



Centre for Atmospheric Research

2018

MONOGRAPH OF ATMOSPHERIC RESEARCH

Edited by A.B. Rabiou and O. E. Abiye

A Publication of
CENTRE FOR ATMOSPHERIC RESEARCH
National Space Research and Development Agency
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PREFACE

The Centre for Atmospheric Research was established in January 2013 with a compelling mission to improve our understanding of the behaviour of the entire spectrum of the Earth's atmosphere; promote capacity development in relevant atmospheric sciences as a way of facilitating international competitiveness in research being conducted by atmospheric scientists; and disseminate atmospheric data/products to users towards socio-economic development of the Nation. CAR's extant core research focus includes: space weather, tropospheric studies, atmospheric research software and instrumentation development, microgravity and human space technology, and atmospheric chemistry and environmental research.

Pursuant to the above, The *Monograph of Atmospheric Research* published by the Centre for Atmospheric Research (CAR), is a collection of peer-reviewed manuscripts in Atmospheric Sciences and closely related fields. This maiden edition comprises articles presented during two separate workshops; *1st National Workshop on Microgravity and Environmental Research* (26 - 29 November, 2017) and *1st National Workshop on Air Quality* (13 - 16 March, 2018). Such workshops are integral part of CAR's capacity building program and they were primarily aimed at advancing the course of atmospheric research in Nigeria towards sustainable development. The Microgravity workshop was geared towards introducing new research opportunities in space life science by simulating microgravity conditions here at the earth's surface as a means of investigation space biological environment. The Air Quality workshop was organized in collaboration with Ministry of Environment and Nigerian Meteorological Agency (NIMET). The workshop analysed current Air Quality scenario in Nigeria, explored new opportunities for collaborative research and offered novel means of improving the present quality of life of the populace without jeopardizing the chance of the future generation. Cumulatively 196 participants participated in these two workshops and about 52 articles were eventually submitted for publication consideration in this monograph. The twenty-one articles in this very monograph are the articles that eventually made it through the rigorous peer-review process. We remain grateful to the reviewers for doing thorough work on the articles.

Thus, we are very pleased to present the *2018 Monograph of Atmospheric Research* which contains twenty-one articles, including some review papers, to readers in all spheres of interest across Nigeria and beyond. It is our hope that this effort will continue and will serve as a reference to atmospheric researchers in Nigeria.

Prof. A. B. Rabi and **Dr. O. E. Abiye**,
Editors



Urbanization, industrialization and air pollution in Nigeria: review of health, climate change and economic implications

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ABSTRACT

Urbanization is a process whereby populations move from rural to urban area, enabling cities and towns to grow. People have to an increasing extent congregated in urban areas since the beginning of the industrial revolution such that as of 2005, more than half of us lived in cities. Mega cities defined by population greater than 10 million are about 28 in number. Urban areas have been most projected to have future growth in the world's population. The rate of urban growth in Nigeria is one of the highest in the world as reported in the National Economic Empowerment and Development Strategy (NEEDS) document. However, air pollution often plagues industrialized cities, particularly during their early development. The rapid industrialization in Nigeria during the 1970's saw the establishment of car assembly plants, breweries and distilleries, detergent and cement manufacturing, textile and paper mills, food and beverage processing factories. This sudden increase in national wealth did not coincide with cautious planning with reference to environmental impacts. In Nigeria, in spite of warnings from non-governmental organizations, international multilateral agencies and researchers, the rate of industrialization continues to outpace initiatives to manage and protect the environment. Against this backdrop, this paper reviews journal, newspapers, bulletins, magazines, blogs, internet sites, etc., to examine the health, climate change and economic implication of air pollution in Nigeria in which some of the worst cities in the world for air pollution are in according to data released by the World Health Organization (WHO). Measures to improved air quality in the country in general were also suggested.

Keywords: *Urbanization, Industrialization, Air Pollution, Health, Climate Change, Economy, Nigeria*

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INTRODUCTION

Since the beginning of the industrial revolution, people have increasingly congregated in urban areas so that as of 2005, more than half of us lived in cities (Cohen, 2006). There are about 28 megacities, defined by populations greater than 10 million. Most projected future growth in the world's population will occur in urban areas (United Nations, 2014).

Air pollution often plagues industrialized cities, particularly during their early development. Air pollution is addition of harmful substance to the atmosphere resulting in damage to the environment, human health and quality of life (Cooper and Alley, 1994).

Air pollution as defined by World Bank (1978) is the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odour, smoke, or vapour in such quantity, characteristics and duration as to make them actually or potentially injurious to human, plant or animal life, or property, or which unreasonably interferes with the comfortable enjoyment of life and property (Adegbola, 2015). There has been episodes of high levels of sulfurous smog which killed or sickened thousands in Donora, Penn., in 1948, as well as in London in 1952 (Bell and Davis, 2001; Helfand et al., 2001). Other cities—primarily in the industrialized regions of the United States and Europe—also suffered from notoriously bad

air quality. These events were the result of very high emissions of sulfur dioxide, smoke, and other particles during stagnant, foggy weather conditions.

About half of Nigeria's total 170 million population now lives in cities compared to 35% in 1990, generating 60% of the country's gross domestic product (GDP) (Rouhana, 2016). Rapid urbanization that is largely unplanned and uncoordinated, has deepened the deficit of services in many Nigerian cities, which includes access to land and housing, basic services, solid waste and waste water management, among others. In addition, the rapid industrialization in Nigeria during the 1970's saw the establishment of car assembly plants, breweries and distilleries, detergent and cement manufacturing, textile and paper mills, food and beverage processing factories. This sudden rise in national wealth was not accompanied by careful planning in respect of environmental impacts (Pambazuka News, 2002). Despite warnings from non-governmental organizations, international multilateral agencies and researchers, the rate of industrialization continues to outstrip initiatives to manage and protect the environment.

Against this backdrop, this paper reviews the health effect of air pollution in Nigeria in which some of the worst cities in the world for air pollution are in according to data released by the World Health Organization (WHO) (Parke, 2016). Air

pollution is the world's largest single environmental health risk, as recognized by the World Health Organization (WHO) and a significant number of epidemiological studies which have reported the adverse impacts of air pollution exposure on human health in recent years. The WHO estimates that outdoor air pollution exposure leads to approximately 3.7 million premature deaths annually worldwide (Nyhan, 2015).

The paper also reviews the economic implication of the health hazard and climate change associated with air pollution in Nigeria. It attempts to translate the cost of premature deaths into an economic language that resonates with policy makers so that more resources will be devoted to improving air quality. According to McCauley (2016) and World Bank (2016), air pollution costs the world economy \$5 trillion per year as a result of productivity losses and degraded quality of life, according to a joint study by the World Bank and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. These productivity losses are caused by deaths due to diseases caused by air pollution. The industrial revolution having its principal source of energy as fossil fuel which is setting a steady emission increase of carbon dioxide and other greenhouse gases which trap heat causing an increase of temperature in the lower atmosphere and all the hallmarks of climate change: rising sea levels, more extreme weather, heat-related deaths, and increasing transmission of infectious diseases.

METHODOLOGY OF THE STUDY

This study adopted a content analysis of studies on health, climate change and economic implications of air pollution in Nigerian cities from existing literature. A general search was conducted in different online database sources such as Google Scholars, Springer Link, Wiley, Science Direct, JSTOR, Emerald full text, Scopus, and EBSCO HOST etc. From this search, a number of journal articles, conference and other types of work were found and studied to determine which articles were empirically good enough to be included in the review of this paper. Also, libraries were visited to extract secondary data from journals, bulletins, textbooks and newspapers.

Nigerian Cities and Air Pollution: Overview

Nigeria is an emerging economy in Sub-Saharan Africa, and the most populous country in Africa. The population of Nigeria was approximately 182.2 million people as of 2015 (Allafrica, 2016). Nigeria's cities have been increasingly growing due to economic progress and have become destinations for rural-to-urban migration (Worldatlas, 2018). With multiple cities boasting populations exceeding one million, it's no wonder that Nigeria is one of the most populous countries in the world. Its biggest city, Lagos, contributes 9 million residents to the total population, while there are also 79 cities with a minimum population of 100,000 and 249 cities with populations that surpass 10,000. Nigeria has a total of 36 states, and 774 Local Government Areas that are spread across the 39th most populous country in the world (World Population Review, 2017).

About 52% of Nigeria's population lives in rural areas. While this is a fairly high percentage, the rural populations have dwindled down in recent years, down from 85% in 1960 (World

Population Review, 2017) to 51.40 as of 2016 (Index Mundi, n.d.a). Its highest value over the past 56 years was 84.59 (about 85%) in 1960, while its lowest value was 51.40 in 2016 (Index Mundi, n.d.a). This reduction in numbers is likely due to problems faced in the rural areas of Nigeria, which includes a lack of or sporadic electricity, sanitary conditions, and of course, the lack of industry. Many natives are moving into urbanized, developed areas to take advantage of job opportunities and to avoid a life of poverty found in many of the smaller cities and villages in the country. It should be equally noted that much of the industries and commercial activities in Nigeria are mainly concentrated in the state capitals leaving other parts of the state underdeveloped and deserted.

Nigeria has 7 cities with more than a million people, 80 cities with between 100,000 and 1 million people, and 248 cities with between 10,000 and 100,000 people. The largest city in Nigeria is Lagos, with a population of 9,000,000 people (World Population Review, 2017).

In 2015, according to the World Bank report, 94% of the population in Nigeria was exposed to air pollution levels that surpass WHO recommendations (Ekeanyanwu, 2017). Nigeria has the largest number of most polluted cities in the world. As a matter of fact, four of the worst cities in the world for air pollution are in Nigeria, according to data released by the World Health Organization (WHO) in 2016 (see Figure 1 for those polluted cities in Nigeria).

Onitsha has the undignified honor of being labeled the world's most polluted city for air quality, when measuring small particulate matter concentration (PM_{10}). A booming port city in southern Nigeria, Onitsha recorded 30 times more than the WHO's recommended levels of PM_{10} (Parke, 2016). The other three cities named and shamed in the WHO report for high PM_{10} levels are the transport hub of Kaduna, in the north, which came fifth, followed by the cities of Aba -- in sixth place -- and Umuahia, in 16th position, which are both trade centers in southern Nigeria (Parke, 2016).

Causes of Air Pollution and Identification of Pollutants in Nigerian Cities

Air pollution which consists of indoor and outdoor pollutant has been a public concern in Nigeria. The indoor air pollution occurs inside homes, school and offices, as results from product of use in construction material (cement, asbestos roofing and ceiling sheet). Building materials including carpeting and plywood emit formaldehyde (H_2CO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled. Intentional air pollution is introduced with the use of air fresheners, incense and other scented items. Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out (John, 1985; Foresthill, 2016). Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation. Also emission of Nitrogen oxide, and sulphur oxide in air-conditioned houses, gas stove and some volatile organic compounds like Alkanes and furmaldehyde. Smoking cigarettes indoor releases the



Figure 1: Map of Nigeria showing the four most polluted cities according to data released by the World Health Organization (WHO) in 2016

Source: (Parke, 2016).

carcinogens and other toxins that they contain. Also, inadequacy of general ventilation indirectly provokes some damages to human health. This is because a lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses.

In Nigeria, outdoor air pollution emanates from three major sources-energy generation, industry and transportation-all of which increase with population and economic growth. Rapid urbanization is a major contributing factor to all the three major sources.

The distribution of industries in Nigeria is not uniform as they are concentrated in the urban centers. Major industrial centers in the country include Lagos, Port Harcourt, Ibadan, Kano and Kaduna. The industries range from oil and gas, chemicals, cement, textiles, iron and steel, plastics, etc (Ibrahim and Abdullahi, 2004). Even though these industries are located in industrial estates, uncontrolled urban growth has resulted in the expansion of residential buildings very close to the industries. These industries release large quantities of gaseous wastes into the air which are sources air pollution.

Also, degraded air quality in key urban centers, such as Lagos, Port Harcourt, Kano amongst others, is as a result of the heavy dependence on oil-dominated transportation. Motor vehicles produce more air pollution than any other single human activity (World Resources Institute, 1996). Transportation requires huge amounts of energy. Globally, 20% of all energy produced is used for transportation. Of this, between 60 and 70% goes toward transporting people, and the rest toward moving freight (World Energy Council, 1993). In addition, power plants, factories, and other stationary sources including the thousands of privately owned petrol and diesel generators used for power failure backups degrade the air quality of major urban centers in Nigeria.

The situation is compounded by poor urban transportation planning as manifested by congestion in both large and small cities of Nigeria. Clogged city streets exact a major toll on

economic productivity and exacerbate air pollution. In highly congested city centers, traffic can be responsible for as much as 90 to 95% of the ambient carbon monoxide levels, 80 to 90% of the nitrogen oxides and hydrocarbons and a large portion of the particulates, all posing a significant threat to human health and natural resources (World Resources Institute, 1996).

There is also air pollution emitted from indiscriminate dumping of solid waste in cities which decomposes to a number of gases, that are present in the exposed dumping solid waste, including ammonia (NH_3), carbon dioxide (CO_2), Carbon monoxide (CO), Hydrogen H_2 , Hydrogen Sulphide (H_2S), Methane (CH_4), Nitrogen (N_2) and an exposed solid waste can produce some odorous material in the atmosphere (methane and carbon dioxide), can be released by both convective flow and diffusion to different strata of soil, (CO) Carbon monoxide, (SP) Suspended or settled particle (HC) Hydrocarbon, (NO_2) Nitrogen Oxide, (SO_2) Sulphur oxide (Prasad, 1995).

In addition waste burning method of disposal as practiced by most residents of the urban centers results in air pollution due to release of gases such as carbon monoxide, sulphur dioxide, oxides of nitrogen, halogenated carbons and other particulate matter (Ibn Al-Gargani, 2012).

There is inadequate electric power supply to households, businesses and industries. The result is that many households, businesses and even industries operate small, medium and large capacity fossil fuel electric power generators for electric power supply whose exhaust is a source of air pollution that releases poisonous carbon monoxide. A recent study conducted in 2010 showed that small household generators in Nigeria operate an average of six (6) hours daily, while average distance of generator away from buildings was 5.6m. These alongside poor ventilation have negatively influenced the quality of indoor air in the households causing air pollution (Stanley et al., 2010).

The air quality degrading substances of major concern in Nigeria include sulphur dioxide, hydrogen sulphide, nitrogen oxide, cement kiln dust and other particulate matter and heavy

metals (*Pambazuka News*, 2002) (see Table for classification of air pollutants and Table 2 for source and content of pollutant. Also, see the year and quantity of pollutants in Nigeria in Table 3).

Public Health Effects of Air Pollutants

The respiratory system is the primary indicator of air pollution effects in humans as carbon dioxide diffuses through the capillary wall into the alveolus while oxygen diffuses out of the alveolus into the blood cell. The difference in partial pressure of each of the gas causes it to move from the higher to lower respiratory track causing a great cardio-respiratory ailment amongst the heavy smokers and people living in industrial

areas. Some chronic respiratory disease like Bronchial-Asthma are aggravated by air pollution, example, former workers of Nkalagu cement industry in Enugu State (Otti and Ogbuagu, 2014). Carbon monoxide, an air pollutant reacts with haemoglobin in the blood to form carboxylhaemoglobin (COHb) which effectively deprives the blood of oxygen. The excess COHb can cause a severe heart disease which can limit the patient from performing certain exercise. Ferris (1978) stated that a concentration of 20ppm of carbon monoxide for eight hours will result in a carboxyl haemoglobin level of about 2.8% and the average concentration of carbon monoxide inhaled in cigarette smoke is 200 to 400ppm. This shows that in some industrialized cities, their sensitive population are those with

Table 1: Classification of Air Pollutants

Class	Subclass	Member of Substance
Particulate	-Solid	-Dust, smoke, fumes, etc.
	-Liquid	-Mist, spray
Gases	-Hydrocarbon	-Methane, Ethylene, butane etc
	-Oxide of carbon	-Carbon monoxide, carbon dioxide, carbon dioxide
	-(organic) Gases	-Sulphuric dioxide, sulphuric trioxide
	-(inorganic) Gases	-Nitrogen dioxide, Nitric oxide
	-Others	-Hydrogen sulphide, Hydrogen fluoride and ammonia

Source: Otti and Ogbuagu (2014)

Table 2: Source and content of pollutant

	Source	CO	SP	SO ₂	HC	NO ₂	Total
A	Transport	3.5	0.07	0.045	0.039	0.455	4.415
B	Fuel combustion (power heating)	0.05	0.07	0.95	0.01	0.53	1.665
C	Industrial process solid waste disposal	0.29	0.165	0.19	0.54	0.035	1.24
D	Forest Fire Agriculture Burning	0.31	0.045	0.	0.12	0.01	0.485
	Total	4.27	0.39	1.185	1.09	1.035	7.97

Source: Otti and Ogbuagu (2014)

Table 3: Year and Quantity of pollutant

Year	CO	SP	SO ₂	HC	NO ₂	Total x (102) Tonne
2000	1.71	0.9	1.012	0.027	1.015	4.124
2001	2.01	0.75	1.015	0.035	1.018	4.828
2002	2.23	0.66	1.110	0.050	1.025	4.481
2003	2.59	0.62	1.209	0.076	1.048	5.537
2004	3.07	0.58	1.201	0.085	1.047	6.072
2005	3.30	0.53	1.197	0.090	1.045	6.935
2006	3.75	0.47	1.191	0.100	1.041	6.552
2007	4.08	0.41	1.189	0.120	1.039	6.838
2008	4.27	0.39	1.815	1.09	1.035	7.970

Source: Otti and Ogbuagu (2014)

heart and circulating ailments, chronic pulmonary disease and developing fetuses. The effects of hazardous air pollutants in the lungs of most industrial workers are generally higher than in the ambient air and this is obvious because the low level of toxic air is found in ambient air Nitrogen dioxide (NO₂) also has effect that can result in cough and irritation of respiratory tract. According to Hardoy et al (2001), at 5ppm, Nitrogen dioxide has a pungent odour and the concentration in tobacco smoke is high, can slightly increase the respiratory illness and decrease in pulmonary function associated with concentration of Nitrogen oxide. Otti and Ogbuagu (2014) demonstrated in Table 4 more public health effects of some of the pollutants.

Generator fumes contribute significantly to the atmospheric level of Polynuclear Aromatic Hydrocarbons (PAHs) and PAHs have long been reported as the largest class of “cancer-causing” chemical compounds. This suggests a significant risk of cancer to the population in an environment where the use of generator is commonplace.

In summary, air pollution is a significant risk factor for a number

of pollution-related diseases and health conditions including respiratory infections, heart disease, chronic obstructive pulmonary disease (COPD), stroke and lung cancer (WHO, 2014). The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing, asthma and worsening of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency room visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics (Vallero, *n.d.*).

Air Pollution Effect on Climate Change

By trapping the earth's heat in the atmosphere, greenhouse gases lead to warmer temperatures and all the hallmarks of climate change: rising sea levels, more extreme weather, heat-related deaths, and increasing transmission of infectious diseases like

Table 4: Public health effects

Chemical Equation	Reaction to Health
$\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2$	Irritates the alveoli of the lungs, results in coughing. Premature death of ill cigarette smokers and elderly person
$\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$ (Sulphuric acid) $\text{SO}_3 + \text{H}_2 \rightarrow \text{H}_2\text{SO}_4$ (Sulphuric acid)	Irritates the mucous membrane of respiratory tract and foster the development of chronic respiratory disease. It decreases exercise tolerance in healthy persons.
$\text{CO} + \text{Hb} \rightarrow \text{COHb}$	Reduces the capacity of the blood to carry oxygen. Reduces physical activity in heart and lung diseases.
$\text{C}_2\text{O} + \text{H}_2\text{aO}_9\text{N} \rightarrow 11\text{CH}_4 + 9\text{CO}_2 + \text{NH}_3$ (Hydrocarbon) (ammonia)	Irritating and choking, aggravates unhealthiness. Suspended particulates, settleable particulates, particulate matter, poses health hazards to humans, particularly those susceptible to respiratory illness (Pope, 2002).

Source: Otti and Ogbuagu (2014)

Lyme. Evidences have shown that climate change impacts on Nigeria arises from various climate change related causes experienced due to the increase in temperature, rainfall, sea level rise, impact on fresh water resources, extreme weather events, flooding, drought in the north and increased health risk (Ebele and Emodi, 2016).

Carbon dioxide and methane are responsible for large percent of the country's total greenhouse gas emissions. Carbon dioxide comes from combusting fossil fuels, and methane comes from natural and industrial sources, including the large amounts that are released during oil and gas drilling (Millerand Writer, 2017). Another class of greenhouse gases, hydrofluorocarbons (HFCs), are thousands of times more powerful than carbon dioxide in their ability to trap heat. These chemicals are used in air conditioners and refrigerators (NRDC, 2017). All these factors are also related to climate change. Higher temperatures draw moisture out of the soil and into the air; this dries out the soil and, in turn, dries out the vegetation, making it more vulnerable to wildfires. The smoke from wildfires remains in the air for a long time and can travel long distances. This type of air pollution kills nearly half a million people prematurely every year, worldwide.

RESULTS OF THE REVIEW

Air Pollution Mortality in Nigeria

The World Health Organization estimated in 2014 that every year air pollution causes the premature death of some 7 million people worldwide (WHO, 2014b). India has the highest death rate due to air pollution (Harris, 2014). India also has more deaths from asthma than any other nation according to the World Health Organization. Air pollution is killing about 4,000 people in China a day, accounting for 1 in 6 premature deaths in the world's most populous country, a new study finds (Borenstein, 2015). There is a positive correlation between pneumonia-related deaths and air pollution from motor vehicle emissions (Guardian Media Group, 2008).

Air pollution causes 467,000 premature deaths a year in Europe (BBC, 2016). An important cause of these deaths is nitrogen dioxide and other nitrogen oxides (NOx) emitted by road vehicles. In a 2015 consultation document, the UK government disclosed that nitrogen dioxide is responsible for 23,500 premature UK deaths per annum (Motorway, n.d.). Across the European Union, air pollution is estimated to reduce life expectancy by almost nine months (BBC, 2005). Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections (WHO, 2014). Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year. Children are particularly at risk due to the immaturity of their respiratory organ systems (Muoria, 2015).

In a study by Yaduma *et al* (2012) on the estimates of mortality cases emanating from particulate pollution in Nigeria in 2006. The result reveals that if particulate pollution in Nigeria was mitigated to the WHO standard, this would have led to a decrease in premature mortality by about 58,200 to 78,800 people in 2006.

Table 5: Mortality Costs of PM₁₀ Pollution in Nigeria

	b_{lower DRC,}	b_{upper DRC,}
	mortality	mortality
Mortality Cases	58,207	78,822

Source: Yaduma et al (2012)

In the study, Nigeria's crude mortality rate and population estimates were respectively 1.7 percent and 142.7 million people, these mortality estimates are therefore approximately 2.2 percent and 3.3 percent of total (implied) deaths for 2006 – 2.4 million people. Hence, these results imply significant benefits in the form of mortality reductions to be expected from the abatement of particulate pollution.

An organization, Global Initiative for Food Security and Ecosystem Preservation, has called for the ban of coal mining in Nigeria. The organization reported that 3.7 million Nigerians die prematurely from inhalation of air polluted by coal mining (Ibeh, 2018). Coal mining cities in Nigeria include Enugu, Okaba Coal Field, Kogi State, Owupka Mine, Benue State.

There is also a reported that the nation records almost 65, 000 deaths annually due to exposure to household pollution (Adanikin, 2017). It was blamed on the rising incident of deforestation and use of woods for cooking, especially among rural communities and some city dwellers. Figure 2 shows premature mortality due to non-communicable Diseases (NCD) such as cancer, cardiovascular diseases, etc. It shows also the adult risk factors.

Climate change could negatively impact human health in developing country like Nigeria. Climate change affects human health directly or indirectly in many ways. Changes in temperature, precipitation, rising sea levels, increasing frequencies have great implications on human health in the area of injury, illness, morbidity and mortality. Rising sea level is anticipated as a result of climate change. Hence flooding may result which is likely to increase the vulnerability of the poor to malaria, typhoid, cholera and pneumonia. Also temperature and rainfall dynamics may increase the distribution of disease vectors such as dengue, malaria and incidence of diarrheal disease (Haines *et al.*, 2006).

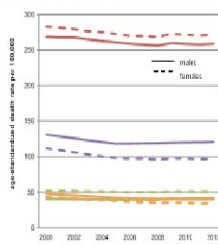
The Guardian Newspaper of 30th march 2010 reported that within one week in the early of 2009 over 209 people were killed by meningitis in Nigeria and Niger republic (The Guardian Newspaper, 2010, pp.45). It is believed that climate change will increase threats to human health thereby affecting their productivity. Already a study by the World health Organization shows that climate change is the cause of 150,000 deaths every year (UNFCCC, 1992). Heavy rainfall events can also carry terrestrial micro-biological agents into drinking water sources which eventually lead to outbreak of Cryptosporidiosis, giardiasis, amoebiasis, typhoid and other infections (Lisle, 1995; Rose, 2000).

Nigeria

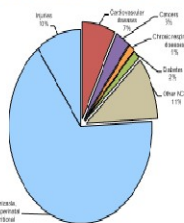
Total population: 189 000 100
Income Group: Lower middle

Percentage of population living in urban areas: 45.5%
Population proportion between ages 30 and 70 years: 27.7%

Age-standardized death rate*



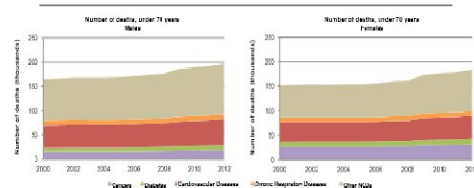
Proportional mortality % of total deaths, all ages, both sexes*



Total deaths: 2,003,000
NCDs are estimated to account for 54% of total deaths.

Premature mortality due to NCDs*

The probability of dying between ages 30 and 70 years from the 4 main NCDs is 20%.



Adult risk factors

	males	females	total
Current tobacco smoking (2011)	11%	2%	6%
Total alcohol per capita consumption, in litres of pure alcohol (2010)	14.9	5.1	10.1
Relative blood pressure (2008)	33.9%	36.1%	34.8%
Obesity (2006)	4.8%	6.4%	6.0%

National systems response to NCDs

Has an operational NCD unit/branch or department within the Ministry of Health, or equivalent	No
Has an operational multisectoral national policy, strategy or action plan that integrates several NCDs and shared risk factors	No
Has an operational policy, strategy or action plan to reduce the harmful use of alcohol	No
Has an operational policy, strategy or action plan to reduce physical inactivity and/or promote physical activity	No

Figure 2: Non-communicable Diseases (NCD)

Source: WHO (2014a)

Recent evidence showed that typhoid is mostly triggered in high temperature and increased humidity over the years is a proof of climate change (Ebele and Emodi, 2016). A large part of Nigeria's economy is dependent on natural resources that are vulnerable to climate impacts. When resources are affected, the health of Nigerians can also be affected.

Economic implication of Air pollution for Nigeria

Air pollution has emerged as the deadliest form of pollution and the fourth leading risk factor for premature deaths worldwide. Those deaths cost the global economy about US\$225 billion in lost labor income in 2013, a new study finds, pointing toward the economic burden of air pollution (World Bank, 2016).

The Cost of Air Pollution: Strengthening the economic case for action, a joint study of the World Bank and the Institute for Health Metrics and Evaluation (IHME), seek to estimate the costs of premature deaths related to air pollution, to strengthen the case for action and facilitate decision making in the context of scarce resources. An estimated 5.5 million lives were lost globally in 2013 to diseases associated with outdoor and household air pollution, causing human suffering and reducing economic development (World Bank, 2016). While pollution-related deaths strike mainly young children and the elderly, premature deaths also result in lost labor income for working-

age men and women. The report finds that annual labor income losses cost the equivalent of almost 1 percent – 0.83 percent – of Gross Domestic Product (GDP) in South Asia (World Bank, 2016). In East Asia and the Pacific, where the population is ageing, labor income losses represent 0.25 percent of GDP, while in Sub-Saharan Africa, where air pollution impairs the earning potential of younger populations; annual labor income losses represent the equivalent of 0.61 percent of GDP (World Bank, 2016).

When looking at fatalities across all age groups through the lens of “welfare losses”, an approach commonly used to evaluate the costs and benefits of environmental regulations in a given country context, the aggregate cost of premature deaths was more than US\$5 trillion worldwide in 2013 (World Bank, 2016). In East and South Asia, welfare losses related to air pollution were the equivalent of about 7.5 percent of GDP.

From the result of the study by Yaduma *et al* (2012) on the estimates of mortality cases emanating from particulate pollution in Nigeria in 2006 which reveals a premature mortality of about 58,200 to 78,800 people, these results imply a mortality related welfare loss of \$28.46 billion to \$38.54 billion given by the lower and upper coefficients of the PM₁₀ DRCs respectively (see Table 6).

Table 6: Economic Cost of PM₁₀ Pollution in Nigeria

	b _{lower} DRC, mortality	b _{upper} DRC, mortality
Economic Cost (millions of US\$)	28.46	38.54
Economic cost as a percentage of GDP	19.4	26.3

Source: Yaduma *et al* (2012)

This loss translates to 19.4 to 26.3 percent of the nation's 2006 GDP. In other words, had the nation mitigated its particulate pollution to the WHO standards, it could have avoided at least 58,207 premature deaths and recorded an avoided mortality related welfare loss of \$28.46 billion in 2006.

However, the value for public health expenditure (as % of GDP) in Nigeria was 0.92 as of 2014. Its highest value over the past 19 years was 1.47 in 2007, while its lowest value was 0.60 in 1996.

From the report by Unah (2017), it was revealed that floods from climate change are ravaging farms in Nigeria. According to this report, unprecedented levels of flooding in 2002 affected 30 of the country's 36 states, causing damage estimated by the government at \$16.9 billion. Rivers overflowed their banks, washing away farmland, settlements, and crucial infrastructure. By mid-October, at least 431 people were dead and 1.3 million displaced from their homes (Unah, 2017).

According to the Emergency Events Database (EM-DAT). EM-DAT launched by Centre for Research on the Epidemiology of Disasters (CRED), the 10 deadliest natural disasters in Nigeria between 1980 and 2011 were climate related (drought and flood). This climate change increases epidemic risk. It was reported that 19,537 lives were claimed and they were epidemic in nature (Odjugo, 2012). The deadliest of the epidemic is the bacterial

infectious disease (Cholera) which started 6th of May, 1991. It affected 10,000 people and killed 7,289 people in Bauchi and Kaduna States of Nigeria. The least among the 10 is also cholera that claimed 353 lives in July 2010. The 10 costliest disasters in Nigeria destroyed property worth \$189.5bn (N30.3trillion) (Odjugo, 2012).

Limitations of the Existing Literature

The empirical literature review shows that empirical studies conducted in Nigeria on health, climate change and economic implications of air pollution in Nigerian cities from existing literature are scanty. Some reports were mere comments and do not have empirical backings. However, to the best of the authors' knowledge, the only existing empirical study on Nigeria estimated mortality and economic costs of particulate air pollution in general and focused mainly on particulate matter (PM₁₀) neglecting the effect of other major pollutants such as ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, lead. In addition, much attention was not given in the study to Nigerian cities where commercial and industrial

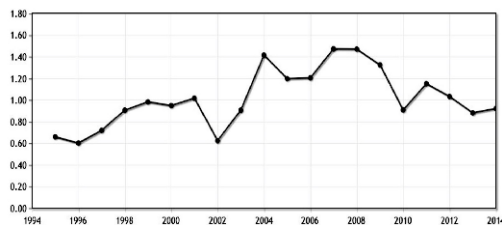


Figure 3: Health expenditure, public (% of GDP)

Source: Indexmundi (n.d.b)

activities are intense and air pollution concentrated and dispersed or transported to other parts of the country.

Nonetheless, it is understandable regarding the scanty nature of literature on economic valuation of air pollution in Nigeria due to the fact that assessment of the economic costs of air pollution (AP) is a fairly new branch of research in the fields of environmental and health economics. According to Miller (2000), while epidemiological studies have assessed the health costs of AP since the 1940s, it was not until the early 1990s that economists made an effort in assessing these costs.

CONCLUSION AND RECOMMENDATIONS

Urban dwellers in Nigeria are among the millions of people particularly in developing countries that live in cities with unhealthy air due to pollution from automobiles, factories, power plants, etc. According to Laura Tuck, Vice President for Sustainable Development at the World Bank "Air pollution is a challenge that threatens basic human welfare, damages natural and physical capital, and constrains economic growth. By supporting healthier cities and investments in cleaner sources of energy, we can reduce dangerous emissions, slow climate change, and most importantly save lives". This paper is of the opinion that the most effective method of controlling air pollution is to minimize the rate of production of pollutant in the first place. As such:

-All the equipment using gasoline and diesel in factories must be maintained to reduce excessive production of incomplete combustion of organic particles. Consequently, all the house roofs that are constructed with asbestos sheet should be changed to corrugated aluminium to avoid cancerous effects. Better still, new technologies should be developed to design products/materials of low emission or zero emission in these sectors.

- more effort should be made to ensure effective refuse collection in the urban centers that way waste materials do not accumulate in the locality to be burnt or incinerated. Similarly, more efforts should be made to mitigate odours and reduce methane emissions from landfills in the metropolis. In this regard, government should introduced capping (greening), a scientific term for reducing the foul odour at dump sites by covering the whole site with laterite.

- More effort should be made by the government and private sector in improving electricity power supply in the country to meet utility usage that way it would not warrant the use of petroleum powered generators to supply electricity.

- The World Bank project at curbing pollution by supporting a new rapid bus system in Lagos should be extended to other cities of the country. This will help take cars off the road and make transportation more efficient. In the same vein, vehicle inspection should be intensified in all cities to ensure drivers not only service their cars periodically but also old vehicles that emit too much smoke are taken off the roads and only vehicles in good condition ply the roads.

- There is the need to continuously enlighten and educate the public about the causes and effects of air pollution so that they realize the dangers and health hazards of living in polluted environment.

REFERENCES

- Adanikin, O. (2017) Nigeria records 65, 000 deaths annually due to air pollution – Saraki. <http://thenationonline.ng/nigeria-deaths-pollution-saraki/>
- Adegbola, O. (2015) Air pollution in Nigeria. <https://tunza.eco-generation.org/ambassadorReportView.jsp?viewID=13295>
- Allafrica (2016) Nigeria: The elephant in the room - Nigeria's population growth crisis. <https://allafrica.com/stories/201612210486.html>
- Bell, M. L. and Davis, D. L. (2001) Reassessment of the lethal London fog of 1952: Novel indicators of acute and chronic consequences of acute exposure to air pollution. *Environ. Health Perspect.*, 109(3), 389–394.
- BBC (February 21, 2005) "Air pollution causes early deaths". Retrieved August 14, 2012 from "news.bbc.co.uk, <http://news.bbc.co.uk/2/hi/health/4283295.stm>
- BBC (23 November, 2016) Air pollution causes 467,000 premature deaths a year in Europe. <https://www.bbc.com/news/world-europe-38078488>.
- Borenstein, S. (2015) Air pollution in China killing 4,000 people every day. <https://www.independent.co.uk/news/world/asia/air-pollution-in-china-killing-4000-people-every-day-10455409.html>
- Cohen, B. (2006) Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technol. Soc.*, 28(1), 63–80, doi:10.1016/j.techsoc.2005.10.005.
- Copper, C.D. and Alley, F. C. (1994) "Air pollution control" Waveland Press (USA).
- Ebele, N.E. and Emodi, N. V. (2016) Climate change and its impact in Nigerian economy. *Journal of Scientific Research*

- and Reports, 10(6), 1-13.
- Ekeanyanwu (2017) Nigeria is a 'Breeding ground for child deaths'. <https://www.thecable.ng/with-four-of-the-worlds-most-polluted-cities-nigeria-is-breeding-ground-for-child-deaths>
- Ferris, B.G. (1978) "Health effects of exposure to low level of regulated air pollution. Journal of the Air Pollution Control Association, 28(1), 482-492.
- Foresthill (2016) Burning wood produces wood smoke and air pollution! http://www.foresthillmessenger.com/news/regional/burning-wood-produces-wood-smoke-and-air-pollution/article_53f030a0-c7fe-11e6-9e77-ef0f33726edb.html
- Guardian Media Group (2008) "Study links traffic pollution to thousands of deaths". The Guardian. London, UK: Guardian Media Group. 2008-04-15. Archived from the original on 20 April 2008. Retrieved 2008-04-15
- Haines N, Korats R.S.D., Campbell- Lendrum, C. and Corralan C. (2006) Climate change and human health: Impacts, vulnerability and public health. Journal of the Royal Institute of Public Health, 2(2), 120-585.
- Harris, G. (2014) 'Beijing's air would be called good in Delhi'. The New York Times International Weekly 2nd February.
- Hardoy, J.E., Mitlin, D. and Satterthwaite, D. (2001) Environmental problems in an urbanizing world, London: Earthscan Publications.
- Helfand, W. H., Lazarus, J. and Theerman, P. (2001). Donora, Pennsylvania: An environmental disaster of the 20th century. Am. J. Public Health, 91(4), 553.
- Ibeh, N. (2018) 3.7 million Nigerians die prematurely due to air pollution from coal mining - group warns FG. <https://www.naija.ng/1139120-37-million-nigerians-die-prematurely-due-air-pollution-coal-mining-group-war.html#1139120>
- Ibn Al-Gargani, A.K. (2012) Environmental pollution control in Nigeria: Problems, solutions and advocacy. Retrieved from www.scribd.com/.../environment
- Ibrahim, S. and Abdullahi, I. L. (2004) Constraints to industrial pollution abatement in Nigeria. Biological and Environmental Sciences Journal for the Tropics, 1(1), 94-98.
- Index Mundi (n.d.a) Nigeria - Rural population (% of total population). <https://www.indexmundi.com/facts/nigeria/indicator/SP.RUR.TOTL.ZS>
- Indexmundi (n.d.b) Nigeria - Health expenditure. <https://www.indexmundi.com/facts/nigeria/health-expenditure>
- John, J.M. (1985) Encyclopedia of chemical processing and design. Marcel Dekker. ISBN 0-8247-24917. pp: 144.
- Lisle, J.T. (1995) Cryptosporidium contamination of water in the US and UK: A mini- review. Aqua, 44(1), 103-117.
- McCauley, L. (8 September 2016) «Making case for clean air, World Bank says pollution cost global economy \$5 trillion». Common Dreams. Retrieved 3 February 2018.
- Miller T (2000) Variations between countries in values of statistical life, Journal of Transport Economics and Policy 34(2), 169-188.
- Miller, S.G. and Writer, S. (2017) Here is how climate change can cause more air pollution. <https://www.livescience.com/57913-climate-change-will-increase-air-pollution.html>
- Motorway (n.d.) "Complete guide to the 'toxin tax' for diesel cars". Retrieved 25 May 2017.
- Muoria, S. (2015). Air Pollution in Kenya. <https://tunza.eco-generation.org/ambassadorReportView.jsp?viewID=13312>
- Nyhan, M. (2015). Coping with air pollution in an age of urbanization. <https://anglejournal.com/article/2015-06-protecting-urban-populations-from-air-pollution-in-an-age-of-global-urbanisation/>
- NRDC (2016) Air Pollution: Everything You Need to Know. <https://www.nrdc.org/stories/air-pollution-everything-you-need-know>
- Odjugo, P. A. O. (2012) Global natural disasters and their implications on human sustainability. Journal of Sustainable Development and Environmental Protection, 2 (1), 18-35.
- Otti, V.I. and Ogbuagu F.U. (2014) Environmental health effects of exposure to air pollution in industrialized areas . Civil and Environmental Research, 6 (5), 80-84.
- Pambazuka News (2002) Air pollution and industrialization in Nigeria. <http://www.pambazuka.org/land-environment/air-pollution-and-industrialization-nigeria>
- Parke, P. (2016) Dirtied by success? Nigeria is home to city with worst PM₁₀ levels. <https://nationaldailyng.com/14588-2/>
- Prasad, A. (1995) "Air pollution control technologies for nitrogen oxides". The National Environment Journal, May/ June 46-50.
- Rose, J.B.S. (2000) Climate and water borne outbreaks in the US: A preliminary descriptive analysis. Journal of the American Water Association, 92(1), 1194-1199
- Rouhana, S. (2016) Urbanization in Nigeria: planning for the unplanned. <http://blogs.worldbank.org/african/urbanization-in-nigeria-planning-for-the-unplanned>.
- Stanley, A.M., Mbamali, I. and Dania, A. A. (2010) Effect of fossil-fuel electricity generators on indoor air quality in Kaduna Nigeria. Retrieved from www.abu.ng/publications/2012-03-3
- The Guardian Newspaper (2010, pp 45) Heat, dusty weather raise health concerns. Climate change effects in Nigeria 30th March . Pittock AB.
- Unah, L. (2017) Floods From Climate Change Are Ravaging Farms in Nigeria. <https://www.globalcitizen.org/en/content/nigeria-farmers-flooding-climate-change/>
- UNFCCC (1992) United Nations Framework Convention on Climate Change. <https://unfccc.int/resource/docs/convkp/conveng.pdf>
- United Nations (2014) World urbanization prospects: 2014 Revision Highlights, New York.
- Vallero, D. A. (n.d.) "Fundamentals of air pollution". Elsevier Academic Press.
- Worldatlas (2018) Biggest cities in Nigeria. <https://www.worldatlas.com/articles/biggest-cities-in-nigeria.html>
- World Bank (2016) Air pollution deaths cost global economy US\$225 Billion. www.worldbank.org/en/.../2016/.../air-pollution-deaths-cost-global-economy-225-bill.
- World Bank: Institute for Health Metrics and Evaluation at University of Washington - Seattle (2016) The cost of air pollution: Strengthening the economic case for action(PDF). Washington, D.C.: The World Bank. p. xii.
- World Bank (1978) "Relieving traffic congestion: The Singapore area license scheme." World Bank Staff Working Paper 281, World Bank, Washington, D.C.
- World Energy Council (1993) Energy for tomorrow's world: The realities, the real opportunities and the agenda for achievement, Kogan Page, London/New York.
- WHO (2014a) World Health Organization – Non-communicable diseases (NCD) country profiles, 2014. apps.who.int/iris/bitstream/10665/128038/1/9789241507509_eng.pdf
- WHO (2014b) "7 million premature deaths annually linked to air pollution". Retrieved 25 March 2014. www.who.int/mediacentre/news/releases/2014/air-pollution/en/
- World Population Review (2017) Population of cities in Nigeria (2018). <http://worldpopulationreview.com/countries/nigeria-population/cities/>
- World Resources Institute (1996) The urban environment 1996-1997. WRI with the World Bank and the United Nations, Washington, DC. 1996:86.
- Yaduma, N., Kortelainen, M. and Wossink, A. (2012) Estimating mortality and economic costs of particulate air pollution in developing countries: The case of Nigeria, The School of Economics Discussion Paper Series EDP-1223, Economics, The University of Manchester.



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