Ambient Air Quality and The Incidence of Selected Diseases: Some Urban Health Observations in Lagos, Nigeria

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The quality of air is determined by the extent of atmospheric pollution. The USEPA identifies six criteria pollutants namely particulate matter (PM), ground level ozone, carbon monoxide, sulphur oxides, nitrogen oxides and lead exposure as toxic and injurious to human health. Thus, the need to examine ambient air quality and incidence of selected diseases in Lagos, Nigeria. The data for the study include a five year sampling on criteria pollutants and data on selected airborne diseases that were collected for the same period of time. Data analysis adopted the use of multiple regression in examining the relationship between ambient criteria pollutants and the occurrence of diseases. GIS procedure was also employed to produce a map showing the spatial pattern of criteria pollutants. The findings reveal an R2 of 19.8, 13.9, 8.9, 8.4 and 16.8 percent respectively for asthma, bronchitis, heart failure, lung cancer and tuberculosis. The results show a low level of association and this was attributed to other causal factors responsible for the occurrence of the selected diseases. However, this study provides evidence of an association between outdoor air pollution and increased risk from these diseases. Therefore, the study recommends that governments, and other stakeholders in health sectors should harmonise efforts, resources and ideas towards effective planning, monitoring, policy implementation and provision of facilities that could control and ameliorate the presence of pollutants to which urban residents are exposed thereby reducing the health effects from such exposures.

Keywords: *Airborne diseases, Air pollution. Criteria pollutants, Ambient air*

Introduction

Water is one of the most important resources without which no existence is possible. Though the hydrosphere is estimated to contain about 1.36 billion Km^3 of fresh water, 99.9 percent of this is locked up in seas and oceans with only 0.3 percent available for the use of man through sources such as rivers, streams, springs, groundwater and aquifers (Wilson, 1978). Apart from water being required by man, the resource is also of great demand in the maintenance of ecological balance. However, the world is currently experiencing scarcity of fresh water supply, most especially in the developing countries. According to UNICEF (2016) women across the world spend 200 million hours a day to search and collect water. Because scarcity of water is increasing, there is thus the need to plan, monitor and manage the resources especially for the purpose of sustainable development (Iroye, 2017).

Among the oldest water sources in the world are rivers (Higler, 2012). Rivers and their catchments constitute an important part of the natural environment and play an integral part in the sustainability and

Among such factors include natural processes of precipitation, weathering and erosion and anthropogenic activities such as urban development, industrialisation, transportation and agricultural activities.

One of the factors of quality impairment of surface water is pollution by heavy metals. Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic and poisonous even at low concentrations. According to Tam and Wong (2000), heavy metals are one of the most serious pollutants in man's natural environment due to their toxicity, persistence and bioaccumulation problems. As a result of human activities, the rate and degree of heavy metal pollution in natural water bodies have been on the increase. According to Wangboje and Ekundayo (2013), presence of heavy metals in water bodies is leading to a variety of negative impacts with consequent effect on ecosystem.

In surface water such as rivers and other natural aquatic ecosystems, heavy metals occur naturally in low concentrations, normally at the nanogram to microgram per litre level. In recent times, however, its occurrence has become a problem of increasing concern (Islam *et al.*, 2015). This situation according to Biney *et. al.* (1991) and Martin *et al.*, (2015) has arisen as a result of rapid growth of population, increased urbanisation, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices, as well as non-enforcement of environmental regulations. The major routes of heavy metal uptake by man are through food, drinking water and air. For example, aquatic animals, most especially fish which are consumed by man, are a source of mercury (Hg) contamination.

1.0 Introduction and Statement of the Problem

Studies have shown that over half of the global population live in urbanised areas (United Nations, 2012) with consequent urbanization and intense human activities occasioned by resource consumption. There is also an increase in chemical emissions and waste disposal resulting in a variety of environmental problems, including the potentially toxic criteria pollutants (Charlesworth *et al*., 2010). Urban air quality in many large cities are adversely affected by air pollution such as particulate matter (PM2.5 and PM10) and other criteria air pollutants (Laro& Raheem, 2017). This is worsened by increasing population of such cities with tendencies to generate more waste and pollutants. The sustainable cities and communities of the SDG s was premised on the understanding of sustained clean air, inclusive, resilient and safe environment in our cities. The dynamics of the population, its demography and activities combine to threaten the attainment of the SDG s except deliberate steps are taken to address the tendencies. One of such tendencies is increased pollution of the ambient environment with consequences on air quality in cities.

Air is one of the most important constituents of man s environment. An average human being requires about 12kg of air each day, which is nearly 12 to 15 times greater than the amount of food consumed (Garg, 2006). Clean and pure air is very essential for human health and survival. Any change in the natural and normal composition of air that may adversely affect the living system, particularly the human life invariably causes air pollution (Garg, 2006). The World Health Organisation (WHO) defines air pollution as limited to situations in which the outer ambient atmosphere contains materials in concentrations which are harmful to man and his environment (Anjaneyulu, 2005). A substance in the air that can cause harm to humans and the environment is known as an air pollutant and air pollutants are expressed as a ppm or ug/m3 which is subjected to change to variations of temperature and pressure (Das, & Behera, 2008). Air pollution is a problem that is directly related to the number of people living in an area and the kinds of activities they engaged in. In a place where the population is low and their energy usage is also low, the impact of people in creating pollution is minimal. However, where the population is high, the area urbanised and industrialised with high energy usage, large quantities of pollutants are released into the environment. It is clearly obvious that the greater the concentration of people in one area, the greater the amount of pollution, and the greater the sophistication of a society, the more intricate and poignant its pollution (Inyang, 1978).

The United States Environmental Protection Agency (USEPA, 2012) classified air pollutants into two groups: criteria and hazardous air pollutants (HAPs). The criteria pollutants are pollutants that can have an adverse effect on health and the environment. They include particulate matter, oxides of nitrogen, oxides of sulphur, carbon (II) oxide and lead. Emission of air pollutants is caused by different anthropogenic activities which can be categorised into their source groups: motor traffic, industry, power plants and domestic fuel (Lirong*et al*., 2004; Olukayode, 2005; Mathuros*et al*., 2006).

Air quality can be a critical reflection of the ambient atmospheric pollution, relative to the potential to inflict harm on the environments (WHO, 2002). Air is said to be polluted when there is „the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odour, smoke, or vapour in such a characteristics and duration as to make them actually or potentially injurious to human, plant or animal life, or property or which interferes with the comfortable enjoyment of life and property (World Bank, 1978). Human health is threatened with diseases and early mortality as a consequent of pollution particularly in emerging economies facing rapid industrialisation and urbanisation. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma (WHO, 2014). Moreover, reduction in outdoor air pollution also reduces emissions of CO2 and short-lived climate pollutants such as black carbon particles and methane, thus contributing to the near and long-term mitigation of climate change (WHO, 2014).

Ground level ozone (O3), oxides of nitrogen (including NO, NO2, and NOx), carbon monoxide (CO), and sulphur dioxide (SO2) are not only pollutants themselves but also react with many other compounds such as volatile organic compounds (VOCs) leading to

changes in atmospheric composition (Atkinson, 2000). Researchers have shown that air pollution leads to detrimental impact on the environment such as haze, smog and acid rain particularly in urban and industrialised cities with high vehicular traffic. A number of epidemiological studies have also shown that PM10 is associated with morbidity and mortality rates particularly due to cardiovascular and respiratory illnesses (Peters *et al*., 2001; Nigel *et al*., 2002; Pope *et al*., 2002; Lirong*et al*., 2004). Exposure to carbon monoxide can result in fatigue, headaches, dizziness, loss of consciousness and even death. Nitrogen oxides and sulphur dioxide have been shown to have association with immune system impairment, exacerbation of asthma and chronic respiratory diseases, reduced lung function and cardiovascular disease (Osuntogun& Koku, 2007; Hopkins *et al*., 2009).

Lagos, the commercial hub of Nigeria, has over 60% of industry concentration in Nigeria. These industries contribute significantly to air pollution because of the emission of smokes and gases of various magnitudes due to their diesel powered engines. In this way, industrial sites are always polluted above the accepted level. Akinola *et al*. (2014) posited that the increasing human activities, especially industrial and vehicular emissions are posing great environmental challenges that have resulted in loss of life and destruction of properties in the state. The overall effects of air pollution on Lagos residents and environments contribute to drag in the efforts for its most sustainable development programs (Akinola *et al.* 2014). Air pollution, particulate matter, especially the smaller particles, has harmful effects on human health. Cases of respiratory diseases and even death have been reported in Lagos (Ogunbi et al., 1978; Olowoporoku*et al.*, 2012). An epidemiological study by (Olowoporoku*et al.*, 2012) showed a growing evidence of relationship between air pollution and mortality, hospital admissions for respiratory or cardiovascular disease and an associated increased risk of myocardial infarction in Lagos. Although, much can be done to improve the choice and citing of trees and other vegetation for air quality, the greatest benefits will be achieved if people can be close to, or even within, green infrastructure when moving around towns and cities. For instance, the largest decreases in particulates due to uptake by vegetation were in the green spaces themselves (Tiwary, 2009).

However, Nigeria is among the few countries with no effective procedures or framework for managing ambient air quality (Koku &Osuntogun, 2007). There are no coordinated or continuous assessments to inform an appropriate policy framework to manage the local air pollution that residents of cities such as Lagos routinely experience (Taiwo, 2009).

Study Area

Lagos state is located between latitudes 6º.35N to 6.58ºN and longitudes 3º.45 E to 3.75ºE of the Greenwich meridian in the South western part of Nigeria. The state has a tropical wet and dry climate with an all year round precipitation in many parts of the state. Wet season is characterised by a double maxima of rainfall usually from March to July and the other in late August to early September. A dry spell may occur from late September to early November. The annual mean rainfall is between 1381.7mm and 2733.4mm in recent time from one location to another. The maximum temperature ranges between 29°C - 34°C, the lowest being in the month of July and the highest in February and a minimum temperature varies between 24°C - 28°C. The relative humidity varies seasonally with an average of 70% throughout the year.

The vegetation of the study area is made up of two types namely; swamp forest of the coastal belt and dry lowland rain forest. The swamp forest is a combination of mangrove forest and coastal vegetation developed under the brackish conditions of the coastal areas, swamp fresh water lagoons and estuaries. Lying to the north of the swamp forest is the lowland (tropical) rain forest zone which stretches from Ikeja through Ikorodu. Economically valuable trees such as teak, tripochiton, seletrocylon (arere), bancleadiderrichil (opepe) and terminahia (idigbo) can be found in some parts of the study area. Lagos State occupies an area of 3,577 square kilometres, which represents 0.4% of Nigeria landmass with a marine shoreline of about 180km extending inland to a maximum distance of about 32km. Lagos is the most populous city in Nigeria, the second fastest-growing city in Africa and the seventh in the world (www.lagosstate.gov.ng). The NPC (2016) estimated the population of Lagos state at around 21 million, making Lagos the largest city in Africa.

The study area accounts for over 60% of the federation s total industrial investment and the largest concentrations of industries can be found in Ikeja, Alimosho and Kosofe Local Government areas (www.lagosstate.gov.ng). Other specific locations of numerous industries include Apapa, Surulere, Shomolu, Mushin, Oshodi-Isolo, Agege, AmuwoOdofin, and Ikorodu among others. See fig. 1 for the map of the study area.

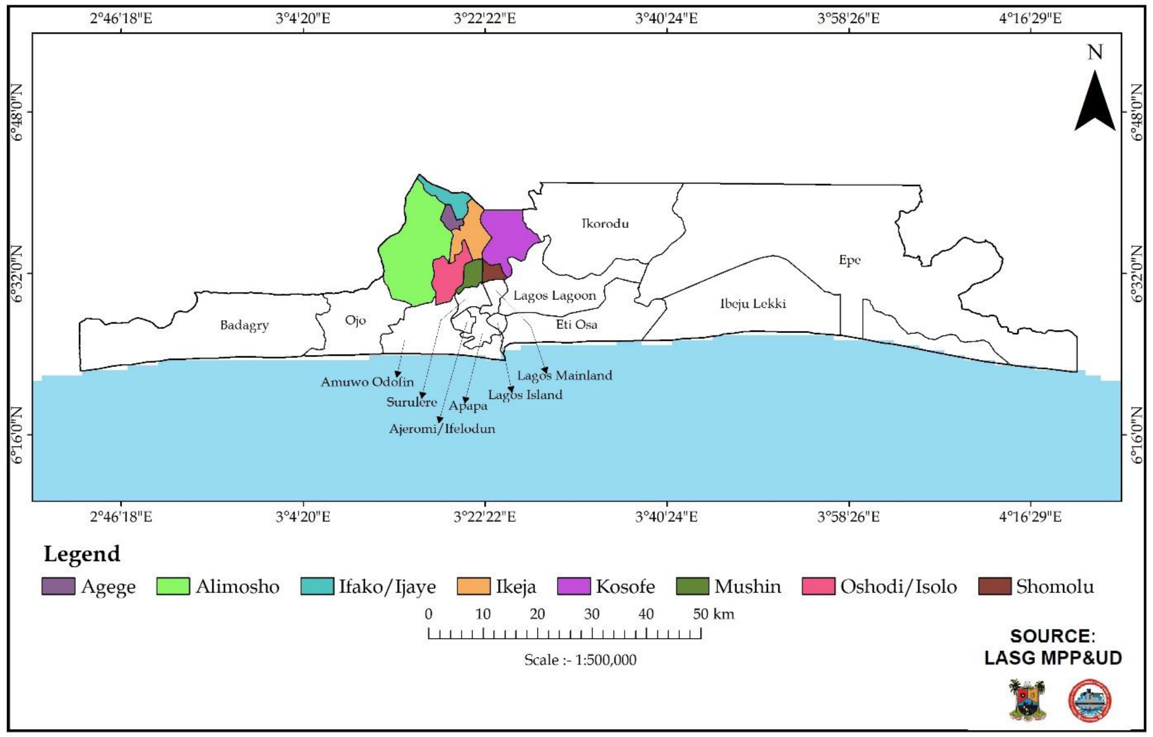

Figure 1. Lagos State showing sample areas

According to Brunekreef (2005), ambient particulate matter levels in cities of developing countries including Nigeria are generally much higher than in developed countries because of dispersed heating with small-scale solid fuel use, uncontrolled industrial emissions, and the large numbers of non-catalyst two-stroke engine vehicles. Ediagbonya*et al.* (2012) proposed that atmospheric environmental problems had received scanty attention in Nigeria but were gradually becoming a subject of increasing national significance because air pollution is a major threat to human life. Most people inhale pollutants while at home or commuting to work irrespective of the mode of transportation (Ekpenyong*et al.*, 2012). Depending on the dose and the exposure time, these pollutants have the potential to cause far reaching adverse health effects in man, but principally affecting the respiratory and cardiovascular systems (Ekpenyong*et al.*, 2012).

The World Health Organisation (2002) reported that about 2.4 million people worldwide (including about 93,700 Nigerians) die each year from causes directly attributable to air pollution. Akinola *et al.* (2014) indicated that studies have shown that in Lagos State vehicular emissions are the highest point source contributors to carbon emission into the environment, followed by the manufacturing industries. Unending traffic jams in Lagos metropolis also results in commuters spending several unproductive hours in traffic and increased avoidable emissions of CO2 and other pollutants. A study conducted by the Lagos Metropolitan Transport Management Authority (LAMATA) on air quality between 2003 and 2007 indicated that vehicular emission contributes approximately 43% ambient air pollution in Lagos. The continuous expansion, population increase and transformation of the Lagos city have contributed to its present polluted state. However, assessment of the health effect of air pollution in developing countries is difficult because of lack of cohesive air quality policies in combination with poor environmental monitoring and a paucity of disease surveillance data (Briggs, 2003). Therefore, this study becomes imperative in examining the relationship between criteria air pollutants and incidence of some selected diseases.

The aim of the study is to examine the ambient air quality and the incidence of selected diseases in Lagos. This is with a view to investigating the relationship that may exist between the spatial pattern in the exposure to ambient air quality and the incidence of selected diseases in Lagos, Nigeria.

Materials and Methods

Data required and sources

The sources of data for this study are both primary and secondary sources. The primary sources include the coordinates of the sample sites. The secondary data includes five years data of criteria pollutants. The pollutants are Particulate matter (PM2.5, PM10), Ground level (O3) Nitrogen dioxide (NO2), sulphur dioxide (SO2), and carbon dioxide (CO)

Guideline for PM2.5, PM10, SO2, NO2, CO and ground level O3, were also obtained from the WHO publications, five (5) year data on air pollution, maps, and statistical data obtained from published works.

Data collection

Study sites were selected with a view to giving a holistic representation of air quality status of the area. The study area was categorised into three groups based on the predominant land use types. Thus, Lagos was divided into high traffic, industrial and residential areas. Areas considered as residential areas were land use in which housing predominates. In the light of the above, state government staff quarters and estates owned by private agencies were also considered. The high traffic areas are the major road intersections where high volumes of traffic are experienced during the peak hours of the day while areas with high concentration of industries were considered as industrial areas. It must be noted that this categorisation is not water tight as these characteristics may occur in all areas with varying intensities (See table 1)

Direct measurement of coordinates of the fifteen sample sites from the field with the aid of the global positioning system GPS.

The secondary data required for this study were sourced from the Lagos State Ministry for Environment and Ministry of Health, Lagos state. The data are:

Data on Criteria pollutants: The data on criteria pollutants were obtained from Ministry of Environment (2009-2013) Lagos State. The data are particulate matter (PM2.5 andPM10), Ground level Ozone, Nitrogen dioxide, Sulphur dioxide and Carbon monoxide. This was required for the study because the atmospheric pollutants have the potentials for deterioration and damage to both public health and the environment. Data on air quality related diseases such as bronchitis, lung cancer, asthma and heart failure were sourced from Lagos State University Teaching Hospital, Gbagada, Mushin, Isolo and Somolu General Hospital in the area of study from 2009-2013. This is with a view to giving an accurate representation of the data. Map of the study area was obtained from Lagos State Ministry of Physical Planning and Urban Development

Table 1: Showing Sites Distribution in the Study Area.

LAND USE TYPE	LOCATIONS/SITES
RESIDENTIAL	Agege Housing Estate; Oko-Oba
	Ikeja G.R.A: Sobo Arobiodu street.
	Magodo Estate : CMD Road, Shangisha
	Ogba Staff Quarters; Ogba
	Secretariat; Alausa : front of Skye bank
HIGH TRAFFIC	Maryland Junction, Ikeja
	General Hospital: Frontage of LASUTH
	Ojodu-Berger : Berger Roundabout
	Iyana-Ipaja : Under Bridge
	Oshodi B/Stop : Oshodi
INDUSTRIAL	Specomil : Inside Ikeja Industrial Estate
	Wemabod : Adjacent Guinness Nigeria PLC office
	Wempco : Industrial Estate Ogba
	Ize-Iyamu
	Matori

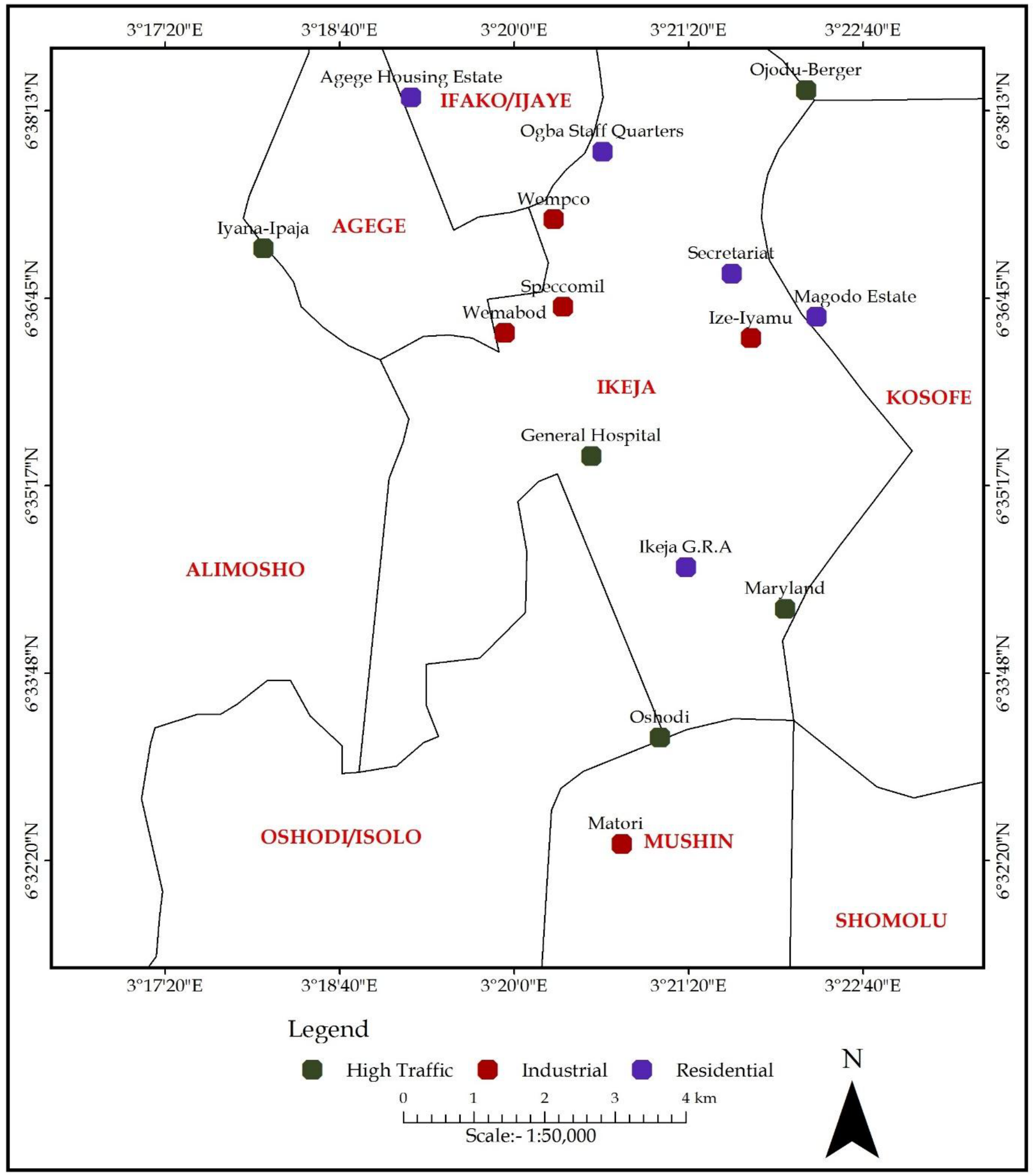

Figure 2: Sampling Sites in the Study Area
Source: Author's Fieldwork, 2016

Methods of data analysis

Arc GIS was employed to produce the map of the spatial distribution of criteria pollutants in Lagos area. To examine the relationship between the five criteria pollutants and the occurrence of five selected diseases in Lagos State, a multiple regression analysis was used. The regression model is denoted as:

$$Y = a + bx_1 + bx_2 + bx_3 + bx_4 .....bx_n + e \qquad ....(1)$$

Y = dependent variables; X = independent variables
a = the intercept constant; b = regression co-efficient;
e = residual error term

Where, Y = Selected diseases
X1- X6= Criteria pollutants i.e. PM2.5, PM10, SO2, NO2, CO and O3
X1 = PM2.5 (mg/m3)
X2 = PM10 (mg/m3)
X3= SO2 (ppm)
X4 = NO2 (ppm)
X5 = CO (ppm)
X6 = O3 (ppm)

Note.

*This model was repeated for each of the diseases.
*Mean of selected diseases for the period of study was adopted as the measure of disease occurrence
*Mean of criteria pollutants for the period of study was adopted as the measure of pollutants

Results and Discussion.

Criteria pollutants and the occurrence of asthma

The dependent variables are the reported cases of asthma while the independent variables are the six criteria pollutants (PM2.5, PM10, CO, NO2, SO2,and O3,). Table 2 show the results of the multiple regression analysis with an Rwhich signifies that the identified criteria pollutants accounted for 19.8% variability in the reported cases of asthma in the study area. This low percentage is expected because the criteria pollutants used in this study are not the only determinant of incidence of asthma, though they can precipitate the disease, but this is also a function of the level of exposure of the individual. Earlier, the Committee on the Medical Effects of Air Pollution (COMEAP) (1995) concluded that exposure to ambient concentrations of air pollutants is associated with an increase in exacerbations of asthma in susceptible populations such as children and elderly. The question of whether air pollution causes asthma is still open for debate. However, there is evidence to suggest causation. 2

Table 2: Model summary of Relationship between asthma and criteria pollutants

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.445[a]	.198	-.011	1.00538504

a. Predictors: (Constant), $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2,and O_3
Source: Author's Computation, 2016

Table 3, shows that for every 1% increase in PM10, CO2, SO2, O3, there is 1.34%, 0.094%, 2.218%, and 23.708% increase in the occurrence of asthma in the study area, respectively. This is represented in the expression below:

$$Asthma = -2.647 - 1.413_{Pm2.5} + 1.337_{Pm10} + .094_{CO} - 3.605_{No_2} + 2.218_{So_2} + 23.708_{O_3} \text{ ....eq. 2}$$

As shown above, ground level ozone gases are the most important criteria pollutants associated with asthma in the study area. The model summary (Table 2) for asthma and criteria pollutants indicates that about 20% of the variation observed in asthma occurrence could be attributed to the occurrence and variation in criteria pollutants in sampled sites.

Table 3: Relationship between asthma and criteria pollutants

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-2.647	1.581		-1.675	.108
PM2	-1.413	1.944	-.495	-.727	.475
PM10	1.337	1.110	.690	1.204	.241
CO	.094	.291	.221	.323	.749
No_2	-3.605	2.325	-2.219	-1.550	.135
So_2	2.218	1.993	1.648	1.113	.277
O_3	23.708	12.563	.465	1.887	.072

a. Dependent Variable: (Asthma)
Source: Author's Computation, 2016

Also, as shown in (Table 3) for every 1% decrease in PM2.5 and NO2, there is -1.413% and -3.605% decrease in the occurrence of asthma in the study area, respectively. This result coincides with the findings of Koren (1995) that the concentration of ambient particulate matter with PM10, primarily in combination with high sulphur dioxide (So2) and sulphate particulate matter has been associated with increased hospitalisation for asthma.

Criteria pollutants and the occurrence of bronchitis

In this study, bronchitis is the dependent variable, while the independent variables are the six criteria pollutants (PM2.5, PM10, CO,

NO2, SO2,and O3). Table 4 shows the results of the multiple regression analysis with an R2 which signifies that the identified criteria pollutants accounted for 13.9% variability in the reported cases of bronchitis in the study area. This low percentage was due to the fact that the criteria pollutants used in this study were not the only determinant of incidence of bronchitis. The United States National Heart, Lung and Blood Institute (2011) established that chronic bronchitis is caused by repeated irritation and damage of the lung and airway tissue, and smoking is the most common cause of chronic bronchitis, with other causes including long-term exposure to air pollution, dust and fumes from the environment, and repeated episodes of acute bronchitis. A substantial body of epidemiological research corroborates the assertion that outdoor air pollution, and in particular traffic-related air pollution, is a contributing factor to premature respiratory mortality and morbidity (Kunzliet al., 2000).

Table 4: Model Summary of Relationship between Bronchitis and Criteria Pollutants

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.373[a]	.139	-.085	1.04164544

a. Predictors: (Constant), $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3

Source: Author's Computation, 2016

Table 5, show that for every 1% increase in PM_{10}, SO_2, O_3, there is 1.028%, 1.974%, and 9.619% increase in the occurrence of bronchitis in the study area, respectively. This is represented in the equation below:

$$Bronchitis = .085 - 2.299_{Pm2.5} + 1.028_{Pm10} - .018_{CO} - 2.352_{No_2} + 1.974_{So_2} + 9.619_{O_3} \text{ …………eq. 3}$$

As indicated above, ground level ozone gases are the most important criteria pollutants associated with bronchitis in the study area. The model summary (Table 4) for bronchitis and criteria pollutants indicates that about 10% of the variation observed in bronchitis could be attributed to the occurrence of criteria pollutants in the area of study.

[illegible]

[illegible]	[illegible] Coefficients		[illegible] Coefficients	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
t a 2.5	[illegible]2.299	[illegible]	[illegible].805	[illegible]1.142	[illegible]
t a 10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
/ h	[illegible].018	[illegible]	[illegible].041	[illegible].058	[illegible]
b h 2	[illegible]2.352	[illegible]	[illegible]1.447	[illegible].976	[illegible]
{h 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
h 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Dependent Variable: (Bronchitis)

Source: Author's Computation, 2016

Based on the results in Table 5, for every 1% decrease in $PM_{2.5}$, CO and NO_2, there is -2.299%, -0.018% and -2.352% decrease in the occurrence of bronchitis in the study area, respectively.

Relationship between criteria pollutants and the occurrence of heart failure

The American Heart Association (2010) issued a scientific statement concluding that exposure to air pollution contributes to cardiovascular illness and mortality. It was elaborated that short-term exposure to air pollution can increase the risk of heart failure, heart attack, stroke and arrhythmias in susceptible people, such as the elderly or those with pre-existing medical conditions. In this study, heart failure is the dependent variable, while the independent variables are the criteria pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3). Table 6 shows the results of the multiple regression analysis with an R^2 of 0.089, which signifies that the identified criteria pollutants accounted for 8.90% variability in the reported cases of heart failure in the study area. The reason for this low percentage can be attributed to the fact that criteria pollutants alone does not determine the incidence of heart failure, pre-existing medical conditions and susceptibility are also a major factor to be considered. This result corroborates the assertion posited by the American Heart Association.

Table 6: Model summary of relationship between heart failure and criteria pollutants

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.298[a]	.089	-.149	1.07194240

a. Predictors: (Constant), $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3

Source: Author's Computation, 2016

Table 7, shows that heart failure hospitalisation was associated with criteria pollutants. However, for every 1% increase in PM_{10}, CO, SO_2, O_3, there is 1.274%, 0.018%, 2.114%, and 10.607% increase in the occurrence of heart failure in the study area, respectively. Also, for every 1% decrease in $PM_{2.5}$ and NO_2, there is -2.525%, and -2.469% decrease in the occurrence of heart failure in the study area, respectively.

***Table 7:** Relationship between Heart Failure and Criteria Pollutants*

Model	Unstandardised Coefficients B	Unstandardised Coefficients Std. Error	Standardised Coefficients Beta	t	Sig.
(Constant)	-.208	1.685		-.123	.903
$PM_{2.5}$	-2.525	2.072	-.884	-1.218	.235
PM_{10}	1.274	1.184	.658	1.076	.293
CO	.018	.310	.043	.058	.954
NO_2	-2.469	2.479	-1.519	-.996	.330
SO_2	2.114	2.125	1.570	.995	.330
O_3	10.607	13.395	.208	.792	.437

a. Dependent Variable: (Heart Failure)

Source: Author's Computation, 2016

Based on the results in Table 7, the relationship between heart failure and criteria pollutants can be written as shown in equation 4.

$$HeartFailure = -.208 - 2.525_{Pm2.5} + 1.274_{Pm10} + .018_{CO} - 2.469_{No_2} + 2.114_{So_2} + 10.607_{O_3} \text{ ……………..eq. 4}$$

Relationship between criteria pollutants and the occurrence of lung cancer

The International Agency for Research on Cancer (2013) classified ambient air pollution as a cancer-causing agent (Carcinogen, group 1). The IARC evaluation showed an increasing risk of lung cancer with increasing levels of exposure to outdoor air pollution and particulate matter. In this study, the dependent variable is Lung cancer, while the independent variables are the criteria pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3). the results of the multiple regression analysis with an R

Table 8: Model Summary of Relationship between Lung Cancer and Criteria Pollutants

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.290[a]	.084	-.155	1.07467988

a. Predictors: (Constant), $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3

Source: Author's Computation, 2016

As indicated in Table 9, for every 1% increase in PM10, CO, SO2, O3, there is 1.048%, 0.177%, 1.343%, and 8.665% increase in the occurrence of lung cancer in the study area, respectively. Also, for every 1% decrease in PM2.5 and NO2, there is -2.638%, and -1.900% decrease in the occurrence of lung cancer in the study area, respectively.

Table 9: Relationship between lung cancer and criteria pollutants

Model	Unstandardised Coefficients		Standardised Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	.150	1.690		.089	.930
$PM_{2.5}$	-2.638	2.078	-.924	-1.270	.217
PM_{10}	1.048	1.187	.541	.883	.386
CO	.177	.311	.416	.570	.574
No_2	-1.900	2.486	-1.169	-.764	.452
So_2	1.343	2.130	.998	.630	.535
O_3	8.665	13.429	.170	.645	.525

a. Dependent Variable: (Lung Cancer)

Source: Author's Computation, 2016

Based on the results in Table 9, the relationship between lung cancer and criteria pollutants can be written as shown in equation 5.

$$LungCancer = .150 - 2.638_{Pm2.5} + 1.048_{Pm10} + .177_{CO} - 1.900_{No_2} + 1.343_{So_2} + 8.665_{O_3} \quad \text{…………………eq. 5}$$

Relationship between criteria pollutants and the occurrence of tuberculosis

Despite the established relationship between tobacco smoking, active and passive smoking, indoor air pollution and Tuberculosis, the impact of outdoor air pollution on the development of Tuberculosis has not been affirmed. In this study, analysis of criteria pollutants data and formally reported Tuberculosis cases was carried out. Tuberculosis is the dependent variable, while the independent variables are the six criteria pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3). As indicated in Table 10, the result of the multiple regression analysis is shown with an R

Table 10: Model summary of relationship between tuberculosis and criteria pollutants

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.410[a]	.168	-.049	1.02408237

a. Predictors: (Constant), $PM_{2.5}$, PM_{10}, CO, NO_2, SO_2, and O_3

Source: Author's Computation, 2016

Table 11, shows that for every 1% increase in PM_{10}, CO, SO_2, O_3, there is 1.332%, 0.026%, 2.392%, and 18.860% increase in the occurrence of tuberculosis in the study area, respectively. $PM_{2.5}$ and NO_2 concentrations were not associated with the incidence of tuberculosis. However, for every 1% decrease in $PM_{2.5}$ and NO_2, there is -1.621%, and -3.581% decrease in the occurrence of tuberculosis in the study area, respectively.

Table 11: Relationship between tuberculosis and criteria pollutants

Model	Unstandardised Coefficients		Standardised Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-1.762	1.610		-1.094	.285
PM2	-1.621	1.980	-.567	-.819	.421
PM10	1.332	1.131	.688	1.178	.251
Co	.026	.296	.062	.089	.930
No_2	-3.581	2.369	-2.204	-1.512	.144
So_2	2.397	2.030	1.781	1.181	.250
O_3	18.860	12.796	.370	1.474	.154

a. Dependent Variable: (Tuberculosis)

Source: Author's Computation, 2016

However, this study provides evidence of an association between outdoor air pollution and an increased risk of tuberculosis (TB). Hwang *et al.* (2014) achieved similar results in his study of "Impact of outdoor air pollution on the incidence of tuberculosis in the Seoul metropolitan area, South Korea". Based on the results in Table 11, the relationship between tuberculosis and criteria pollutants can be written as shown in equation 6.

$$Tuberculosis = -1.762 - 1.621_{Pm2.5} + 1.332_{Pm10} + .026_{CO} - 3.581_{No_2} + 2.397_{So_2} + 18.860_{O_3} \quad \text{………………eq.6}$$

Some urban health observations and concluding remarks

From the findings, it was observed that there are spatial variations in the distribution of criteria pollutants in the Lagos area. Within the residential area, Ikeja GRA and Magodo have the highest concentration of $PM_{2.5}$, PM_{10} SO_2 and NO_2. In high traffic areas, Ojodu-Berger and Iyana-Ipaja have the highest concentration of criteria pollutants while Ize-Iyamu, Matori and Specomil in industrial areas have the highest level of criteria pollutants. Among the three landuse types, the high traffic has the highest concentration of pollutants (see figure 3). However, long-term exposure to $PM_{2.5}$ is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 µg/m^3 of $PM_{2.5}$ (Pope *et al.,* 2002). Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable. For example, exposure to PM affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function (WHO, 2011). The ambient concentration of carbon monoxide (CO) was observed to be lower. The levels of urban energy consumption and pollution in Lagos areas are worrying, thus a serious challenges to the attainment of the goal eleven of the sustainable development goals.

In conclusion, it was observed that sources of criteria pollutants in Lagos area are attributed to exhaust of vehicles (especially the old commercial vehicles and most cars in Nigeria are second hand cars popularly called Tokunboh) as well as the fumes emitted from the manufacturing factories which are evidently not kept in check. It was also observed that areas such as Oshodi, Ikeja, Iyana Ipaja, Ojota, Ojodu Berger showed a high concentration level of ambient criteria pollutants. It was revealed in this study that ground level ozone, sulphur dioxide and nitrogen dioxide are the most important contributors to the occurrence of asthma, bronchitis and tuberculosis occurrence. The study also affirmed the relationship between criteria pollutants and the occurrence of asthma, bronchitis, heart failure, lung cancer and tuberculosis. Although the incidence and aggravation of these diseases cannot be directly attributed absolutely to these pollutants, deliberate regulatory and control measure by the state would do a lot more good than inactions. However, high concentration and influx of people to Lagos make it imperative to build urban resilience which is crucial to avoid human, social and economic losses.

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