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An Assessment of the Impact of Poor Indoor Air Quality on Public Health in Nigerian Urban Environments; Case Study of FCT, Abuja

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Abstract: Poor indoor air quality (P-IAQ) poses significant challenges to public health, environmental sustainability, and socio-economic development, particularly in urban areas of developing countries. This issue aligns with the United Nations Sustainable Development Goal (SDG) 3 (Good Health and Well-being) and intersects with other SDGs. Despite the urgency of the problem, research exploring the interplay between urban air pollution, PIAQ, and health outcomes in healthcare settings remains limited. This study conducts a systematic literature review (SLR) of peer-reviewed articles published between 2020 and 2024 across major databases, including PubMed, Scopus, ScienceDirect, and Web of Science. It examines the impacts of P-IAQ on health outcomes in urban healthcare facilities in Nigeria, focusing on indoor environmental quality (IEQ) factors such as ventilation, thermal comfort, and air quality. The review identifies that improved indoor air quality significantly enhances patient recovery rates, reduces stress, shortens hospital stays, and boosts the performance of healthcare staff. The study further explores the disparities in health outcomes between purpose-built and retrofitted healthcare facilities, highlighting the combined effects of urban air pollution and IAQ dynamics. Based on these findings, an evidence-informed conceptual framework is proposed, integrating urban air pollution sources, IAQ determinants, and health outcomes. The framework also outlines actionable mitigation strategies, emphasizing the role of building design and urban policies in enhancing IAQ standards in healthcare facilities. The insights from this research provide a critical foundation for advancing sustainable building practices and informed policymaking aimed at mitigating P-IAQ and improving health outcomes in urban environments.

Keywords: Systematic Literature Review (SLR), Indoor Air Quality (IAQ), Public Health, Urban Air Pollution, Healthcare Facilities, Mitigation Strategies.

I. Introduction

The World Health Organization (WHO) defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 2024). Recognizing the rapid pace of urbanization globally, the WHO has emphasized the importance of "healthy housing," which prioritizes indoor air quality (IAQ) as a critical determinant of well-being (WHO, 2020). Poor indoor air quality (PIAQ) significantly contributes to adverse health outcomes, particularly in urban environments, where industrialization, transportation, and inadequate waste management practices exacerbate the problem. These challenges are especially pronounced in developing countries, including Nigeria, where urban air pollution and substandard IAQ collectively threaten public health.

Air pollution, both indoor and outdoor, is a major global concern. The WHO estimates that fine particulate matter (PM2.5) exposure contributed to 4.2 million deaths worldwide in 2019, with 89% of these premature deaths occurring in low- and middle-income countries (WHO, 2022). Nigeria, and particularly its Federal Capital Territory (FCT), Abuja, faces compounding challenges from rapid urbanization, industrial emissions, vehicular pollution, and the reliance on fossil fuels. These pollutants contribute to severe respiratory and cardiovascular illnesses, which are further exacerbated in healthcare facilities where IAQ is often overlooked.

Indoor air quality is a key component of indoor environmental quality (IEQ), encompassing elements such as ventilation, thermal comfort, and lighting. Research has consistently shown that poor IAQ in healthcare facilities adversely impacts patient recovery rates, prolongs hospital stays, and diminishes staff performance (Chauhan et al., 2023; Shen, 2023). Conversely, good IAQ improves health outcomes and enhances the overall quality of care. However, the interplay between urban air pollution, IAQ, and public health remains underexplored, particularly in Nigerian urban environments where healthcare facilities serve as critical points of intersection between built environment quality and health outcomes.

The usage of fossil fuels releases massive amounts of CO2 (Carbon dioxide), a major greenhouse gas (Environmental Protection Agency, 2022) that contributes to global warming and is the most well-known source of air pollution. Also, the use of fossil fuels and other pollutant contained substances contributes to unhealthy air (Xie et al., 2017) through the release of air pollutants, such as lead (Pb), particulate matter ($PM_{2.5}$) and 10, nitrogen oxides (NOx), sulphur dioxide (SO2), carbon monoxide (CO), ozone (O3), ammonia (NH4), volatile organic compounds (VOCs) (such as methane (CH4) and benzene (C6H6), and others, which harm humans and ecosystems (Vallero, 2015; Manisalidis et al., 2020).

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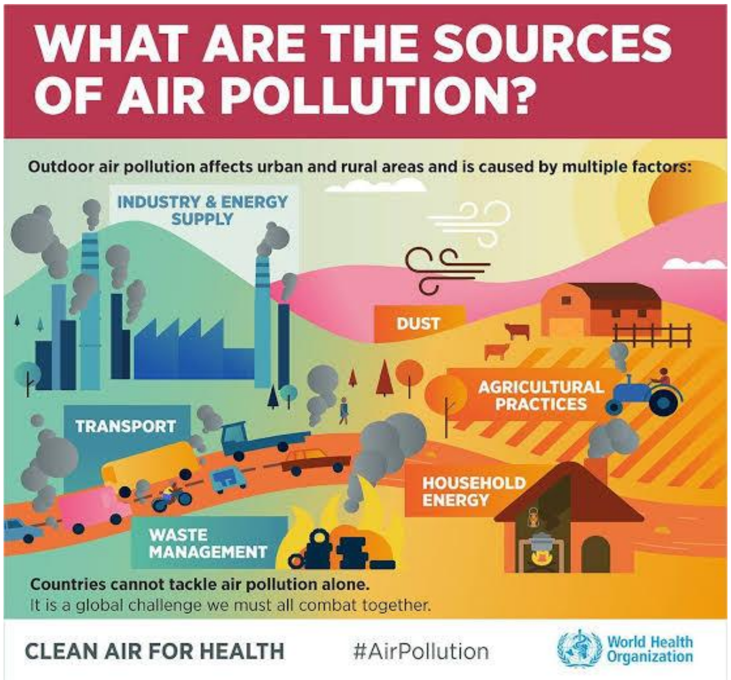
Figure 1: Main sources of PAQ according to the World Health Organization



Source (WHO, 2022c)

Scholars illustrate that factors such as industrialization, rapid urbanization, and natural phenomena contribute to environmental degradation, including changes in air quality, (Voumik and Sultana, 2022). Industries release emissions containing air pollutants such as volatile organic compounds, PM, and other air pollutants because of inappropriate waste management. (Bharath, 2021; Taghizadeh et-al., 2023). It is not only industrialization but also other human activities, such as rapid urbanization, (Zhang 2022), that contribute to air pollution as it is directly related to the construction of industries; increased transport, which releases emissions containing air pollutants; deforestation; changes in land use; and the notable increase in the use of air conditioning, (Riotous 2020).

Natural phenomena such as volcanic eruptions and wildfires also contribute to air pollution because they emit air pollutants such as sulfur dioxide, carbon monoxide, and harmful fine particulates known as $PM_{2.5}$ into the atmosphere and affect air quality once the concentration of these pollutants is above acceptable limits, (UNEP, 2023). Air quality guidelines differ from country to country. Many countries have established national air quality guidelines to control environmental pollution. For example, in the UK, the annual average of PM_{10} (should not exceed 40 µg/m3 and for $PM_{2.5}$ it should not exceed 10 µg/m3, and the acceptable daily average for PM_{10} is 50 µg/m3.[23] The acceptable daily mean concentration for $PM_{2.5}$ is 25 µg/m3 in Australia, 35 µg/m3 in the United States, and 30 µg/m3 in Canada. (UK Government 2023). The WHO established globally acceptable limits to guide other countries to have global guidelines (WHO 2022) The WHO Air Quality guidelines state that the acceptable daily mean concentration for $PM_{2.5}$ should not exceed 15 µg/m3 and for PM_{10} it should not exceed 45 µg/m3. Compared to the annual concentration, WHO indicates that acceptable limits for $PM_{2.5}$ are 5 µg/m3 and for PM10 it is15 µg/m^3, (WHO 2022).

This study seeks to assess the impact of PIAQ on public health in Nigerian urban environments, focusing on Abuja as a case study. Specifically, it investigates the disparities in IAQ between purpose-built and retrofitted healthcare facilities and their implications for patient and staff well-being. The objectives are, to identify key pollutants affecting IAQ in urban healthcare settings, to examine the relationship between IAQ and health outcomes in these facilities, and to propose a conceptual framework for integrating IAQ improvements into building design and urban policies.

II. Literature Review

This section provides a comprehensive review of the existing literature relevant to the impact of poor indoor air quality (PIAQ) on public health in urban environments, with a specific focus on healthcare facilities in Abuja, Nigeria. Key areas include definitions and frameworks for understanding air quality (AQ), sources and dynamics of PIAQ, factors influencing indoor air quality (IAQ), its health impacts, and measures to mitigate poor AQ. The literature review also explores public perceptions of AQ and its influence on urban health outcomes, with special attention to healthcare facilities as critical public spaces.

Overview of AQ and Notable AQ Events Chronology

Air quality, both indoor and outdoor, has been recognized as a determinant of human health for centuries. Historical records from as early as Hippocrates' era (circa 400 BC) link air quality to public health. The industrial revolution exacerbated air pollution,

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with significant health impacts noted in urban centers reliant on coal and other fossil fuels. Events such as the 1952 Great Smog of London, which caused approximately 4,000 deaths, underscore the urgency of addressing AQ issues (Mosley, 2012; Fowler et al., 2020). These events have catalyzed legislative measures and technological advancements aimed at improving AQ.

In urban Nigeria, particularly Abuja, sources of PIAQ include dust, biomass burning, emissions from vehicular traffic, and industrial activities. These contribute to elevated concentrations of pollutants, posing risks to residents' health and particularly to vulnerable populations in healthcare settings. In 1952, the famous Great Smog which resulted in the death of about 4000 inhabitants of London in Great Britain is one of the AQ events that defined the menace of PIAQ and the need to curtail it (Mosely, 2012; Fowler et al., 2020; History, 2022). There have been other notable global events on AQ, and actions introduced to mitigate PIAQ (Fowler et al., 2020). These events which are shown in Table 1 are pieces of evidence of early recognition of PAQ as a health and environmental risk factor, the establishment of laws to mitigate PAQ, exacerbation of PAQ during the industrial revolution, early identification of air pollution (AP) dispersion and measurement, recognition of regional AQ problems, political attention on AQ, satellite monitoring of AQ.

Table 1: Some notable AQ events and publications

1980s–1990s	Eutrophication of ecosystems by nitrogen deposition recognized.
1991	Canada-USA AQ Agreement.
1993	The 'Six Cities' study in North America re-focuses attention on the human health effects of air pollution PM_{10}.
1995	Launch of the first satellite for passive remote sensing atmospheric composition (GOME) for global ozone monitoring.
2000s	The increasing domination of global emissions and adverse effects of SO_2 and NO_x in Asia.
2006	2006 Southeast Asian haze. Caused by biomass or forest burning in Indonesia which affected neighbouring countries too.
2010	Extensive indication of recovery from effects of acid deposition in Europe and North America with the decline in emissions of SO_2 and NO_x.
2012	Beijing Smog, 13th January, with concentrations of PM and SO_2 similar to the Great London Smog of 1952.
2015	Global SO_2 emissions reduced by 15% from the 1990 peak, while all other air pollutants still increasing.
2018	1. Emissions of SO_2 and NO_2 declining rapidly in China. 2. Peak global NO_x emission? Global emissions of NH_3 and VOC continue to rise.
2020	COVID-19: The global pandemic dramatically reduces emissions of industrial- and transport-related emissions of SO_2, NO_x, VOC and primary PM.

Source: History, 2022

Definitions of AQ and Air Pollution

Air quality (AQ) is a measure of the cleanliness of air and its suitability for human health. Good AQ implies pollutant concentrations below established thresholds, while poor AQ signifies harmful levels of contaminants. WHO (2022) defines air pollution as the presence of physical, chemical, or biological agents in the air that may adversely affect human health and the environment. Indoor air pollution (IAP) refers specifically to the contamination of air within built environments.

AQ is commonly assessed using the Air Quality Index (AQI), which quantifies pollutant concentrations against standard levels established by agencies such as WHO. The AQI provides a numerical value to represent health risks associated with AQ, as shown in Table 2.1.

Table 2.1: Air Quality Index

AQI Range	Description	Health Implications
0–50	Good	Minimal or no health risk
51–100	Moderate	Acceptable; some sensitive groups may be affected
101–150	Unhealthy for sensitive groups	Individuals with respiratory or heart issues may experience discomfort

Source: Authors' work, (2024)

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The concentrations of air pollutants determine AQ, an example being the AQ Index (AQI), based on the standard levels and guidelines which should not be exceeded as recommended or required by a competent authority such as the WHO, environmental protection agencies, local environment, or health agencies (Table 2.2). These standards and guidelines differ between organizations and nations and are used to monitor and manage the AQ within their territory.

AQI is assessed with the formula: $AQI = \frac{Pollutants' \ Concentration}{Pollutants' \ Standard \ Level} \ x \ 100$

Table 2.2: AQ index values and levels of health concern

AQ Index (AQI)	Air Pollution Category	Level of Health Worry
0 to 50	Excellent	No Health implication
51 to 100	Good	Some pollutants may affect hypersensitive people.
101 to 150	Lightly Polluted	Unhealthy for sensitive groups of people
151 to 200	Moderately Polluted	Unhealthy
201 to 300	Heavily Polluted	Very unhealthy
301 to 500	Severely Polluted	Hazardous

Source: Adapted from European Environment Agency, 2022

Sources of PIAQ in Urban Healthcare Facilities

P-IAQ in healthcare settings arises from both external and internal sources:

- External Sources: Dust from surrounding arid regions, vehicular emissions, and agricultural practices such as bush burning.
- Internal Sources: Poor ventilation, use of biomass fuels, and inadequate maintenance of HVAC systems.

Impacts of PIAQ on Public Health in Urban Healthcare Facilities

Poor IAQ in healthcare facilities has been linked to:

- Increased respiratory illnesses, asthma, and cardiovascular diseases.
- Higher rates of hospital-acquired infections (HAIs).
- Reduced staff productivity and patient recovery rates.

Strategies for Improving AQ in Urban Healthcare Settings

Effective mitigation measures include the implementation of efficient ventilation systems, adoption of AQ monitoring technologies, and establishment of strict policies for controlling urban air pollution.

III. Methods

Research Design

The study employs a mixed-methods approach combining a systematic literature review (SLR) with field data collection. This approach ensures a comprehensive understanding of the relationship between IAQ and public health in Abuja's urban healthcare facilities.

Study area

The Federal Capital Territory (FCT), Abuja, is characterized by arid conditions and high levels of particulate matter. Healthcare facilities in both urban centers and peri-urban settlements were selected to capture a broad spectrum of IAQ challenges, (Sulaymon et al., 2020) This to a large extent affects the residents and the indoor air quality of health facilities surrounding these activities.

Systematic Literature Review Protocol

The study applied a systematic literature review (SLR) to provide insights into the impact of IAQ parameters and identify gaps in knowledge within the domains of IAQ for healthcare facilities. This approach has been applied in previous studies to identify gaps in knowledge (Olanrewaju, et-al., 2022) and provide an overview of the current state of knowledge, (Fonseca, et al., 2022). This section offers a comprehensive insight into the SLR process, consisting of two sequential phases: the development of the SLR protocol (Step I) and the implementation of the SLR (Step II), as illustrated in Figure 3.0. The initial phase of SLR protocol development comprises four consecutive sub-steps: defining the research purpose, formulating research questions, and selecting relevant keywords and databases. Subsequently, the second stage involves sub-steps: refining search strings and retrieving articles, establishing clear inclusion and exclusion criteria, reviewing titles and abstracts, and conducting data extraction.

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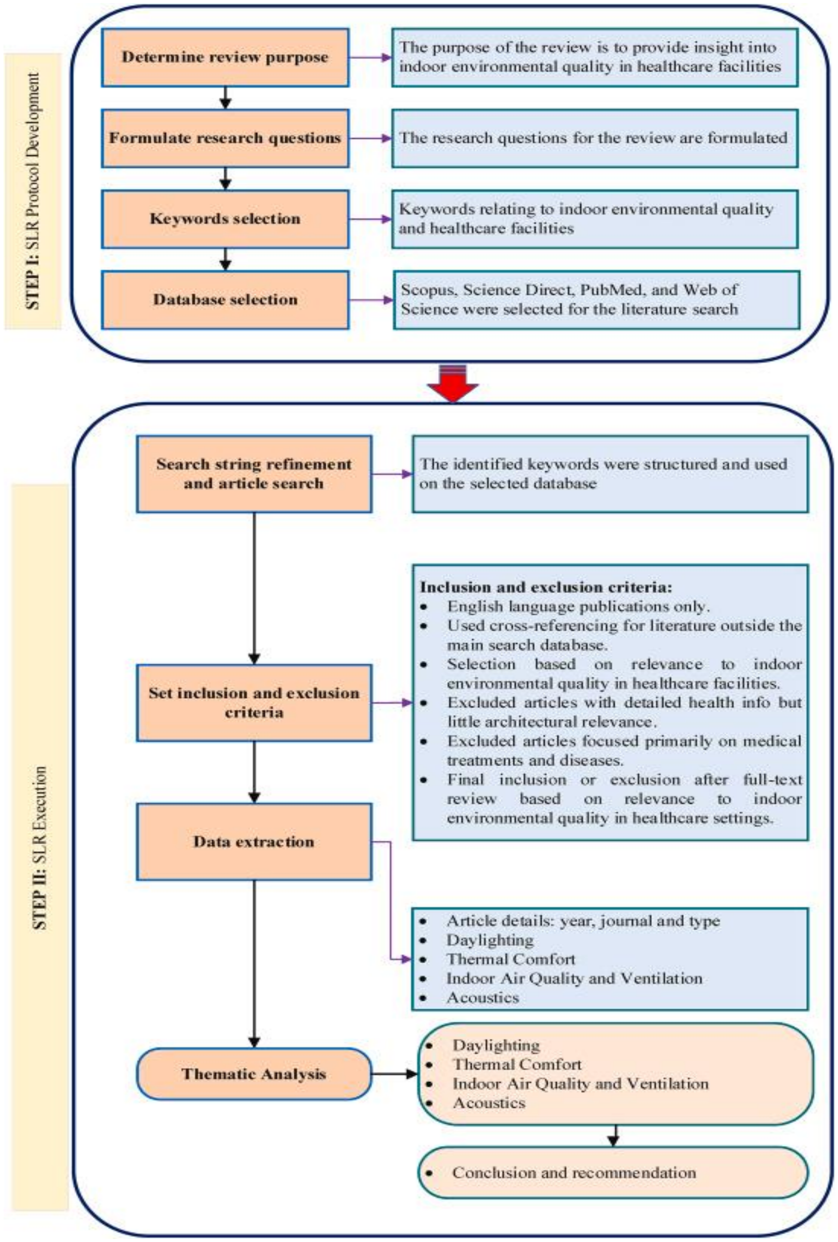
Figure 3.0: Systematic literature review process



Source: (Fonseca, et al., 2022).

Database selection

The selection of an appropriate database for conducting a systematic review is a critical decision that significantly influences the comprehensiveness and rigor of the review process. The databases selected for the SLR were Scopus, Science Direct, PubMed, and Web of Science. These databases were selected due to their coverage of extensive construction-related research, while PubMed was selected due to its recognition in the health field. In addition, recent studies that combined Scopus, Science Direct, Web of Science and PubMed in the construction domain have achieved remarkable results (Arshad et-al., 2023). Including Scopus, ScienceDirect, PubMed, and Web of Science in the SLR enhances the literature search's comprehensiveness, quality, and reliability. It allows access to various sources, conducts precise searches, and traces research development over time. This approach aligns with the rigorous standards expected in SLR and helps ensure the review is robust and credible.

Field Data Collection

Primary data was collected from selected healthcare facilities in Abuja using:

i. AQ Monitoring Instruments: Measuring CO_2 levels, particulate matter, and VOC concentrations.

ii. Surveys and Interviews: Capturing perceptions of patients and healthcare staff on IAQ and its health impacts.

IV. Results

Framework for IAQ dynamics in healthcare facilities

Indoor Air Quality (IAQ) significantly affects public health, impacting individuals e.g patient well-being, staff productivity, and healthcare outcomes. This systematic literature review investigates the effects of IEQ, including air quality, temperature, lighting, and noise, on healthcare facilities. It proposes a framework, analysed. The framework aims to understand how IEQ influences health outcomes, patient and staff satisfaction, healthcare-associated infection rates, patient and staff well-being, staff productivity, and length of stay. The framework also shows the interrelationship between different constructs of IEQ.

Numerous studies stress the importance of IEQ in healthcare settings (jafarifiroozabadi, et-al., 2023; Deng, et-al., 2023; Shajahan,e, et-al., 2019). Poor air quality, inadequate lighting, and excessive noise can affect patient recovery and increase healthcare-associated infections. Healthcare professionals' performance and job satisfaction are linked to the quality of their working environment. However, a comprehensive understanding of these relationships is needed, given the unique challenges of healthcare facilities. It is anticipated that improving the IEQ can enhance health outcomes, patient and staff satisfaction, healthcare-associated infection rates, patient and staff well-being, staff productivity, and length of stay, subsequently leading to improved IEQ in healthcare facilities.

Framework for IAQ Dynamics in Urban Healthcare Facilities

The findings of this study reveal significant links between IAQ parameters and health outcomes in urban healthcare settings.

Table 4.0: IAQ parameters and health outcomes

Parameter	Impact on Health and Performance
Ventilation	Reduces incidence of respiratory conditions and HAIs
Thermal Comfort	Enhances patient recovery and staff productivity
Particulate Matter	Increases risk of respiratory diseases and asthma

Source: Authors' Work, (2024)

The parameters in the conceptual model are justified as follows.

i. **Health outcomes:** The IEQ of healthcare facilities greatly impacts patient health outcomes, encompassing physical and physiological aspects. Factors like the psychological state of patients can affect their healing process (Basu, et-al., 2022), emphasizing the role of a positive and supportive indoor environment. Improved IEQ leads to better patient health outcomes. For instance, reducing indoor pollutants and ensuring adequate ventilation can decrease the incidence of hospital-acquired infections, respiratory conditions, and allergic reactions. Adequate lighting and noise control can also reduce patient stress (Kamdar, et-al., 2012; Dubose, et-al., 2016), aiding in faster recovery.

ii. **Patient and staff satisfaction:** A comfortable indoor environment, characterized by appropriate temperatures, good air quality, and noise control, can significantly improve patient satisfaction (Shen, et-al., 2023). Elements like natural lighting and views of nature can also contribute to a more pleasant stay (Iyendo, et-al., 2016), positively impacting patient perceptions and experiences.

iii. **Healthcare-associated infection rates:** Poor indoor air quality and inadequate ventilation can lead to acute respiratory illnesses, trigger asthma symptoms (Wimalasena, et-al., 2021), and even contribute to chronic conditions like Sick Building Syndrome (SBS).

Proposed Mitigation Strategies

The study recommends:

- Adoption of energy-efficient HVAC systems to improve ventilation.
- Regular AQ monitoring and maintenance of facilities.
- Policy interventions to reduce external pollution sources.

Implications for Urban Public Health

Enhancing IAQ in healthcare facilities can lead to:

- Reduced healthcare-associated infections.
- Improved patient outcomes and staff satisfaction.
- Greater resilience against the health impacts of urban pollution.

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V. Discussion and Conclusion

This study assesses the impact of poor Indoor Air Quality (IAQ) on public health in Nigerian urban environments, using the Federal Capital Territory (FCT), Abuja, as a case study. The findings address the research aim and objectives, emphasizing the interplay between IAQ and public health outcomes in residential, healthcare, and urban contexts. By bridging the gap between urban environmental dynamics and indoor conditions, the study highlights practical and policy-driven solutions for mitigating IAQ-related health risks.

Discussion

This research demonstrates that poor IAQ significantly contributes to public health challenges, particularly respiratory illnesses, cardiovascular diseases, and other health complications in urban areas. Factors such as inadequate ventilation, high particulate matter (PM), carbon dioxide (CO_2), and toxic emissions from biomass burning and waste mismanagement exacerbate these issues. These findings align with the first objective, which sought to identify factors influencing IAQ in Nigerian urban environments.

The study reveals that urban air pollution infiltrates indoor spaces through porous building envelopes, poorly designed ventilation systems, and suboptimal building materials. This addresses the second objective of investigating IAQ levels and pollutant sources. Healthcare facilities, residential homes, and commercial spaces are particularly vulnerable, with healthcare settings posing compounded risks due to high occupancy and exposure to infectious particles.

The third objective, evaluating the relationship between IAQ levels and health outcomes, was achieved by analyzing data from existing literature and linking poor IAQ to delayed recovery rates, increased patient morbidity, and reduced staff productivity in healthcare facilities. Furthermore, the research correlates IAQ factors with building components, addressing the fourth objective by emphasizing the role of design elements such as windows, ventilation systems, and materials in influencing indoor conditions.

Contributions and Implications

The study makes several key contributions. First, it provides a conceptual framework integrating urban air pollution, IAQ dynamics, and public health outcomes. This framework serves as a tool for architects, urban planners, and policymakers to design and retrofit buildings with improved IAQ standards. Second, the study highlights actionable strategies, including green building materials, real-time air quality monitoring, and sustainable waste management practices, that can be adopted in Abuja and other similar urban environments.

This work bridges the gap between global IAQ research and the specific realities of Nigerian urban settings, emphasizing both healthcare and residential contexts. Unlike previous studies that treat IAQ in isolation, this research integrates indoor and outdoor air quality challenges, offering comprehensive solutions tailored to local conditions.

Future Research Directions

Despite the significant findings, several areas warrant further investigation:

1. Quantitative Impact Analysis: Future studies should measure the direct impact of IAQ on public health outcomes, such as recovery times and workforce productivity.
2. Comparative Studies: The performance of purpose-built versus retrofitted buildings in managing IAQ should be analyzed to guide design choices.
3. Localized Standards: Developing context-specific IAQ standards and policies for urban environments in low- and middle-income countries is essential.
4. Longitudinal Studies: Research should explore the long-term effects of poor IAQ on public health and urban sustainability.

Conclusion

This study underscores the critical role of IAQ in shaping public health outcomes in Abuja’s urban environments. By addressing the research questions and objectives, it highlights the need for integrating urban planning, building design, and policy measures to improve IAQ. The findings serve as a roadmap for architects, urban planners, healthcare administrators, and policymakers to prioritize IAQ through targeted interventions, ultimately fostering healthier, more sustainable urban living conditions in Nigeria.

With its comprehensive approach, this research lays the groundwork for advancing IAQ standards in Nigerian cities, ensuring that indoor spaces contribute positively to public health and environmental sustainability.

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