Centre for Atmospheric Research CAR

National Space Research and Development Agency NASRDA

Federal Ministry of Science & Technology

Our Mandates

The Center for Atmospheric Research is a research and development center of NASRDA committed to research and capacity building in the atmospheric and related sciences. CAR shall be dedicated to understanding the atmosphere—the air around us—and the interconnected processes that make up the Earth system, from the ocean floor through the ionosphere to the Sun's core. The Center for Atmospheric Research provides research facilities, and services for the atmospheric and Earth sciences community.

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Air Quality Issues in National Planning: Assessing Present Status and Predicting Future Trends in Nigeria

A compendium

Edited by

Professor Babatunde Rabiu,
Director/Chief Executive
Centre for Atmospheric Research,
National Space Research & Development Agency,
Kogi State University Campus, Anyigba, Nigeria

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Being full texts of the invited papers delivered at the
3rd Ekundayo Elisha Balogun National Symposium on
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Editorial Comment: Air Quality Issues in National Planning: Assessing Present Status and Predicting Future Trends in Nigeria

The articles in this compendium were reviewed and edited full texts of invited papers delivered at the 3rd Ekundayo Elisha Balogun National Symposium on Atmospheric Research and 2019 Air Quality Workshop organised by our Centre for Atmospheric Research in collaboration with Bowen University, Nigeria. The two events: 3rd Ekundayo Elisha Balogun National Symposium on Atmospheric Research and 2019 Air Quality Workshop; are two different activities that were purposefully merged into one singe mega event due to some constraints. This merging has eventually brought about the papers printed in this booklet. The theme of the supper symposium, "Air Quality Issues in National Planning: Assessing Present Status and Predicting Future Trends in Nigeria " is in line with the main objectives of the United Nations' sustainable development goals SDGs 2030. The theme of this symposium has direct bearing with 10 out of the 17 SDGs of the United Nations. The ten goals are: Goal 2, Zero Hunger; Goal 3, Good Health and Well-being; Goal 6, Clean Water and Sanitation; Goal 7, Affordable and Clean Energy; Goal 9, Industry, Innovation and Infrastructure; Goal 11, Sustainable Cities and Communities; Goal 13, Climate Action; Goal 14, Life Below Water; Goal 15, Life on Land; Goal 17, Partnerships for the Goals.

The Centre for Atmospheric Research Centre 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.

As at today, CAR runs 27 weather stations under the Tropospheric Data Acquisition Network TRODAN projects. Its our pleasure to note that 5 of our hybrid automated atmospheric parameters monitors At

PaM deployed to designated locations measures several atmospheric parameters and some Greenhouse Gases (GHGs) on real time basis at 1-minute interval and transmit same at near real time to dedicated server for global usage.

The host University of the combined event, Bowen University, has become a centre of excellence in atmospheric research due to the commitment of her management in providing support base for deployment of high tech facilities for studying different spectrum of the atmsopgher efrom the lower atmosphere to the heliopshere. Today, Bowen University is hosting assorted facilities such as Space weather ad Earth's movement monitoring magnetometer, hybrid automated atmospheric parameters monitors, and GNSS receiver for monitor Space weather. The University has already broken the ground in preparation for the arrival of the 1st Super dual Equatorial Radar Network in the world which is capable of transforming upper atmospheric research in Africa.

The articles in this compendium are not just educative, but readily capture the sense of direction being followed at our Centre for Atmospheric Research. It is hoped that the readers of this compendium will find it useful. More information about our Centre can be obtained at: www.carnasrda.com.

Professor Babatunde Rabiu
Director/Chief Executive, Centre for Atmospheric Research, Anyigba, Nigeria.

Table of Contents

THE PRESENT STATUS OF AIR QUALITY AND THE PREDICTION OF FUTURE TRENDS

Dr. Rose A. ALANI
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Our planet earth is presently far from what it was created to be. When the Creator made it he saw it was good. Now we have made it

not to be good any longer by our activities. We have made the earth a poison to lives that inhabit it. If air pollution continues as it is, what will be our fate?We are almost at the peak of making our planet earth completely inhabitable due to air pollution. It is time to retrieve our steps. What am I driving at? The theme "Air Quality Issues in National Planning: Assessing Present Status and Predicting Future Trends" is very timely. The topic "The present status of air quality and the prediction of future trends" is extremely important to us today.We should know what we are facing now and what is facing us in the future in order to come together and work towards the sustainability of our planet earth. The step we are taking today may look like a scratch on the surface but it is a step towards restoring our planet earth to what it was created to be."We know that what we are doing is like a drop in the ocean. But if the drop were not there, the ocean would be missing something" (Mother Teresa).

I want to appreciate the Centre of Atmospheric Research, Nigeria for giving me the honour and the privilege to present this paper. I am a chemist. I know everyone would agree with me that a chemist has a lot to do with issues regarding air quality. Our slogan in the Chemical Society of Nigeria says "WHAT ON EARTH IS NOT CHEMISTRY?" Well, as an environmental chemist, I specialize in trace analyses which involves the exposure of hidden contaminants and situations that threaten the environment and human lives. I will try my best in this presentation to also expose the present status of air quality locally and globally and also predict the future trends, knowing that poor air quality is very deadly and threatens sustainability and therefore demands timely attention. I will showcase some of the findings from my air quality monitoring researches.

The questions that would be answered in the course of this presentation are: **What is air quality? Of what importance is it to us? How does poor air quality threaten our nation and the globe as a whole? What is our experience in Nigeria? What are the challenges? How do we monitor air quality? How much data do we**

have on air quality in Nigeria? What are the technicalities involved in providing solutions to poor air quality? Which agencies are in charge?

INTRODUCTION

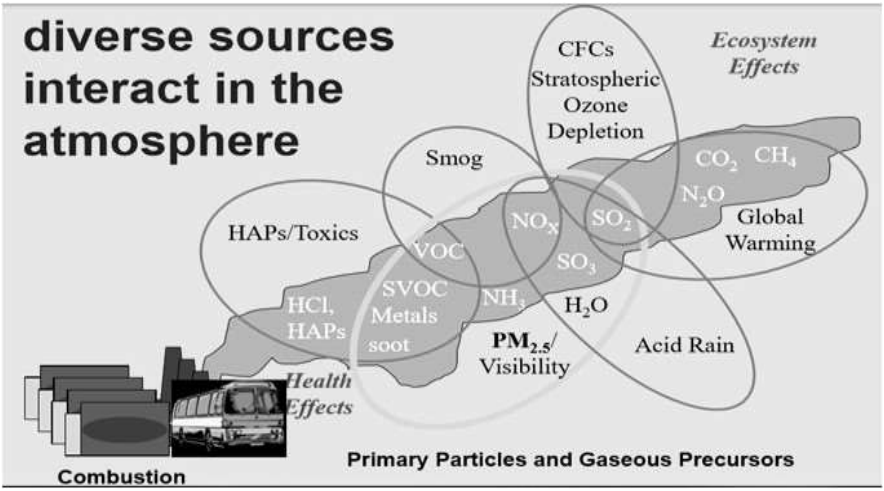
Nigeria, located in West Africa, has a total land area of 983,213 square kilometres. Presently, its estimated population is over 201 million people (World Bank Population figures) yielding an average density of more than 200 persons per square kilometres. Industrial activities, in its modern forms, are relatively recent in the history of Nigeria's economic development. The ongoing development without appropriate environmental protection policies to guide it now results in indiscriminate siting of industries, deforestation and other human activities that result in the release of unacceptable levels of toxic and dangerous industrial wastes and effluent emissions into the environment. The most common method of waste disposal in Nigeria is waste transfer from one region to another and indiscriminate open waste incineration. The waste incineration method of waste disposal often results in air pollution due to the release of gases such as carbon monoxide, sulfur dioxide, oxides of nitrogen, halogenated carbons, and other particulate matter. Pollution due to traffic constitute up to 90 – 95% of the ambient CO levels, 80 – 90% of NOx, hydrocarbon and particulate matter in the world, posing a serious threat to human health, as reported by Savile, (1993). In Nigeria much attention is focused on general industrial pollution and pollution from the oil industries, with little attention on the effects of air pollution from mobile transportation sources (Magbabeola, 2001).

Air pollution

Air pollution is the introduction of harmful or excessive quantities of substances such as gases, particles, chemicals and biological molecules into Earth's atmosphere, thus resulting in poor air quality. This may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built

environment. Air pollution is by far the most harmful form of pollution in the environment because it has a very short response time to changes in atmospheric emission and is a relatively well-mixed environmental medium.

Directly-emitted gases, such as oxides of nitrogen, sulfur dioxide, ammonia, and volatile organic compounds, transform to PM2.5.



Air pollutants include: Criteria pollutants (i.e., CO, SO2, NO2, O3, PM2.5/PM10, and, Pb); Light scattering and absorbing suspended matter (PM) and gases (e.g., SO4=, NO3-, NH4+, OC, EC, sea salt, soil, and NO2); Hazardous Air Pollutants (HAPs, or toxics; e.g., persistent organic pollutants [POPs] and metals [e.g., As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn]); Oxidizing pollutants (e.g., H+, SO4=, and O3); Depositing pollutants (e.g., SO2, HNO3, O3, soot [BC], and soil dust); Reduced sulfur compounds and certain VOCs; and Climate forcers (e.g., BC, O3, CO2, CH4, and halocarbons [Freon-122]).

Ambient air pollution is a major contributor to human mortality and morbidity (Cohen et al., 2005). Five pollutants with strong adverse health effects are particulate matter (PM), ozone (O_3), carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). Among them, PM (a complex, multi-phase system of all airborne solid and liquid organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets having aerodynamic particle sizes from below 0.01-100 ìm) has received significant attention in recent years due to its adverse impact on health, and is the most relevant indicator for urban air quality (Cohen et al., 2005. Emissions from diverse sources interact in the atmosphere and directly-emitted gases, such as oxides of nitrogen, sulfur dioxide, ammonia, and volatile organic compounds, transform to PM2.5. Globally, ambient particulate matter caused 2.9 million premature deaths, or 8.6

percent of total global deaths in 2017.In West Africa, it was responsible for about 79,800 premature deaths in the same year.The problem is particularly acute in Nigeria, the country with the highest number of premature deaths (49,100 deaths, or 61 percent of the West Africa's total) due to ambient PM pollution in 2017(GBD 2017 Risk Factor Collaborators. (2018).

Air pollution in Nigeria

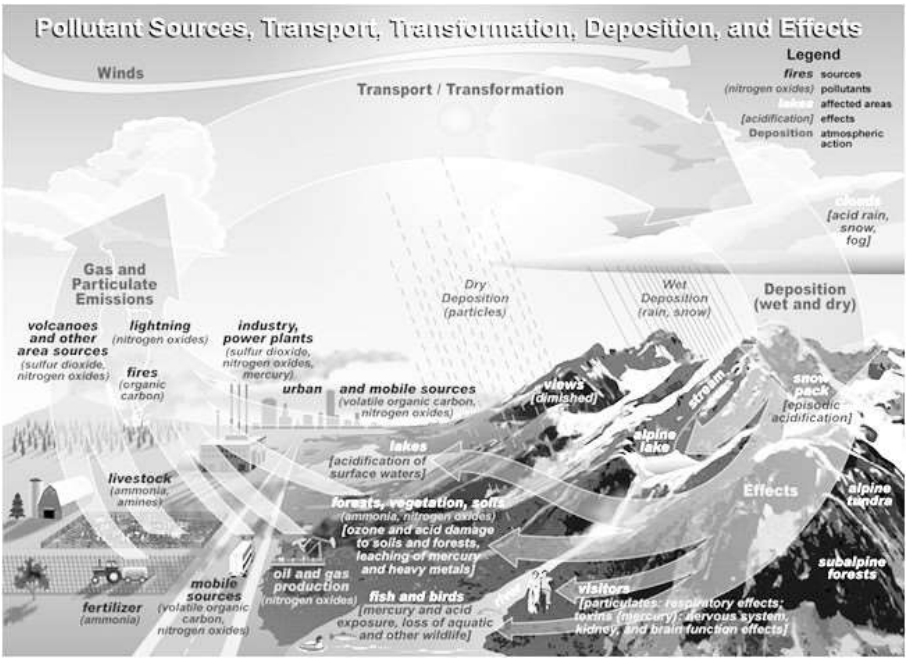
Air pollution problem is escalating in Nigeria as experienced in key commercial cities (Lagos, Port Harcourt, Onitsha, Kaduna and others) in the country. Nigeria is a large and fast growing economy with challenging and dynamic megacities which face a lot of pressures. Not too long ago, released data by the World Health Organization (WHO) showed four cities in Nigeria as the worst cities in the world for air pollution, with Onitsha, a city in Eastern Nigeria labelled as the world's most polluted city for air quality when measuring small particulate matter concentration (PM_{10}). Other three cities named 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. Effects of PM size and chemical composition, as well as gaseous pollutants, are yet to be addressed in Nigeria. Sources of air pollutants are also not yet adequately quantified in Nigeria. Presently very little has been done in the area of air quality monitoring in Nigeria and therefore not much can be concluded on the state of air pollution in the country. Around Nov., 2016 the State Government and residents noticed a strange, sudden appearance and deposition of black particulate matter (Black Soot) on Cars, rooftops, floors, etc in Port Harcourt and its Environs. Rivers State and indeed Port Harcourt being an oil and gas industrial hub could presently be the most polluted place in sub-Sahara Africa, as evidenced by the presence of Black Soot (Black particulate matter PM2.5) hanging on its atmosphere. With the situation of black soot in Port Harcourt, it is certain that there is a serious air pollution problem though the true cause is yet to be identified but industrial pollution is suspected. Other probable causes are gas flaring,

emissions coming from discrete sources such as the several unregulated local/indigenous crude oil refining point and a lot of other carbon emitting human activities. According to Alani et al., (2011), gas flaring is still practiced in the Niger Delta, and this impacts on the food chain, ecosystem and human health significantly. Gas flaring is a significant environmental and economic problem in and Nigeria emits approximately 70 million metric tons of carbon dioxide annually (US EIA1999). It may have also migrated from distances far away from the city. This means that the source may even be outside from our immediate vicinity. The air around us matters. It affects us in ways we can see, and also in ways we cannot see. Pollution can build up in isolated pockets, and local sources for example near industry or a busy road can add to the overall poor air quality. Also the weather conditions in an area play a part in the quality of the air. Pollutant sources in Nigeria: Waste Dumping, Waste burning, Vehicle Exhaust, Diesel Generators, Industrial, Agriculture, Construction, Cooking, Saharan Dust in Northern Nigeria, etc. Nigeria is a large and fast growing economy with challenging and dynamic megacities which face a lot of pressures. Effects of PM size and chemical composition, as well as gaseous pollutants, are yet to be addressed in Nigeria. Sources of air pollutants (outdoor and indoor) are also not yet adequately quantified in Nigeria.

Presently very little has been done in the area of air quality monitoring in Nigeria and therefore not much can be concluded on the state of air pollution in the country. According to Tawari & Abowei (2005), air pollution studies in Nigeria are few and independently carried out. Developing analytical capacities can also support broader thematic considerations. It is important to understand the chemical and physical properties of atmospheric pollution, know how to apportion PM chemical constituents to pollution sources, and be able to evaluate their adverse effects on health, visibility, climate, and ecosystem. Gases as well as primary particles need to be measured (real-time measurement) for relating emissions to effects. Multiyear $PM_{2.5}$ database is needed for quantifying pollution source contributions and evaluating the effectiveness of control measures. Accurate measurements of toxic

air pollutants at trace levels are essential to proper assessments. There is therefore an urgent need to monitor the ambient air quality and also carry out source characterization. Short and long term sampling/bulking of ambient air for permanent gases, volatile/semivolatile compounds, particulate matters and various pollutants is very important. The need to monitor air quality in the major cities in Nigeria to generate baseline data necessary for policy making cannot be over emphasized.

Mechanism of air pollution



INDOOR AND OUTDOOR AIR POLLUTION

Both indoor and outdoor air pollution can occur but the later is often not as deadly as the former due to dispersion process. Dispersion is the process by which contaminants move through the air and a plume spreads over a large area, thus reducing the concentration of pollutants it contains. The degree of instability of the atmosphere and the prevailing wind turbulence play great roles in outdoor air pollutants dispersion. On the other hand, the quality

of air indoors is a problem in many buildings in developed countries because they were built to be airtight and energy efficient. Chemicals from burning fuels, smoking and other sources in the building accumulate and create a pollution problem. Indoor air pollution is also a serious problem in many developing societies. In homes where open fires burn, especially when the climate is cold, the pollutionfrom the fires accumulates and exposes the inhabitants, especially women, to the risks associated with smoke inhalation. Indoor air pollution has been identified as one of the foremost global environmental problems (World Bank, 1993). An SPM level of 50-100 ìg/m3 may cause health effects (WHO, 1987a). Rural people in developing countries may receive as much as two thirds of the global exposure to particulates. Women and young children suffer the greatest exposure. WHO estimated indoor air pollution (IAP) to be responsible for 2.2 million deaths each year.

Sources of outdoor air pollution in Nigeria

These include: Dump sites, Open incinerations, Power generators, Vehicular emission, Use of chemicals, Agricultural source, Biological source, Industrial source, Gas flaring etc.

We have undertaken studies along the highways (Lagos – Abuja to and fro, also Lagos - Ibadan to and fro) and within major cities to check the percentage of smoking vehicles. From the studies: 60 to 70 % of the heavy duty vehicles (including trucks, tankers, tippers etc.) smoke heavily, about 35% of them are smoking, about 10% of tricycles, popularly known as 'keke Maruwa', smoke, about 3% of private vehicles smoke, about 7% of commuter minibuses smoke, and with in Lagos, even the government owned BRT buses smoke heavily. The health hazards from vehicular air pollution on our highways and even within the cities are very high.

Sources of indoor air pollution in Nigeria

Sources of indoor air pollution in Nigeria include: Open fires, burning of biomass fuel, coal, kerosene used for cooking, heating and lightning;Tobacco smoke; Building materials (asbestos, cement); Volatile organic compounds VOCs (paints, glues, varnishes, perfumes, sprays, insecticides) etc.

EFFECTS OF AIR POLLUTION

The impacts of air pollution on health, environment and economy are significant. Below are the adverse effects from different pollutant mixtures

Air Pollutant	Effects
• Criteria pollutants (i.e., CO, SO_2, NO_2, O_3, $PM_{2.5}$/PM_{10}, and, Pb)	• Adverse health and ecosystem effects
• Light scattering and absorbing PM and gases (e.g., $SO_4^{=}$, NO_3^{-}, NH_4^{+}, OC, EC, sea salt, soil, and NO_2)	• Adverse visibility, health and ecosystem effects
• Hazardous Air Pollutants (HAPs, or toxics; e.g., persistent organic pollutants [POPs] and metals [e.g., As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn])	• Carcinogenic health effects (cancer, reproductive or birth defects) • Adverse environmental effects (bioaccumulation of Hg in fish and lakes)
• Oxidizing pollutants (e.g., H^+, $SO_4^{=}$, and O_3)	• Destruction of forests, crops, and lakes
• Depositing pollutants (e.g., SO_2, HNO_3, O_3, soot [BC], and soil dust)	• Soiling and degradation of buildings, antiquities, vehicles, and clothing
• Reduced sulfur compounds and certain VOCs	• Unpleasant odors
• Climate forcers (e.g., BC, O_3, CO_2, CH_4, and halocarbons [Freon-122])	• Alter earth's radiation balance (e.g., absorbing electromagnetic radiation, depleting stratospheric O_3, and changing cloud cover and water vapor)

Health effects of air pollution

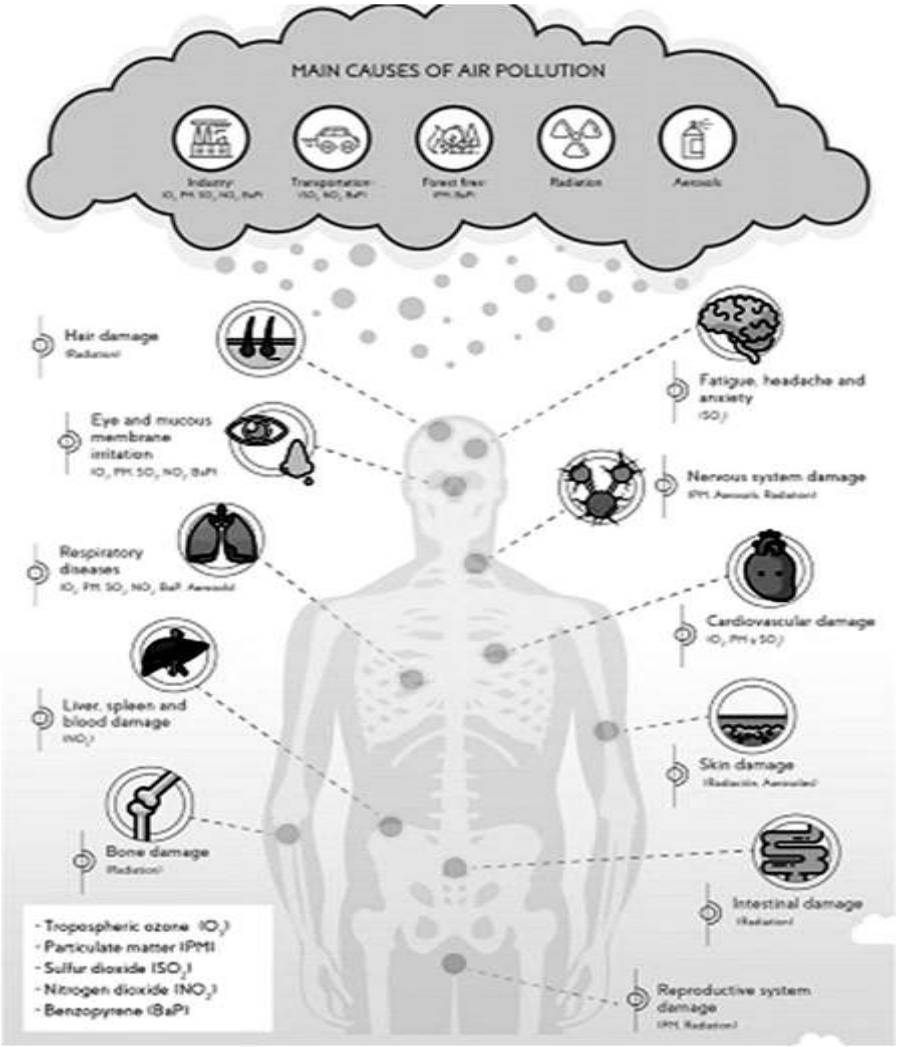
Air is an entry point into food chains and a global transport medium. When humans live in polluted environment, contaminants often have serious effects on their health, and is also life threatening. Health, economic and environmental impacts from air and water pollution are significant. When air quality is poor it is unhealthy, especially for people who are sensitive to it such as children, older adults, or people with heart disease, asthma, and other respiratory ailments. The average person takes about fourteen breaths a minute. Air pollution is more deadly than any other life threatening disease; therefore the quality of our air is vital to our well being. In Africa, there is uncertainty in Air Pollution Health Effects due to lack of exposure data – observations in many regions are unavailable.

Research on the health effects of total suspended particles (TSP) in ambient air has focussed increasingly on particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter less than 10 ìm. The health community generally recognizes that these particles may cause significant adverse health effects. PM-mortality effect estimates are consistently larger for longer time scales of exposure. The different air pollutants have their different levels for adverse health effects. It is important to note that some pollutants that cause adverse effects are not yet measured or managed.

Considering the case of black soot in Port Harcourt, some content of the Soot (Benzo a&b pyrene) has been reported to have Carcinogenic properties. Health experts have implicated black soot to: Coronary heart disease, Asthma and bronchitis, Cancer of the lung and other parts of the body, and Congenital/birth defects. Health experts have warned that, in the next 1520 years, out of every 100 persons, 10 will develop cancer if nothing is done.

Health effects of air pollution include: Asthma, Lung cancer, CO poisoning, Respiratory diseases, Cardiovascular damage, Fatigue, headaches and anxiety, Irritation of the eyes, nose and throat,

Damage to reproductive organs, Harm to the liver, spleen & blood, Nervous system damage and Death. Air pollution affects every organ in the body.



Environmental effects of air pollution

Global climate change: EPA determined in 2009 that emissions of carbon dioxide and other long-lived greenhouse gases that build up in the atmosphere endanger the health and welfare of current and

future generations by causing climate change and ocean acidification. Long-lived greenhouse gases, which trap heat in the atmosphere, include carbon dioxide, methane, nitrous oxide, and fluorinated gases. These gases are produced by a numerous and diverse human activities.The risks to public health and the environment from climate change are substantial and far-reaching. Scientists warn that carbon pollution and resulting climate change are expected to lead to more intense hurricanes and storms, heavier and more frequent flooding, increased drought, and more severe wildfires - events that can cause deaths, injuries, and billions of dollars of damage to property and the nation's infrastructure. Carbon dioxide and other greenhouse gas pollution leads to more frequent and intense heat waves that increase mortality, especially among the poor and elderly (USGCRP (2009). Other climate change public health concerns raised in the scientific literature include anticipated increases in ground-level ozone pollution (CCSP (2008), the potential for enhanced spread of some waterborne and pestrelated diseases (Confalonieri et al., 2007), and evidence for increased production or dispersion of airborne allergens (Confalonieri et al., 2007).

Ozone layer depletion: The ozone (O_3) layer in the stratosphere protects life on earth by filtering out harmful ultraviolet radiation (UV) from the sun. When chlorofluorocarbons (CFCs) and other ozone-degrading chemicals are emitted, they mix with the atmosphere and eventually rise to the stratosphere. There, the chlorine and the bromine they contain initiate chemical reactions that destroy ozone. This destruction has occurred at a more rapid rate than ozone can be created through natural processes, depleting the ozone layer. Higher levels of ultraviolet radiation reaching Earth's surface lead to health and environmental effects such as a greater incidence of skin cancer, cataracts, and impaired immune systems. Higher levels of ultraviolet radiation also reduce crop yields, diminish the productivity of the oceans, and possibly contribute to the decline of amphibious populations that is occurring around the world. Countries around the world are

phasing out the production of chemicals such as CFCs, halons, methyl chloroform and carbon tetrachloride and hydrochloro fluorocarbons (HCFCs) that destroy ozone in the Earth's upper atmosphere under an international treaty known as the Montreal Protocol.

More environmental effects of air pollution include acid rain, damage buildings, eutrophication, crop and wildlife damage, etc.

Economic effects of air pollution

Cities are nowadays at the center of economic activities, and urbanization is an unavoidable path to development (Folberth et al., 2015).However, high rates of urbanization and industrial development entail growing number of vehicles, increased fossil fuel combustion, higher volume of waste burnt and industrial releases. All these activities greatly contribute to increasing pollutant emissions in the atmosphere.

The cost of mortality is estimated based on the Value of Statistical Life (VSL), which reflects people's willingness to pay to reduce their risk of death runs into billions of dollars in Nigeria yearly, according to a study under the World Bank Pollution Management and Environmental Health (PMEH) project.

The cost of morbidity includes resource costs (i.e. financial costs for avoiding or treating pollution-associated illnesses), opportunity costs (i.e. indirect costs from the loss of time for work and leisure), and disutility costs (i.e. cost of pain, suffering, or discomfort). The costs of damages from environmental effects of air pollution in Nigeria are also in billions of dollars yearly.

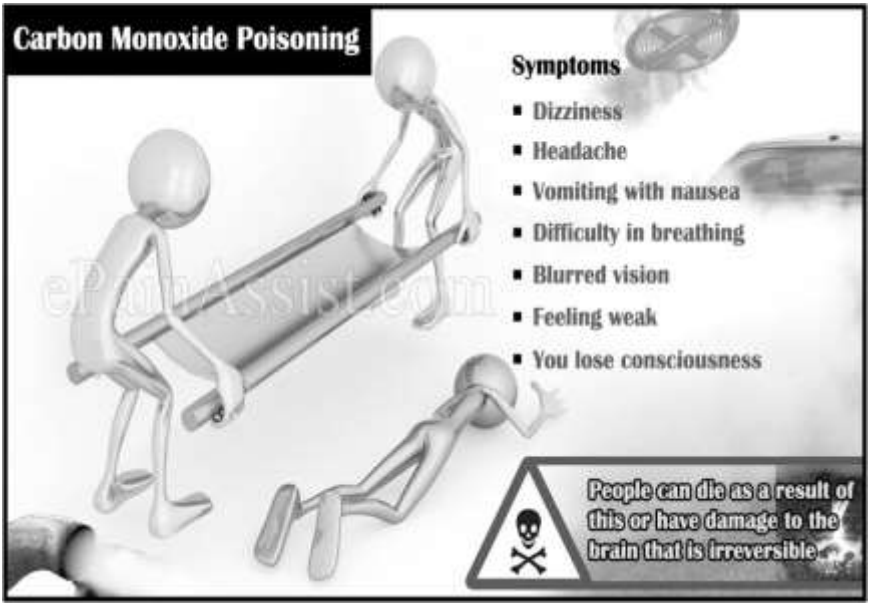
CARBON MONOXIDE (CO) POISONING

You can't see it, taste it or smell it. It can kill quickly and with no warning. Knowing the signs could save life.

Table 1: CO Symptoms

Concentration (ppm CO)	Symptoms
50	No adverse effects with 8 hours of exposure
200	Mild headache after 2-3 hours of exposure
400	Headache and nausea after 1-2 hours of exposure
800	Headache, nausea and dizziness after 45 minutes of exposure; collapse and unconsciousness after 2 hours of exposure
1,000	Loss of consciousness after 1 hour of exposure
1,600	Headache, nausea and dizziness after 20 minutes of exposure
3,200	Headache, nausea and dizziness after 5-10 minutes of exposure; collapse and unconsciousness after 30 minutes of exposure
6,400	Headache and dizziness after 1-2 minutes of exposure; unconsciousness and danger of death after 10-15 minutes of exposure
12,800 (1.28% by volume)	Immediate physiological effects; unconsciousness and danger of death after 1-3 minutes of exposure

*ppm = parts per million



- Water heaters which are based on gas
- Charcoal grills and kerosene space heaters
- Diesel and gasoline powered generators
- Propane based heaters and stoves
- Forklifts fueled by propane
- Smoke from cigarette
- Indoor tractor pulls
- Spray paint, paint removers, solvents and degreasers.
- Mosquito coils






CO poisoning treatment

1. **Get the Person to Fresh Air**: Move the person away from carbon monoxide area.If the person is unconscious, check for injuries before moving.Turn off carbon monoxide source if you can do so safely.
2. **Call emergency number 911** but in Nigeria call **112**, **767**, **122** or **199**.
3. **Begin cardiopulmonary resuscitation** (**CPR), if Necessary**: If the person is unresponsive, not breathing, or not breathing normally:Perform CPR for one minute before calling the emergency number if you are alone. Otherwise, have someone else call and begin CPR.Continue CPR until the person begins breathing or emergency help arrives.
4. **Follow Up**: Once at the hospital, the person is treated with 100% oxygen. Depending on the severity of the carbon monoxide exposure, oxygen is delivered in different ways.Mild poisoning is treated with oxygen delivered by a mask.Severe carbon monoxide poisoning may require placing the person in a full body, high pressure chamber to help force oxygen into the body.

AIR QUALITY MONITORING

Air quality monitoring methods include active, passive and realtime.

Map of Lagos showing the 5 POPs sampling sites **ACTIVE**

AIR QUALITY MONITORING IN LAGOS

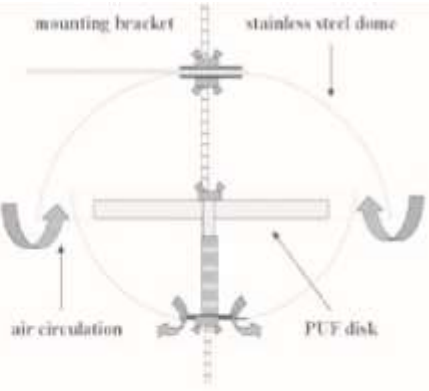
Above are the low, medium and high volume active air samplers. These are filter-based PM sampling systems. Ambient particle sampling has multiple goals which include: Determination of compliance with air quality standards; Examination of the extent and causes of elevated concentrations; Enhancement of the understanding of chemical and physical properties of atmospheric pollution; Apportionment of PM chemical constituents to pollution sources; and the evaluation of adverse effects on health, visibility, climate, and ecosystem.Ambient Sampling System require: Well-

defined size fractions (PM2.5 and PM10); Suitable for sampling in urban and nonurban environments; Accurate and precise measurements; Multiple substrates for a variety of chemical analyses; Compatibility with chemical analysis methods; Flow rate stability; Availability of equipment and ease of operation.

Table 1: Elemental Characterisation of $PM_{2.5}$ in Agege, Oshodi and Unilag

S/N	Metal	Concentrations (ng/m^3)		
		Agege	Oshodi	Unilag
1				294.4±18.5
	Ca	289.8±116.6	184.3±65.4	
2	Fe	195.9± 87.3	196.9±49. 5	109.5± 44.2
3	K	60.6±15.1	43.1±14.6	57.1±27.4
4				44.8±16.8
	Ni	25.4±17.6	67.2±28.3	
5	Ti	18.5±5.1	22.7±2.1	18.9±5.3
6	Zn	16.6±1.6	11.3±2.7	17.5±5.9
7	Co	15.5±4.2	20.1±2.4	6.7±2.8
8	Cu	9.5±0.9	47.5±7.4	ND
9	V	8.9±1.2	6.0±1.4	9.9±0.8
10	Sc	4.8±1.7	3.2±0.7	4.3±0.4
11	Ge	ND	2.4±0.6	1.9±0.7
12	Se			ND
		ND	24.14±4.2	
13	Rb	ND	7.4±1.8	ND
14	Mn	3.9±1.6	6.2±0.7	ND
15	Kr	ND	1.2±0.4	ND
16	Br	1.5 ±0.8	ND	ND
17	Ga	1.7 ±0.9	ND	ND
18	Cr	ND	1.6±0.4	ND
19	As			ND
		ND	ND	

The $PM_{2.5}$ in all the selected locations was found below the regulatory



Passive sampler

New PUF Sample

limits of 25 µg/m^3 and clearly indicated a good air quality in the rainy season.

PASSIVE AIR QUALITY MONITORING IN LAGOS

Passive sampling is ongoing but some results have been obtained as shown in the compared data on flame retardants in mega cities below:

Passive air sampling in Nigeria for the analysis of POPs, in collaboration with the Global Atmospheric Passive Sampling (GAPS) Network, Environment Canada:

Compared data on flame retardants in mega cities

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

GAPS MEGACITIES

First Results for Flame Retardants in Urban Air across the Globe

Amandeep Saini, Sita Chinnadurai, Jasmin Schuster, Tom Harner et al.
Air Quality Processes Research Section,

- **Coauthors:** Narumol Jariyasopit *(Bangkok, Thailand)*, Eftade Gaga *(Istanbul, Turkey)*, Jerzy Falandysz *(Warsaw, Poland)*, Kurunthachalam Kannan *(NY, USA)*, Gavin Stevenson & Alan Yates *(Sydney, Australia)*, Andy Sweetman *(London, UK)*, Begoña Jiménez *(Madrid, Spain)*, Beatriz Aristizabal Zuluaga & Nestor Yezid Rojas Roa *(Bogota, Colombia)*, Maria Tominaga *(São Paulo, Brazil)*, Omar Amador *(Mexico City, Mexico)*, Karina Miglioranza *(Buenos Aires, Argentina)*, Carlos A. Manzano *(Santiago, Chile)*, Rose Alani *(Lagos, Nigeria)*, Vincent Madadi *(Nairobi, Kenya)*, Tamer Shoeib *(Cairo, Egypt)*, Ravindra Sinha *(Kolkata, India)*, Jianmin Ma *(Beijing, China)*, Takahiro Nishino *(Tokyo, Japan)*, R. Suresh *(New Delhi, India)*
- **United Nations Environment Programme (UNEP) and Chemicals Management Plan (CMP) for financial support**

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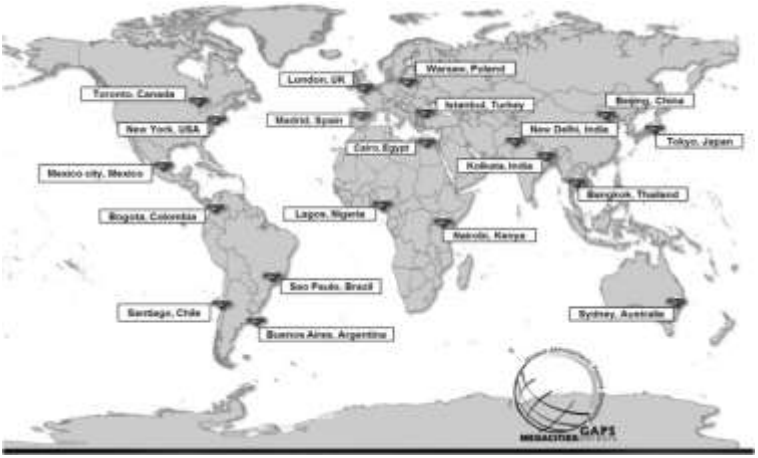

- Organophosphate esters (OPEs)
  - 18 compounds
  - Flame retardants, plasticizers, additives
- Hexabromocyclododecane (HBCDD)
  - α, β and γ isomers
- Polybrominated diphenyl ether (PBDEs)
  - 14 congeners: Penta, Octa & Deca BDEs
- New flame retardants (NFRs)
  - 15 compounds, e.g. Pentabromobenzene (PBBZ), Pentabromotoluene (PBT), Hexabromobenzene (HBB), Ethylhexyl-tetrabromobenzoate (EHTBB), Dechlorane plus (DP), Decabromodiphenylethane (DBDPE)

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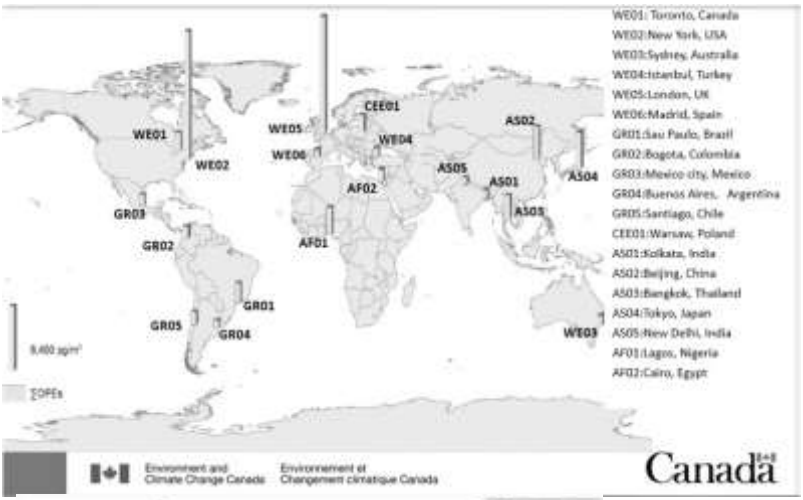

WE01: Toronto, Canada
WE02:New York, USA
WE03:Sydney, Australia
WE04:Istanbul, Turkey
WE05:London, UK
WE06:Madrid, Spain
GR01:Sao Paulo, Brazil
GR02:Bogota, Colombia
GR03:Mexico city, Mexico
GR04:Buenos Aires, Argentina
GR05:Santiago, Chile
CEE01:Warsaw, Poland
AS01:Kolkata, India
AS02:Beijing, China
AS03:Bangkok, Thailand
AS04:Tokyo, Japan
AS05:New Delhi, India
AF01:Lagos, Nigeria
AF02:Cairo, Egypt

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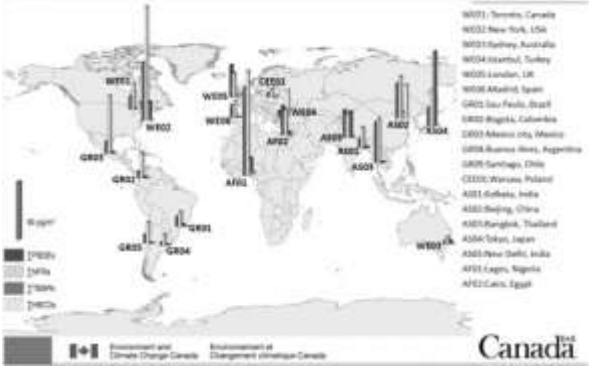
Canada



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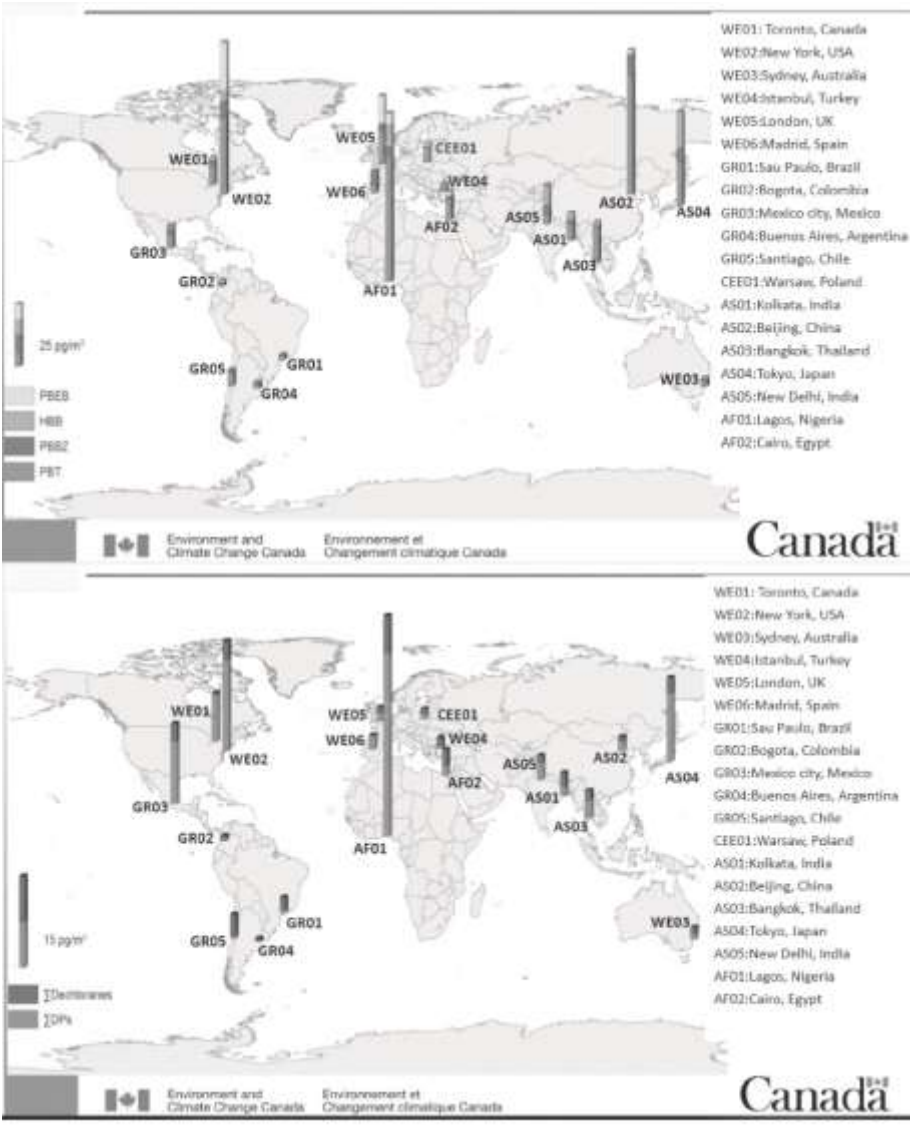


Passive air monitoring in collaboration with POPs monitoring Network under the Southern Contaminants Programme (SCP) in collaboration with Chinese Academy of Sciences (CAS):

Result processing is in progress in Guangzhou Institute of Geochemistry,

Guangzhou, China.

REAL-TIME AIR QUALITY MONITORING IN LAGOS Using Air Quality Egg:

Millions of people in Nigeria are predisposed, vulnerable and are adversely affected daily by the negative environmental health impact of Air Pollution. The health of the present and future generation is bleak if this life threatening trend continues. **The solution is to use instruments which can analyze samples for many compounds quickly, simultaneously, and with little operator intervention over long periods of time to produces data in real time, with no chemical waste generated.** We use smart **sensing** devices that detect pollutants at the speed of light, thus producing real-time results. There is need for real-time and urgent air quality monitoring as air pollution can be very deadly within hours. Emissions from diverse sources interact in the atmosphere and directly-emitted gases, such as oxides of nitrogen, sulfur dioxide, ammonia, and volatile organic compounds, and then transform to $PM_{2.5}$. All these deadly gaseous pollutants, including $PM_{2.5}$ can be measured real-time, both indoor and outdoor, for immediate actions to save lives. In the past the sensors were very expensive, and the tasks were performed only by trained scientists using very sophisticated and very expensive equipment, but there are smart sensing devices such as Air Quality Eggs (AQE) that are affordable and can be assembled and operated by almost anyone.AQE manufactured by Wicked Device can offer the solutions of timely and accurate air quality monitoring as described earlier. Air Quality Egg

is Wi-Fi enabled. One can configure the egg with the phone app and connect it to Wi-Fi network. This can sense Carbon Monoxide, carbon dioxide, Sulfur Dioxide, Nitrogen Dioxide, Ozone, Volatile Organic Compounds and Fine particulates, PM_1, $PM_{2.5}$ and PM_{10}. AQE uses chips photonics, an evolving technology that transfers data by light, allowing computing literally at the speed of light.

Air Quality Egg


Location
GPS


AQI
121
Unhealthy for Sensitive Groups
34
29.4
78
101.1
42
36
26
76
5.6

28

Table 2: Some real-time results from a location in Lagos

Time	Temp°C	Humidity %	PM1.0 ug/m3	PM2.5 ug/m3	PM10 ug/m3	SO2 ppb	NO2 ppb	Barometric Pressure
43142.92	28.04	80.53	39.6	58.8	69.8	538.95	35.2	---
43142.92	28.02	80.51	40.2	59.9	70.7	542.66	33.09	101148.5
43142.92	28.02	80.52	41	61.5	72.1	550.42	33.19	101149
43142.92	28.02	80.53	41.9	63.1	73.6	555.98	34.69	101147.6
43142.92	28.01	80.52	42.7	64.6	74.8	556.66	34.61	---
43142.92	28.03	80.36	43.8	66.5	76.4	549.72	34.83	101150.9
43142.92	28.03	80.73	44.9	68.5	78	555.24	35.23	101155.7
43142.93	27.86	81.1	46.2	70.4	79	603.97	25.48	101160
43142.93	27.82	81.24	45.3	68.5	77	612.43	26.66	101158.3
43142.93	27.84	80.99	45	67.3	76.2	614.26	22.74	---
43142.93	27.87	81.02	44.8	66.6	75.7	611.64	23.35	101160.8
43142.93	27.9	80.8	44.6	65.7	75	597.79	21.22	101152.2
43142.93	27.98	80.54	42	55.5	68	525.13	10.46	101155
43142.94	28.01	80.46	42.4	56.1	67.7	570.17	35.96	101154.3
43142.94	28.03	80.44	42.2	56.5	68.3	541.6	34.64	101157.9
43142.94	28.03	80.51	42	56.4	68	548.48	31.07	101157.8

DEVELOPMENT OF AIR POLLUTANTS SENSORS USING INFRARED (IR) SPECTROPHOTOMETER

CO_2 gas sensing on polyethylenimine (PEI) functionalised graphene was carried out in Institute of photonic Sciences (ICFO), Casteldefells, Barcelona, Spain.

Fourier-transform infrared spectroscopy (FTIR)

Branched PEI of different dilutions was spin-coated on silicon wafer substrate at 6000rpm & 1000rpm/s to obtain the thickness much below 100nm.Characterization the thickness of the different PEI film thicknesses was carried out using profilometry, ellipsometry, and reflected light microscopy methods. CO_2 was captured, and using **Fourier-transform infrared spectroscopy** (**FTIR**) an infrared spectrum of absorption or emission of the CO_2 gas trapped on the PEI surface was obtained. Signals not strong enough were obtained, but were highly enhanced by coating the PEI on graphene.

CURRENT CHALLENGES AND FUTURE TRENDS OF AIR POLLUTION

Air quality will continue to deteriorate in the future if we don't take any action. Urbanization, Industrialization (both in urban and rural areas), Transportation growth pose serious challenges of air pollution. Despite the severity of the challenge, there is very limited progress in implementing comprehensive AQM strategies in many low and middle income countries. There is limited media coverage. There is therefore an urgent need to: Improve understanding of outdoor air pollution and its causes; Install ground level air quality monitoring networks; Identify and assess policy options to improve AQM. Application of AQM planning can lead to investments such as that of the World Bank Pollution Management and Environmental Health (PMEH) program presently ongoing.

World Bank pollution management and environmental health (PMEH) program: establishment of air quality monitoring plan for the city of Lagos

World Bank PMEH programme focuses at strengthening air quality management in seven countries which include Nigeria, Ghana,

China, Vietnam, Egypt, India and South Africa. PMEH provides a systematic approach to development of AQM plan sand also develops AQM plans that lead to investments in concrete actions for pollution reductions Countries/cities/city clusters can customize the approach to address local contexts.

The cost of mortality is estimated into billions of dollars in Nigeria yearly, according to a study under the World Bank PMEH project.The costs of damages from environmental effects of air pollution in Nigeria are also in billions of dollars yearly.

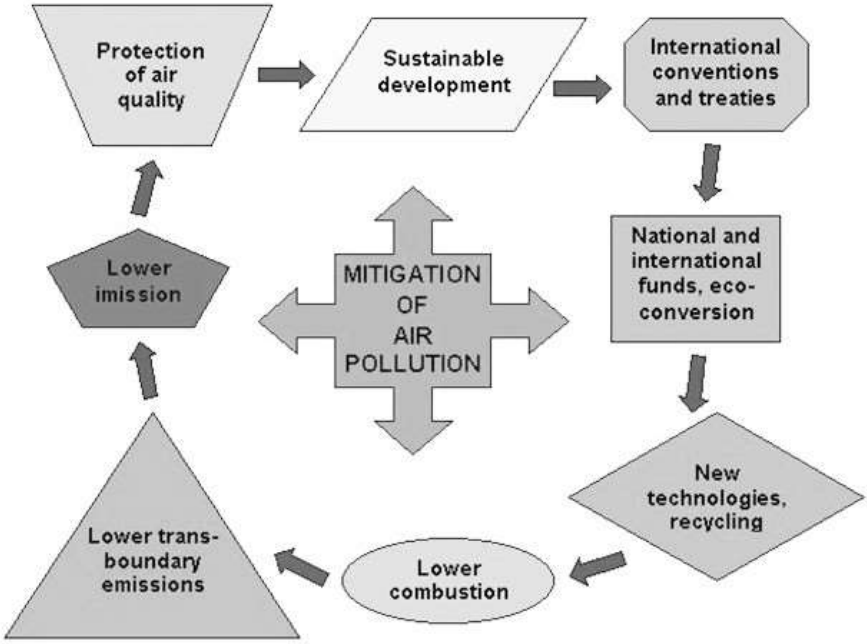
Over 80% of cities exceed WHO guidelines for safe air, 87 percent of world's population

Annual mean concentration of PM2.5 in urban areas (2013)

If pollution continues at its current rate, the future effects could be devastating to human populations and the environment.

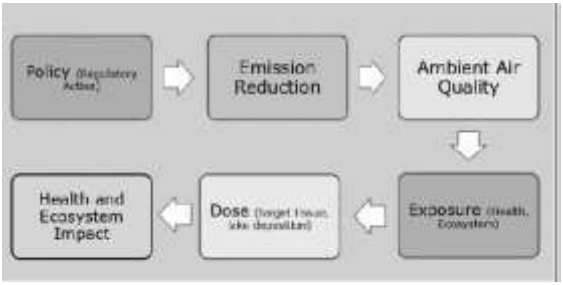
Multi-pollutant air quality networks need to go beyond compliance for criteria pollutants to address multiple monitoring objectives such: Determine compliance; Understand atmospheric processes; Develop/test air quality models; Identify and quantify source contributions; and Estimate immediate and long-term hazards.

Two steps are necessary to make changes for better future are: Mitigation: **Protecting the atmosphere from air pollution is a priority for many countries and international organisations and contributes to the aim of sustainable development. Many conventions and treaties have been signed which limit the emissions of harmful substances into the air and encourage the use of new cleaner**



(1) Adaptation to air pollution: Dealing with a pollutant after it has been emitted, or it can mean changing infrastructure to make it more resilient to heavy rains, floods, or more intense storms. It is always better to deal with pollution by reducing the emissions. Adaptation is more expensive and less certain than mitigation. However, when the will to mitigate is not found, adaptation is the only plan

If necessary steps are taken to control the activities that release air pollutants to the environment, air pollution will be controlled.



Bell et al. (2010) Environ. Sci. Technol. 32

In Nigeria, change our orientation towards activities, use environment friendly materials, phase out the use of electric generating plants, plant trees, remove smoking vehicles from the roads, involve in researches, work together with the regulatory bodies, obey rules and regulations, etc.

CONCLUSIONS

Currently the situation is very bad globally. We are almost at the peak of making our planet earth completely inhabitable due to air pollution. If we continue with the activities that have brought us to where we are now globally, air pollution will destroy the planet earth. If we return to the instructions of the creator and replenish the earth as He instructed us in Genesis 1: 28 instead of destroying it, then we will undo the harm that we did to our planet earth and enjoy the finished good planet earth (Genesis chapter one) which God freely gave to us. We should come together and work towards the sustainability of our planet earth.The entropy (degree of disorderliness) resulting from air pollution can certainly be reversed. My prediction of the future is a bright one. Nothing is impossible for us to handle if we all in the planet earth can work together in unity to address the problem and do things right. The trend will change for the better if the necessary actions are taken to combat air pollution.

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AIR QUALITY RESEARCH IN ACADEMIA: SOME FINDINGS AND FUTURE RESEARCH AT BAYERO UNIVERSITY, KANO, NORTHERN NIGERIA

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Abstract
Air pollution impacts on the quality of air available for us to breathe. This therefore underscores the importance of monitoring, ensuring compliance and regulating the quality of the air around us. Findings

have shown that the most dominant air quality issue in Nigeria is from small scale (indoor, outdoor/roadside, including standby electricity generators powered by petrol or diesel). However, information about the regional distribution of air pollutants in Nigeria is still scanty. In this paper, the findings on air pollution and pollutants by two doctoral research students at Bayero University will be presented. The paper starts with background literature exploring air quality concerns and the relevance of air quality continuous monitoring. The background literature also includes an overview of air quality monitoring instruments. The paper concludes by presenting a proposed research for monitoring indoor and outdoor air quality at the two campuses of Bayero University in Kano, Northern Nigeria.

Keywords: Air Pollutions, Air Pollutants, Air Quality, Monitoring

1. Introduction

Breathing is life and what we breathe is air. The quality of our life and well being therefore depends on the quality of air we breathe. Air pollution impacts on the quality of air available for us to breathe. This therefore underscores the importance of monitoring, ensuring and

regulating the quality of the air around us. We must know the air pollutants, their duration and lifetime, the type of damage they cause, how they are produced and what to do to stop their production or mitigate their effects where they cannot be stopped completely. In recent times, attention has been focused on research that will help in mitigation strategies of air pollution and ensuring clean air for better quality of life. Efforts, such as the Climate and Clean Air Coalition (CCAC), which target short-lived climate pollutants and it has also been shown that air pollution impacts on cognitive performance (Zhang, Chen &Zhang, 2018). Casper (2010) also showed that clean air is very essential for good life and health. There has been great concern on air quality globally and Griffin (2007) has

shown that the most effective technique in tackling or mitigating the negative effect of air pollution is continuous monitoring. Significant contributors of air pollution include black carbon, which is a form of particulate air pollutant usually produced from biomass burning, cooking, diesel exhaust (Casper, 2010) and in the case of Nigeria, standby generators. In times past, outdoor air quality was given more attention with the belief that the indoor was safer (Fisk, *et. al, 1987*). Attention has however now shifted to include monitoring indoor air quality.

2. Background on air pollution

The concern about pollution in general has always focused on the impact of pollution on global climate. Climate Change, which is as a result of some of the impacts of air pollution, has been a front burner topic in academia and outside academia. In spite of skepticism in some quarters, Climate change is still regarded as a threat to human survival on planet earth.

2.1 Air Pollution

Air pollution has been around for time immemorial. Evelyn (1661) wrote:

"… her inhabitants breathe nothing but an impure and thick Mist accompanied with a fuliginous and filthy vapour, which renders them

obnoxious to a thousand inconveniences, corrupting the Lungs, and disordering the entire habits of their Bodies; so that Catharrs, Phthisicks, Coughs and Consumptions rage more in this one City than in the whole Earth …."

The composition of the atmosphere, the air surrounding us and the wind dynamics makes air pollution very poignant. It is a foregone conclusion that greenhouse gases emissions into the atmosphere, which has upset the natural balance has significant effect manifested, at least in our part of the world in flooding on one hand and extreme aridity and desertification on the other, extreme temperatures and other extreme weather events. In Nigeria, significant air pollution is a result of fossil fuel burning, the production of black carbon (soot) also referred to as Particulate Matter (PM).The major sources of these in Nigeria are: stand-by generators for electricity, biomass/bush burning, cooking with firewood, diesel exhausts and industries. PM apart from its effect on climate through increased absorption of solar radiation has a health concern as well.

2.2 Air pollutants classification

There are two main categories of pollutants in the ambient air that are of concern. These two categories are termed criteria pollutants and non-criteria pollutants. Criteria air pollutants are those air contaminants for which numerical concentration limits have been set as the dividing line between acceptable air quality and poor or unhealthy air quality. The national ambient air quality standard is the concentration of a given air pollutant in the ambient air, usually over a specified period of time. This is a concentration below which the U.S. Environmental Protection Agency believes have no long-term adverse health effects. The criteria air pollutants include four gases and two solids. The solid air pollutants are released directly into the air as suspended solid particles. Major sources are industries (Cement production) and motor vehicles. When contained in air, they can be inhaled and ingested (APL, 2019). The criteria air pollutants

are listed in Table 1, while the non-criteria air pollutants are listed in Table 2.

Table 1 Criteria Air Pollutants

Nitrogen dioxide	**NO_2**
Sulfur dioxide	**SO_2**
Carbon monoxide	**CO**
Ozone	**O_3**
Particulate matter	**PM10, PM2.5**
Lead	**Pb**

Non-criteria pollutants tend to be several orders of magnitude lower in concentration than the criteria pollutants. For instance, it would not be uncommon to find ambient carbon monoxide in the parts per million ranges, whereas ambient concentrations of a hazardous air pollutant, such as benzene, would be in the range of parts per billion.

Table2. Non-Criteria Air Pollutants

Benzene
Bis(2-ethylhexyl)phthalate
Carbon tetrachloride
Chloroform
Dibutyl phthalate
Ethylene dichloride (1,2 dichloroethane)
Formaldehyde
Mercury compounds
Methylene chloride
Perchloroethylene (tetrachloroethylene)
Trichloroethylene

SOURCE: http://www.epa.gov/ttn/atw/nata/haptbl.html

2.3 Indoor and Outdoor Air Pollutants

Indoor air pollutants differ slightly from outdoor mainly because indoor air pollutants do not include Sulphur Dioxide (SO_2). Indoor air pollutants, however, include radon and formaldehyde. While both

indoor and outdoor air pollutants can include carbon monoxide, carbon monoxide is more deleterious indoor.

There are two main factors that govern the concentration of indoor air pollutants: (i) the source strength of the pollutant and (ii) its removal rate. The various sources of indoor air pollution include:

Residents and pets that generate carbon dioxide, moisture, odors, and microbes through normal biological processes. Other potential sources of indoor air pollution may include: combustion appliances, building materials, furnishings, insulation, tobacco smoke, and the soil under and around the building itself. Air flow into and out of a building is usually the principal means of removing these indoor contaminants. Reducing air flow rates is one of the most costeffective ways of improving the energy efficiency of residential buildings. Although effective in conserving energy, reducing the air exchange rate in a building usually slows the transport of indoorgenerated air pollutants to the outside, thus, trapping the pollutants inside (Fisk, et al 1987).

Outdoor air pollution result mainly from combustion of fossil fuels, industrial processes, agricultural processes, waste incineration and natural processes like volcanoes, sandstorm, etc. Sources of outdoor air pollution and severity are also determined by location; the sources of outdoor air pollution generally differ in rural areas from urban areas.

2.4 Air Quality and Ambient Air

Air quality is a measure of the cleanliness of the air we breathe; the maintenance of a standard for the air to be free of detriments to our health. In talking about air quality, a term, known as 'ambient air' needs to be defined. Ambient air is the part or portion of the Earth's atmosphere that is referred to as the 'breathing zone'. (Griffin, 2007). This is the zone that contains the air that we breathe. The zone is within the lowest portion of the atmosphere. The composition of the breathing zone is as shown in Tables 3:

Table 3: Composition of the Clean Atmosphere near Sea Level (a) Permanent Gases

Constituent	Chemical Formula	Percentage by Volume (Dry Basis)	Parts per Million by Volume
Nitrogen	N_2	78.084	-
Oxygen	O_2	20.946	-
Argon	Ar	0.934	-
Neon	Ne	-	18.2
Helium	He	-	5.2
Krypton	Kr	-	1.1
Hydrogen	H_2	-	0.5
Nitrous oxide	N_2O	-	0.3
Xenon	Xe	-	0.09

(a) Variable Gases

Constituent	Chemical Formula	Parts per Million by Volume
Water vapor	H_2O	
Carbon dioxide	CO_2	0.035
Methane	CH_4	1.5
Carbon monoxide	CO	0.1
Ozone	O_3	0.02
Ammonia	NH3	0.01
Nitrogen dioxide	NO_2	0.001
Sulfur dioxide	SO_2	0.0002
Hydrogen sulfide	H_2S	0.0002

(Source: Griffin, 2007)

3. Concerns on Air Pollution and Air quality monitoring

The concern about air pollution has been a long term one. Griffin surmises that “Air pollution reached its worst in the Great London Smog Disaster of December, 1952”. It was reported that during the event, the contributing factors ranged from air stagnation, temperature inversion, extreme cold of the London region, excessive reliance fossil fuels for heating, the switch from electric trolleys to

41

diesel buses for public transport, lack of controls on industrial sources. All of the aforementioned resulted in an extreme case of air pollution that lasted for nearly two weeks. The research then showed mortality estimates of about 4,000 deaths in the period immediately following the event were, with actual record showing that about 12,000 people died as a direct result of the Great London Smog Disaster (Griffin, 2007), while thousands suffered from respiratory ailments. Sadly, the situation is no better today.

4. Particulate Matter

Particulate matters (PM) are fine particles with very small diameters that can easily pass through the lung filters while breathing. PMs have very acute health effects. High concentrations of fine particulates can affect mortality rates, with increased incidences of respiratory diseases. Particulate Matter such as PM2.5 directly irritates the respiratory tract, constrict airways, and interfere with the mucus lining of the lung passages. PM is particularly dangerous because the fine particulates (PM2.5) act as carriers for toxic contaminants, particularly, heavy metals. This occurs when the contaminants exist in a fume or a vapor state and condense onto the fine particulates. In the alveolar regions, heavy metals may be absorbed into the blood and circulated to other parts of the body. PM, and in particular the fine-particulate (PM2.5) have an effect visibility reduction as well. Visibility loss will then manifest in other safety concerns such as psychological stress and air travel safety and even road travel safety.

5. Research findings

Many research findings have drawn more attention and concern on the need to maintain good air quality. A recent study (Bennet, et.al, 2019) has shown that air pollution and poor air quality has worrying effect on life expectancy. The research was on exposure to fine particulate matter pollution (PM2.5) and its hazardous impact on health and a direct estimate of the health and longevity impacts of current PM2.5 concentrations and the benefits of reductions from

1999 to 2015, nationally and at county level, for the entire contemporary population of the contiguous United States.

The researchers used vital registration and population data from the contiguous United States between 1999 and 2015. They also used a statistical model, adjusted for other determinants of mortality such as poverty to directly estimate mortality and life expectancy loss due to current PM2.5 pollution. They found that PM2.5 pollution in excess of the lowest observed concentration (2.8 ìg/m^3) was responsible for an estimated 15,612 deaths (95% credible interval 13,248–17,945) in females and 14,757 deaths (12,617–16,919) in males. Also, the deaths lowered national life expectancy by an estimated 0.15 years for women and 0.13 years for men. A recent report (Crew, 2019) in the UK Mirror shows that air pollution competes with cigarette smoking in causing lung disease. The survey, where this result was obtained was carried out for more than 7,000 adults. The research found that long-term exposure to particulate matter, nitrogen oxide, and black carbon was linked to an increased percentage of emphysema from CT scan results. These results were the same as those seen for cigarette's smokers.

6. Research Findings at BUK

Two PhD researches that have bearings on air pollution were carried out at the department of Physics in Bayero University Kano. One of the researchers examined the dispersion of air pollutants. The impact of air pollutants are compounded by the transport, diffusion and dispersion phenomenon. This is what informed the PhD research by one of the students. The student carried out in-situ measurements and modeling of pollutants, at four industrial sites in Kano metropolis. Since it is known that the transport and dispersion of air pollutants will enable the calculation of downwind ambient pollutant gas concentration, the study is useful in determining safe sites for residential buildings, away from industries. The summary of the findings from the study are:

· Analysis and assessment of the transport and mixing processes of air pollutants from some selected industries in Kano were analyzed.
· The Gasman operating Instrument was used to detect the concentration of the air pollutants from the study area and the results showed that, some of the pollutants are within the air quality standard while some are not.
· It was generally observed from the results that the concentration of some of the pollutants decreases as they are being emitted from the point source to the next level, due to the fact that air pollutant move to places beyond the confine of their origins and therefore distribute the constituents at various places while some increases are due to additional emissions and mixing processes from neighboring industries.
· The mixing of the constituent of the pollutants may lead to chemical reaction that can also produce secondary pollutant (this was not covered in the study).
· It was generally observed from the results that, almost all the selected industries in this study contributed greatly to air pollution.
· This was associated to emissions from the industries, passing by vehicle and other sources, due to the fact that air pollutants move to places beyond the confine of their origins and distribute the constituent at various places as well as the mixing of the constituents which lead to chemical reaction that produce secondary pollutants.
· The result has similar air pollution pattern in related studies such as spatial patterns of urban air pollution in an industrial estate, Lagos-Nigeria by Yusuf et al (2013).
· Based on the results obtained and the air quality index rating, the air released from the industries in the study area is mostly polluted.
· The impact of air pollution include the necrosis of tissues through disruption of cell membrane lipids (saponification) leading to cellular destruction, chronic respiratory problem,

corrosion to various materials which causes damage to cultural resources, cardiovascular defects, serious eye damage and loss of life in some cases.

- In conclusion, it is suggested that government should take appropriate measures to control industrial air pollution in couple with vehicle and other sources of pollution in order to reduce the emission of air pollutants in the study area.

The second research, also by a PhD student identified sources and composition of tropospheric aerosol particles and its influence on climate in that region. In view of the fact that the impact of the studied pollutants on air quality and climate is complicated, and also that this unique environment has not been fully investigated to characterize and identify the percentage contribution of each source, the researcher set out to carry out the study. In the course of the study, it was found that Nigeria is plagued with uncontrolled emissions as there are neither properly established monitoring protocols nor emission inventories baseline for natural and anthropogenic combustion. Thus, emissions are uncertain (Liousse et al., 2014). More or less stringent emission control in the future may have a significant impact on air quality in Nigeria. Some of the summary findings of the research are:

- The AOT (i.e. AOD at 550 nm)model output over Nigeria ranges between 0.5 to 0.7 while the AERONET measurement show in part much higher AOT with densely average concentration of 1 during the Harmattan (winter) months.
- Dust burden shows high concentration of 9×10^{-4} to 1.0×10^{-3} kg/m^2 in the Northern to Central parts of Nigeria and reduces to 6.0×10^{-4} to 8.0×10^{-4} kg/m^2 towards the Southern part.
- Furthermore, high burden of primary organic aerosol (POM) is simulated throughout Nigeria with exception of a small portion of Borno and Sokoto states in the far Northern Nigeria.
- Also, high burden of secondary organic aerosol (SOA) is simulated over the rainforest and monsoon climate

(Southern part) regions in Nigeria and moderate values of SOA over North-Central and far Northern Nigeria.

- Primary Organic Matter (POM) and Secondary Organic Aerosols (SOA) burden are very important for air quality, since they are smaller and therefore adversely affect the respiratory system.
- Differences in AOT between model and observations, in particular the amount of dust, point to shortcomings in the model that could be caused by uncertainties in emissions, transport or meteorology.
- More refined observations of aerosol distributions would be required to identify the composition of aerosols in Nigeria and to identify possible lapses in the model.
- Nevertheless, model results indicate that pollutions from other sources, including biogenic and fossil fuel emissions, may be a significant contributor in PM2.5 pollution in Nigeria.

7. Proposed future research on monitoring of indoor and outdoor air pollution in the two campuses of Bayero University in Kano

In this section, a proposal for a study is presented. The study is expected to be funded by the Non-degree oriented research fund of the Tertiary Education Trust Fund (TETfund).

7.1 Rationale of the proposal

An inception meeting on Air Quality was held in March, 2017 at Abuja through the Federal Ministry of Environment on Short-lived Climate Pollutants organized by the Climate and Clean Air Coalition. The meeting among other things focused on measures to mitigate short lived climate pollutants (SLCPs). Prior to this in 2014, the first West African Workshop on Air Quality was organized by the Center for Atmospheric Research (CAR/NASRDA) in Abuja. The gap in air pollution monitoring, air quality trends were noted, particularly academic data measurements that could be relied upon by policy makers. It is against this background that the current research is

conceived. The current research will form a part of database for air quality measurements that will monitor the trends in air pollutants within the campuses of Bayero University, Kano.

7.2 Aim(s) and Objectives:

The aim of this research is to provide an inventory or a repository for air pollution data and possible impact of the pollutants through measurement of indoor and outdoor air pollutants across selected locations and hot spots at the two campuses of Bayero University in order to inform strategies for safety measures. This aim will be achieved through:

- Continuous monitoring and recording of concentration of PM10, PM2.5, CO and VOCs.
- Development of analytical and assessment tools for analyzing gathered data from the selected locations at the two campuses
- Data analysis, of the measured air pollutants
- Identification of types, duration and lifetimes and recommendation for safety measures.

The objectives of the research are:

(i) To use analysis to determine the most dominant particles size distributions

(ii) To use time series analysis to determine the rate of increase in the most dominant particles size distributions and forecast the possible occurrence or increase of diseases related to aerosols increase, such as lung diseases

To analyze the data using Empirical Orthogonal Function (EOF) to determine the most seasonal increase, so that intense seasonal measures can be advised

7. 3. Significance/Expected Benefit

Particle air pollution occurs as a result of emissions of particulate matter into the atmosphere; contaminating air that we breathe. Particulate matter (PM), also called particle pollution, is a general term for extremely small particles and liquid droplets in the atmosphere. They consist of PM2.5 (fine particles): $d \leq 2.5$ μm, PM10 (coarse particles): $d \leq 10$ μm.

The **Primary** sources include: Incomplete combustion, Automobile emissions, Dust, Cooking and in the case of Nigeria, Standby petrol or diesel-powered generators. Particulate Matter (PM) is hazardous to human health as it causes acute and chronic effects to the respiratory and cardiovascular systems. PM causes a variety of human health and economic impacts each year (e.g., mortality, morbidity, lost income from work absences, costs of health care). Other air pollutants are carbon monoxide, oxides of nitrogen, oxides of sulphur and surface ozone. The absence of accurate data of the concentrations of PM indoors and outdoors of our campuses is a matter of concern. Monitoring and recording of air pollutants indoors and outdoors of selected locations and hot spots will provide an inventory that could be used to make recommendation for safety and precaution measures at the two campuses.

7.4 Research Problem

The following are the research problems regarding air quality in Nigeria:

1. The most dominant air quality issue is small scale (indoor/roadside, including standby electricity generators powered by petrol or diesel)
2. Most pressing of the air pollution concern is probably particulate matter
3. That little is known about which compounds are causing the most problems and they may not necessarily be the same as EU, therefore research to identify which compounds are causing our own problems
4. That little is known about the regional distribution of air quality pollutants in Nigeria
5. That only few long term measurements are available and aircraft campaigns and satellite data are very few
6. Ozone appear to be generally low due to rapid sinks but that local hotspots exists
7. Emissions data are highly uncertain and therefore emission scenario is non-existent

This research hopes to address research problem 1, 2 & 4 by monitoring the indoor and outdoor air quality at the two campuses, ascertaining that the most pressing air pollution concern is particulate matter by measuring the concentration of PM10 and PM2.5 and providing a profile of distribution of air pollutants at the selected locations of the campuses.

7.5 Methodology

The proposed methodology for this research is to start a measurement of air pollutants in four batches of three months continuous measurements. The first two months (September – October, 2019) of the research will be used for sight identification at the two campuses, procurement of the measuring devices and set up at the sites. In the first batch of three months (November, December, 2019 & January, 2020), two outdoor hand-held air quality monitors will be used to continuously measure PM2.5 and PM10 and other air pollutants within two selected locations in the old and new campus respectively. Daytime measurements from 6am to 6pm will be done with the aid of research assistants who will take measurements in shifts (06.00-10.00) (10.00-14.00) (14.00-18.00). One indoor air quality monitor will also be mounted in a location at the two campuses each. The measurements will be continuous in this manner for one month in the two locations for each campus. Then the devices will be shifted to two other locations in the two campuses for a month and then shifted to two other locations in the third month. The indoor monitor will also be shifted to a different location whenever, the outdoor devices are shifted. This will conclude the first batch of three months measurements. In February, 2020, this first set of measurements will be analyzed and a monitoring and evaluation exercise carried out. The second batch of measurements will follow the same pattern as the first and will be in March, April & May, 2020. This will be followed by the Monitoring and Evaluation (M&E) in June, 2020. The third batch of three months measurements will be in July, August & September, 2020 and will be followed by the M&E in October 2020. The fourth and final batch of three months measurements will be from November, December, 2020 and January, 2021. The devices will be shifted to different locations in the cause of the batch measurements to cover as much area as possible both indoor and outdoor during the duration of the measurements. Simultaneous measurements of meteorological parameters of temperature, relative humidity, wind speed and wind

direction will be retrieved from the weather stations in the two campuses to analyze

49

what impact or otherwise these parameters have on the measured air pollutants. The months of February, March and April, 2021 will be dedicated to the final M&E, publicity and dissemination conference and final report writing and submission to funding agency.

8.0 Conclusion

This paper has explored air pollution and air quality. Some recent findings have been highlighted. Some summary of findings on air pollution and air quality of research students have been presented. The paper concluded with a research proposal expected to be carried out in the two campuses of Bayero University in Kano.

Acknowledgements

I would like to thank my student, Maryam Idris, whose research findings summary were presented here and my PhD student, Najib Yusuf. A summary of part of his findings of aerosols burden and impact on air quality is also presented in this paper.

I thank Professor Babatunde Rabiu, DG/CEO: Center for Atmospheric Research (CAR/NASRDA), for organizing this event and for finding me worthy to present a paper at this Honourable symposium. I am grateful for the financial support, which enabled me to attend the event.

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AIR QUALITY ISSUES IN NATIONAL PLANNING: ASSESSING PRESENT STATUS AND PREDICTING FUTURE TRENDS

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Air is one form of matter which affects all living beings and even nonliving things that come in contact with it. The air content is changing with time and more rapidly since the last century at local and global levels.

Burning the land instead of mowing

Fire set up usually by small farmers often grow expanding to cover large land masses.The most recent example is the fire burning uncontrollably in the Amazon forest of Brazil to the extent of chasing out the people who started the fire. What can such farmer plant to harvest enough to compensate the loss of lives and property for the following year and beyond. This is the danger we could experience if we do not control the annual bush burning set up by small time farmers, small rat killers and Fulani herdsmen in Nigeria.

Modern Lifestyle Waste Management

The next danger is modern lifestyle. The world, Nigeria not an exemption is addicted to the use of plastic bags, plastic wraps and plastic containers. These materials which were not predominant four or five decades ago have taken over land and sea and every conceivable space. It will be an important exercise to estimate the surface area occupied by plastic materials in our country and the world over. They have added to the dirty looking cities and hamlets and are prone to fly freely across borders. They also hold and trap solids and liquids making it difficult for evaporation to take place over what they lay, where they lay or what they contain. They prevent biodegradation and encourage bacteria invasion. They clog water flow and block drainages which make it easy for floods to develop and when burnt release toxic gas into the air.

Air pollution and disease

The air content used to be mainly Oxygen, Nitrogen, Carbon dioxide, water vapour and the Inert gases. The story has changed today as it has become globally influenced byoverwhelming what would have been locally constituted. The air continues tomove and the winds develop strength from it. The content from exhaled air from animals and plants have changed in proportion due to change in human population and the way things get done. Farmers used to have small farms but, both the human and animal populations have changed (or modified) and the ratio of human and animals to plants have changed drastically due to new and large municipalities which have developed attributable to urban migration.Mining of minerals and

oil, industrial development that have taken land from plants for buildings, desert encroachment attributable to human activities such as Fulani herdsmen drive further and further southward from the north towards the coast, industrial waste produced pushed into the air including sources such as aviation and space industry among others all produce intruders into the atmosphere.

Effects of extraneous particles into the Air.

The presenceof these intruders into the atmosphere are considered pollution because it changes the ecological balance and has both immediate and delayed consequences. The immediate effects include difficulty in breathing and delayed effects include acid rain, lung damage, obstructions in the metabolism process due to particles that do not aid growth with some coming in by ingestion through plants that draw in the unwanted chemicals through the roots or leaves or even through land or water based animals that humans eat.

Climate Change

The recently much talked about and notable **climate change** issue is one of the delayed effects and may not necessarily derive its cause by the immediate environment but often by very remote causes. The industrialized countries are the worse culprits than the developing countries like Nigeria in polluting the air. The problem is often aggravated by ignorant or unconcerned leaders who only see the immediate money factor side of the coin and lack long time perspective. However, whether you are a developed or underdeveloped country, you become a beneficiary of Climate Change factor one way or another. People in China, Japan and the like are made to wear nose air mask because the heavy air pollution that can affect the lungs and in some localized industrial set ups where the air content is densely polluted.

Pioneer work

There are more effects and this topic could not have been more - timely than as it is being addressed today in this Workshop in honor

of the distinguished and celebrated **Professor EkundayoElisha Balogun**. As at the time when he pushed in to be pioneer in this field of probing the atmosphere, much of the available exploration was based on tedious local measurements that required conscientious supervision of the equipment localized over widely spaced environment and range. The standard of reports to compare with were from the Western world and only few measurements available in the developing countries like ours.But, now more powerful remote and extended measurements are made possible and studies made more global. While most of the meteorological measurement sites are still in the developed countries, foreign lands to Nigeria and Africa, it is now possible to do in Nigeria and Africa con-current in-situ and on the ground measurementsas is done there in the developed countries. It is now possible to monitor measurements being made in Nigeria, Algeria, Italy, UK, China, Asia, USA, Canada and South America concurrently and on a global perspective. This with thanks to pioneers such as Professor E. E. Balogun who saw the wisdom in collaborative research with the developed research laboratories and to facilitate establishment of research centers on our soil wwhich enablescon-current study with those at home in sister research institutions in Nigeria. Presently, the University of Ilorin is having joint research cooperation with Center for Atmospheric Research (CAR) here in Nigeria. The co-operation includes Workshops such as this, Training and joint research expedition.

I want to say that at the University of Ilorin, pioneer work started with Professor T.O. Aro who moved from using mobile Eko sounders instrument to pyranometers, pyhrgeometers, NIP and to having automatic solar tracker through collaboration with the University of Maryland and hence gained contact with NASA in USA. In addition,dedicated Cimel Sun Photometeris employed at the station in having continuous look at aerosols in the atmosphere at selected wavelengths. The University of Ilorin hosts the Cimel and that makes us a member of the global AERONET network. This has not been easy as we have lost the role of the Solar Tracker that carried the NIP and PIR due to power fluctuations experienced from the then NEPA.

However, despite this set-back, we have continued to keep the flag flying by using dedicated solar panels to power the Sun Photometer. We used to carry our floppy disc to available network transmission post in town to process the data, but now it is beamed up through internet facility.

In addition, we have added the Small Particulate Matter Research Unit into our study area by joining on invitation the SPARTAN network hosted by University of Delahousie, Canada. It is co-hosted with the Cimel at Ilorin. This has given us the opportunity to study particulate matters in the air that is moving around us and passing through our air space with spatial and temporal consideration and at localized and dynamic global perspective using both solar radiation and capturing the particles approach.

Benefit from the study

This brings me to the beauty of this study area of the Air and the Atmosphere which is to gain useful knowledge. It allows for core natural scientific study and concurrent spatial study with time that can be measured as a function of geographical location and its influence on the society social development. As the use and users of land surface area change, the air in the immediate and remote atmosphere content ratios and new particulate entrants also change with time. The climate is being modified and health challenges are also being modified. Among the new entrants is nuclear radiation such as from nuclear disasters (e.g Russia's most recent explosion occurring in the last three weeks at a military site where an explosion occurred and released radiation felt as far as in Norway through the atmosphere). There is also fossil fuelpollution from sea spray, oil spills (e.g at the Lagos Bar beach and riverine areas of Nigeria such as at Ogoni land or the current cargo oil spill a few weeks ago occurring in the Persian Gulf near Iran which is being disputed here and there as to who fired shot into oil tanker) and the drying ancient rivers and streams all around us giving way to forest land turning arid land due to felled trees. The list is unending and the **Air, which cannot complain**, continues to host these "**parasites**" of foreign particulate

matters, ions and radiations for long and short times and in the locality or distant shores.

Other indirect influence on the air quality

Other things that indirectly influence the air quality include abuse of drainage resulting in blockage caused by human habit, abuse of ecological plan by local rich champions or ignorant inhabitants, poor housing plan or badly executed housing plan. If you look down from the Aero Plane on the Nigerian Metropolitan cities, with the exception of a very few, they look chaotic as compared to the view you get looking down similarly in Europe or United States with the attendant effect of no free flow of air or replenishment of oxygen from vegetation. The road for the motor vehicles add to our health problems through the air pollution from vehicular exhaust. If you travel by road for upward of two hours and you are forced by condition of the road to keep on an average slow speed, what is inhaled from the air coming from exhaust from vehicles ahead of you is continuous carbon monoxide, carbon di-oxide, and similar sulphurous and nitrous gases which become so nauseating that cause some to vomit or experience stomach upset due to unregulated standard for road worthiness of vehicles. The road worthiness certificate is bought by vehicle owners from government by compulsion as revenue source rather than for air protection in most cases. The component assistance to Government in this respect from NURTW seems not forthcoming.

These are present status of the air quality with little hope of change in trend for the future.

Keeping the flag flying by continual training

The flagset flying by pioneers of the like of Professor Ekundayo Elisha Balogunhas to be kept flying by training younger ones to follow while we encourage the government to actively include the Air Quality in her Planning and Budget allocation. Some literature experts have rightly opined in the saying ”ignorance is a disease.” It is curable by open mind given to education. But where a people's mind is set to be closed to education and is actively being fought by

carnage, murder and abduction, willingly or by inaction, the disease perpetuates. The Yorubas have coined their own “Eni a wi fun, Oba je o gbo” meaning “ may the informed be helped by God to learn and change his or her ways. The corollary also is reported as “ohuntiyiojibara, yioji bara” implying that what will wake sleeping Bara up, will wake him up (when the fire starts to burn the hem of his or her garment. Government cannot pretend forever to be too busy or overwhelmed and soignore to take care of her air. This is one commodity that is still common to all: both rich and poor, young and old, strong and weak, man or woman (and even if you claim you don't know your sex), famous or unknown; you have to breathe air and air does not discriminate. Care has to be taken ofair throughmeteorological studies, solar radiation studies, best option energy selection, social impacts, geographical bearing, as well as science and engineering research and development. If for political exigency at a time, factors such as bush burning by whichever group is not checked, Fulani herdsmen travesty of farmlands with impunity and wanton destruction is not controlled, indiscriminate tree felling and indiscriminate release of industrial waste is ignored, the Yoruba adage will still catch up with us “ohuntiyioji bara, yioji bara” and “ehinni I dun olokuadasii.” Either later in this generation or the one immediately following it, blame will come upon this generation and in particular her government for ignoring to take positive action to protect our air.

Budgeting

It must be said and repeated that Government must make appropriate Budget that includes care of the Air and the Environment. Remember that the Rain cycle goes through the air and the sun that gives us day - time bounces on the earth. The atmosphere is so important that we must make a desperate effort to “repair it” as much as we can. **Repair the Air**. When well advised appropriate budget is made, it MUST be well implemented and sharp practices on the implementation nipped in the butt for the good of all.

Again, CONGRATULATIONS to the celebrated Professor.

Citation for Professor E. E. Balogun

Ekundayo Elisha Balogun was born on July 24, 1937, in Apapa, Lagos, although his parents were from Mopa in Mopamuro local government area of Kogi State, Nigeria.

He attended Apapa Baptist School for his elementary education and Lagos Baptist Academy for his secondary education. On graduation from secondary school in 1957, his name was on the school's DUX BOARD (Leader's Board) as the best all-round student in his graduating year at the school. He shared that distinction with the late Chief Victor AdebisiOnabanjo (1943), former governor of Ogun State, Chief Horatio Ageda (1947) formerly of the Nigerian National Petroleum Corporation (NNPC), Chief MoladeOkoya Thomas (1956), a business magnate, and several other eminent Nigerians who passed through the school and have attained positions of prominence in their various endeavours. His interest in atmospheric sciences started in 1957 after the well-publicized launch, by the Soviet Union, of the first successful Earth satellite, Sputnik 1.

He therefore joined the Nigerian Meteorological Service on December 6, 1957, three days after he completed writing the Cambridge School Certificate Examination. He successfully completed the first meteorological induction course at the Meteorological Training School, Ikeja Airport in 1958. He came first in his class. He gained admission to the Nigerian College of Arts and Science at Ibadan in September 1958, and was sponsored for the Advanced Level Science course in Physics, Mathematics and Chemistry at the College by the Nigerian Meteorological Services. He successfully completed that programme in 1960. In February 1961, he left for the British Royal Air Force Weather Forecasting Training School at Stanmore, Middlesex, England, to train as a Weather Forecaster on the Sponsorship of the Nigerian Government. He also completed the training successfully and returned to Nigeria at the end of 1961.

The African Students Foundation, a Canadian foundation which provided university education for African students offered him scholarship to attend Canada's topmost university, the University of Toronto, Toronto, Ontario, Canada, from where he graduated with a Bachelor of Science degree in Mathematics and Physics, in 1966. He got married on May 21, 1966 at Manor Road United Church, Toronto, to Miss Ebunoluwa Kofoworola Daramola; his long term girlfriend. He left Canada for the United States of America to attend the University of Chicago which, at that time, was an important centre of activities in the applications of satellite observed data.

Professor Balogun obtained his Master and Doctorate degrees from the University of Chicago in 1967 and 1972 respectively. On returning to Nigeria in 1972, he resigned from the Nigerian Meteorological Services to join the University of Ife, (now known as the Obafemi Awolowo University), where he was engaged in research and the teaching of atmospheric physics and meteorology.

In 1975, Professor Balogun spent months at the University of Chicago as a visiting Research Scientist. Professor Balogun was also a visiting Research Scientist at the Space Science and Engineering Centre, University of Wisconsin, Madison, Wisconsin, U.S.A. between 1980 and 1982, where he worked with the late Professor Suomi, one of the world's leading figures in Satellite Meteorology. He has also visited many universities around the world for scientific meetings from the University of Oxford in England, to the University of Beijing in China. Professor Balogun was a frequent visitor to the International Centre for Theoretical Physics (ICTP) in Trieste, Italy; and on some occasions, he was an instructor at ICTP.

As a teacher and academician, he has taught basic physics, atmospheric physics, and meteorology at his home university and many Nigerian universities, including the University of Ibadan, the

Federal Universities of Technology at Minna and Akure, the University of Uyo, and at other universities across the country, at different times during his career. He is an external examiner to many Nigerian universities.

Professor Balogun received first class training in Meteorology and Atmospheric Physics, and has passed on his experience and training to many Nigerians. He has produced half a dozen PhDs and very many students at the Masters level. Many Meteorologists at the Nigerian Meteorological Services have received part of their training under him.

He published several research papers in local and international journals, monographs, and conference proceedings. He was invited by the Vatican Academy of Science to present an original paper on "Space Science, Weather and Man", at the Vatican City in Rome in 1985. His presentation was a contribution to a book.

At his home university – the Obafemi Awolowo University, he was Head, and Professor, Department of Physics; Dean, Faculty of Science; Director, Institute of Ecology and Environmental Studies; and member of many university committees at various times, during his career at the University. In 1998, he pioneered the African Regional Centre for Space Science and Technology Education. He was the founding Director of the Centre. He formally retired from the University in September 2002, but continued as Director of the Centre till 2005.

Professor Balogun is a member of many international and national Societies and Institutes:

- Fellow, Nigerian Meteorological Society (President, 1992 – 1996)
- Member, Nigerian Remote Sensing Society (Vice President, 1992 – 1996)
- Member, Science Association of Nigeria
- Fellow, Nigerian Institute of Physics
- Member, Remote Sensing Society, U.K
- Fellow, Royal Meteorological Society, U.K. (since 1960)

· Member, Nigerian Union of Planetary and Radio Science (Secretary, 1977 – 1979)
· Member, American Institute of Physics, U. S. A.
· Member, New York Academy of Science, 1992
· Fellow, African Academy of Science.

Professor Balogun has served on many national and international scientific organizations:

_ Secretary, Nigerian Union of Planetary and Radio Sciences, September 1977 – November 1979.

➨ Member of the World Meteorological Organization (WMO) Commission on Atmospheric Sciences, July 1978.

➨ Member Ad-hoc Committee, International Working Group on Scientific Planning and Research Aspects of the West African Monsoon Experiment (WAMEX), (WMO), 1974-1975

➨ Chairman, Scientific Planning and Research, Nigerian WAMEX Committee, 1974-1975

➨ Member, Board of Studies, the Polytechnic of Ibadan, Nigeria, 1977 – 1980

➨ Chairman, Sub-Committee on Research for Interministerial Committee on Space Applications in Nigeria, Federal Ministry of Science and Technology, Lagos, 1985 – 1988

➨ Editor, Nigerian Meteorological Journal, 1990 – 1992

➨ Member of the 15-Man Committee on Global Climate Observing System (GCOS) constituted by the World Meteorological Organization/International Council on Scientific Unions/Intergovernmental Oceanographic Commission, January 1992 – June 1997

➨ Member, Ad-hoc Technical Advisory Committee to the Secretary-General, WMO (1999 – 2000)

➨ Chairman, Drafting Committee of the Nigerian Space Policy, 1993. The Nigerian Government adopted a modified version of the policy in 2001.

More than fifteen years after his retirement from meritorious and active service, Obafemi Awolowo University found him worthy of appointment as an Emeritus Professor of Physics.

Professor Balogun is happily married to Ebunoluwa Kofoworola Balogun, and they are blessed with three grown-up children.

63 64