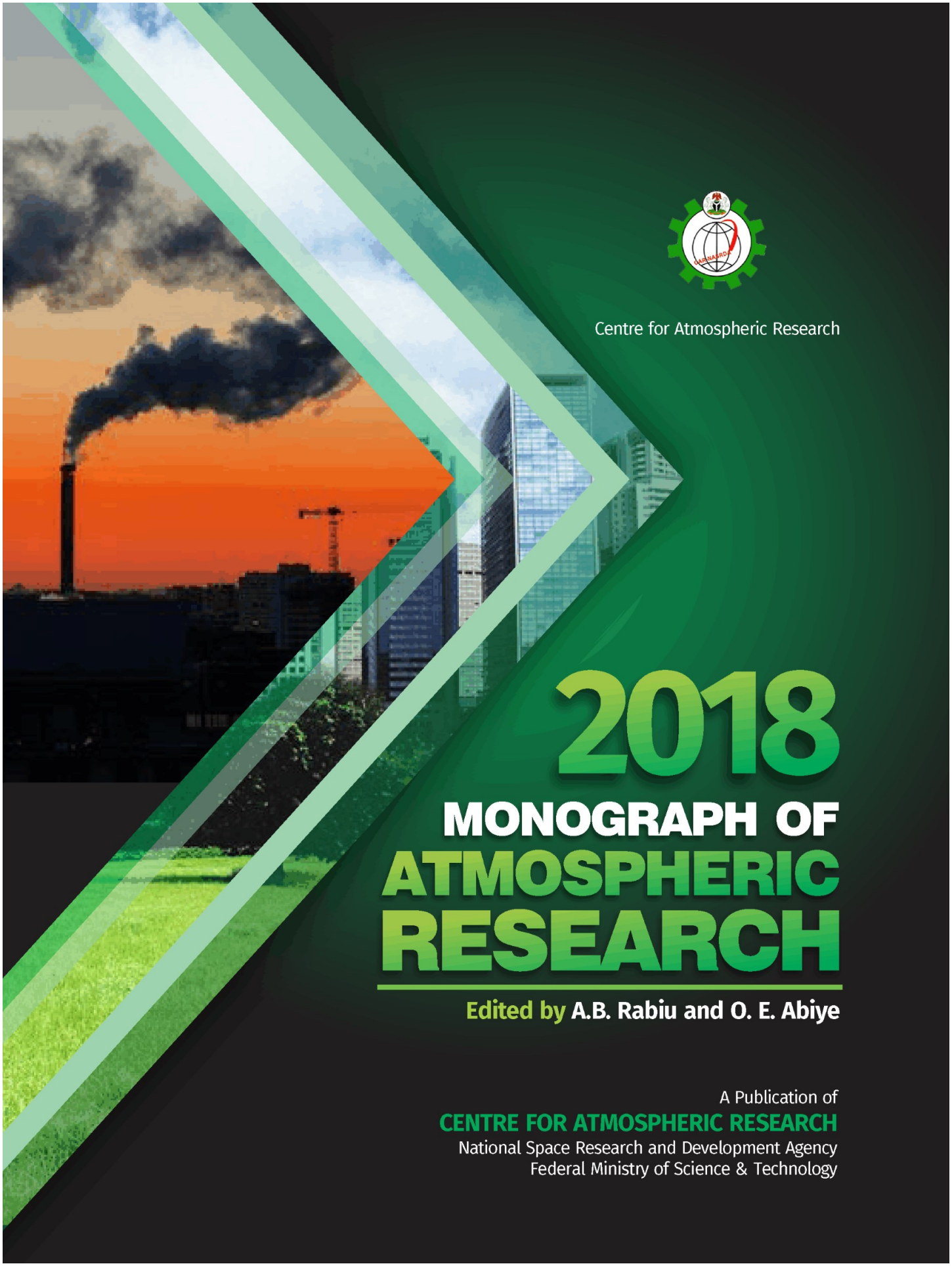

Centre for Atmospheric Research

2018 MONOGRAPH OF ATMOSPHERIC RESEARCH

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

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

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

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

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

Prof. A. B. Rabiu and Dr. O. E. Abiye,
Editors

Centre for Atmospheric Research

Air pollution: Adverse effects on plants, animals, humans, microorganisms and food – a review

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ABSTRACT

All types of pollution (air, water and soil pollution) have an impact on the biotic environment. Air pollutant are; gases, solid particles, aerosols and microorganisms that change the natural composition of the atmosphere, air pollution is said to exist when a wide range of inorganic gases (carbon monoxide, volatile organic compounds (VOCs), nitrous oxides, sulfur dioxide, and ozone), organic compounds, inorganic metallic substances and smoke particles are discharged into the atmosphere by a number of natural and/or anthropogenic. Among all the causes, increased combustion of fossil fuels in the last century is responsible for the progressive change in the atmospheric composition of air pollutant. The effects in living organisms may range from mild discomfort to serious diseases. The diverse emissions into the atmosphere bring about qualitative or quantitative changes in the normal composition of the air that may adversely affect all living organisms in our environment and reduce food quality. Air pollution is now a global issue, the adverse effects on plants, animals, humans, microorganisms and food directly or indirectly are briefly discussed.

Key words: Air pollution, Air pollutant, Living organisms

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INTRODUCTION

Air pollution is a serious menace to all kinds of life and threatens our fragile environment that is so vital for our survival. According to Bell and Treshow (2002), air pollutants are any aerial substances that have the potential to cause adverse effects on man, plants, animals or cultural assets. Air pollution consists of gases, solid particles, aerosols and microorganisms that change the natural composition of the atmosphere. Air pollution is said to exist when a wide range of inorganic gases (carbon monoxide, volatile organic compounds (VOCs), nitrous oxides, sulfur dioxide, and ozone), organic compounds, inorganic metallic substances and smoke particles are discharged into the atmosphere by the motor vehicles, factories, power plants, home furnaces and waste incineration plants. The diverse emissions into the atmosphere bring about qualitative or quantitative changes in the normal composition of the air that may adversely affect animals, human health and plant life (*Shakil, 2007*). There has also been evidence of microbial air pollution; microbiological contamination of air is mostly caused by virus, bacteria and fungi. They can exist in air as an individual entity or create aggregates of biological structures. However, the survival of microbial cells in air depends on their ability to resist different types of stress *viz*., ultraviolet radiation, desiccation and starvation (*Kabir et al., 2016*).

The industrial revolution introduced great strides in technology, society and services; however, it also initiated the production of huge quantities of pollutants emitted into the air with no notion of how they might affect health (*Bonzini et al., 2010; Di et al., 2017*). At the time, smoke from burning coal was the major pollutant, but this was only the beginning of countless air pollutants which have since proven harmful to human health (*Bonzini et al., 2010*). High levels of air pollution have been registered in Mexico City, Rio de Janeiro, Milan, Ankara, Melbourne, Tokyo and Moscow, to name only a few (*Valko et al., 2006*). Since major cities frequently suffer episodes of severe pollution, they require special surveillance to protect the large number of individuals concentrated there and the important economic activities carried out therein. It is precisely due to the flourishing economic activity in these areas that the environment has been relegated to secondary importance (Franchini *et al.,* 2015). On the other hand, different diseases, from respiratory to cardiac ailments, in different degrees of severity from minor irritation to death, have been associated to exposure to air pollution in recent years (Franchini *et al.,* 2015).

Outdoor air pollution is a mixture of thousands of components. Among them, airborne particulate matter (PM) and the gaseous pollutants ozone, nitrogen dioxide (NO_2), volatile organic compounds (including benzene), carbon monoxide (CO), and sulphur dioxide (SO_2) are the most important from a health perspective (*Pant et al., 2016*). Lesser-known substances are continually being added to this number due to the introduction of new manufacturing processes and technologies. Major sources of primary particles such as carbon soot include motorized road traffic, power generation, industrial sources, and residential heating (*Pant et al., 2016*). The re-suspension of soil and road dust by wind or moving vehicles, as well as construction work and industrial emissions, result in the distribution of coarse particles (PM10). Fine particles are derived primarily from direct emissions of combustion processes such as gasoline and diesel fuel, wood burning, coal burning for power generation,

and industrial processes (*Valko et al., 2006*).

Fine particles can travel large distances (more than 100 km), with the potential for high background concentrations over a wide area *(Franchini et al., 2015*). As a consequence, their composition may be extremely heterogeneous, depending on the meteorological conditions and human activities in a particular geographical area (*Di et al., 2017*). Ultrafine particles are fresh emissions from combustion-related sources such as vehicle exhaust and atmospheric photochemical reactions and are recognized as important markers of exposure to traffic exhaust along main roads (*Di et al., 2017*). Fine and ultrafine particles are those associated with the worst effects on health as they can reach the deepest portions of the airways or even reach the blood stream directly (*Cohen et al., 2005; Bonzini et al., 2010*).

Recently, urbanization, industrialization, transportation, and energy consumption are increasing at an unprecedented scale in Nigeria. As a consequence thereof, atmospheric conditions of big cities have been deteriorating, major contributors to environmental degradation are industry and transport (WHO/ UNEP, 1992), urban centres are being badly affected by unchecked toxic industrial emissions, noxious automobile exhaust, dust, prolonged construction and developmental activities along with reduction in green vegetation while in rural communities, bush burning and illegal mining operation accounts majorly for air pollution.

Also, natural causes such as forest or grassland fires and volcanic eruptions around the globe also contribute to the atmospheric pollution. The effects in living organisms may range from mild discomfort to serious diseases such as cancer to physical deformities, air pollution effect man directly or indirectly. There is no doubt that excessive levels of pollution are causing a lot of damage to human and animal health, plants and trees including tropical rainforests, as well as the wider environment. The gross effect of air pollution on man is summarized in Figure 1.

CLASSES OF AIR POLLUTANTS

The main change in the atmospheric composition is primarily due to the combustion of fossil fuels, used for the generation of energy and transportation. Variant air pollutants have been reported, these pollutants differ in their chemical composition, reaction properties, emission, persistence in the environment, ability to be transported in long or short distances and their eventual impacts on human and/or animal health (Di *et al.,* 2017). However, they share some similarities and are grouped to five categories:

Gaseous pollutants (e.g. SO_2, NO, CO, ozone, Volatile Organic Compounds)

Gaseous pollutants contribute to a great extent in composition variations of the atmosphere and are mainly due to combustion of fossil fuels (*Franchini et al., 2016*). Nitrogen oxides are emitted as Nitrogen I Oxide (NO) and rapidly react with ozone or radicals in the atmosphere forming NO_2. Moreover, ozone in the lower atmospheric layers is formed by a series of reactions involving NO_2 and volatile organic compounds, a process initiated by sun light (*Guo et al., 2017*). Carbon monoxide (CO), on the other hand, is a product of incomplete combustion of

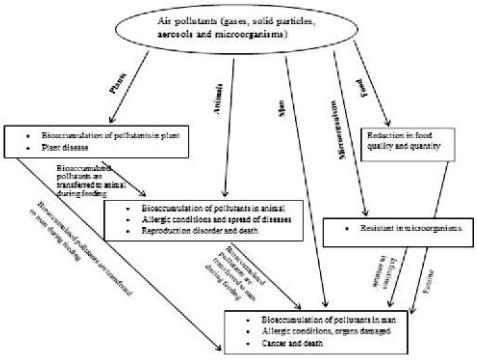

Figure 1: Effect of air pollution on man

fossil fuels (*Valko et al., 2006*). The anthropogenic SO_2 results from the combustion of sulphur-containing fossil fuels and the smelting of sulphur containing ores, while volcanoes and oceans are its major natural sources (*Di et al., 2017*).

Another class of pollutant involved in combustion processes for energy production is volatile organic compounds (VOCs); this is a class of compounds, which includes chemical variants of organic nature such as benzene. Even though the majority of gaseous pollutants are inhaled and mainly affect the respiratory system they can also induce hematological problems and cancer (*Guo et al., 2017*).

Persistent organic pollutants (e.g. dioxins)

Persistent organic pollutants form a toxic group of chemicals. They persist in the environment for long periods of time. Their effects are magnified as they move up through the food chain in a phenomenon known as bio-magnification (*Schecter et al., 2006*). They include pesticides, as well as dioxins, furans and PCBs. Generally, the generic term ''dioxins'' is used to cover polychlorinated dibenzo-dioxins (PCDDs) and poly-chlorinated dibenzo-furans (PCDFs) while polychlorinated biphenyls (PCB) are called ''dioxin like compounds'' and can act similarly in terms of dioxin-type toxicity (*Schecter et al., 2006*). Dioxins are formed by incomplete combustion and whenever chlorine containing materials such as plastics are burned (*Sharma and Agrawal, 2005*).

Heavy metals (e.g. Lead and Mercury)

Heavy metals include basic metal elements such as lead, mercury, cadmium silver nickel, vanadium, chromium and manganese (*Sharma and Agrawal, 2005*). They are natural components of the earth's crust and cannot be degraded or destroyed. These can be transported by air to water and human food supply (Sharma and Agrawal, 2005). In addition, they enter the environment through a wide variety of sources, including combustion, waste water discharges and manufacturing facilities. Most heavy metals are dangerous because they tend to bio-accumulate in the human body (*Schecter et al., 2006*).

Particulate Matter

Particulate matter (PM) is the generic term used for a type of air pollutants, consisting of complex and varying mixtures of particles suspended in the breathing air, which vary in size and

composition, and are produced by a wide variety of natural and anthropogenic activities (*Zhang et al., 2011*). Major sources of particulate pollution are factories, power plants, refuse incinerators, motor vehicles, construction activity, fires, and natural windblown dust (*Di et al., 2017*). The composition of PM varies, as they can absorb and transfer a multitude of pollutants; however, their major components are metals, organic compounds, material of biologic origin, ions, reactive gases, and the particle carbon core (*Zhang et al., 2011*). In addition, the metal content, the presence of PAHs and other organic components such as endotoxins, mainly contribute to PM toxicity (*Pant et al., 2016*).

Microorganisms

One of the indoor and outdoor pollutants is a microorganism (viruses, bacteria and fungi). The presence of these in air is termed bioaerosols or microbial air pollutant; they decrease air quality and affect human health (*Karwowska, 2003*). They originated from droppings and discharged of men and animals, and from contaminated environment. They can exist in air as an individual entity or create aggregates of biological structures. Some microbial cells produce pigments or mucous halo to protect them from harmful effect of ultraviolet radiation. Spore formation is one of most widely used strategies adopted by many microbes to survive in unfavorable conditions and dissemination of offspring. Bioaerosol, are easily transferred by winds and air currents from one ecosystem to another, making them an important vehicle for the spread of hazardous microorganisms (*Brandl et al., 2014*). Bioaerosols occur as droplets or solid particles and derive from a multitude of natural and artificial sources, such as surface waters, dry soils and agricultural activities (*Kabir et al., 2016*).

Effects of Air Pollution on Animals

Acid rain (formed in the air) destroys fish life in lakes and streams. Excessive ultraviolet radiation coming from the sun through the ozone layer in the upper atmosphere which is eroded by some air pollutants may cause skin cancer in wildlife. Ozone in the lower atmosphere may damage lung tissues of animals. It also affects biological functioning of organisms (e.g., toxicity, mortality, effects on growth, or reproduction) (*Lovett et al., 2009*). Studies show that air toxics are contributing to birth defects, reproductive failure, and disease in animals. Persistent toxic air pollutants (those that break down slowly in the environment) are of particular concern in aquatic ecosystems. These pollutants accumulate in sediments and may biomagnified in tissues of animals at the top of the food chain to concentrations many times higher than in the water or air (DEP, 2016). Pathogenic microorganisms present in bioaerosols can cause a severe infection in animals (*Kabir et al., 2016*) ranging from pulmonary to septicemia infection which later result into death. For example, in a damp or wet poultry pen, fungi spores are easily transferred from one bird to another which can lead to allergic reactions or spread of diseases.

Effects of Air Pollution on Plants

The basis for plant damage by air pollution is very complicated. Persistent inversion layers, high temperature and humidity, and the speed and direction of winds can influence the degree of damage. The relative amounts of the various pollutants can vary throughout the year, due to changes in traffic and heating, and industrial production. The action of one pollutant may be enhanced by the presence of an additional pollutant (synergism), thus lowering the concentration needed to damage vegetation (*Caldwell, 2018*).

Air pollution can damage crops and trees in a variety of ways. Ground-level ozone can lead to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests and other environmental stresses (such as harsh weather). Crop and forest damage can also result from acid rain and from increased UV radiation caused by ozone depletion (*DEP, 2016*). Global shortage of food can be attributed to this fact; severity of air pollution on plants and food crops. Acid rain can kill trees, destroy the leaves of plants, can infiltrate soil by making it unsuitable for purposes of nutrition and habitation for plants in other hand, Ozone in the lower atmosphere can prevent plant respiration by blocking stomata (openings in leaves) and negatively affecting plants' photosynthesis rates which will stunt plant growth; ozone can also decay plant cells directly by entering stomata. The susceptibility of pollution stressed plants to microbial pathogens may be altered and the disease development may be influenced. Interactions between air pollutants and plant pathogens on a given host may affect pathogenesis. Thus plant diseases may be either enhanced or suppressed depending upon the nature of the disease and host, the kind and concentration of the air pollutants. Bioaerosols can increase the rate of spreading of plant infection, for instance, fungal spores from the infected pant are easily carried by wind from the infected plants to healthy ones thereby enhancing the spread of pathogens from one plants to another.

Effects of Air Pollution on Humans

The different composition of air pollutants, the dose and time of exposure and the fact that humans are usually exposed to pollutant mixtures than to single substances, can lead to diverse impacts on human health (*Brunekreef and Holgate, 2002*). The adverse effects of air pollution on human is enormous and have been implicated in the following; reduced lung functioning, Irritation of eyes, nose, mouth and throat, asthma attacks, respiratory symptoms such as coughing and wheezing, increased respiratory disease such as bronchitis, reduced energy levels, headaches and dizziness, disruption of endocrine, reproductive and immune systems, neurobehavioural disorders, cardiovascular problems, cancer and premature death.

Humans come in contact with different air pollutants primarily via inhalation and ingestion, while skin contact is a minor route of exposure (*Huang and Ghio, 2006*). Air pollution contributes, to a great extent, to the contamination of food and water, which makes ingestion in several cases the major route of pollutant intake (*Huang and Ghio, 2006*). Absorption of these harmful pollutants may occur through the gastrointestinal and respiratory tract while a number of toxic substances can be found in the general circulation and deposit to different tissues (*Kampa and*

Elias, 2008). In many cases, children may have greater exposure than adults to airborne pollutants; infants and children generally breathe more rapidly than adults, which increases their exposure to any pollutants in the air (*Schell et al., 2006*). Moreso, infants and children often breathe through their mouths, bypassing the filtering effect of the nose and allowing more pollutants to be inhaled (V*alko et al., 2006; Zhang et al., 2011*).

Children are often more susceptible to the health effects of air pollution because their immune systems and developing organs are still immature; for example, Lead that is inhaled is more easily deposited in the fast-growing bones of children (*Zhang et al., 2011*). It may also take less exposure to a pollutant to trigger an asthma attack or other breathing ailment due to the sensitivity of a child's developing respiratory system (*Schell et al., 2006*). Exposure to toxic air contaminants during infancy or childhood could affect the development of the respiratory, nervous, endocrine and immune systems, and could increase the risk of cancer later in life (*Kampa and Elias, 2008*). Exposure to bioaerosol increase the risk of contracting infectious disease, such as influenza, measles and chicken pox which are being transmitted through the air

Symptoms such as nose and throat irritation, followed by bronchoconstriction and dyspnoea are experienced after exposure to increased levels of sulphur dioxide, nitrogen oxides, and certain heavy metals such as arsenic, nickel or vanadium (*Guo et al., 2017*). Similarly, particulate matter that damages the alveolar epithelium and initiates lung inflammation (*Guo et al., 2017*). Air pollutants such as nitrogen oxides also increase the susceptibility of humans to respiratory infections (*Kuo et al., 2006*). The chronic exposure to certain heavy metals and bioaerosol reduces lung function and this is also partly responsible for asthma, emphysema, and even lung cancer (*Guo et al., 2017*).

The gaseous pollutant Carbon monoxide binds to haemoglobin modifying its conformation and reduces its capacity to transfer oxygen (*Bonzini et al., 2010*). This reduced oxygen availability can affect the function of different organs (and especially high oxygen consuming organs such as the brain and the heart), resulting in impaired concentration, slow reflexes, and confusion in affected individuals (*Franchini and Mannuci, 2012*).

The nervous system is mainly affected by heavy metals (lead, mercury and arsenic) and dioxins. Neurotoxicity leading to neuropathies, with symptoms such as memory disturbances, anorexia, anger, fatigue, hand tremors, blurred vision, and slurred speech, have been observed after arsenic, lead and mercury exposure (*Bellinger, 2005*). Dioxins have also been reported to decrease nerve conduction velocity and impaired mental development of infants (*Schecter et al., 2006*).

Heavy metals can induce kidney damage such as an initial tubular dysfunction evidenced by an increased excretion of low molecular weight proteins, which later progress to decreased glomerular filtration rate (GFR) as reported in Huang and Ghio (2006). In addition they increase the risk of stone formation or nephrocalcinosis and renal cancer (*Mannuci et al., 2015*).

Dioxins induce considerable damage to young hepatocytes which is indicated by an increase in levels of certain enzymes in the blood, as well as gastrointestinal and liver cancer (*Mannuci et al., 2015*).

Common cellular mechanism by which most air pollutants exert their adverse effects is their ability to act directly as pro-oxidants of lipids and proteins or as free radicals generators, promoting oxidative stress and the induction of inflammatory responses (*Bellinger, 2005; Mannuci et al., 2015*). In addition, these free radical generators can interfere with signaling pathways within living cells (*Bonzini et al., 2010*).

Furthermore, the toxic effects of heavy metals, apart from inducing oxidative stress, can be also attributed to their ability to substitute diverse polyvalent cations (calcium, zinc, and magnesium) that function as charge carriers or as structural elements in the maintenance of protein conformation (*Valavanidis et al., 2008*). Hence these heavy metal pollutants accumulate in cellular organelles and then interfere with normal cell metabolic functions (*Garza et al., 2006*).

Effects of Air Pollution on Microorganisms

Microorganisms in the atmosphere can come into contact with two kinds of pollutants, namely the solid ones, embedded in airborne particulate matter (PM), and gaseous pollutants, such as ozone (O_3) nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The atmosphere may not strike people as a very suitable habitat for bacteria, but recent studies indicate it harbours diverse bacterial phyla, such as *Firmicutes, Actinobacteria, Proteobacteria*, and *Bacteroidetes*, which may form active bacterial communities (*Gandolfi et al., 2013*). Air pollutants directly toxic to the pathogenic microorganisms possible impair their growth and reproduction and thereby partially or wholly inhibit the diseases. Air pollutants on the other hand, by modifying the host physiology may render it more susceptible to infection and pathogenic damages. Atmospheric pollutants may adversely affect the spore germination, mycelial proliferation, fruiting body formation and spore production by fungi.

It is known from studies in the eastern United States that Nitrogen shifts the activity of soil microorganisms, with some responding positively to nitrogen addition, while others respond negatively (*Carreiro et al., 2000*). Across a gradient of nitrogen deposition, changes in microbial nitrogen cycling activity are seen in some forest types but not others (*Siguenza et al., 2006*). Microbial communities in environment have been observed to become more resistant to radiation, heavy metals and some antibiotics when exposed to pollutants.

Effects of Air Pollution on Food

A large number of experiments in both lab and field have demonstrated that air pollution may damage agricultural outputs, either by reducing yield or by deteriorating product quality. *Avnery et al.* (2011), indicate that the total loss of global staple crop (soybean, maize, and wheat) production due to surface ozone exposure was 79–121 million metric tons in 2000, worth 11–18 billion USD. Therefore, air pollution may reduce food supply in the long run. Air pollution is highly correlated with the food system. Air pollution not only reduces raw ingredients supply

but also obstructs food supply in processing and distribution. Additionally, air pollution may affect consumer behavior in the short run. The impacts of air pollution on consumer demand and food supply would eventually change food price. Air pollution reduces the quality of food and may enhance the proliferation of some food spoilage microorganisms.

CONCLUSION

The increase in air pollution in our environment has largely contributed susceptibility to pathogens and change in infectious disease cycle in plant, animal and human. The effects on plants may as well increase global quest for food because plants are been destroy by the direct and indirect effect of air pollution. Also, global environment may become inhabitable for men someday because of the great deleterious effects of air pollution on human health, treat are been posed to wildlife day by day as a result of increase in global discharge of air pollutant and some species may go to extinction if not controlled. Therefore there is need for multidisciplinary action globally to tackle the menace of air pollution on plants, animals, humans and microorganisms.

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National Space Research and Development Agency
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Our Mandates

The Center for Atmospheric Research, CAR, 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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