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Air Quality Monitoring in Nigeria's Urban Areas: Effectiveness and Challenges in Reducing Public Health Risks

Simeon Ayo-Oluwa Ajayi ^{1*}, Olayemi Oluwatosin Akanji ²

¹ Simeon Ayo-Oluwa Ajayi and ¹Olayemi Oluwatosin Akanji, Nigeria

² Department of Medicine and Surgery, College of Health Sciences, Bowen University, Iwo, Osun State, Nigeria

* Corresponding Author: **Simeon Ayo-Oluwa Ajayi**

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Abstract

This study focuses on evaluating air quality monitoring systems and their effectiveness in reducing public health risks associated with air pollution in the Nigerian context. It focuses on critical urban areas such as Lagos, Abuja, and Port Harcourt which are heavily populated, industrially developed, and have high motor vehicle emissions. The goal is to evaluate the impact of air quality monitoring on public health and inform policy actions. The data was obtained through a systematic review of literature between 2016-2022 which includes government and environmental agency reports, peer-reviewed articles, and case studies. The paper discusses the limited availability of monitoring systems in urban areas of Nigeria, but also highlights the progress made in Lagos which has led to improved health outcomes, including decreased respiratory disease prevalence. On the other hand, gaps in infrastructure, inconsistent monitoring, and lax enforcement pose barriers. The recommendations include the construction of additional automated monitoring stations, the use of mobile units and satellite data, real-time air quality data dissemination to the public, and better enforcement of regulations. The study concludes that, while monitoring is insufficient in Nigeria, it has been effective in reducing air pollution and public health risks in certain metropolitan regions.

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1. Introduction

Monitoring air quality is one of the major components of environmental management, especially in urban areas where population growth, industrialisation, and heavy traffic all have a cumulative effect on the existing pollution level (Croitoru *et al.*, 2020; WHO, 2018) ^[6]. The need to control pollutants such as particulate matter (PM_{2.5} and PM₁₀), nitrogen oxides (NO_x), sulfur dioxide (SO₂), ozone (O₃), and carbon monoxide (CO) is significant, as they are associated with a range of public health issues (Sulaymon *et al.*, 2019; Croitoru *et al.*, 2020; Newell *et al.*, 2017; Manisalidis *et al.*, 2020) ^[6, 14, 12, 11]. Sulaymon *et al.* (2019) ^[14] highlighted that urban centers in Nigeria, including Lagos, Abuja, and Port Harcourt, are particularly susceptible to these issues because of rampant urbanisation coupled with a high concentration of industrial activity, heavy traffic, and informal housing. These cities and their populations in the millions are constantly struggling with air pollution and its severe health consequences. In urban Nigerian areas with the highest air pollution, public health risks are enormous. Estimates from the World Health Organization (WHO, 2020) suggest that air pollution is claiming 120,000 lives prematurely each year in Nigeria, most of which are in urban areas. There is a progressive accumulation of adverse health effects over time due to polluted air in the form of respiratory diseases like asthma, bronchitis, and pneumonia, cardiovascular diseases, and even lung cancer. Children, the elderly, and individuals with pre-existing health conditions tend to suffer the most (Manisalidis *et al.*, 2020) ^[11]. Furthermore, the quality of air compounds negative public health issues in Nigeria where the healthcare system often remains strained and incapable of

treating the ever-growing need for healthcare services relating to pollution-diseases.



Source: BBC News, 2017.

Fig 1: Pupil going to school amidst thick black soot in PortHarcourt



Source: BBC News, 2017

Fig 2: Ambient Air Pollution in Lagos

To address this growing concern, Nigeria has made attempts to install air quality monitoring systems in some of the more developed cities, particularly in Lagos and Abuja. The Lagos State Environmental Protection Agency (LASEPA) has put in place several monitoring stations which record air quality data across the city. This data is available through reports and other public channels. Similarly, the Nigerian National Environmental Standards and Regulations Enforcement Agency (NESREA) has been given the mandate to monitor the air quality of the country as a whole. Despite this progress, however, the effectiveness and coverage of the monitoring systems aimed at measuring air quality in Nigeria remain scant (Mahmud *et al.*, 2022)^[10]. Many Nigerian cities are facing a dearth of monitoring stations, especially in the peripheral areas, and the data that is fetched is often substandard and not released to the public in real time. As a result of the lack of an all-encompassing legal structure together with the absence of an enforcement framework, it enables industries and cars to discharge emissions far above legal limits without any repercussions (Fovwe & Alamiokuma, 2020)^[30].

Although air quality monitoring systems in Nigeria have helped in some way to raise awareness and provide some data, there is still a gap in understanding how they can reduce public health risks. The existence of technology does not guarantee the effectiveness of these systems; rather, the way data informs policy has a more decisive impact. Without robust data analysis, targeted intervention such as improving public transport, stricter regulations on wasteful industries, and enhanced waste management systems will not happen, and thus the monitoring will be ineffective (Alvarez *et al.*, 2020)^[3]. Poor coordination of a national strategy also

contributes to poor quality management and renders the monitoring systems futile.

This paper seeks to systematically review the current state of air quality monitoring in Nigeria's urban areas, evaluate existing monitoring systems, and assess their effectiveness in public health risk mitigation in urban settings in Nigeria. It analyses possible impediments to their effectiveness. In addition, this paper evaluates putative actions taken toward public health risk mitigation pertaining to air pollution, suggesting system enhancements for policy and infrastructure adjustments. By offering a thorough analysis of air monitoring in Nigeria's urban areas, this study aims to support the creation of better air quality control strategies in Nigerian urban cities, eventually reducing public health risks and advancing environmental sustainability.

Air quality monitoring systems in Nigeria

Indicators of pollution and its health implications can be mitigated through effective air monitoring (Mahmud *et al.*, 2022; Manisalidis *et al.*, 2020)^[10, 11]. Air quality monitoring aids governments worldwide in keeping track of pollution levels within particular regions as well as in determining the sources of pollution, monitoring air pollution, and putting in place measures to deal with it. WHO and EPA set the standards for air quality and public health, on the other hand. For example, the World Health Organization has set permissible limits for air pollutants known as particulates with smaller diameters such as PM_{2.5} and PM₁₀, nitrogen oxides (NO_x), sulfur dioxide (SO₂), and carbon monoxide (CO) because it affects human health on the ground, causing severe health problems such as asthma, heart diseases and even lung cancer (WHO, 2020; Valasco & Jarosińska, 2022)^[15]. Many developed countries have accepted the Global standards, however, in Nigeria's urban cities like Lagos, Abuja, and Port Harcourt, implementing these standards remains a challenge because their infrastructure and resources are not up to par when it comes to air quality monitoring.

Monitoring of air quality has commenced in several metropolitan areas of Nigeria, however, these systems are often rudimentary and non-functional (Abulude *et al.*, 2022)^[1]. A major concern for available air quality management resources is in Lagos: with a population of over 24 million inhabitants projected for 2019 (City Population, 2019), traffic jams as well as industrial emissions would make matters worse. Lagos State Environmental Protection Agency (LASEPA) was the first to initiate air quality management for the state. LASEPA maintains a number of stationary monitoring stations located all over the city, measuring concentrations of PM_{2.5}, PM₁₀, sulfur dioxide, nitrogen oxides, and ozone (O₃) (Sulaymon *et al.*, 2019)^[14]. Monitoring stations focus on the central and industrial parts of the city; however, there are huge gaps in coverage in the suburbs and informal areas, where pollution from unregulated activities might be much higher. Indeed, air pollution in Lagos is outraging the limits set by the World Health Organization. The researchers claim that PM_{2.5} concentrations frequently reach 180 µg/m³, with the WHO recommending 25 µg/m³ (Mahmud *et al.*, 2022; Valasco & Jarosińska, 2022)^[10, 15].

Likewise, the air quality in Abuja, the capital city, has been attempted to be managed. The Nigerian National Environmental Standards and Regulations Enforcement

Agency (NESREA) is the primary monitor of the environmental health of the entire country and have attempted to manage the air quality in Abuja, the Federal Capital Territory and some other areas of the Federation. However, the system for monitoring air quality in Abuja is not as advanced as that of Lagos, and it can be said that the monitoring system is still at the developing stage (Sulaymon *et al.*, 2019; Mahmud *et al.*, 2022)^[14, 10]. Governmental and NESREA's attempts to monitor the air pollutants in this post-industrial city have not yielded sufficient results (Yakubu, 2017). Without these stations, there is no way to track air quality reliably, painting an inaccurate overall picture of it.

Modern techniques for air quality monitoring

In Nigeria, the technological approaches to air quality monitoring include the use of air monitoring stations, mobile air quality units, and the growing interest for satellite monitoring (Abulude *et al.*, 2022)^[1]. Stationary monitoring units such as the LASEPA ones in Lagos are more or less permanent and measure pollution for a defined interval. Such stations are data rich and are useful for collecting information on pollution levels, but they have the limitation of being placed only in the developed parts of the city. Therefore, they are not able to capture the pollution levels within informal settlements and highly populated areas.

Mobile air quality units are more useful for flexible monitoring. The mobile units can be placed on vehicles or trailers and driven around the city for real time measurements of pollution levels. This has been made possible by sponsorship from the Clean Air Initiative, which is a Public Private Partnership of the Federal Government of Nigeria (Clean Air Fund, 2022). These units can also be sent to places with no or poor infrastructure and densely populated areas, which helps to improve the representation of the city's air quality.

Nigeria is one of the developing countries that the National Aeronautics and Space Administration (NASA) and the European Space Agency are working toward providing satellite-based monitoring systems for air quality management (Mahmud *et al.*, 2022; RSB Environmental, n.d.)^[10]. Unlike the satellite-based monitoring, ground monitoring of these developing countries air quality is rarely done. This gap in monitoring is being supported by international organizations. Real-time data on a larger scale could be made possible by satellite sensors measuring the air pollutants within wide urban and even rural areas. Their use is not common yet, but international organizations already have explored them. Abulude *et al.* (2022)^[1] confirms that such technology has not been put to practice in Nigeria yet, but the potential use to monitor air pollution in the cities is remarkable.

Government and non-government initiatives

Both government and nongovernmental organizations (NGOs) are working to enhance air quality monitoring in some of the urban cities in Nigeria. NESREA, Nigeria's federal agency responsible for regulating environmental standards, actively develops and supervises the implementation of air quality standards, as well as their monitoring in Nigeria. NESREA has established the National Environmental Air Quality Standards, which contain emissions limits for some air pollutants, and routinely carries out air quality monitoring in selected areas (Federal Ministry of Environment, 2020). Nevertheless, the agency is facing

one of its most challenging times as there is little funding, poor infrastructure, and scant manpower for monitoring and, as a result, measuring, air quality across the country.

At the subnational level, in Lagos, LASEPA is one of the most active agencies in carrying out monitoring of the air quality, but it encounters serious obstacles such as a lack of spatial data infrastructure and data-sharing policies as well as fragmentation of collaborations with other state and federal institutions (Croitoru *et al.*, 2020)^[6]. Other local councils and state-level agencies from other regions like Port Harcourt have been trying to implement some air pollution control and monitoring projects. These are mostly one-off initiatives and are rarely sustained over time.

Initiatives from the private sector and NGOs have also proven useful in assisting government efforts. NEST, an environmental NGO in Nigeria, and other organizations have contributed significantly towards the raising of air quality concerns in the country and better practices of monitoring. NEST has worked with the government of Nigeria and other international organizations to enhance environmental management and air quality monitoring (Agunbiade *et al.*, 2021; Conservation Allies, 2020)^[17, 26]. In addition, global agencies like the United Nations Environment Programme (UNEP) and the World Bank have offered their technical assistance, financing, and specialised services to Nigeria in the construction of air quality monitoring systems. With the Nigerian government working alongside private corporations within the framework of the Clean Air Initiative, mobile monitoring units have been installed in Lagos and other cities to provide real-time data on pollution levels. Remote monitoring capabilities have been acquired through the initiative (Agunbiade *et al.*, 2021)^[17].

In light of the critical air quality problems confronting cities in Nigeria, there is an immediate necessity to strengthen the quality of the existing air quality monitoring network on a national scale. This could be done by improving the networks already in place in Lagos, Abuja, and Port Harcourt, increasing the number of mobile units, and adding a satellite monitoring component to the network infrastructure. Furthermore, enhanced participation from international bodies and private enterprises could further improve the ability of Nigerian cities to control and supervise air quality.

Public health risks associated with inadequate air quality monitoring in urban areas

Manisalidis *et al.* (2020)^[11] attribute industrial processes, vehicle traffic, and overpopulation as causes of excessive emissions of dangerous pollutants such as particulate matter PM_{2.5}, PM₁₀, nitrogen oxides NO_x, and sulfur dioxide SO₂. Ajetunmobi and Ayanrinde (2020)^[2] reported that the existing air quality monitoring systems in Nigerian cities are limited and poorly distributed. This lack exacerbates the public health dangers associated with these pollutants. A lack of credible information about pollution is troubling for citizens as it puts them at increased risk. This discusses the critical public health problems stemming from lack or irregular monitoring of air quality in Nigerian urban cities. The public health risks include:

- **Respiratory Illnesses:** Respiratory diseases such as asthma, bronchitis, and chronic obstructive pulmonary disorder are primarily attributed to air pollution (Newwill *et al.*, 2017). City dwellers in Nigeria, particularly Abuja, Lagos, and Port Harcourt face dangerously high concentrations of particulate matter and other pollutants,

which sharpens the increase of these diseases especially in sensitive groups like children. Asthma is more prevalent in children residing in industrial and high traffic areas of Lagos compared to those living in less polluted areas, Akinyemi and Muhammed (2022) [22] remark. In support of this, the Lagos State Ministry of Health recorded a rise in hospitalisation due to asthma and other associated respiratory ailments (Akpokodje *et al.*, 2022) [18]. Nigeria has some monitoring systems for air quality, for instance, those put in place by NESREA as well as the Lagos State Ministry of Environment. However, the effectiveness and scope of these monitoring systems is still limited. Consequently, a vast majority of Nigerians remain uninformed of the air quality challenges that compromise their health (Edwards *et al.*, 2018; Imran *et al.*, 2019) [7, 8]. The full range of the effects on respiratory health in the environments with minimal such surveillance, as it is in Nigeria, is often significantly underestimated.

- **Cardiovascular Diseases:** The development of cardiovascular disease such as hypertension, heart attack and stroke has been associated with exposure to fine particulate matter, (PM_{2.5}), as well as nitrogen oxides (NO_x) pollutants (Bede-Ojimadu & Orisakwe, 2020; Amegah & Agyei-Mensah, 2016) [5, 4]. These pollutants particularly cause inflammation in the blood vessels and promote arteriosclerosis. In Lagos and other Nigerian urban cities, air pollution markedly contributes to the increasing burden of cardiovascular disease. Akinyemi and Muhammed (2022) [22] showed increased prevalence of hypertension and heart disease among residents living adjacent to major highways and industrial areas in Lagos. On the international level, the American Heart Association attributes approximately 16% of the mortality from cardiovascular disease to air pollution (Lelieveld *et al.*, 2019; Manisalidis, 2020) [9, 11]. Nigeria has some relatively basic air quality monitoring systems, like those operated by NESREA, but these systems do not provide comprehensive information on pollution in urban areas. This lack of monitoring impedes the evaluation of the impact of air pollution on cardiovascular health, hindering public health efforts.
- **Premature Mortality:** Air pollution increases long-term mortality associated with chronic conditions such as respiratory and cardiovascular diseases (Akinyemi & Muhammed, 2022) [22]. As noted by the WHO, air pollution accounts for over 120,000 premature deaths each year in Nigeria, with urban epicenters like Lagos and Port Harcourt suffering the most. (WHO, 2020) These figures, however, could be an underestimate because the monitoring systems for air quality are not extensive. The lack of more comprehensive monitoring data makes it difficult to track the full scale of mortality linked to air pollution in Nigerian cities.

Methodology

This study employed a systematic review approach to air quality monitoring within Nigeria's urban areas to assess its effectiveness in reducing public health risks. The review concentrated efforts on reputable sources to collect data, including peer-reviewed journals, governmental and intergovernmental agency publications, and environmental reports. Major data repositories and databases such as Google Scholar, PubMed, JSTOR, Lancet, as well as institutional

repositories were utilised for compiling the studies. The selection criteria centred on studies published from 2016 to 2022 that specifically concentrated on air quality monitoring in heavily industrialised and overpopulated areas. For that purpose, the terms "air quality monitoring" and "public health" were utilised as keywords.

Alongside the literature review, a case study was adopted to analyse the effectiveness of air quality monitoring in improving public health outcomes in Lagos and Port Harcourt. The case study was informed by other independent studies and reports from environmental agencies, including the Lagos State Environmental Protection Agency (LASEPA) and the Nigerian Environmental Standards and Regulatory Agency (NESREA).

Effectiveness of air quality monitoring in reducing health risks

The effectiveness of air quality monitoring systems lies in alleviating the health impacts of pollution, especially for urban populations. For the cities of Lagos, Abuja, and Port Harcourt, air quality monitoring offers valuable information that assists in pinpointing pollution hotspots, informing relevant policies, and framing appropriate measures for public health (Sulaymon *et al.*, 2019; Noah *et al.*, 2022) [14, 13]. Even though the effectiveness of monitoring in health risk reduction is still a work in progress, some positive results are surfacing where effective monitoring has been done. This chapter discusses the relationship between air quality monitoring and public health in Nigerian cities, the influence of public health policies and monitoring data on health interventions, and presents case studies of health outcomes showing in depth evaluation of health changes.

Connection between monitoring and public health outcomes

Air quality monitoring is critical in determining the levels of harmful pollutants in the environment as well as the impact on public health. In a city like Lagos, where air pollution is of paramount concern, the establishment of air quality monitoring systems has resulted in some positive changes. The assessment of air quality has aided the determination of some of the hotspots for high concentrations of PM_{2.5} and nitrogen oxides (NO_x) which are associated with respiratory and cardiovascular diseases (Lelieveld *et al.*, 2019) [9]. Lagos State's Ministry of Environment is for instance documenting frequent exceeding of the international health benchmarks for air pollution in some of the industrial zones as a public health concern. While there are gaps in the comprehensive air quality monitoring system in the country, activities in major urban areas have so far aided focused interventions.

For example, the monitoring activities conducted by the Nigerian Environmental Standards and Regulatory Agency (NESREA) and Lagos State Ministry of Environment have led to public awareness campaigns aimed at informing residents of the health effects of air pollution. These interventions have been associated with a declining trend in some health problems, especially chronic respiratory diseases such as asthma, in the populations living near high pollution areas.

Public health policy and interventions

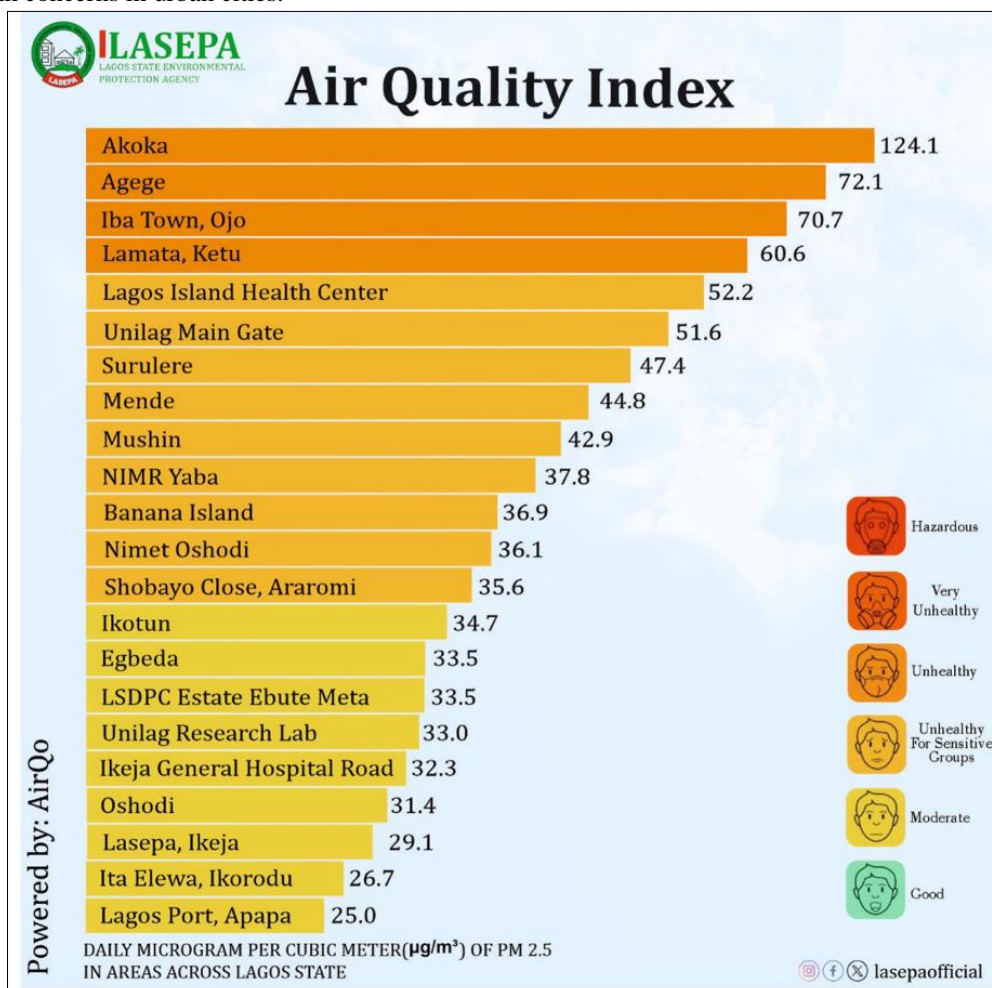
Public health policies in Lagos has been influenced significantly by the availability of air quality data. Monitoring air quality and its relation to traffic provided the

basis for the city's traffic management policies. Lagos went on to restrict commercial vehicles from driving into peak traffic areas during peak hours in 2019 to reduce congestion and emission (Akinyemi & Muhammed, 2022) [22]. Akinyemi and Muhammed (2022) [22] state that emissions decreased 10-15% as a result of this policy change. Such improvements in pollution levels positively impact public health by reducing the prevalence of respiratory diseases such as asthma and bronchitis.

Furthermore, the Federal Government of Nigeria has used air quality data for policy making to directly control emissions from industries. The NESREA air quality reports showing increased concentration of pollutants around the industrial area in Port Harcourt led to more stringent policies on emissions from oil refineries and cement manufacturers. These regulatory measures are still being enforced today, but they are a significant advancement toward better air quality and related health concerns in urban cities.

Case studies of measurable health improvements

In some urban cities in Nigeria with instituted air quality monitoring systems, there are examples of measurable improvements in public health. One example is Lagos, where monitoring data collected in 2017 showed the Apapa area was heavily polluted due to industrial emissions and port traffic. In response to the problem, the Lagos State Government initiated programs aimed at reducing industrial emissions in the region and improving traffic management. This led to a noticeable improvement in the respiratory health complaints of the residents. According to a report by the Lagos State Health Service in 2019, there was a 20% decrease in hospital admissions for asthma in Apapa after the measures were introduced.



Source: LASEPA

Fig 3: Apapa Area Sees Reduction in Air Quality Index after Air Monitoring informed Policy Intervention.

Another case is Port Harcourt, where NESREA's air quality checking unveiled significant pollution from oil and gas industry activities. This prompted the federal government of Nigeria and the state authorities to cooperate with Environmental Non-Governmental Organizations (NGOs) to control emission levels more stringently. As a consequence, preliminary reports showed a reduction in the level of pollution and improvement in the respiratory health indicators like chronic obstructive pulmonary disease (COPD). Although these initial observations are

encouraging, further in-depth investigations are essential to definitively conclude that regulated monitoring efforts can substantially mitigate air pollution and its associated health burdens.

Monitoring air quality in Nigerian cities has resulted in improvements in some health indicators, achieving better health outcomes due to intervention policies aimed at raising public awareness and adjusting environmental policies. Case studies from Lagos and Port Harcourt demonstrate that there is a need for effective use of air quality data to initiate health

improvement actions through environmental policy and health intervention planning. Without a doubt, extending monitoring efforts throughout all urban areas is critical in fulfilling the enhanced protective health policies, yet the existing initiatives suggest that air quality monitoring can effectively reduce health risks associated with air pollution.

Challenges of air quality monitoring in Nigeria

- **Limited coverage in urban areas:** Air quality monitoring in Nigeria only covers a few major urban centres such as Lagos, Abuja, and Port Harcourt, while other urban areas, especially those with industrial activities, remain poorly monitored. For instance, Abeokuta, Ogun State, which hosts two cement factory along with other industries, has very little air quality infrastructure. For such areas, this monitoring gap has the potential of creating dangerous information voids about pollution levels in rapidly industrialising urban areas with heavy population densities.
- **Inconsistent data collection and reporting:** One of the monitoring air quality challenges is the inconsistency of data collection. Many monitoring stations contend with irregular maintenance, technical failures, and lack of resources, leading to unreliable or missing data (Abulude *et al.*, 2022)^[1]. This issue makes it significantly more difficult to forecast and track long-term pollution trends and pose public health risks in relation to the ever-invasive air pollution problem.
- **Insufficient technological infrastructure:** Several Nigerian cities suffer from a lack of modern and active surveillance technologies. While some areas utilise stationary sensors, the gaps in the monitoring network coverage do not adequately represent the pollution levels across different industrial and residential zones. There is also insufficiency of mobile air quality units, which could be useful for evaluating air quality in highly populated regions.
- **Lack of public access to data:** The associated information of the air quality is not easily accessible to the wider public. In most instances, monitored data is retained within government departments or is not made accessible to the general public which creates a gap in public knowledge regarding the air quality and pollution levels. This data gap creates significant challenges because members of the public do not have access to timely information that enables them to evade areas with dangerous air quality conditions.
- **Inadequate enforcement of regulations:** Even in the case where a monitoring system is operational, there are gaps concerning the implementation of the strategies based on the gathered data (Mahmud *et al.*, 2022)^[10]. Certain industries, as well as the transportation hubs, situated in polluted areas, continue dominant service delivery without compliance to the pollution control requirements, stagnating emission reductions and adversely the public health.
- **Systemic Issues:** In Nigeria, underfunding, shifts in priorities of the government, and bribery top the list of systemic challenges to proficient air quality monitoring. Although some initiatives exist, they suffer from a lack of funding for equipment maintenance and network expansion. In addition, some air quality monitoring efforts are inefficient as they are not given priority due to other political or economic considerations (Abulude *et*

al., 2022)^[1]. Corruption further exacerbates the issues by contributing to the environmental governance deficit where funds earmarked for environmental monitoring are partially allocated. These issues distort reality and obstruct the establishment of effective comprehensive monitoring systems that accurately assess the impacts of the policies to safeguard public health.

Conclusion

In the case of Nigeria, the public health benefits, alongside the pollution management aspects, make air quality monitoring in urban regions particularly important. Although the current air quality monitoring system is not comprehensive or resilient enough to meet the evolving challenges, attempts of monitoring in places like Lagos have proven effective. These initial efforts have not only stimulated broader awareness but also catalysed significant policy shifts, including the imposed restrictions on vehicular traffic and enhanced emissions control, which have resulted in improved public health. However, these efforts are still minimal in scope and require considerable expansion, both conceptually and in practice, to other industrial metropolitan areas for more comprehensive data collection and effective health interventions. The overall infrastructure for conducting air quality monitoring in Nigeria is still inadequate, with extensive gaps in coverage and weak enforcement. These efforts would significantly enhance the understanding of pollution levels, which would in turn, contribute to improving air quality and reducing public health risks in urban areas in the nation.

Recommendations and future directions in air quality monitoring in Nigeria's urban areas

- **Improvement of monitoring systems:** For effective tracking and air quality evaluation, Nigeria ought to increase the number of monitoring stations, especially in urban and industrialized regions. There is high pollution from industrial activities and traffic in Lagos and Port Harcourt, which result in significant health problems such as respiratory and cardiovascular diseases. Increased monitoring networks, especially in heavy-polluted areas like Apapa, can help provide real-time information and tracking of PM_{2.5} and NO_x emissions. Such information is vital for assessing the health risks and planning appropriate public health responses.
- **Deployment of mobile monitoring units:** Including mobile air quality units into the overall strategy can enhance data collection in dense urban areas suffering from heavy traffic. For example, during the Clean Air Initiative in Lagos, mobile units were disseminated to monitor pollution where there was little or no stationary monitoring, and they proved to be useful. These units allow for greater flexibility and responsiveness to the demand for monitoring within the air quality management system since their results can be transmitted instantly to dictate emergency public health measures required to alleviate public health risks associated with pollution surges.
- **Integration of satellite monitoring:** NASA and some other international agencies have professionally implemented satellite-based air quality monitoring. This technology can greatly aid in the enhancement of air quality data collection in Nigeria by supplementing ground based systems. For instance, in places like Abuja

where there are limited ground stations, satellite data can address significant gaps. This improvement in monitoring air pollution will provide an opportunity for trend identification and risk assessment, which can in turn be used to formulate policies designed to avert public health concerns resulting from air pollution.

- **Public access to air quality data and media engagement:** Real-time air quality data accessibility contributes to the active protection of people's health with respect to pollution. The air quality index (AQI) system, which is also employed in India, provides real-time updates on the level of pollution to the residents and it could similarly be adopted by Nigeria. With the application of such systems alongside media awareness, Nigeria will be able to mitigate the health impacts associated with air pollution. Once informed, the public can take preemptive actions, such as minimising outdoor activities when pollution levels are high. Such measures foster transparency and responsibility wherein locals and industries are socially obliged to reduce emission thus improving general public health.
- **Stricter emission standards for industries and transport:** Reducing pollution in these sectors is critical in minimising the public health threat that will persist over time. Pollution from the oil and gas industry in Port Harcourt is now known to be a factor in the development of respiratory and cardiovascular conditions. Better enforcement of emission standards with the aid of regular inspections and fines for failure to comply will significantly mitigate the damage of pollution. Furthermore, cleaner technologies in industry and transport should be adopted to lower pollution and improve public health by reducing harmful exposure.
- **Collaboration with international organizations:** International collaboration with agencies, such as the United Nations Environment Programme (UNEP), and the World Bank, greatly improves the air quality monitoring systems in Nigeria. Often, these experts bring along funds which are useful in the expansion of monitoring networks and the overall precision of pollution data. Proper use of these collaborations enables Nigerian urban cities to install advanced air quality monitoring systems which are necessary for detecting health risks and planning targeted protective health measures aimed at air pollution vulnerable population.
- **Increased funding and legislative oversight:** The Nigerian government should prioritise increasing funding and expenditure for air quality monitoring infrastructure. Agencies like NESREA requires adequate funding to maintain and further expand their monitoring networks. Also, stricter oversight of air quality monitoring systems in Nigeria, especially from the upper chamber of legislature, the Nigerian Senate, is necessary to ensure that funding, when provided, is relevant and spent appropriately to achieve desired air quality monitoring system implementations. These measures will address fundamental issues such as lack of funding and corruption will enhance the realisation of air quality monitoring systems with robust data collection responding to informed health policies where policies reduces risk factors to public health. Legislative oversight will guarantee that air quality degradation response programmes are not lost to short-sighted political or economic interests guaranteeing the residents

long term health advantages.

References

1. Abulude FO, Acha S, Arifalo KM, Akinnusotu A, Dare Oluwagb SD, Al Shoumik BA, *et al.* Monitoring of air quality with satellite-based sensor: The case of four towns in Southeast, Nigeria. *ASEAN J Sci Eng.* 2022;3(1):39–46. Available from: https://www.researchgate.net/publication/359109076_Monitoring_of_air_quality_with_satellite-based_sensor_The_case_of_four_towns_in_Southeast_Nigeria
2. Ajetunmobi DT, Ayanrinde AW. Environmental problems due to industrial waste: A study of Port-Harcourt black soot. *RSIS Int.* 2020;549–51. Available from: https://scholar.google.com/citations?view_op=view_citation&hl=en&user=BnpDAYgAAAAJ&citation_fo_r_view=BnpDAYgAAAAJ:08ZZubdj9fEC
3. Alvarez CM, Hourcade R, Lefebvre B, Pilot E. A scoping review on air quality monitoring, policy and health in West African cities. *Int J Environ Res Public Health.* 2020;17(23):9151. <https://doi.org/10.3390/ijerph17239151>
4. Amegah AK, Agyei-Mensah S. Urban air pollution in Sub-Saharan Africa: Time for action. *Environ Pollut.* 2016;220:738–43. <https://doi.org/10.1016/j.envpol.2016.09.042>
5. Bede-Ojimadu O, Orisakwe OE. Exposure to wood smoke and associated health effects in Sub-Saharan Africa: A systematic review. *Ann Glob Health.* 2020;86:32.
6. Croitoru L, Chang JC, Akpokodje J. The health cost of ambient air pollution in Lagos. *J Environ Prot.* 2020;11(09):753–65. <https://doi.org/10.4236/jep.2020.119046>
7. Edwards Q, Mallhi AK, Zhang J. The association between advanced maternal age at delivery and childhood obesity. *J Hum Biol.* 2018;30(6):e23143.
8. Imran S, Patel RS, Onyeaka HK, Tahir M, Madireddy S, Mainali P, *et al.* Comorbid depression and psychosis in Parkinson's disease: A report of 62,783 hospitalizations in the United States. *Cureus.* 2019;11(7).
9. Lelieveld J, Klingmüller K, Pozzer A, Pöschl U, Fnais M, Daiber A, *et al.* Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions. *Eur Heart J.* 2019;40(20):1590–6. <https://doi.org/10.1093/eurheartj/ehz135>
10. Mahmud K, Mitra B, Uddin MS, Hridoy AE, Aina YA, Abubakar IR, *et al.* Temporal assessment of air quality in major cities in Nigeria using satellite data. *Atmos Environ X.* 2022;20:100227. <https://doi.org/10.1016/j.aeoa.2023.100227>
11. Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: A review. *Front Public Health.* 2020;8. <https://doi.org/10.3389/fpubh.2020.00014>
12. Newell K, Kartsonaki C, Lam KBH, Kurmi OP. Cardiorespiratory health effects of particulate ambient air pollution exposure in low-income and middle-income countries: A systematic review and meta-analysis. *Lancet Planet Health.* 2017;1:e368–80.
13. Noah GU. Interdisciplinary strategies for integrating oral

- health in national immune and inflammatory disease control programs. *Int J Comput Appl Technol Res.* 2022;11(12):483–98.
14. Sulaymon ID, Mei X, Yang S, Chen S, Zhang Y, Hopke PK, *et al.* PM_{2.5} in Abuja, Nigeria: Chemical characterization, source apportionment, temporal variations, transport pathways and the health risks assessment. *Atmos Res.* 2019;237:104833. <https://doi.org/10.1016/j.atmosres.2019.104833>
 15. Velasco RP, Jarosińska D. Update of the WHO global air quality guidelines: Systematic reviews – An introduction. *Environ Int.* 2022;170:107556. <https://doi.org/10.1016/j.envint.2022.107556>
 16. Yakubu O. Particle (SOOT) pollution in Port Harcourt Rivers State, Nigeria—Double air pollution burden? Understanding and tackling potential environmental public health impacts. *Environments.* 2017;5(1):2. <https://doi.org/10.3390/environments5010002>
 17. Agunbiade ME, Olajide O, Bishi H. Urban governance and smart future cities in Nigeria: Lagos flagship projects as springboard? *African Minds eBooks;* 2021. https://doi.org/10.47622/9781928502159_10
 18. Akpokodje J, Weaver C, Fagbeja M, Forastiere F, Spadaro J, Johnson TM, *et al.* Air quality management planning for Lagos State. *World Bank;* 2022. Available from: <https://documents1.worldbank.org/curated/en/099720110142219998/pdf/P1644150e07f52021086e9055e237327ee.pdf>
 19. Federal Ministry of Environment. National environmental standards for air quality. 2020. Available from: <http://www.environment.gov.ng> [Accessed 17 Apr 2022].
 20. Federal Ministry of Environment. National Environmental Standards for Air Quality. 2021. Available from: <https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standards-for-air-quality/> [Accessed 13 Mar 2022].
 21. World Health Organization. Ambient air pollution: A global assessment of exposure and burden of disease. Geneva: WHO; 2020.
 22. Akinyemi M, Muhammed M. The cost of Lagos' poor air quality on lives and properties. *HumAngle.* 2022 Jan 28. Available from: <https://humanglemedia.com/the-cost-of-lagos-poor-air-quality-on-lives-and-properties/> [Accessed 20 Mar 2022].
 23. BBC News. Nigeria's Port Harcourt covered in mystery cloud of soot. 2017 Mar 4. Available from: <https://www.bbc.com/news/world-africa-39040868>
 24. City Population. Lagos State, Nigeria - population statistics, charts, map and location. 2019. Available from: <https://citypopulation.de/en/nigeria/metrolagos/> [Accessed 20 Mar 2022].
 25. Clean Air Fund. Lagos and air pollution. 2022. Available from: <https://www.cleanairfund.org/clean-air-african-cities/lagos/> [Accessed 17 Apr 2022].
 26. Conservation Allies. Nigerian Environmental Study Action Team (NEST) - Conservation Allies. 2020 Mar 26.
 27. LASEPA. Air Quality Index. Nigeria air pollution: Real-time Air Quality Index (AQI). Available from: <https://aqicn.org/station/@418324/> [Accessed 19 Mar 2022].
 28. RSB Environmental. Air quality measured: Methods and techniques explained. Available from: <https://rsbenv.com/how-is-air-quality-measured>
 29. UN Environment Programme (UNEP). Actions on Air Quality: A global summary of policies and programmes to reduce air pollution. 2021. Available from: <https://www.unep.org/resources/report/actions-air-quality-global-summary-policies-and-programmes-reduce-air-pollution> [Accessed 16 Apr 2022].
 30. Fovwe DF, Alamiokuma GI. Pollution Bloom: An appraisal of the hazardous effects of mining of precious stones in Zamfara State. 2020. Available from: <https://ideas.repec.org/a/zib/zbngr/v4y2020i1p35-41.html>
 31. NASREA. National Environmental (Air Quality Control) Regulations, 2020. Available from: [Nested.gov.ng](http://www.nasrea.gov.ng)