Air Quality and Public Health in Metropolitan Cities in Nigeria: Implications. A Review

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ABSTRACT

Air pollution in Nigeria's urban areas, driven by rapid urbanization, industrialization, and human activities, poses significant public health and environmental challenges. This review discusses the sources, trends, and impacts of air pollution across the country, highlighting the seasonal and regional variations in air quality. Major sources of pollutants, including industrial emissions, vehicular exhaust, biomass burning, and waste management practices, are examined, along with their contribution to particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx), and 1-nitropyrene (1-NP) levels. The health impacts of air pollution are profound, affecting respiratory, cardiovascular, reproductive, and neurological systems. Vulnerable groups, including children and pregnant women, are particularly at risk. Furthermore, air pollution contributes to environmental degradation, economic losses, and reduced life expectancy. The review emphasizes the need for effective policies and interventions to mitigate air pollution and improve public health. Addressing these issues is crucial for safeguarding the well-being of Nigeria's growing urban population and ensuring sustainable development. The urgent need for comprehensive air quality management strategies and public awareness initiatives is underscored to prevent the long-term consequences of air pollution on health and the environment. By implementing effective policies, embracing cleaner technologies, and raising public awareness, Nigeria can tackle air pollution and protect the well being of its growing urban population. A commitment to these measures will not only improve air quality but also contribute to sustainable development and a healthier future for all.

Keywords: air pollution, urbanization, health hazard, economic loss, Nigeria

INTRODUCTION

Nigeria, located in West Africa, is bordered by Benin Republic to the west, Niger to the north, Chad to the northeast, and Cameroon to the east [1]. The country covers an area of approximately 923,768 square

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kilometres, making it the 32nd largest country in the world. The Niger and Benue Rivers are the two major rivers, forming a confluence at Lokoja and flowing into the Gulf of Guinea. Nigeria's climate varies significantly, from the tropical climate in the south to arid conditions in the north [2].

Nigeria has experienced rapid urbanization over the past few decades. Approximately 52% of people reside in urban settings as of 2020, a considerable rise from 17% in 1960 [3]. The urbanization rate is driven by both natural population growth and rural-to-urban migration [3]. Major urban centres include Lagos, Kano, Ibadan, Onitsha, Abuja, and Port Harcourt. Nigeria's largest metropolis, Lagos, is the country's financial and commercial centre and is among the world's fastest-growing cities. Rapid urbanization has led to the expansion of cities, increased demand for housing, infrastructure, and services, and significant environmental challenges, including air pollution [3,4].

Air quality is a critical environmental and public health issue [5]. In Nigeria, understanding air quality and its implications for public health is crucial due to the rapid urbanization, industrialization, and significant population growth that the country has experienced. Poor air quality has direct and severe impacts on health, the environment, and the economy [6]. One significant risk factor for some health problems is air pollution [7] Air pollution is a global health hazard, significantly affecting respiratory, cardiovascular, and overall health. In Nigeria, exposure to high levels of air pollutants, such as particulate matter (PM), nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), 1-nitropyrene (1-NP), and ozone, is associated with respiratory and cardiovascular diseases, adverse pregnancy outcomes, and increased mortality rates [7]. Recent studies emphasize the role of air pollution in contributing to millions of premature deaths globally every year, making it the second leading risk factor for mortality, surpassed only by high blood pressure. Studies have shown a strong link between exposure to air pollution and an increased risk of cardiovascular diseases, including hypertension, heart attacks, stroke also long-term exposure to air pollution in Lagos, Nigeria's largest city, was associated with a 20% increase in the risk of hypertension [8, 9]. Air pollution can also exacerbate other risk factors for heart disease, such as diabetes and obesity. Furthermore, Studies have shown that exposure to air pollution can impair insulin sensitivity and increase the risk of developing diabetes [10]. It can also contribute to weight gain and obesity by disrupting metabolic processes [10]. The mechanisms by which air pollution contributes to cardiovascular diseases are complex and involve several pathways, including inflammation, oxidative stress, and endothelial dysfunction [10].

Exposure to pollutants like $PM_{2.5}$ and PM_{10} can cause or exacerbate conditions such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer [9]. Studies have shown that urban areas in Nigeria, particularly in cities like Lagos, Onitsha, and Port Harcourt, have high levels of these pollutants, leading to increased respiratory morbidity [9]. Additionally, pregnant women who are exposed to air pollution run a greater chance of experiencing unfavourable outcomes like stillbirth, premature birth, and low birth weight. These risks highlight the importance of monitoring and improving air quality to protect maternal and child health in Nigeria [11]. It is estimated in Nigeria, that thousands of premature deaths each year are attributable to poor air quality, emphasizing the urgent need for intervention and policy implementation [6].

Compromised air quality jeopardizes human health and degrades the environment [5]. Airborne pollutants contribute to acid rain, which damages soil composition, water resources, and biological diversity. Pollutants such as ground-level ozone also harm vegetation, diminishing agricultural yields and threatening food security [12]. The health consequences of air pollution impose substantial economic burdens due to the treatment of pollution-related illnesses, and productivity declines when individuals suffer from sickness or experience premature mortality. Therefore, addressing air quality challenges can generate considerable economic advantages by lowering healthcare expenditures and enhancing workforce productivity [13, 14]. Nigeria's rapid industrialization and urbanization are primary drivers of air pollution [15]. The growth of urban centers and the surge in vehicular traffic, industrial operations, and the utilization of generators due to inconsistent electricity supply are major contributors to pollutant release [16].

This review aims to underscore the harmful health effects of air pollution in Nigeria’s metropolitan areas and its health implications.

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Figure I: Map of Nigeria with Bordering Countries

Trends and Main Sources of Air Pollution in Nigeria

Since the beginning of the millennium, there has been massive migration towards urban cities across the globe [16,17]. According to [17], younger African generations are speedily relocating to urban communities in search of greener pastures and job opportunities and Nigeria with the majority young adult population is not left out of this trend. Recently released data has predicted that by 2035, more people will live in urban communities than in rural areas contrasting the data obtained in the last two decades [18]. This rapid growth of city populations has the potential to escalate the number of fatalities related to air pollution. As urban areas expand, the concentration of pollutants can intensify, posing a significant health risk to residents [19].

Industrial activities are a huge source of air pollution in Nigeria [20]. These activities release diverse pollutants into the atmosphere, including particulate matter (PM), sulfur oxides (SOx), 1-nitropyrene (1-NP), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOCs). While these pollutants have varying compositions, they often share similar mechanisms of action. Upon inhalation, these pollutants are metabolized by specific cytochrome P450 enzymes, which further transform them into toxic forms through epoxidation and hydroxylation reactions [20]. The resultant reactive metabolites forms DNA and protein adducts [20], induce oxidative stress and cell damage [21], initiate inflammatory responses as seen in asthma and chronic obstructive pulmonary diseases [20, 21], and causes several forms of cell death and non-apoptotic cell death, exhibiting characteristics of paraptosis and necroptosis. Industries such as cement production, steel manufacturing, and petrochemical plants emit large quantities of pollutants to the environment. For instance, cement plants release PM and SOx, contributing to respiratory issues and environmental degradation [21]. Nigeria's oil and gas sector is a major contributor to air pollution [22]. Gas flaring, a common practice in oil extraction, releases significant amounts of CO_2 below 20 ppm, 1NP 0.13 pmol/g, Sox with levels exceeding 20 micrograms per cubic meter (µg/m3) for 24-hour average exposure, and methane, impacting both local air quality and contributing to global climate change [23]. Besides CO2, gas flaring releases NOx, SOx, and methane. These pollutants have local and regional impacts on air quality, contributing to acid rain, respiratory problems, and other health issues. Methane, while a less abundant greenhouse gas than CO2, has a much higher global warming potential over a shorter timeframe, making it a significant contributor to climate change [23] Mining, particularly artisanal and small-scale gold mining (ASGM) as seen in Zamfara State, can have devastating localized environmental and health consequences Mining activities, particularly in the region where these activities are carried out have been associated with the release of toxic metals and dust particles [24].

Vehicular emissions are a predominant source of air pollution in urban areas of Nigeria [25]. The rapid increase in the number of vehicles with poor vehicle maintenance, fuel quality and bad roads, exacerbates these issues. Vehicles emit PM, NOx, CO, and VOCs, which contribute to urban smog and respiratory problems [26]. Older vehicles, often lacking modern emission control technologies, are particularly problematic. Heavy traffic in cities like Lagos, Abuja and Onitsha often leads to prolonged idling and increased emissions, worsening air quality. The use of low-quality fuels with high sulfur content further increases the emission of harmful air pollutants [27].

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Biomass burning, including the burning of wood, crop residues, and animal dung for cooking now a common practice is a major source of indoor and outdoor air pollution in Nigeria. A significant number of the Nigerian population relies on biomass for cooking, leading to the emission of PM, CO, and VOCs. Indoor air pollution from biomass burning is also a major health risk, especially for women and children who spend significant time near cooking stoves. Furthermore, open burning of agricultural residues and forest clearing for farming releases large amounts of pollutants, affecting both air quality and contributing to deforestation and soil degradation [28, 29, 30]. Improper waste management practices, including open burning of waste, contribute significantly to air pollution in Nigeria [31] also open burning of municipal solid waste is common in many Nigerian cities due to inadequate waste collection and disposal systems [32]. Released PM, NOx, CO, and toxic compounds such as dioxins and furans, have serious health and environmental impacts. Also, poorly managed landfills emit methane, a potent greenhouse gas, and other pollutants that contribute to air pollution and climate change [33].

Figures 2A & B: A tricycle rider and a street food hawker moving past a cloud of smoke. IMAGE culled from CSDevNet and Press Africa

Figures 2 C & D: A busy road with heavy vehicular activities in one of Nigeria city and mounds of copper wire, animal bones, and discarded tires, fires burn day and night

Changes in air quality depends on season and region in Nigeria

Seasonal Changes

Air quality in Nigeria varies significantly with the changing seasons which is influenced by the country's diverse climatic conditions [34]. Nigeria experiences two primary seasons, wet and dry seasons. During the dry season, especially between December and February, Nigeria is affected by Harmattan winds, which blow from the Sahara Desert [35]. These winds carry large amounts of dust and particulate matter, significantly degrading air quality. The dry season also sees an increase in biomass burning for agricultural purposes and cooking, releasing significant amounts of PM, CO, and other pollutants [36]. The reduction in rainfall means pollutants remain in the air longer, exacerbating air pollution. The lower humidity during this period means fewer natural processes to clean the air, leading to higher concentrations of pollutants [37]. The wet season brings heavy rains that help to wash away airborne pollutants, generally leading to improved air quality [38]. Rainfall reduces the concentration of PM and other pollutants in the atmosphere. By absorbing CO2 and other

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pollutants, more vegetation growing during the wet season can also benefit air quality by lowering air pollution levels [39].

Regional Changes

Nigerian air quality varies greatly from region to region, primarily due to industrialization, geographic factors, and urbanization. Lagos, the biggest city in Nigeria and a major commercial centre, regularly suffers from excessive air pollution because of heavy traffic, industrial pollutants, and the burning of refuse [40]. The city's rapid urbanization has outpaced infrastructure development, leading to significant air quality challenges [40]. Known for its abundant oil deposits, the Niger–Delta region of Nigeria suffers from severe air pollution due to gas flaring, legal and illegal industrial activities, and transportation emissions. One significant environmental and public health concern has been the "black soot" which contaminates the air and makes air pollution unavoidable [41].

As the capital city of Nigeria, Abuja also faces air quality issues primarily from vehicular emissions and construction activities. However, its air quality is generally better than Lagos and Port Harcourt due to lower industrial activity [42]. Significant air pollution is a problem for the city of Kano, a major economic and industrial hub in northern Nigeria, as a result of burning biomass, heavy traffic, and industrial emissions. During the Harmattan season, there is often a lot of dust in the area [43]. Furthermore, in the northeastern part of Nigeria, Maiduguri faces air quality challenges due to desertification and frequent dust storms, especially during the dry season [44]. Conflict and displacement have also led to increased biomass burning as displaced populations rely on wood for cooking and heating. Another commercial city, Onitsha has some of the highest levels of PM pollution in Nigeria, primarily from vehicular emissions, industrial activities, and waste burning [45]. A former coal mining town, Enugu still faces air quality issues related to illegal mining activities and, the burning of coal and other biomass for energy. The quality of air in rural areas is generally better than in urban centres due to lower levels of industrial activity and vehicular traffic [42].

Review of Some Air Pollutants in Nigeria

Air pollution has well-documented adverse effects on the climate, respiratory health and overall well-being. Exposure to various air pollutants can lead to a range of respiratory conditions, from acute symptoms to chronic diseases. Significant effects on respiratory health are possible, especially in high-pollution areas and among vulnerable populations [9].

Particulate Matter (PM)

Particulate matter (PM) refers to a complex mixture of tiny solid particles and liquid droplets suspended in the air. These particles vary significantly in size, composition, and origin. Also, a factor in determining the health impacts of PM is its size. PM of 10 micrometers (μm) or less in diameter, often referred to as PM10 is deleterious [46]. Smaller particles, measuring 2.5 micrometres or less in diameter, have the potential to enter the air and during circulation, can go deep into the lungs, creating serious health hazards like respiratory infections, lung cancer, and heart disease [47]. In Nigeria, common sources of PM include industrial emissions, vehicle exhaust, biomass burning, and dust from unpaved roads and construction sites.

Carbon Monoxide (CO)

Carbon Monoxide is a colourless, odourless gas that can be harmful when inhaled in large amounts [48]. It interferes with the blood's ability to carry oxygen to cells and tissues. Short-term exposure to high levels of CO can cause harmful health effects by reducing the amount of oxygen that can be transported in the bloodstream to critical parts of the body. Symptoms include headaches, dizziness, weakness, nausea, confusion, and in severe cases, death [49]. Major sources of CO in Nigeria include motor vehicle exhaust, industrial processes, residential heating, and the burning of biomass and fossil fuels [23].

Nitrogen Oxides (NOx)

Nitrogen Oxide refers to several gases of nitrogen and oxygen, examples being nitrogen dioxide, NO2 and nitric oxide, NO [50]. These are some of the gases that pollute the air, and they possess some impacts on

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human health as well as on the environment. High concentrations of NOx can cause inflammation of the human respiratory system worsening respiratory diseases, and decreased lung capacity [51]. Prolonged exposure results in chronic bronchitis and other respiratory diseases and increased incidence of respiratory illnesses. NOx is mainly formed during combustion, in vehicles, power plants, and industrial areas for example [52] Transportation remains prominent in Nigeria, and is equally associated with NOx emission, as are other industrial processes.

Nitropyrene (1-NP)

1-Nitropyrene (1-NP) is a nitropolycyclic aromatic hydrocarbon (nitro-PAH), a class of environmental pollutants generated from the incomplete combustion of carbonaceous organic fuels, biomass, and other compounds, and is very selective for diesel exhaust [53]. Different researchers have identified the presence of 1-NP in the environment and farm produce like in soils, road clouds of dust, rice, cabbages and air [54, 55]. Due to the high lipid solubility, 1-NP accumulates in the gastrointestinal tract, respiratory system, and skin [56]. 1-NP is one of the most prevalent nitro-PAHs in urban atmosphere and a significant source of mutagenic and carcinogenic impact [57–59]. The measured 1-NP exposures were near the concentrations in the air while the urban ambient the concentrations in air ranged from 10 to 1000 pg/m3 [60].

Sulfur Oxides (SOx)

Sulfur Oxides, particularly sulfur dioxide SO_2, are gases produced by volcanic eruptions and industrial processes, in particular, burning fossil fuels that include sulfur compounds [61]. Increased symptoms of asthma and bronchoconstriction are two respiratory issues that SO_2 can bring on. Extended exposure can exacerbate cardiovascular disorders and cause respiratory illnesses [9]. In Nigeria, SOx emissions primarily come from the process of producing power through burning coal and oil and industrial processes, as well as from vehicular emissions.

Health implication of air pollution

For adults, children, and newborns, air pollution can have a significant negative influence on their health and development [62]. Nigerian air pollution has a direct correlation to urbanization since people migrate to the urban settlements in search of job opportunities, and better living conditions which are far better than what is obtained in the rural communities. This situation has contributed to the development of various pathways involved in the onset and progression of numerous air pollution-related diseases in Nigeria. These detrimental effects can negatively impact respiratory health, cognitive function, overall development, and ultimately, lifespan [62, 63].

Effect on the development of the Brain

Air pollution has been increasingly recognized for its impact on neurological health, including cognitive function and mental health [64]. Exposure to air pollution, particularly fine particulate matter $PM_{2.5}$ and NO_2, has been associated with accelerated cognitive decline and an increased risk of neurodegenerative diseases such as Alzheimer's disease and Parkinson’s disease [65]. Long-term exposure to $PM_{2.5}$ is linked to a higher risk of cognitive impairment and dementia [66]. Air pollution can also affect mental health, contributing to conditions such as depression and anxiety. Scientific evidence has established a correlation between exposure to high levels of air pollution and increased prevalence of mood disorders and psychological stress [67].

Effect on the Reproduction

Air pollution can adversely affect reproductive health, impacting fertility and pregnancy outcomes [68]. Reduced fertility in both men and women has been related to exposure to air pollutants including $PM_{2.5}$ and NOx. A study in Environmental Health indicates that increased exposure to air pollution correlates with extended time to conception and a higher risk of infertility in women [69]. Exposure to high air pollution levels heightens the risk of negative outcomes in pregnancy, such as low birth weight, premature delivery, and stillbirth. Also, many scientific reports have shown a clear link between air pollution and these adverse effects [70].

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Effect on Children and Young Adults

Children are particularly vulnerable to the detrimental effects of air pollution, which can compromise their health both immediately and over the long term. Exposure to high levels of air pollutants is linked with significant impacts on lung function and the potential for developmental delays in youth. Specifically, pollutants like particulate matter and 1-nitropyrene have been associated with an increased risk of asthma and other allergic conditions in children. Additionally, there is substantial evidence to suggest a strong link between airborne aerosol contaminants and the prevalence of asthma and allergic rhinitis among the pediatric population [71 – 73].

Effect on General Well-Being

Air pollution affects overall well-being and quality of life, impacting daily functioning and long-term health [74]. Research published in Sleep Medicine Reviews has shown that exposure to pollutants such as $PM_{2.5}$ and NO_2 is associated with sleep problems, including difficulty falling asleep and poor sleep efficiency. High levels of air pollution are associated with a rise in hospital admissions for various health issues, such as respiratory and cardiovascular conditions. Research has consistently shown that as air pollution increases, so do the number of emergency room visit and hospitalizations [75].

Effect on Life Expectancy

Another impact of air pollution is the reduction of human lifespan, with data indicating that high levels of air pollutants reduce the lifespan of an individual [76]. Elevated $PM_{2.5}$ level has been shown to significantly reduce life expectancy. Also, a higher concentration of $PM_{2.5}$ may shorten life by several months to years [75]. A similar study indicated that the loss of years due to air pollution is substantial, and it can be equated to the loss due to smoking. Air pollution significantly reduces life expectancy, with the most severe impacts occurring in highly polluted regions which could experience a reduction in life expectancy by multiple years due to high concentrations of PM and associated hazards [76, 77].

CONCLUSION

The review highlighted the consequences of air pollution in the urban cities across Nigeria which is attributable to many factors including migration, illegal activities in the mining industries, vehicular activities, and reckless burning of biomass with seasonal and regional changes. The dangers involved if air pollution is not checked or better still regulated could take many decades to eradicate. Some of the hazardous effects of polluted air in Nigeria as compared across cities range from neurological disabilities, respiratory diseases, reproductive challenges and life expectancy. In the quest for a better living condition which encourages migration to urban cities, a lot of unwholesome activities carried out by humans contribute significantly to the destruction of the ecosystem that helps balance the environment. The consequences of living around polluted air are dire and needs everyone to commit towards having a less air-polluted environment in our communities.

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Conflict of Interest

None to declare

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REFERENCES

1. Udo, R. K. (2023). Geographical regions of Nigeria. Univ of California Press.
2. Lawal, M. A., & Omosanya, K. O. (2023). Multidecadal changes in planform morphology of the confluence of River Niger and River Benue, West Africa. Journal of Hydrology, 623, 129764.
3. Obi-Ani, N. A., & Isiani, M. C. (2020). Urbanization in Nigeria: The onitsha experience. Cities, 104, 102744.
4. Agunbiade, M. E., Olajide, O., & Bishi, H. (2021). Urban governance and smart future cities in Nigeria: Lagos flagship projects as springboard? Refractions of the National, the Popular and the Global in African Cities, 127.
5. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. Frontiers in public health, 8, 14.
6. Pona, H. T., Xiaoli, D., Ayantobo, O. O., & Tetteh, N. D. (2021). Environmental health situation in Nigeria: current status and future needs. Heliyon, 7(3).
7. Lelieveld, J., Pozzer, A., Pöschl, U., Fnais, M., Haines, A., & Münzel, T. (2020). Loss of life expectancy from air pollution compared to other risk factors: a worldwide perspective. Cardiovascular research, 116(11), 1910-1917.
8. Miller, M.R & Newby D.E. (2020). Air pollution and cardiovascular disease: car sick, Cardiovascular Research, Volume 116, Issue 2, 1 February, Pages 279–294, https://doi.org/10.1093/cvr/cvz228
9. Bălă, G. P., Râjnoveanu, R. M., Tudorache, E., Motișan, R., & Oancea, C. (2021). Air pollution exposure—the (in) visible risk factor for respiratory diseases. Environmental Science and Pollution Research, 28(16), 19615-19628.
10. Bowe B, Gibson AK, Xie Y, Yan Y, Donkelaar AV, Martin RV, Al-Aly Z. Ambient Fine Particulate Matter Air Pollution and Risk of Weight Gain and Obesity in United States Veterans: An Observational Cohort Study. Environ Health Perspect. 2021 Apr;129(4):47003. doi: 10.1289/EHP7944. Epub 2021 Apr 1. PMID: 33793302; PMCID: PMC8016176
11. Bekkar, B., Pacheco, S., Basu, R., & DeNicola, N. (2020). Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: a systematic review. JAMA network open, 3(6), e208243-e208243.
12. Ramya, A., Dhevagi, P., Poornima, R., Avudainayagam, S., Watanabe, M., & Agathokleous, E. (2023). Effect of ozone stress on crop productivity: A threat to food security. Environmental Research, 116816.
13. Pandey, A., Brauer, M., Cropper, M. L., Balakrishnan, K., Mathur, P., Dey, S., ... & Dandona, L. (2021). Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019. The Lancet Planetary Health, 5(1), e25-e38.
14. Mujtaba, G., & Shahzad, S. J. H. (2021). Air pollutants, economic growth and public health: implications for sustainable development in OECD countries. Environmental Science and Pollution Research, 28, 12686-12698.
15. Akinsola, F. A., Ologundudu, M. M., Akinsola, M. O., & Odhiambo, N. M. (2022). Industrial development, urbanization and pollution nexus in Africa. Heliyon, 8(11).
16. Mangaraj, P., Sahu, S. K., Beig, G., & Yadav, R. (2022). A comprehensive high-resolution gridded emission inventory of anthropogenic sources of air pollutants in Indian megacity Kolkata. SN Applied Sciences, 4(4), 117.
17. Kraas, F., Aggarwal, F., Coy, S., Mertins, M. (2014). Megacities: Our Global Urban Future. Dordrecht, Neth.: Springer eds.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue I January 2025

18. UNEP (United Nations Environ. Program). (2014). revision of the World Urbanization Prospects. United Nations Environment Programme. 014. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization prospects.html
19. Pieterse, E., Parnell, S., Haysom, G. (2015). Towards an African Urban Agenda. Nairobi: Economic Commission for Africa.
20. Owili, P. O., Lien, W. H., Muga, M. A., Lin, T. H. (2017). The associations between types of ambient PM 2.5 and under-five and maternal mortality in Africa. Int. J. Environ. Res Public Health 14:359.
21. Raimi, M. O., Adio, Z., Emmanuel, O. O., Samson, T. K., Ajayi, B. S., & Ogunleye, T. J. (2020). Impact of sawmill industry on ambient air quality: A case study of Ilorin Metropolis, Kwara State, Nigeria. Energy and Earth Science, 3(1).
22. Elehinafe, F. B., Ezekiel, S. N., Okedere, O. B., & Odunlami, O. O. (2022). Cement industry–Associated emissions, environmental issues and measures for the control of the emissions. Mechanical Engineering for Society and Industry, 2(1), 17-25.
23. Okedere, O. B., Elehinafe, F. B., Oyelami, S., & Ayeni, A. O. (2021). Drivers of anthropogenic air emissions in Nigeria-A review. Heliyon, 7(3).
24. Romsom, E., & McPhail, K. (2021). Capturing economic and social value from hydrocarbon gas flaring and venting: solutions and actions (No. 2021/6). WIDER Working Paper.
25. Ogelekaa, D. F., & Alaminiokumab, G. I. (2020). Pollution Bloom: An Appraisal of The Hazardous Effects of Mining of Precious Stones in Zamfara State. Geological Behavior (GBR), 4(1), 35-41Volume.
26. Fakinle, B. S., Odekanle, E. L., Olalekan, A. P., Ije, H. E., Oke, D. O., & Sonibare, J. A. (2020). Air pollutant emissions by anthropogenic combustion processes in Lagos, Nigeria. Cogent Engineering, 7(1), 1808285.
27. Goodsite, M. E., Hertel, O., Johnson, M. S., & Jørgensen, N. R. (2021). Urban air quality: sources and concentrations. Air Pollution Sources, Statistics and Health Effects, 193-214.
28. Sadiq, A. A. (2022). Effect of particulate emissions from road transportation vehicles on health of communities in urban and rural areas, Kano State, Nigeria (Doctoral dissertation, Université Claude Bernard-Lyon I).
29. Almsatar, T. (2020). Environmental issues of biomass-burning in sub-Saharan African countries. Biomass burning in sub-Saharan Africa: Chemical issues and action outreach, 1-14.
30. Ali, M. U., Yu, Y., Yousaf, B., Munir, M. A. M., Ullah, S., Zheng, C., & Wong, M. H. (2021). Health impacts of indoor air pollution from household solid fuel on children and women. Journal of hazardous materials, 416, 126127.
31. Bisht, A., Nitin, K., Vishal, K., & Akanksha, B. (2020) "A review on the role of emerging anthropogenic activities in environmental degradation and emphasis on their mitigation." Archives of Agriculture and Environmental Science 5, no. 3: 419-425.
32. Daffi, R. E., Chaimang, A. N., & Alfa, M. I. (2020). Environmental impact of open burning of municipal solid wastes dumps in parts of Jos Metropolis, Nigeria. Journal of Engineering Research and Reports, 12(3), 30-43.
33. Aluko, O. O., Obafemi, T. H., Obiajunwa, P. O., Obiajunwa, C. J., Obisanya, O. A., Odanye, O. H., & Odeleye, A. O. (2022). Solid waste management and health hazards associated with residence around open dumpsites in heterogeneous urban settlements in Southwest Nigeria. International Journal of Environmental Health Research, 32(6), 1313-1328.
34. Nelson, P. F. (2023). Environmental issues: emissions, pollution control, assessment, and management. In The coal handbook (pp. 31-76). Woodhead Publishing.
35. Ayejoto, D. A., Egbueri, J. C., Agbasi, J. C., Omeka, M. E., Unigwe, C. O., Nwazelibe, V. E., ... & Pande, C. B. (2023). Influence of seasonal changes on the quality of water resources in southwestern Nigeria: a review. Climate change impacts on Nigeria: environment and sustainable development, 423-447.
36. Sufiyan, I., Mohammed, K. D., Bello, I. E., & Zaharadeen, I. (2020). Impact of harmattan season on human health in Keffi, Nasarawa State, Nigeria. Matrix Science Medica, 4(2), 44-50.
37. Zhao, H. (2022). Biomass burning emission and impacts on air pollution in China. In Asian Atmospheric Pollution (pp. 335-347). Elsevier.

38. Eguiluz-Gracia, I., Mathioudakis, A. G., Bartel, S., Vijverberg, S. J., Fuertes, E., Comberiati, P., & Hoffmann, B. (2020). The need for clean air: the way air pollution and climate change affect allergic rhinitis and asthma. Allergy, 75(9), 2170-2184.
39. Xu, X., Xia, J., Gao, Y., & Zheng, W. (2020). Additional focus on particulate matter wash-off events from leaves is required: A review of studies of urban plants used to reduce airborne particulate matter pollution. Urban Forestry & Urban Greening, 48, 126559.
40. Wei, C., Wang, M., Fu, Q., Dai, C., Huang, R., & Bao, Q. (2020). Temporal characteristics of greenhouse gases (CO2 and CH4) in the megacity Shanghai, China: Association with air pollutants and meteorological conditions. Atmospheric Research, 235, 104759.
41. Croitoru, L., Chang, J. C., & Kelly, A. (2020). The cost of air pollution in Lagos. World Bank Group.
42. Ajetunmobi, D. T., & Ayanrinde, A. W. (2020). Environmental Problems due to Industrial Waste: A Study of Port-Harcourt Black Soot.
43. Chukwu, T. M. (2023). Assessment of air quality in urban settings in Nigeria: a comparison of perceptual indicators, causes and management in Abuja and Enugu (Doctoral dissertation, University of Surrey).
44. Mohammed, M. A., Bulama, K., Usman, A. A., Modu, M. A., Bukar, A. M., Lawan, A. K., & Habib, G. A. (2020). Psychosocial perception of the effects of harmattan dust on the environment and health of building occupants in Maiduguri, Nigeria. Facilities, 38(13/14), 893-912.
45. Nyakuma, B. B., Oladokun, O., Mahmoud, A. S., Adebayo, V. B., Ajibade, S. S. M., El-nafaty, A. S., & Jagun, Z. T. (2022). Urban Air Pollution and its Effects on Health, Safety and the Environment in Nigeria: A Concise Review. Petroleum & Coal, 64(3).
46. Matthews, A. A., Ee, P. L. R., & Ge, R. (2020). Developing inhaled protein therapeutics for lung diseases. Molecular biomedicine, 1(1), 11.
47. Honish, R. L. (2021). Chest and Lung Diseases. Psychology Press. In Over 55 (pp. 81-100).
48. Yadava, R. N., & Bhatt, V. (2021). Carbon monoxide: Risk assessment, environmental, and health hazard. In Hazardous Gases. Academic Press (pp. 83-96).
49. Baj, J., Karakuła-Juchnowicz, H., Teresiński, G., Buszewicz, G., Ciesielka, M., Sitarz, R., & Maciejewski, R. (2020). COVID-19: specific and non-specific clinical manifestations and symptoms: the current state of knowledge. Journal of clinical medicine, 9(6), 1753.
50. Schlesinger, R. B., & Lippmann, M. (2020). Nitrogen oxides. Environmental toxicants: human exposures and their health effects. 721-781.
51. Lee, Y. G., Lee, P. H., Choi, S. M., An, M. H., & Jang, A. S. (2021). Effects of air pollutants on airway diseases. International journal of environmental research and public health. 18(18), 9905.
52. Lasek, J. A., & Lajnert, R. (2022). On the issues of NOx as greenhouse gases: an ongoing discussion. Applied Sciences, 12(20), 10429.
53. Gao, Y., Yang, L., Chen, J. et al. (2018). "Nitro and oxy-PAHs bounded in PM2.5 and PM1.0 under different weather conditions at Mount Tai in Eastern China: sources, long-distance transport, and cancer risk assessment," Science of the Total Environment, vol. 622-623, pp. 1400–1407,
54. Uno, S., Tanaka, H., Miki, S. et al., (2011). "Bioaccumulation of nitroarenes in bivalves at Osaka Bay, Japan," Marine Pollution Bulletin, vol. 63, no. 5-12, pp. 477–481.
55. Deng, K., & Chan, W. (2017). "Development of a QuEChERS-based method for determination of carcinogenic 2-nitrofluorene and 1-nitropyrene in rice grains and vegetables: a comparative study with benzo[a]pyrene," Journal of Agricultural and Food Chemistry, vol. 65, no. 9, pp. 1992–1999.
56. Yadav, I. C., Devi, N. L., Singh, V. K., Li, J., Zhang, G. (2018). "Concentrations, sources and health risk of nitrated- and oxygenated-polycyclic aromatic hydrocarbon in urban indoor air and dust from four cities of Nepal," Science of The Total Environment, vol. 643, pp. 1013–1023.
57. Bamford, H. A., Bezabeh, D. Z., Schantz, S, Wise, S. A., Baker, J. E. (2003). "Determination and comparison of nitrated-polycyclic aromatic hydrocarbons measured in air and diesel particulate reference materials," Chemosphere, vol. 50, no. 5, pp. 575– 587.
58. Landvik, N. E., Gorria, M. V. M. et al (2007). "Effects of nitrated polycyclic aromatic hydrocarbons and diesel exhaust particle extracts on cell signalling related to apoptosis: possible implications for their mutagenic and carcinogenic effects," Toxicology, vol. 231, no. 2-3, pp. 159–174.
59. Kirouac, K. N., Basu, A. K., and Ling, H. (2013). "Replication of a carcinogenic nitropyrene DNA lesion by human Y-family DNA polymerase," Nucleic Acids Research, vol. 41, no. 3, pp. 2060– 2071.

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60. IARC, (2014). "Diesel and gasoline engine exhausts and some nitroarenes," IARC monographs on the evaluation of carcinogenic risks to humans, vol. 105, pp. 9–699.
61. Hung, Y. T., & Ashner, I. (2020). Sulfur Dioxide Emission and Mitigation. In Handbook of Environment and Waste Management: Acid Rain and Greenhouse Gas Pollution Control (pp. 627-658).
62. Wang, P., Chen, K., Zhu, S., Wang, P., & Zhang, H. (2020). Severe air pollution events not avoided by reduced anthropogenic activities during COVID-19 outbreak. Resources, Conservation and Recycling, 158, 104814.
63. Lelieveld, J., Pozzer, A., Pöschl, U., Fnais, M., Haines, A., & Münzel, T. (2020). Loss of life expectancy from air pollution compared to other risk factors: a worldwide perspective. Cardiovascular research, 116(11), 1910-1917.
64. Delgado-Saborit, J. M., Guercio, V., Gowers, A. M., Shaddick, G., Fox, N. C., & Love, S. (2021). A critical review of the epidemiological evidence of effects of air pollution on dementia, cognitive function and cognitive decline in adult population. Science of the Total Environment, 757, 143734.
65. Tham, R., & Schikowski, T. (2021). The role of traffic-related air pollution on neurodegenerative diseases in older people: an epidemiological perspective. Journal of Alzheimer's Disease, 79(3), 949-959.
66. Grande, G., Wu, J., Ljungman, P. L., Stafoggia, M., Bellander, T., & Rizzuto, D. (2021). Long-term exposure to PM 2.5 and cognitive decline: a longitudinal population-based study. Journal of Alzheimer's Disease, 80(2), 591-599.
67. Newbury, J. B., Stewart, R., Fisher, H. L., Beevers, S., Dajnak, D., Broadbent, M., & Bakolis, I. (2021). Association between air pollution exposure and mental health service use among individuals with first presentations of psychotic and mood disorders: retrospective cohort study. The British Journal of Psychiatry, 219(6), 678-685.
68. Canipari, R., De Santis, L., & Cecconi, S. (2020). Female fertility and environmental pollution. International journal of environmental research and public health, 17(23), 8802.
69. Gaskins, A. J., Minguez-Alarcon, L., Williams, P. L., Chavarro, J. E., Schwartz, J. D., Kloog, I., & EARTH Study Team. (2020). Ambient air pollution and risk of pregnancy loss among women undergoing assisted reproduction. Environmental research, 191, 110201.
70. Conway, F., Portela, A., Filippi, V., Chou, D., & Kovats, S. (2024). Climate change, air pollution and maternal and newborn health: An overview of reviews of health outcomes. Journal of Global Health, 14.
71. Brumberg, H. L., Karr, C. J., Bole, A., Ahdoot, S., Balk, S. J., Bernstein, A. S., & Trasande, L. (2021). Ambient air pollution: health hazards to children. Pediatrics, 147(6).
72. Paciência, I., Cavaleiro Rufo, J., & Moreira, A. (2022). Environmental inequality: Air pollution and asthma in children. Pediatric Allergy and Immunology, 33(6).
73. To, T., Zhu, J., Stieb, D., Gray, N., Fong, I., Pinault, L., & Dell, S. (2020). Early life exposure to air pollution and incidence of childhood asthma, allergic rhinitis and eczema. European Respiratory Journal, 55(2).
74. Abed Al Ahad, M., Demšar, U., Sullivan, F., & Kulu, H. (2022). Air pollution and individuals' mental well-being in the adult population in United Kingdom: A spatial-temporal longitudinal study and the moderating effect of ethnicity. Plos one, 17(3), e0264394.
75. Nhung, N. T. T., Schindler, C., Chau, N. Q., Hanh, P. T., Dien, T. M., Thanh, N. T. N., & Künzli, N. (2020). Exposure to air pollution and risk of hospitalization for cardiovascular diseases amongst Vietnamese adults: Case-crossover study. Science of The Total Environment, 703, 134637.
76. Hadei, M., Shahsavani, A., Krzyzanowski, M., Querol, X., Stafoggia, M., Nazari, S. S. H., & Khosravi, A. (2020). Burden of mortality attributed to PM2.5 exposures in cities of Iran; contribution of short-term pollution peaks. Atmospheric Environment, 224, 117365.
77. Yin, P., Brauer, M., Cohen, A. J., Wang, H., Li, J., Burnett, R. T., ... & Murray, C. J. (2020). The effect of air pollution on deaths, disease burden, and life expectancy across China and its provinces, 1990–2017: an analysis for the Global Burden of Disease Study 2017. The Lancet Planetary Health, 4(9), e386-e398.