Correlation Analysis of Long Term Exposure of Particulate Matter and Vehicular Traffic, on the Incidence of Respiratory Diseases in Two Urban Areas in the Philippines

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Abstract. A number studies reported in literature have highlighted the role of road traffic in pushing up the levels of ambient particulate matter as well as the contribution of particulate matter in increasing the incidence of certain respiratory health endpoints. This study investigates the evidence of the impacts of traffic by looking at the situation at the city-level through the assessment of the relationship of PM_{10} concentration, traffic in passenger car units, and incidence of asthma and acute bronchitis among children ages 0 to 59 months in two major Philippine cities.

Results indicate a positive correlation between annual level of particulates and traffic in both cities. Assessing the correlation between particulate pollution and public health requires quantitative knowledge about the relationship between exposure and health. The risk assessment conducted revealed that 8% and 12% of children getting sick of asthma in Quezon City and Makati City respectively may be attributed to particulate matter exposure. On the other hand, 3% and 6% of acute bronchitis cases in Quezon City and Makati City respectively are likely due to particulates. GIS was also utilized to estimate the PM_{10} concentration per district in both cities and the number of children that might be exposed to it. The study found that a sizable number of children in both cities live in polluted areas making PM_{10} a persistent environmental health hazard for children 0-59 months.

Keywords: traffic, particulate matter, respiratory diseases, correlation

1. Introduction

In the Philippines, particulate matter (PM) is considered a primary concern. A World Bank study (2007) found out that particulate matter levels in urban areas are in an average three times higher than rural cities. Approximately 12 million Filipinos residing in Metropolitan Manila, the country's economic center, are faced with the health burden brought about by elevated PM. A study by Simpas, et.al. (2014) revealed that particulate pollution in Metro Manila is more apparent in areas closer to major roads. Similarly, statistics from the Department of Environment and Natural Resources (DENR) shows that eighty-four percent (84%) of particulate pollution belongs to the transport fleet such as motorcycles, tricycles, and jeepneys. Hence, transport is considered to have an active role in elevating particulate pollution in the region.

PM is a well-documented pollutant. Many international agencies like the World Health Organization (WHO), US EPA, and European Union have selected particles as indicators in the assessment of air pollution that harms wellbeing (An , Hou, Li , & Zhai, 2013). Hence, monitoring is essential to achieve control in the amount of particulates released in the atmosphere. The Philippine Government, through the DENR and the Department of Health (DOH), among others, has been continuously making efforts to address particulates pollution, especially those coming from mobile sources. Studies that underline the significance of exposure to PM_{10} are essential to complement the growing body of literature that even acute exposure to particulate pollution may have harmful effects to health.

This exploratory research aims to determine the potential role of traffic congestion on the levels of ambient particulate matter and incidence of asthma and acute bronchitis among children (0-59 months) in Quezon City (QC) and Makati City from years 2011 to 2015.

2. Methodology

2.1 Study Area

To do a comparative assessment of the environmental health conditions, the study was carried out in two cities—Quezon City and Makati City.

Quezon City is the former capital of the Philippines and the largest city of Metropolitan Manila. It is almost one-fourth the area of Metro Manila. Due to its area and location, the city is the strategic junction point for major thoroughfares and transportation networks. It is easily accessible from highways and mass rail transit systems of the metropolis. Approximately 14% of the City's land area is used for roads and highways. On the other hand, Makati City is located at the center of Metro Manila. and is widely known for its commercial areas that support its recognized role as the Philippine's financial and business center. Makati houses the largest number of multinational and local corporations in the country. These include major banks, stores, as well as foreign embassies.

2.2. Study Framework and Definitions of Variables Used

Figure 1 shows the framework of the study. Three types of data were utilized: (i) health outcomes (acute bronchitis and asthma); (ii) ambient PM10 concentration; and (iii) traffic congestion in terms of annual average daily traffic in passenger car units. The table that follows summarizes the variables and data used and their definitions in the context of the study.

2.3 Data Analysis

Replacing Missing Values

Incomplete datasets are common in every study, moreso on researches regarding air pollutants. Missing values are usually trimmed or winsorized, that is removed from the dataset or replaced by a value. Ordered mean is usually substituted in place of missing values. While this is a common practice, it must be noted that out of 144 PM10 data points, 21 or 14.6% of which are missing. Removing a significant number of values would definitely affect the characteristics of the dataset. Thus, it is recommended to replace missing values. Based on the book Environmental External Costs of Transport, Dockery *et al*. proposed the conversion of TSP values to PM10 using the equation:

$$PM_{10} = TSP \times 0.55$$

Replacing missing values can also be done by projection based on previous records. Forecasting models can either

Figure 1. Framework of the Study

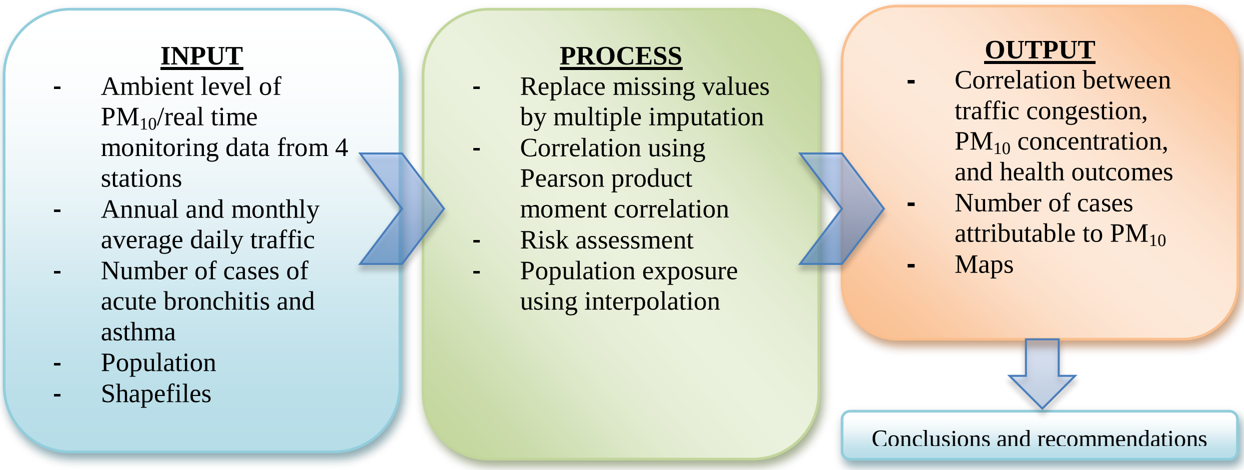

Table 1. Summary of Data Used and Level of Aggregation

Variables	Definition	Level of Aggregation	Source of Data	Time Reference
Morbidity Data (incidence)	Number of illnesses per cause per year. Diseases included – asthma and acute bronchitis	Monthly	City Health Office	2011-2014
Particulate Matter, 10µm (PM_{10})	Suspended particulate with aerodynamic diameter of 10 µm	City-wide monthly averages	Environmental Management Bureau	2011-2014
Passenger Car Units	Unit used for traffic capacity and is not in number of vehicles per hour but in PCU	Average PCU per year	Metropolitan Manila Development Authority	2011-2014

be linear or complex. And while there has been a long standing non-significant difference between the application of the two, recent literature surveying projection models conclude that complex models tend to project more accurate values. The specific type of complex model, however, depends on the characteristics of the dataset.

There are two main types of complex time series modelling: ARIMA (Autoregressive Integrated Moving Average) and Artificial Neural Networks (ANN). ARIMA works best for shorter reference periods. Furthermore, ANN requires the collation of other pertinent values on humidity, precipitation, and other factors related to particulate matter concentration. Given the dataset available, the R software's ARIMA model was used to forecast the years and months without recorded PM10 nor TSP values.

Identifying Correlation

Pearson product moment correlation was used to identify the type of relationship between ambience concentration, traffic congestion, and incidence of health outcomes. The correlation coefficient can take values between -1 through 0 to +1. Positive values denote positive linear correlation whilst negative values denote negative linear correlation. The closer the value is to 1 or –1, the stronger the linear correlation. A value of 0 denotes no linear correlation.

GIS Application

GIS was used to estimate the PM_{10} concentration per district in both cities and the number of children that might be exposed to it. To do this, the particulate concentrations were spatially interpolated using kriging spatial interpolation. Kriging was chosen over other interpolation techniques since the data is known to have directional bias.

Population data and particulate matter concentrations from the three monitoring stations were spatially interpolated at approximately 1 km × 1 km. Both data were then overlaid using the GIS spatial information analysis function to analyze the population exposure levels in various concentration ranges. Following similar studies such as that of Sun, An, Tao, & Hou (2013), the population-weighted exposure level (PWEL) was calculated using the formula below to correct the lack of sensitivity:

$$PWEL=\sum(Pi\times Ci)/\sum Pi$$

where P_i is the population in grid i, and C_i is its average PM_{10} concentration.

3. Results and Discussion

There are a wide variety of correlation types for different circumstances. This study utilized Pearson's correlation coefficient to measure the strength of linear relationship between particulate pollution and PCU, particulate pollution and several respiratory diseases, and several respiratory diseases and PCU. Literature suggests the following verbal description of the absolute value of r:

- .00 - .19 "very weak"
- .20 - .39 "weak"
- .40 - .59 "moderate"
- .60 - .79 "strong"
- .80 - 1.0 "very strong"

Table 2 shows the correlation between PM_{10} and PCU, PM_{10} and asthma, PM_{10} and acute bronchitis, PCU and asthma, and PCU and acute bronchitis in Quezon City.

Table 2. Summary of Correlation of Variables in QC

Variables	Traffic	Asthma	Acute Bronchitis
PM_{10}	0.465	-0.309	-0.197
Traffic	1	-0.690	-0.936

Result shows a moderate positive correlation (r=0.465) between PM_{10} and traffic. This affirms related literatures that products from road transport such as tail exhaust, products of abrasion processes and re-suspended road dust (Gertler, Gillies, & Pierson, 2000) are among the many sources of particulate matter in urban areas. Different factors such as the development of low to high-rise condominiums, road constructions, and fire events, inter alia, also contribute to particulate pollution in Quezon City.

The retrospective analysis of ambient PM_{10} concentrations and cases of respiratory diseases as well as traffic and cases of respiratory diseases showed negative correlations. The findings are not aligned with studies, which have demonstrated that acute increases in PM_{10} and occurrence of traffic congestion result in increased hospital admissions for asthma, greater use of asthma medication, and more consultations with general practitioners; similarly, contributory to spikes in cases of acute bronchitis. This is expected for asthma since its number of cases is decreasing while the population increases over the past four years. Either the families of children (0-59 months) are able to manage the risk factors involved in the development of asthma exacerbations or a number of families prefer to seek medical attention in hospitals instead of primary health care facilities.

However, when the monthly average PM_{10} concentrations were correlated with the monthly cases of asthma (please refer to Annex II for the detailed results); cool and dry months (October/November to February) generally resulted to a positive correlation. Such finding cannot be drawn for hot and dry months (March to May) as well as wet and rainy (June to September/October) months. Even though particulates remain suspended in the atmosphere for longer periods of time on hot days, findings show that in Quezon City the higher concentration of PM_{10} occur during the windy and cool months when particulates and various other air pollutants move around the atmosphere. This phenomenon may have triggered the increases in the number of cases of asthma in the study population. One must note however that in reality, asthma symptoms can flare at any time of year due to various other triggers.

Annual incidence of acute bronchitis and annual concentration of particulates also yielded a negative correlation. Positive correlations were drawn from wet and rainy season or the months of May to October. This might be due to the usual occurrence of acute bronchitis in cool (cold) weather when a cold or flu virus attacks the airways. Similarly, the annual incidence of acute bronchitis and annual average of traffic correlation resulted to an almost perfect negative relationship. That is, the increase of passenger car units in the city eventually resulted to the same proportional decrease in the acute bronchitis morbidity. Again, this is likely because of acute bronchitis resulting from a viral infection, rather than the allergens in the air. The decreasing acute bronchitis incidence pattern is due to a lot of other factors but traffic. Evidently, the correlation between asthma and traffic and acute bronchitis and traffic yielded negative results. When PM_{10} and PCU, PM_{10} and asthma, PM_{10} and acute bronchitis, PCU and asthma, and PCU and acute bronchitis in Makati City were correlated, only one pair—PM_{10} and AADT—yielded positive relationship. These findings are akin to Quezon City's correlation.

Table 3. Summary of Correlation of Variables in Makati City

Variables	PCU	Asthma	Acute Bronchitis
PM_{10}	0.817	-0.131	-0.919
PCU	1	-0.588	-0.614

Looking at the monthly data, similar patterns may be observed on the levels of particulates and cases of asthma from July to September. These variables in these months yielded a positive correlation.

Aside from quantifying the risks anchored to PM_{10}, it is also crucial to estimate exposures of the population—both with and without disease. It is viewed as the initial step in formulating exposure data for quantitative assessment of harmful PM_{10} pollution. Difficulties arise in this undertaking since monitoring of PM concentrations is often scarce: even in metropolitan cities such as Quezon City and Makati City have only one or few monitors to represent several million people; even worse in rural areas where monitoring may be almost non-existent. Monitoring stations are also often highly biased in their distribution towards certain types of site (often depending on their specific purpose). In the case of the study area, all monitoring stations are roadside, having the intention of really tracking air quality of residential and commercial communities nearby. As a consequence, simply averaging data from several monitoring sites, or using the nearest site to represent exposures, can be highly misleading. The DENR's Air Quality Status of Report also presents averages of pollutant concentrations from different monitoring stations per area/s. A more sophisticated method of estimating exposures is through population weighting as it presents realistic outcomes of population to particulate concentrations. Weighting adjustment (Figure 2 and Figure 3) reveals that there are more children (53,723) exposed to harmful particulate levels (>60 mg/m3) in Makati City. Quezon City has similar situation with over 50% of its children (237,982) residing in polluted areas.

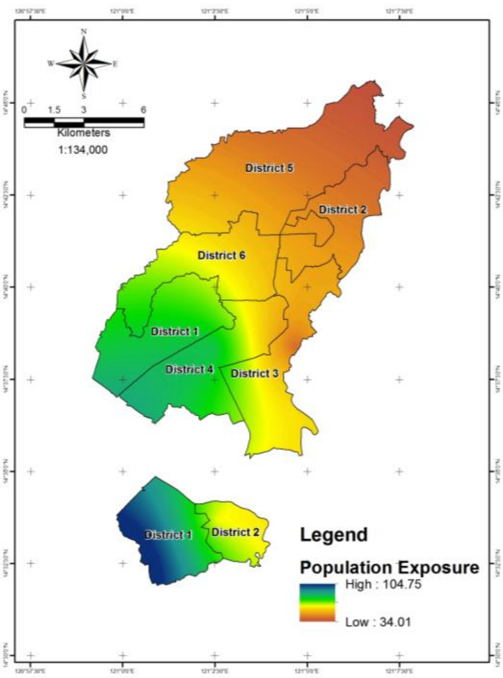

Figure 2. Population Exposure Concentration

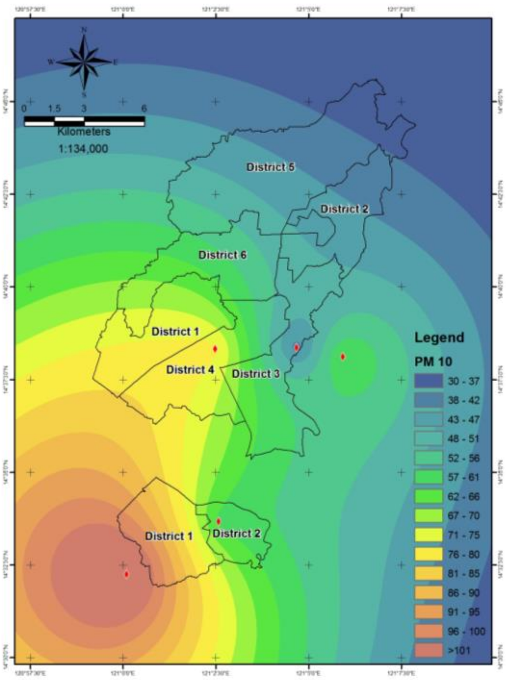

Figure 3. Population Weighted Exposure Level

4. Conclusion

The study explores the link between PM_{10}, asthma, acute bronchitis, and traffic in Quezon City and Makati City. Results show that PM_{10} is positively correlated with traffic in both cities. All other variables when correlated yielded negative relationship. Nevertheless, it can be assumed that traffic is contributory to ambient particulate matter. The population distribution by exposure level shows thousands of children (0-59 months) reside in polluted areas.Whereas the study effectively accomplished its objectives, it also provided the foundation for further researches to improve the results of the study. Additional variables such as meteorological factors are important to strengthen the foundation for associations. Similarly, site-specific and comprehensive health and air quality data, which are not readily available during the course of the study, will increase the accuracy of the results. A large dataset for all three variables are needed to be analyzed in order to define and point out the factors that lead to outcomes. The correlation and risks assessment envisioned in this work are necessarily dependent on continuous monitoring of particulates concentrations, accuracy of diagnosis of diseases, and regular traffic count.The study likewise supports stronger implementation of policies such as the Clean Air Act at the national level as well as adoption of these at the local level. Other systems and technologies that the study recommends are the creation of green routes especially for school children, installation of vehicle air filter to trap potentially harmful vehicle exhaust particles, improvement in the auditing of vehicle and factory emissions, and upgrading of classroom ventilation to lessen the exposure of children to particulates.

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