of Trinidad (Beckles et al 2015). It is widely known that oil refineries and waste incineration are sources of PAHs. Addressing the various routes of transmission of pollutants is necessary because air pollution may affect our bodies in more than one way. It is essential to understand how air pollution can enter our bodies because this gives us the knowledge of various ways we can treat and prevent health issues.

NOx, PM 2.5 and PM 10 are pollutants that are commonly produced from fuel combustion and industry, but there is an array of other chemicals that are produced from these processes that are also associated with lung cancer. These chemicals are harder to regulate because they are generated from anthropogenic activities that are deemed as necessary. To reduce the amount of these pollutants released into the air, we will have to change the way we produce, consume, and dispose the products we use.

Health Implications

Trinidad has among the highest rates of cancer incidence and mortality in the Americas. The government has taken limited steps to address this issue, but they need support. Trinidad was advised by other global organizations to address their high incidence of mortality of cancer by looking at treatment and the personal behaviors of their citizens (PAHO 2013). Globally, most health policies prioritize behavioral change rather than environmental factors associated with public health (Cohen 2000). This pathway to solving health problems is understandable because developing countries feel the pressure to industrialize so they can build up their economies, but since they often lack a regulatory infrastructure to limit the pollution caused by industrialization, they suffer more from environmental health hazards (Adger et al. 2002, McMichael 2000). These environmental health hazards can lead to harm in human health, but since these countries are so dependent on their industries, this remains an area of research that goes unstudied in developing countries.

We need to confront health from a different angle. Treatment, while though important, will only help to decrease mortality and morbidity rates of lung cancer. Screening is also a vital measure in stopping the progression of lung cancer. However, to decrease the incidence of cancer, we need to take preventive measures. These measures can take a variety of forms. Independent researchers and community organizations can surveil their own communities and continue to address their health concerns to their city government. The government of Trinidad may want to look at their job market and see how they can shift it to reduce the amount of pollution that is being produced by industries and figure out how to accurately support their citizens economically. Since Trinidad has a strong foundation in producing energy, this would be a great place for them to start looking and building an economy on alternative sources of energy. The Air Pollution Rules is a good step towards reducing air pollution, and would advocate that all industries should be air monitored daily. The EMA could go a step further and regulate the type of pollution that is being produced, by banning harmful chemicals. The only way to do this is to understand how the citizens of Trinidad are developing cancer.

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