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Review Article

A Review on Air Pollution and a Link with Neurodegenerative Diseases in Nigeria

Abayomi O. Ajagbe[1], Oluwanisola A. Onigbinde[1], Ebenezer O. Ajiboye[2], Michael K. Ajenikoko[3], Lukeman A. J. Shittu[4], Yosef T. Dabi[5], Ifukibot L. Usende[6]

[1]Department of Anatomy, Faculty of Basic Medical Sciences, Nile University of Nigeria, Abuja, Nigeria; [2]Department of Physiology & Anatomy, Ajayi Crowther University, Oyo, Nigeria; [3]School of Biomedical Sciences, Kent State University, Ohio, United State; [4]Department of Research and Development, Jireh Laboratories International LLC, Alief, Texas, United State of America; [5]Department of Medical Laboratory Science, Wollega University, Ethiopia; [6]Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Abuja, Abuja, Nigeria

ABSTRACT

Pollution is a common and inevitable situation, encompassing environmental threats and virulent composites from the air, water, soil, and food. Air pollution is becoming a global health challenge, affecting millions of lives. Although many of these pollutants have been identified, this paper is reviewing the established link between air pollution and neurodegenerative disease due to the increase in cases of neurodegenerative disease in middle- and low-income countries like Nigeria. This article reviewed the establishment of a possible relationship between air pollution and neurodegenerative diseases in Nigeria and Africa. Different literature sources were reviewed to identify the sources of air pollution, determine the level of awareness among citizens on the effects of air pollution, know the incidence of neurodegenerative diseases in air-polluted areas, life expectancy in such areas, existing diseases caused by air pollution, and their relationship with neurodegenerative diseases. Available literature on heavy metal pollutants in the brains of animal models from different zones of Nigeria and evidence of neurodegeneration in different animal species was also reviewed. In conclusion, one major setback is that there is no specific data on the prevalence of neurodegenerative diseases in major air-polluted areas in Nigeria, hence, the need for awareness to alert occupants and citizens to neurodegenerative diseases and their connection with air pollution. It is also advised that the government implement steps to solve these difficulties, such as the employment of biodegradation and bioremediation in the removal of contaminants.

Keywords
Air pollution, Nigeria, Neurodegenerative diseases, Bioremediation, Particulate matter

Correspondence: Ifukibot L. Usende, PhD; Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Abuja, Abuja, Nigeria. E-mail: ifukibot.usende@uniabuja.edu.ng; Phone Number: +2348037386219; ORCID: 0000-0002-3894-1426

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Introduction

Humans and animals are all surrounded by environmental threats and virulent composites from the air, water, and soil, and pollution is an inevitable situation (Igado et al. 2008; Usende et al. 2016, 2017, 2018a, 2018b, 2020, 2022a, 2022b; Calderón-Garcidueñas et al. 2021). The most common form of pollution in Nigeria is air pollution, due to frequent exposure to neurotoxic organic and inorganic mixtures from fossil fuel combustion (Olopade et al. 2005; Igado et al. 2018; Usende et al. 2016, 2017, 2018a, 2018b, 2022a, 2022b).

Air pollution is evolving into a global health challenge that is affecting millions of lives (Mir Alvarez et al. 2020; Abulude et al. 2021; Jo et al. 2021). It is one of the most life-threatening environmental pollutants that pose immediate danger across the globe (Kim et al. 2020).

According to the World Health Organisation (2022) and Ladan (2013), air pollution is a condition where the atmosphere consists of materials with concentrations that are deleterious to man and his environment. These materials are called air pollutants and are measured as parts per million or micrograms per cubic metre (ug/m^3) (Ladan 2013). Thus, any deviation in the natural and expected air

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configuration, which may negatively affect humans, can lead to air pollution.

Air is an imperative component of the environment in which, when at rest, the normal adult inhales eight litres of air per minute, which adds up to 11,000 L of air per day for survival (Ladan 2013; Nimsatkar et al. 2020). Hence, any inhalation of polluted air will have adverse effects on the body in general and on the central nervous system specifically. Air pollution can be categorised into different categories, such as household air pollution, particulate matter (PM) pollution, ozone pollution, etc. (Kim et al. 2020; Rhew et al. 2021). However, Abulude et al. (2021) principally classified air pollution based on exposure into: outdoor and indoor air pollutions. A complex mixture of PM, gases, organic compounds and inorganic compounds are present in outdoors and indoors exposures. The PM can be grouped based on its aerodynamic diameter into coarse particles (PM > 2.5 to < 10 um), fine particles (PM < 2.5 μm) and ultrafine particle matter (PM < 100 nm) (Kim et al. 2020; Rhew et al. 2021). Origins of fine particle ($PM_{2.5)}$ are mineral matter, road dust, industry and oil fuel combustion (Rhew et al. 2021).

Industrial waste and sewage, which mostly include hazardous organic and inorganic substances containing heavy metals that might either be essential or non-essential, are other significant contributors to air pollution. Essential heavy metals, including copper, iron, manganese, nickel, and zinc, are necessary for physiological and biochemical activities throughout the life cycles of both humans and plants, but they may become deadly when above the maximum limits (Verma and Jaiswal 2016; Yan et al. 2020). On the other hand, non-essential heavy metals such as vanadium lead, cadmium, arsenic, and mercury are extremely virulent in high exposure and may cause environmental pollution that severely affects a variety of physiological and biochemical processes (Avila-Costa et al. 2004, 2005, 2006; Calderon-Garciduenas et al. 2003; Lidsky and Schneider 2003; Usende et al. 2016, 2017, 2018a, 2018b, 2020, 2022a, 2022b).

These heavy metals can enter the food chain via crops and aggregate in the human body via bio-magnification, thus posing a great threat to human health (Lidsky and Schneider 2003; Avila-Costa et al. 2004; Usende et al. 2016, 2017, 2018a, 2018b; Yan et al. 2020).

Due to their small sizes, these $PM_{2.5}$ remain in the aerosphere as airborne particles, where they can effortlessly infiltrate the main organ of respiration (lungs) and spread to the body through blood vessels, leading to unfavourable health challenges and neurodegeneration (Fig. 1) (Kim et al. 2020). The World Health Organisation (WHO) reported an annual mortality of 2.4 million persons due to air pollution, with varying diseases such as heart disease, lung cancer, and chronic and acute respiratory diseases (Sierra-Vargas and Teran 2012; Abulude et al. 2021).

Prolonged exposure to fine dust swiftly degenerates the immune system and increases the chance of cardiovascular, skin, and respiratory diseases (Kim et al. 2020; Jankowska-Kieltyka et al. 2021). Exceptionally, $PM_{2.5}$ and nitrogen oxides (NO_X), which are a combination of nitrogen dioxide (NO_2) and nitric oxide (NO), have been recognised to influence the central nervous system (CNS) thereby leading to systemic inflammation, neuroinflammation and oxidative stress which are part of the hallmark features of neurodegenerative diseases (Usende et al. 2016; Kim et al. 2020; Jo et al. 2021; Usende et al. 2022b).

Nigeria is one of the fastest-developing countries in Africa, with its urban and rural centres swiftly growing in population, industries, and economy. A high degree of various diseases ranging from respiratory diseases, strokes, heart diseases, lung cancer, and premature mortality have been reported recently to occur due to the inhalation of unhealthy air (Abulude et al. 2021). A study has also shown an elevated shift in vehicular-derived air pollution in major cities of Nigeria due to high vehicular traffic with higher discharges of PM and unburnt hydrocarbons. Interestingly, the high quantities of aromatic hydrocarbons, carbon monoxide (CO), and PM are linked mostly to places close to bus stops and industries within and around the metropolis (Olowoporoku et al. 2011).

According to a 2018 World Bank report, Lagos State, Nigeria, lost over 2.1 billion USD (indicating 2.1% of its gross domestic product) due to diseases and early mortalities of 11,200 individuals as a result of ambient air pollution. Out of this figure, 60% were children under five years old, while the remaining percentages were adults (Olowoporoku et al. 2011; Abulude et al. 2021). According to Nwachukwu et al. (2012), between 2003 and 2007, the River State of Nigeria was reported to have extremely greater air pollutants than the WHO parameters. Air pollution-related diseases like cerebrospinal meningitis, chronic bronchitis, measles, pertussis, pulmonary tuberculosis, pneumonia, and upper respiratory tract infection were reported in the state (Yakubu 2017).

In 2016, air pollution contributed to roughly six million deaths in Nigeria, with diseases ranging from strokes, lung disease, lung cancer, bronchitis, asthma, heart attacks, and eye and skin diseases (TBP 2019). These health conditions are due to polycyclic aromatic hydrocarbons, NO_2, and SO_2, which are principal components of fine dust. The authors citing the environmental performance index for air quality report update of 2016, ranked Nigeria 152nd out of 180 countries in the world with severe air pollution. The latest WHO air pollution database update in 2016 and documented also revealed that air quality in numerous locations in Nigeria attains vicious to unsafe degrees of $PM_{2.5}$. This indeed is a call for great and quick attention regarding air quality in Nigeria (Abulude et al. 2021).

Major Sources of Air Pollution in Nigeria

Nigeria, as an oil exploration and industrialization region of Africa, is endowed with numerous manufacturing industries, oil refineries, and local factories, which have consequently resulted in more environmental challenges (Igado et al. 2008; Usende et al. 2016; 2017, 2018a, 2018b, 2020, 2022a, 2022b). Of note are the extremely industrialised cities, which have become densely populated due to massive migration from rural to urban centres as a consequence of poor infrastructural development and insecurity in rural areas (Pona et al. 2021; Wada et al. 2022). During the production of oil via mining or drilling, petroleum hydrocarbons are often discharged into the environment, and spillage of oil into the environment does occur due to operational failures and vandalization (Adekunle et al. 2013, 2015; Olaolorun et al. 2021; Usende et al. 2022b). Hydrocarbon components of drilling fluids are mono-aromatics known as BTEX (benzene, toluene, ethylbenzene, and xylene), and BTEX compounds are highly volatile and are easily evaporated in warm or hot climates in tropical regions where humans are exposed through inhalation (Adekunle et al. 2013, 2015). Majorly, the gas stream is saturated with volatile organics and oxides of carbon (COx), sulphur (SOx), and nitrogen (NOx) that are susceptible to fuel constituents, and the PM commonly discharged during the process is around 10 µm (Ana 2011).

The chief origins of outdoor gaseous discharges in Nigeria are presented in Figure 2 and are from industries, automobile exhaust, electrical generating plant exhaust at homes and business centres (on account of the epileptic power supply), discharges from the incineration of wastes, and gaseous release from dumpsites. Specific to Nigeria is the high importation of second-hand vehicles that might have been used for years and conventionally produced high gaseous discharge as a result of insufficient combustion oil and fuel impurities (Pona et al. 2021). Like what is obtained in other countries of the world, exhaust emanating from vehicles into the air is one of the principal culprits of air pollution (Ladan 2013). In Nigeria, bad roads have often led to heavy vehicular traffic, leading to heavy vehicular exhaust and higher air pollution (Ladan 2013; TBP 2019).

Unlawful importation of electronic waste (e-waste), which is discarded electrical and electronic equipment, to dumpsites in the south-western region specifically and, by extension, other regions of Nigeria, has been a notable challenge to air pollution due to scavengers going to the dumpsites and burning down the e-waste to extract some vital parts of it for sale (Alimba and Bakare 2016; Usende et al. 2022a). The incomplete burning of this e-waste causes air pollution and pollutes the environment (Pona et al. 2021). Bush burning is another habitual event in Nigeria that is often performed before land cultivation for farming and when hunting for game, and these processes lead to the discharge of numerous forms of gaseous pollutants and PM into the atmosphere (Ana 2011).

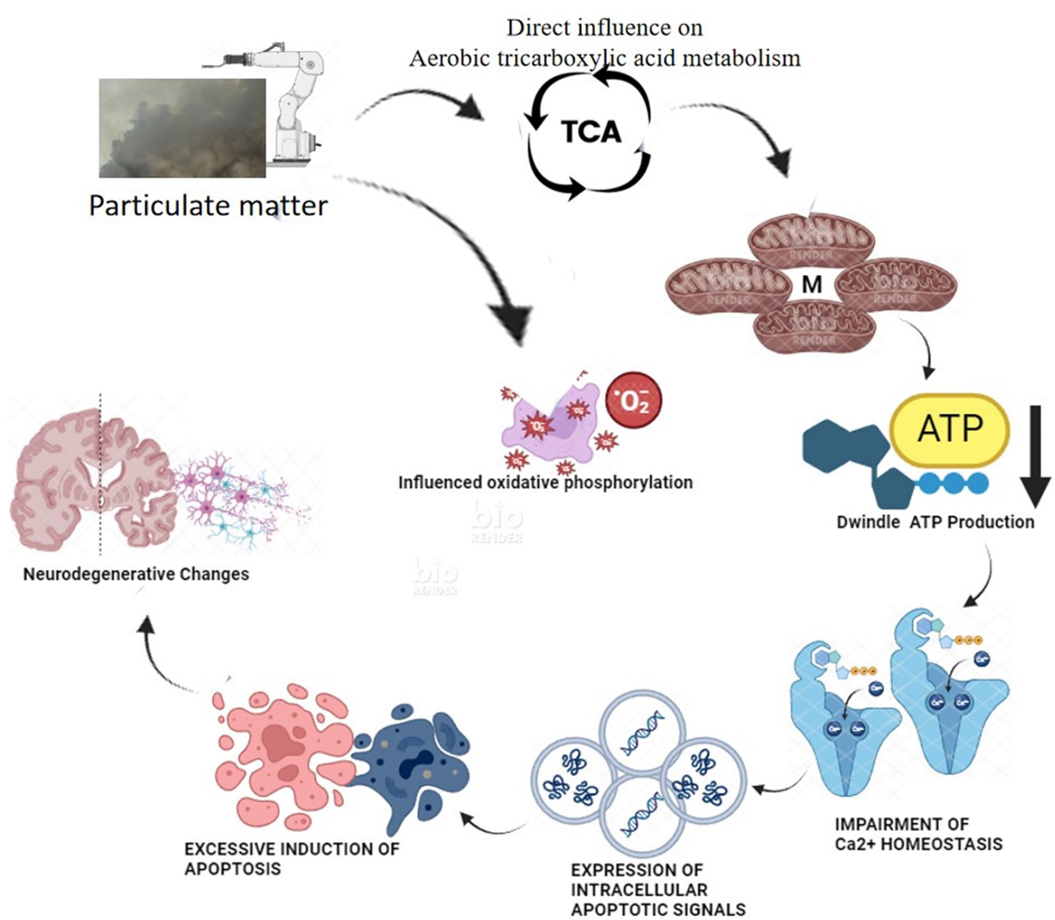

Fig. 1: $PM_{2.5}$ Mechanism of action in neurodegeneration. Created in Biorender.com

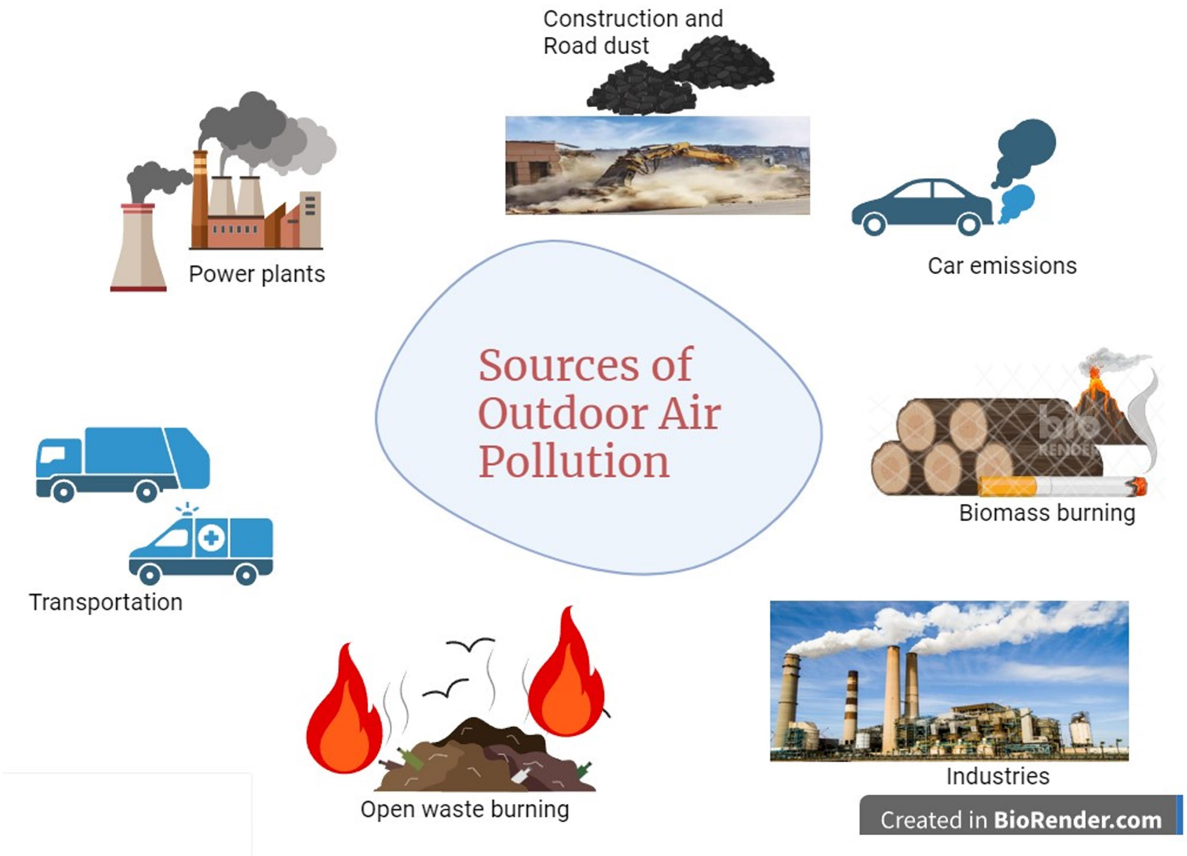

Fig. 2: Major sources of outdoor air pollution in Nigeria. Created in BioRender.com

Besides, due to the high level of poverty in Nigeria, many households rely on firewood and charcoal to generate energy for cooking, which has subsequently contributed to the increase in the air pollution crisis in Nigeria (TBP 2019). As stated in previous works of literature (Ana 2011; Adekunle et al. 2013, 2015), gaseous pollutants from cooking releases are CO, carbon dioxide, sulphur dioxide (SO_2), NO_2, and PM. The PM produced is in the form of carbon black, sooth and fly ash and most often within 10 µm in size (Ana 2011). Sadly, most of the cooking happened indoors, causing a rise in the quantity of fine PM released, which could surpass the air quality guidelines by twenty times. In 2012, according to the WHO, Lagos state alone witnessed approximately seven million mortalities on account of indoor and outdoor air contamination (TBP 2019).

Air Quality Index in Nigeria

The Air Quality Index (AQI) is a measure used to describe the daily air quality. The AQI is employed by the Environmental Protection Agency to modulate the five chief pollutants under the Clean Air Act, which are: ground-level ozone, PM, carbon monoxide, SO_2 and NO_2 (Abulude et al. 2021). Data for Nigeria's air quality status held in the Little Green Data Book 2015 reported that Nigerians are exposed to air pollutants at 94%, which is also greater than the 72% of sub-Saharan Africa's minimum according to the WHO guidelines. As a result, Nigeria has been named one of the top five countries in the world for premature death due to air pollution (Yakubu 2017).

Life expectancy has generally increased, with the average age of the world population increasing from 66.4 years in 2000 to 71.4 years in 2015. Even though the increases were highest in Africa between those years (an increase from 50.6 to 60 years), the continent still has the lowest life expectancy in the globe. Nigeria has the worst situation. In Nigeria, individuals live an even lower average lifetime of 54.4 years, with air pollution being implicated as one of the major causes. Nigeria has the largest number of premature deaths attributed to air pollution in Africa and is among the top five countries worldwide. In Nigeria, exposure to air pollution (both ambient and household-coupled) has been linked to an estimated 5.4 million disability-adjusted life years and 114 thousand annual deaths, with a corresponding economic cost of about USD 112 billion (Etchie et al. 2018).

Currently, there is no data on the average life expectancy for most air-polluted cities in Nigeria. There is also no extensive and pragmatic database on the degree of the menace of air pollution and its harmful impacts or connection with neurodegenerative diseases in Nigeria (Ana 2011).

Table 1: Air Pollution Database 2016 from World Health Organization (WHO) of some Cities in Nigeria

s/n	City	$PM_{2.5}$ Concentration	$PM_{2.5}$ AQI	Health Impact	Year
1	Onitsha	594	500	Hazardous	2009
2	Kaduna	423	449	Hazardous	2013
3	Aba	373	416	Hazardous	2009
4	Umuahia	274	324	Hazardous	2009
5	Owerri	158	208	Very unhealthy	2009
6	Nsukka	117	183	Unhealthy/ harmful	2009
7	Enugu	115	182	Unhealthy/ harmful	2009
8	Ile-Ife	103	175	Unhealthy/ harmful	2010
9	Abakaliki	88	168	Unhealthy/ harmful	2009
10	Afikpo	72	159	Unhealthy/ harmful	2009
11	Nnewi	57	151	Unhealthy/ harmful	2009
12	Orlu	52	142	Unhealthy for sensitive groups	2009
13	Lagos	73.2	-	Unhealthy	2021

Air Quality Monitoring in Nigeria (2022)
AQI - Air Quality Index

Table 2: Air Quality Monitoring Database for some Cities in Nigeria with the Worst Air Quality

S/N	City	AQI
1	Abuja	130
2	Maiduguri	126
3	Calabar	123
4	Benin City	107
5	Lagos	82

Air Quality Monitoring in Nigeria (2022)
AQI - Air Quality Index

Available Data on Environments most prone to Air Pollution in Nigeria

In consonance with the research by the University of Chicago's Air Quality Life Index (AQLI), air pollution is next to human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) in terms of its effect on life expectancy in Nigeria. Based on the latest AQLI report in 2021, it was shown that an average individual living around the Niger Delta region of Nigeria is likely to lose six years of life expectancy if the air pollution situation around the area is not controlled (Atcmask 2018). Four towns in Nigeria, Aba, Kaduna, Onitsha, and Umuahia, made up twenty of the most severely polluted cities in the world, according to a WHO assessment of air pollution levels ($PM_{2.5}$ and PM_{10}) between 2008 and 2013. Onitsha was deemed the most polluted, with levels thirty times higher than the WHO's recommended 20 ug/m^3 annual mean, while Kaduna, Aba, and Umuahia reported levels of 21, 19, and 18 times higher, respectively (Yakubu 2017).

Besides, in 2017, Nigeria recorded more than 114,000 deaths due to air pollution, with a death rate of 307.4 for every 100,000 individuals, according to the WHO. Nigeria's annual mean concentration of PM2.5 pollutants was again reported to be 46.3 g/m^3, as per the WHO reports of September 2021. This is also nine times greater than the WHO guidelines for outdoor air quality (Atcmask 2018). Moreover, the latest report on the air pollution database from the World Health Organisation disclosed that air quality in some cities in Nigeria attains $PM_{2.5}$ concentrations and still ranges from unhealthy to unsafe degrees (Air Quality Monitoring in Nigeria 2022).

Incidence of Neurodegenerative Diseases in Nigeria

Results of the epidemiologic studies on dementia (which encompasses most neurodegenerative diseases) in Nigeria from 1990 to 2018 disclosed that the incidence of dementia in Nigeria was 4.9%, with an incidence significantly higher in women than men. Sadly, various regions of the country still associate dementia with the normal ageing process, and victims are labelled and abandoned in the belief that their condition is beyond any medical intervention. Moreso, many sufferers of this disease also delay seeking medical care and endure poor outcomes due to low access to mental health services and high out-of-pocket expenses that only a few can afford (Adeloye et al. 2019). One major setback is that there is no specific data on the prevalence of neurodegenerative diseases in major air-polluted areas.

The connection between Neurodegenerative Diseases and Air Pollution

Parkinson disease, Alzheimer's disease, and associated dementia are the most frequent neurodegenerative diseases in the world (Kim et al. 2020; Shi et al. 2020). Globally, approximately six million individuals have Parkinson's disease, while a million have Alzheimer's disease and associated dementia (Shi et al. 2020). One study conducted in Rome discovered an affirmative link between residential vulnerability to NO_X, ozone, and hospitalisation for dementia (Kim et al. 2020).

Reports related to epidemiology have revealed that on subjection to fine PM (PM < 2.5 μm), there is a high risk of developing Alzheimer's disease and dementia (Kim et al. 2020; Shi et al. 2020). These reports further disclosed that in apolipoprotein E (ApoE)-1-mutant mice subjected to fine dust, the number of dopamine cells dwindled by 29% compared with the control group. In addition, it was further proposed that fine dust ($PM_{2.5}$) can activate cognitive damage and neurodegeneration via alterations in the structure and function of the mitochondria. This will consequently affect aerobic tricarboxylic acid metabolism and oxidative phosphorylation, causing hyperphosphorylation of tau in the cerebral cortex and the generation of an excess of reactive oxygen species (ROS) (Kim et al. 2020).

The entry of air pollutants through the airways may lead to lung disease (Olopade et al. 2005; Igado et al. 2008; Usende et al. 2017). These particles can also reach the olfactory bulb of the brain via axons from the olfactory mucosa (Igado et al. 2008; Sierra-Vargas and Teran 2012; Kim et al. 2020; Wang et al. 2021). Air pollutants, chiefly $PM_{2.5}$ and NO_X, are known to affect the central nervous system, resulting in systemic inflammation, neuroinflammation, and oxidative stress (Block and Calderón-Garcidueñas 2009; Kim et al. 2020; Hahad et al. 2020; Wang et al. 2021; Usende et al. 2016; 2022b). Other effects include poor brain health and an increased prevalence of neurological and psychiatric disorders, as well as decline in cognitive function, dementia, anxiety, depression, schizophrenia, and attention deficit hyperactivity disorder (Kim et al. 2020; Myhre et al. 2018).

Incidence of Neurodegenerative Diseases Caused by Air Pollution in Nigeria

The prevalence of neurodegenerative diseases caused by air pollution in Nigeria is currently underreported or largely not available. This is partly due to the limited number of experts (neurologists and immunologists) and is majorly compounded by widespread cultural misconceptions about neurological diseases. Inadequate laboratory and basic requisite knowledge for proper diagnosis is also lacking. Nanoparticles and other constituents of air pollution can easily infiltrate into the nose, bypassing the blood-brain barrier, and invade the brain through the olfactory receptor cells and perineural spaces (Igado et al. 2008; Calderón-Garcidueñas et al. 2018; Jankowska-Kieltyka et al. 2021). Hence, olfactory bulbs have become a principal target for understanding the connection between air pollution and neurodegenerative disease pathology (Calderón-Garcidueñas et al. 2018).

Toxicological studies have proposed various prospective activities through which air pollution may contribute to neurodegenerative development, such as systemic and brain inflammation, which boosts the pathogenic alteration of alpha-synuclein (-syn), hastening the progression of Parkinson's and Alzheimer's diseases (Kilian and Kitazawa 2018; Shi et al. 2020). Inhalation of NO_2 has been said to provoke the aggregation of amyloid beta 42 (Aβ42) and lessen cognitive function via prostaglandin E_2 (PGE_2) metabolism, resulting in synaptic dysfunction conjoined tauopathy and an upsurge in the amounts of proinflammatory markers in the brain (Jo et al. 2021). Categorically, neuroinflammatory activities are made up of an elevated manifestation of cyclooxygenase with increased quantities of prostaglandin E2, which have been related to various neurodegenerative disorders, namely Parkinson and Alzheimer's diseases, and amyotrophic lateral sclerosis (Bartels and Leenders 2010).

Heavy Metal Pollutants in the Brains of Animal Models from Different Zones of Nigeria and Evidence of Neurodegeneration

In Nigeria, and especially in the Niger Delta region as well as other regions of the country, air pollution results mainly from the combustion of fossil fuels (Igado et al. 2008; Usende et al. 2017, 2022b), including all motor vehicle emissions, fireplaces, power plants, and barbecues (Igado et al. 2008). Reports have also implicated smelters, waste incinerators, and other industrial activities as the culprits for emissions of varieties of acidic, organic, and metallic compounds, individually or as mixtures, significantly affecting health (Bascom 1996). Recently, interest has been in quantifying heavy metals and ions in different brain regions and other tissues in different animal species in Nigeria (Olopade et al. 2005; Igado et al. 2008; Usende et al. 2017).

Earlier, Olopade et al. (2005) reported high concentrations beyond acceptable limits of ions and heavy metals, including fluoride, cobalt, arsenic, mercury, and nickel, in the cerebral cortex of West African dwarf goats sampled from Sokoto and Bodija, Ibadan, and implicated air pollution as the reason for these high concentrations. Igado et al. (2008), on the other hand, reported increased concentrations of vanadium, iron, lead, copper, molybdenum, and aluminium in different brain regions, including the olfactory brain, cerebellum, thalamus, frontal cortex, and hippocampus, of West African dwarf goats sampled from Ibadan, Nigeria. More recently, Usende et al. (2017) performed an assessment of the concentration of different heavy metals in the brain and other organs of African giant rats (AGRs) from three agro-ecological zones of Nigeria with different industrial activities and showed that the major environmental heavy metal pollutants of the mangrove/freshwater swamp were vanadium and selenium, while those of the woodland/tall grass savannah agro-ecological zones were zinc, lead, and selenium. They showed that the concentration of vanadium was more than twofold higher in the brain of AGR sampled from the mangrove/freshwater swamp. They concluded that the high concentrations of these metals in the mangrove/freshwater swamp and woodland/tall grass savannah agro-ecological zones may be related to increased mineral exploitation and the activities of militants in pipeline vandalization in this zone.

Based on the findings of Usende et al. (2017), interest is now on the rise concerning the use of AGR as a model for air pollution and vanadium neuroecotoxicology and to determine levels of animal and human exposure (Olaolorun et al. 2021; Usende et al. 2022b), due to the exploratory activities of this rodent. To begin to explore the neurodegenerative consequences of these heavy metals, Usende et al. (2022b) processed the brain of these AGR from high vanadium and high lead zones for immunohistochemical and immunofluorescence staining and analysis and reported that brains from these heavy metal polluted zones had decreased density of immunoreactive neurons, shrinkage of immunostained soma, and decreased dendritic arbours and neuropil in dopaminergic neurons, basically in the substantia nigra, pars compacta, parvalbumin interneurons in the hippocampus and prefrontal cortex, as well as melanin-concentrating neurons and orexin-A neurons in the lateral hypothalamus. The neuronal damages seen in these brain regions corresponded to classical scanty or loss or destruction of the extracellular matrix and perineuronal nets around these neurons and astrocytes and microglia activations in brains of AGR sampled from the high vanadium and lead zones (Usende et al. 2022b).

Government Interventions on Air Pollution in Nigeria

In 1988, the Nigerian government instituted environmental legislation through the Federal Environmental Protection Agency Act, purposed to dwindle the atmospheric effect of the diverse pedigrees of pollution from the oil and gas industries. However, this act failed to address issues of air pollution that may occur as a result of increased vehicular traffic evolution in urban centres, elevated dependence on petrol and diesel-fuelled generators for power supply at homes and public facilities, and uncurbed open incineration of waste, among others. Moreover, in 1999, the Federal Ministry of the Environment was created to tackle the challenges of industrial and urban pollution and marine and coastal resource degradation. In 2007, a new agency called the National Environmental Standards and Regulations Enforcement Agency was also inaugurated, with one of its principal agendas being "improve air quality" by December 2010. Sadly, till date (12 years after the inauguration of the last agency), there has been no improvement in Nigeria's air quality, and none of these agencies has performed beyond expectations (Olowoporoku et al. 2011).

Conclusion and Recommendations

In Nigeria, environmental pollution via the haphazard disposal of domestic, agricultural, and industrial waste with no consideration of health or environmental influence is at its peak. This calls for urgent attention from the government and the entire populace. There's a need for accurate education on waste disposal and air pollution, including awareness to alert and sensitise them to air pollution and its connection with neurodegenerative diseases. Besides, comprehension of the effects of PM on cognitive function and diseases of the central nervous system is imperative, as global depletion of air pollution has a direct impact on dwindling the prevalence of neurodegenerative diseases. One major setback is that there is no specific data on the prevalence of neurodegenerative diseases in major air-polluted areas in Nigeria. Hence the need for awareness to alert occupants and citizens to neurodegenerative diseases and their connection with air pollution. Several agencies saddled with the responsibility of regulating pollution should henceforth be proactive; besides, non-governmental organisations should also help in this fight.

As a possible solution, we recommend the use of biodegradation and bioremediation for the removal or reduction of pollutants in Nigeria. Various classes of microorganisms that are available in nature may provide a way out for the degradation and bioremediation processes of removing toxic industrial wastes via their metabolic procedures. Bioremediation involves the use of microbes to detoxify and degrade environmental pollutants (Singh and Gupta 2016). It also employs greatly inexpensive and low-technology techniques that have received universal approval. Polycyclic aromatic hydrocarbons pesticides, polychlorinated biphenyls metals, nitrogen compounds, compounds, non-chlorinated pesticides and herbicides, and radionuclides are examples of dangerous organic waste that can be degenerated by microorganisms.

Recently, research is focused on the development of genetically modified microbes or consortia for the detoxification of environmental pollutants, which has not also been employed in Nigeria, hence the need to look in this direction. Furthermore, information regarding air quality vigilance has not been generated by Nigeria's air quality monitoring, even when air quality levels are suspected to be harmful to the citizens' health; hence, there is a need to work on this shortcoming and ensure there is an up-to-date database on air quality for public consumption. The government and concerned authorities should make sure imported vehicles are properly checked; more public enlightenment on waste management and disposal can never be overemphasised; the cost of herbicides to reduce bush burning; and mental health services should also be regulated at affordable prices.

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Conflict of Interest

None declared.

Authors' Contribution

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by AOA, OAO, EOA, MKA, LAS, YTD and ILU. The first draft of the manuscript was written by AOA and ILU. All authors read and approved the final manuscript.

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