

Research Article

Air Pollution and Non-communicable Diseases (NCDs) in Sub-Saharan African Cities: A Review

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Abstract

This study explores the complex relationship between air pollution and non-communicable diseases (NCDs) in Sub-Saharan African cities. By conducting a comprehensive review of 200 scholarly papers, the research synthesizes existing knowledge to elucidate the extent and nature of this association. Sub-Saharan Africa faces unique challenges due to rapid urbanization, industrialization, and transportation growth, which significantly contribute to deteriorating air quality. The review reveals that air pollution in Sub-Saharan Africa, driven by biomass burning, vehicular emissions, industrial activities, and dust, substantially contributes to high rates of NCDs such as respiratory diseases, cardiovascular diseases, cancer, and diabetes in urban areas. Notably, asthma affects 10-15% of the urban population, chronic obstructive pulmonary disease (COPD) impacts 8-12% of adults, and acute respiratory infections occur in 20-30% of children. Hypertension and ischemic heart disease affect 15-20% and 5-10% of the population, respectively, while lung cancer and type 2 diabetes affect 2-5% and 5-8% of the population, respectively. Addressing air pollution is crucial for improving public health in the region. The review identifies key pollutants of concern, including particulate matter, nitrogen dioxide, and sulfur dioxide, and examines their linkages to prevalent NCDs. Furthermore, the study discusses the methodological approaches employed in existing literature, identifies gaps, and proposes avenues for future research to enhance understanding and mitigate the health impacts of air pollution in this region.

Keywords

Air Pollution, Non-communicable Diseases (NCDs), Sub-Saharan Africa, Urban Health

1. Introduction

Air pollution, both outdoor and indoor, is a critical global issue that stifles economic growth, worsens poverty and inequality, jeopardizes human health, and drives climate change [1]. Outdoor air pollution accounted for 4.2 million premature deaths in 2019 worldwide, predominantly due to

cardiovascular and respiratory diseases, as well as cancers caused by fine particulate matter (PM) [2]. This issue is particularly prevalent in densely populated urban areas due to lower atmospheric diffusion capability and the accumulation of air pollutants [3]. Similar studies show that air pollution

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was responsible for 1.1 million deaths across Africa, including both outdoor and indoor pollution. Of this total, outdoor air pollution alone contributed to around 400,000 fatalities [4]. Low- and middle-income countries are disproportionately impacted, accounting for 89% of air pollution-related deaths [5]. According to the World Health Organization (WHO), many of these deaths, particularly in regions like South-East Asia, the Western Pacific, and Sub-Saharan Africa, often go unreported [6].

Effective policies to mitigate air pollution must involve multiple sectors, including energy, transport, waste management, and urban planning [7]. Modern strategies include the adoption of electric and hydrogen vehicles, the use of renewable energy sources such as solar and wind, advanced waste-to-energy technologies, and the creation of green urban spaces through vertical forests and green roofs [8]. However, these technologies face challenges such as high initial costs, limited infrastructure, and technological limitations. Key pollutants include PM, carbon monoxide (CO), ozone (O₃), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂) [9].

Sub-Saharan Africa is experiencing rapid urbanization, with the urban population expected to double by 2050, driven by factors such as rural-urban migration, natural population growth, and the reclassification of rural areas as urban [10]. However, this urbanization is often unplanned and unregulated, leading to the development of informal settlements and slums, which lack access to essential services and infrastructure [11]. The level of industrialization in Sub-Saharan Africa is relatively low compared to other regions, with many countries primarily dependent on the extraction and export of raw materials [12]. Weak infrastructure, limited access to energy, and a lack of skilled labor have hindered industrial development [13]. Nevertheless, rapid urbanization and industrialization in the region have led to increased air pollution, particularly in major cities, attributed to the use of solid fuels for cooking and heating, as well as emissions from vehicles and industries [14].

Air pollution contributes to non-communicable diseases (NCDs) through mechanisms such as the inhalation of fine particulate matter and gases, leading to systemic inflammation, oxidative stress, and endothelial dysfunction [15]. These processes result in cardiovascular and respiratory diseases. Carcinogenic compounds and heavy metals increase the risks of cancer and other NCDs by causing DNA damage and toxicity [16]. Additionally, air pollution induces epigenetic changes and modulates the immune system, promoting chronic conditions like diabetes and neurodegenerative diseases [17].

The WHO defines NCDs also known as chronic diseases, as non-transmissible diseases of long duration, such as mental health conditions, stroke, heart disease, cancer, diabetes, and chronic lung disease. Addressing air pollution through comprehensive policy action is crucial for protecting public health and mitigating the risk of NCDs [18]. Consequently,

the burden of NCDs, such as cardiovascular diseases, diabetes, and cancer, is increasing in Sub-Saharan Africa, driven by factors like urbanization, lifestyle changes, and the growing prevalence of risk factors such as physical inactivity, unhealthy diets, and tobacco use [19]. Air pollution in Sub-Saharan African cities is a growing concern, particularly regarding its impact on public health and NCDs [20]. Rapid urbanization and economic growth have led to increased pollution from vehicles, industries, and household fuels, which are linked to higher rates of cardiovascular diseases, respiratory conditions, and cancer [21]. Studies indicate that exposure to pollutants like PM_{2.5} significantly raises the risk of these diseases, with NCDs already causing 30% of deaths in the region [22]. The World Health Organization warns that this burden will likely increase, exacerbated by worsening air quality [23].

Thus, this review aims to examine the relationship between air pollution and NCDs in Sub-Saharan African cities, summarizing current knowledge on air pollution levels and sources, the prevalence and types of NCDs, and highlighting key empirical studies. It highlights key research gaps, suggests future research directions, and explores the policy and public health implications, providing actionable recommendations for stakeholders.

2. Methodology

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a structured and transparent approach. The primary aim was to investigate the relationship between air pollution and non-communicable diseases (NCDs) in Sub-Saharan African cities, focusing on studies published up to May 19, 2024.

2.1. Search Strategy

A comprehensive search was carried out in three major scientific databases: PubMed, Web of Science, and Scopus. The search was conducted for studies published up to May 19, 2024, using database-specific filters and Boolean operators to refine results. The search terms combined keywords related to air pollution and NCDs. The search syntax was adapted to each database, as follows:

- 1) Keywords: "air pollut," "outdoor air pollut*," "Non-Communicable Diseases (NCDs)," "Urban Health," "Sub-Saharan Africa*," "Policy Interventions," "Risk Factors," "Particulate Matter (PM)*".
- 2) Filters applied: Studies published in English, focusing on urban settings in Sub-Saharan Africa.

In addition to database searches, manual searches of reference lists of included articles were conducted to identify further relevant studies that might have been missed. Additionally, grey literature databases, such as OpenGrey and

WHO Global Health Library, were searched to capture studies not available through traditional academic publishing channels, minimizing publication bias.

2.2. Inclusion and Exclusion Criteria

Predefined inclusion and exclusion criteria were applied to ensure relevance and quality:

Inclusion Criteria:

- 1) Peer-reviewed articles published in English.
- 2) Studies focused on urban settings within Sub-Saharan Africa.
- 3) Studies examining the relationship between air pollution and NCDs (e.g., cardiovascular diseases, respiratory conditions).

Exclusion Criteria:

- 1) Non-English publications.
- 2) Studies not addressing the relationship between air pollution and NCDs.
- 3) Studies not conducted in Sub-Saharan African cities.

2.3. Screening Process

All identified articles were imported into EndNote reference management software, and duplicates were removed. A two-stage screening process was employed:

- 1) Title and Abstract Screening: Two independent reviewers screened the titles and abstracts of the identified studies based on predefined eligibility criteria. Disagreements were resolved by a third reviewer.
- 2) Full-Text Review: Articles that passed the title and abstract screening were retrieved for full-text review by two independent reviewers. Discrepancies were again resolved by a third reviewer.

2.4. Data Extraction Process

Data were extracted using a standardized data extraction form. Two independent reviewers performed the data extraction to ensure consistency and accuracy. Any discrepancies were resolved through discussion or by consulting a third reviewer. The following data were extracted from each study:

- 1) Study characteristics: Authors, year of publication, study design, and location.
- 2) Population characteristics: Sample size, age, gender, and socioeconomic factors.
- 3) Exposure variables: Types of air pollutants (e.g., PM_{2.5}, NO₂).
- 4) Outcome variables: Types of NCDs (e.g., cardiovascular, respiratory).
- 5) Risk factors: Socioeconomic and environmental factors.
- 6) Policy interventions: Local or national policies on air quality and urban health.

2.5. Risk of Bias Assessment

The risk of bias for each included study was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies. The scale evaluates studies on three domains: selection of study groups, comparability, and ascertainment of outcomes. Each study was independently assessed by two reviewers, and disagreements were resolved through consensus.

The risk of bias assessment informed the interpretation of the findings by highlighting potential biases in study designs, data collection methods, and statistical analyses. Studies with a high risk of bias were not excluded, but were interpreted with caution in the final analysis.

2.6. Quality Assessment of Studies

To assess the methodological rigour of each included study, the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist was applied. This ensured that all relevant observational studies met high standards in reporting and transparency. Each study's adherence to the STROBE criteria was documented in a supplementary table and considered in the overall synthesis.

2.7. Data Synthesis and Analysis

Given the heterogeneity in study designs, populations, pollutant types, and health outcomes, a meta-analysis was not feasible. Instead, a narrative synthesis was employed to summarize the findings. The synthesis focused on:

- 1) Patterns and trends: How various types of air pollution (e.g., PM_{2.5}, NO₂) are linked to specific NCDs.
- 2) Geographical variations: Differences in health outcomes across different Sub-Saharan African cities.
- 3) Policy interventions: The role of air quality regulations in mitigating the effects of pollution on NCDs.
- 4) Where possible, subgroup analyses were performed based on city population size, air pollution levels, and types of NCDs. Heterogeneity in the studies was explored by looking at differences in study design, exposure assessments, and outcome definitions.

2.8. PRISMA Flow Diagram

A PRISMA flow diagram was used to track the inclusion and exclusion process, detailing the number of studies identified, screened, excluded (with reasons), and included in the final review (Figure 1).

2.9. Summary of Evidence

A summary figure (Figure 1) was created to highlight the key characteristics of each included study. The figure includes:

- 1) Study location: City or region in Sub-Saharan Africa.
- 2) Type of NCD: Specific diseases (e.g., asthma,

hypertension).

- 3) Air pollutants examined: Types of pollutants (e.g., PM_{2.5}, CO).
- 4) Study design: Cross-sectional, cohort, case-control.
- 5) Sample size: Number of participants.

2.10. Limitations and Future Research

The review identified several limitations, such as inconsistent exposure measurements and limited data availability in some regions. Further research is needed to address these gaps, particularly longitudinal studies that can better assess causality.

3. Air Pollution in Sub-Saharan African Cities

The National Ambient Air Quality Standards indicate that air pollutants originate from both natural sources and human activities [7, 24]. Urbanization and industrialization are key drivers of air pollution. Rapid industrial growth and increasing urban population density lead to elevated emissions of pollutants, with significant adverse effects on both human health and the environment [2, 25]. Numerous studies have analyzed air pollution levels in urban areas worldwide, revealing that pollution from sources such as transportation, industry, and energy production is a critical issue in many cities globally [26]. According to the World Health Organization (WHO), over 90% of the global population resides in areas where air quality exceeds WHO-recommended limits. Major urban centers in Asia, Africa, and parts of Latin America consistently report some of the highest levels of air pollution [27]. Common pollutants of concern include particulate matter (PM_{2.5} and PM₁₀), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and ground-level ozone (O₃). Although air pollution research in Sub-Saharan Africa is relatively limited compared to other regions, some studies have documented the detrimental health impacts of these pollutants on local populations and communities [28]. For example, Sub-Saharan African cities face rapid urbanization, a predominantly young population, and significant challenges related to infrastructure and economic stability, in contrast to North African cities, which have benefitted from more established urban development, more stable populations, and stronger economic frameworks. While both regions face distinct challenges, they are at different stages of urban development and demographic transitions.

A study conducted by the United Nations Environment Programme asserts that air pollution is a growing concern in many African cities, with sources including vehicle emissions, waste burning, and industrial activities [29]. Furthermore, studies in cities like Accra (Ghana), Addis Ababa (Ethiopia), and Nairobi (Kenya) have documented high levels of particulate matter and other pollutants that often exceed national and international standards. Factors

contributing to poor air quality in the region include rapid urbanization, limited access to clean energy sources, and inadequate air quality monitoring and management systems [2, 30].

Air pollution levels, however, vary significantly depending on the season and location. For example, in urban areas, pollution levels are frequently higher during the winter months due to increased use of heating systems. Additionally, specific geographic factors, such as proximity to industrial areas or major transportation routes, can contribute to higher pollution levels [31]. Urban air pollution originates from various sources, each degrading air quality in cities worldwide [32]. Significant contributors include vehicular emissions from cars, trucks, buses, and motorcycles. These vehicles emit pollutants such as NO_x, carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs) as by-products of combustion [33]. Diesel vehicles are particularly known for their high levels of PM emissions [34]. Industrial activities also play a major role in urban air pollution, particularly in countries with extensive oil and mineral production such as Nigeria, Angola, Algeria, Libya, South Africa, the Democratic Republic of Congo, and Zimbabwe [35]. Factories, power plants, and construction sites release pollutants including SO₂, NO_x, CO, PM, VOCs, and heavy metals like lead and mercury [36]. These emissions have considerable health and environmental impacts on surrounding communities [37, 38].

Burning fossil fuels such as coal, oil, and natural gas for heating releases harmful pollutants into the air, contributing to poor air quality. In regions where wood-burning stoves or fireplaces are prevalent, pollution levels tend to rise even more during the colder months [39]. Agricultural activities contribute to urban air pollution through practices such as livestock farming, crop residue burning, and the application of fertilizers and pesticides [40]. These activities release pollutants including ammonia (NH₃), methane (CH₄), nitrous oxide (N₂O), and PM into the atmosphere, particularly in rural areas adjacent to urban centers [41]. Waste disposal and landfill emissions further exacerbate the issue. The open burning of waste, emissions from landfills, and waste treatment facilities release methane (CH₄), volatile organic compounds (VOCs), and other pollutants into the air, contributing to urban pollution [42]. Construction and demolition activities also release dust and PM, adding to local air pollution [43]. Africa is home to five of the ten most polluted countries in the world in terms of outdoor PM_{2.5} concentrations [44]. This means that air pollution levels in some African countries are significantly higher than the global average. While South Africa alone is not among the top ten, its major emission sources are the electricity sector, the metals industry, and the transportation sector [45]. This indicates that industrial activity and transportation are significant contributors to air pollution in the country [46]. It's important to remember that these are only snapshots of the situation, and they can vary greatly depending on the location

and time of year.

The World Bank's World Development Report defines urbanization as the proportion of a country's population residing in cities with a minimum of 20,000 inhabitants. The report further operationalizes development through the Human Development Index (HDI). Notable regional disparities exist between sub-Saharan African cities and those in other parts of Africa, particularly concerning urbanization rates, lifestyles, population sizes, economic development, infrastructure, and demographic trends [47].

In sub-Saharan Africa, urbanization remains comparatively lower but is experiencing rapid growth, primarily driven by rural-to-urban migration [48]. However, many urban areas in this region tend to be less developed with regard to infrastructure and service provision. Conversely, cities in North Africa and the Mediterranean region generally demonstrate higher levels of urbanization and more established urban infrastructure, influenced by historical ties to Europe, colonial legacies, and earlier phases of urban development [49]. These authors also note that cities such as Cairo, Algiers, Tunis, and Tripoli are more developed, densely populated, and characterized by lifestyles shaped by distinct cultural, religious, and traditional contexts.

Furthermore, major cities such as Lagos, Kinshasa, and Johannesburg are among the most populous on the continent, often exceeding 10 million residents, with high growth rates [50]. In contrast, although some cities in North Africa are also large, their population growth tends to be more stable or gradual compared to the rapid expansion observed in many sub-Saharan urban centers. A study by Choplin and Hertzog (2020) highlights that many cities in sub-Saharan Africa are still in the process of developing essential infrastructure, such as roads, sanitation systems, and a reliable electricity supply [51]. These economies are largely driven by agriculture, mining, and informal sectors. In contrast, cities in other regions of Africa tend to have more advanced infrastructure and more diversified economies, including manufacturing, services, and tourism. This development is often shaped by their historical growth patterns and closer proximity to Europe.

Demographically, cities in sub-Saharan Africa are marked by predominantly young populations, with high fertility rates and significant informal settlements or slums. These areas often fail to fully represent the socioeconomic diversity of residents, as they do not always reflect the broader economic conditions or living standards [52].

While other African cities also have youthful populations, demographic growth in these regions is generally more stable. In fact, some urban areas now feature a growing proportion of middle- and upper-middle-class residents, reflecting more diversified economic development [53].

In addition to health challenges like communicable and non-communicable diseases, sub-Saharan Africa grapples with the pressures of rapid urbanization. These include air pollution, climate change, the expansion of slums, poor urban

planning, and inadequate service delivery [54]. In contrast, other regions of Africa face their own unique challenges, such as updating historical urban layouts and incorporating modern infrastructure into older city districts.

4. Non-Communicable Diseases (NCDs) in Sub-Saharan Africa

Global health agencies emphasize the growing threat of NCDs in low and middle income countries, citing their significant contribution to preventable illnesses and premature mortality [55]. NCDs account for approximately 71% of all deaths worldwide, leading to prolonged illness, disability, and significant impacts on life quality and economic productivity [56].

In Africa, the dual burden of communicable and NCD shampers the objectives of Agenda 2063, which seeks a prosperous and peaceful continent [57]. The African Union reports that NCDs cause millions of premature deaths and substantial economic losses, with their impact on public health and national economies continuing to rise [58]. While human activities are the main drivers of urban air pollution, natural sources such as wildfires, dust storms, and volcanic eruptions also contribute substantial amounts of pollutants [59]. These events can significantly worsen urban air quality, especially in regions located downwind [60]. NCDs, which are chronic conditions not transmitted from person to person, include cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes. [61] highlighted that NCDs have multifaceted causes, involving genetic, physiological, environmental, and behavioral factors. Cardiovascular diseases and diabetes are often linked to metabolic risk factors such as high blood pressure, high cholesterol, and high blood glucose levels [62]. Cancers can result from genetic mutations and exposure to carcinogens like tobacco smoke, radiation, and certain chemicals [63]. Chronic respiratory diseases are associated with long-term exposure to pollutants, including tobacco smoke, indoor air pollution, and occupational chemicals [64]. According to the National Institutes of Health (NIH), NCD risk factors are categorized into modifiable and non-modifiable factors. Modifiable factors include unhealthy diet, physical inactivity, tobacco use, and harmful alcohol consumption, leading to conditions like obesity and high blood pressure [65]. Non-modifiable factors include age, gender, and genetic predisposition, with risk increasing with age and certain genetic traits [66]. Tackling NCDs necessitates a comprehensive approach, encompassing the promotion of healthier lifestyles, implementation of public health policies to mitigate risk factors, and provision of effective management and treatment [67]. Public health interventions such as anti-smoking campaigns, promotion of physical activity, improvement of diet quality, and regulation of alcohol consumption play pivotal roles in reducing NCDs [68]. Furthermore, early detection and timely treatment can

prevent complications, enhance outcomes, and mitigate the broader societal and economic impacts of NCDs [69]. Research underscores the link between air pollution and NCDs, with diseases such as heart disease, stroke, lung cancer, and chronic obstructive pulmonary disease (COPD) being associated with air pollution [70]. PM_r, notably PM_{2.5}, is identified as a particularly concerning pollutant. The United Nations recognizes both indoor and outdoor air pollution as significant risk factors for NCDs [71]. Lee and colleagues' review found a strong link between exposure to PM_{2.5} and PM₁₀ and various adverse health effects, including heart disease, stroke, and blood pressure irregularities. They concluded that air pollution significantly raises the risks of heart attacks, strokes, and other cardiovascular diseases [72]. Additionally, exposure to PM and O₃ is associated with higher rates of cardiovascular mortality and morbidity. [73]. Air pollution, especially PM_{2.5} aggravates respiratory conditions like asthma and COPD, with heightened risks for vulnerable groups such as the elderly and pregnant women [74]. Long-term exposure increases the risk of respiratory diseases, lung cancer, and type 2 diabetes due to its role in insulin resistance [75]. Hwang et al. (2020) found that short- and mid-term exposure to air pollution affects biological markers related to diabetes, suggesting implications for healthcare policies [76]. Exposure to air pollutants like PM and polycyclic aromatic hydrocarbons is linked to increased cancer risks, including lung, bladder, and breast cancers [77].

Anyanwu et al. (2024) reported that air pollution is the most common environmental exposure in sub-Saharan Africa, predominantly associated with respiratory diseases [15, 78]. Glenn et al. (2022) highlighted significant concerns regarding non-communicable respiratory diseases and air pollution in Africa, emphasizing the need for targeted studies and policies [79]. Rother (2020) highlighted that climate change worsens NCDs in urban sub-Saharan Africa. The study calls for integrating environmental health into climate strategies, focusing on reducing air pollution and other environmental risks. This aligns with the Sustainable Development Goals to protect urban health in the region. [80]. A 2018 study in the South African Medical Journal found that air pollution increased the risk of hypertension, type 2 diabetes, and obesity in South African adults [81, 82]. Another study in the highveld region, known for its high pollution levels, reported more respiratory symptoms and reduced lung function among residents [83]. Hence, tackling the growing burden of NCDs in Sub-Saharan Africa requires a multi-sectoral approach that involves governments, healthcare providers, civil society organizations, and individuals working together to implement effective strategies for prevention, early detection, and management of these chronic conditions.

5. Air Pollution and NCDs: Mechanisms and Pathways

Air pollution is a significant environmental risk factor

linked to the development of NCDs through various mechanisms [84]. NCDs, such as cardiovascular diseases, respiratory diseases, and cancer, are chronic conditions often resulting from long-term exposure to risk factors like air pollution [45, 85].

Although the biological mechanisms underlying NCDs vary by condition, shared pathways such as inflammation, oxidative stress, metabolic dysfunction, and environmental factors play a central role in their development [86]. Air pollution has both short-term and long-term health effects, including respiratory issues, aggravation of existing conditions, and cardiovascular problems. Long-term effects include chronic respiratory diseases, cardiovascular diseases, and cancer [87]. A 2019 study in Rwanda examined cardiovascular disease (CVD) mortality linked to air pollution, attributing 689 deaths to outdoor air pollution and 2,788 deaths to indoor air pollution [88]. In the DRC, air pollution from vehicles, industrial activities, and the burning of solid fuels in households is associated with a rise in diabetes and cancer. Emerging evidence suggests that air pollution may increase the risk of type 2 diabetes and certain cancers, although further research is needed to confirm these associations [89]. Li and colleagues identified that DLEU1 is increased in breast cancer, promoting cell growth, invasion, and resistance to cisplatin. This happens because DLEU1 competes with miR-99b, which leads to higher HS3ST3B1 levels. This finding emphasizes the significance of the DLEU1/miR-99b/HS3ST3B1 pathway in breast cancer and suggests DLEU1 as a potential target for treatment. [90]. The relationship between air pollution and NCDs is complex and influenced by various factors, including socioeconomic status, lifestyle choices, and pre-existing health conditions [91]. To accurately assess this connection, it is essential for researchers to consider these determinants. Certain populations such as children, pregnant women, the elderly, and individuals with underlying health issues are particularly vulnerable to the adverse health effects of air pollution [92]. Many Sub-Saharan African countries face significant challenges due to limited research capacity and insufficient funding, which hinder the development of comprehensive epidemiological studies [93]. Addressing these obstacles requires the implementation of rigorous research methodologies and sustained investment in local research infrastructure. Researchers employ a range of techniques to assess air pollution exposure, including satellite imagery, ground-based monitoring stations, and predictive modeling [94]. Epidemiological approaches such as cross-sectional, case-control, and cohort studies have been widely used to investigate the associations between air pollution and NCDs, including cardiovascular conditions, respiratory illnesses, and diabetes. Overall, the link between air pollution and NCDs is complex and multifaceted, involving a range of biological and physiological mechanisms. Addressing air pollution through effective environmental policies and public health interventions is crucial for mitigating the burden of NCDs and

promoting overall health and well-being.

6. Empirical Evidence from Sub-Saharan Africa

Although recent research has begun to explore the link between air pollution and NCDs in sub-Saharan Africa, the body of evidence remains limited. Nevertheless, existing studies underscore the significant health impacts of air pollution in the region [95]. Egondi et al. (2016) studied in Nairobi, Kenya, and discovered a notable link between short-term exposure to PM_{2.5} and respiratory issues, especially in children and the elderly [96, 102, 97]. In the same way, Amegah et al. (2013) reported an increased incidence of hypertension and other cardiovascular diseases linked to long-term exposure to air pollution in Accra, Ghana [98]. Mubarak, T. (2020) conducted an investigation on the prevalence of cardiovascular diseases in Kampala and found that residents exposed to higher levels of air pollution had a higher prevalence of cardiovascular diseases, including hypertension and ischemic heart diseases [99]. Wichmann and Voyi (2012) conducted a study in the Gauteng province, South Africa, which demonstrated a strong correlation between ambient air pollution and hospital admissions for respiratory and cardiovascular diseases [100, 109]. Recently, Singh et al. (2020) examined the health impacts of air pollution in Durban, South Africa, and found that long-term exposure to air pollution was associated with increased mortality rates from cardiovascular diseases, underscoring the severe health risks posed by poor air quality [101, 110]. Awokola et al. (2022) also reported a higher incidence of respiratory diseases, including bronchitis and asthma, for individuals living in areas with high levels of PM_{2.5} and NO₂ in Lagos, Nigeria. Hence, highlighting the pervasive impact of air pollution on respiratory health in one of Africa's largest cities [102, 111]. In the same way, Jagger, P. et al. (2024) in Lilongwe, Malawi, observed that higher levels of PM_{2.5} were associated with increased rates of respiratory diseases, including asthma and COPD [103, 112].

Mirroring the globally observed trends, the above studies indicate that air pollution is a significant risk factor for NCDs in Sub-Saharan African urban areas, underscoring the urgent need for effective air quality management and public health interventions to mitigate the health impacts of air pollution in the region. Based on the available studies, various pollutants have been identified as major contributors to air pollution in Sub-Saharan Africa, including PM_{2.5} and PM₁₀, NO, SO₂, and volatile organic compounds (VOCs). As indicated in Figure 1, the studies have shown that approximately 35% of urban areas in the region exceed the WHO guideline limits for

PM_{2.5} (Annual mean: 5 µg/m³), and 40% for PM₁₀ (Annual mean: 15 µg/m³), 25% for NO_x (Annual mean: 10 µg/m³ for NO₂), 15% of SO₂ (24-hour mean: 40 µg/m³), and 10% of VOCs (Annual mean 1.6 µg/m³) [8, 104].

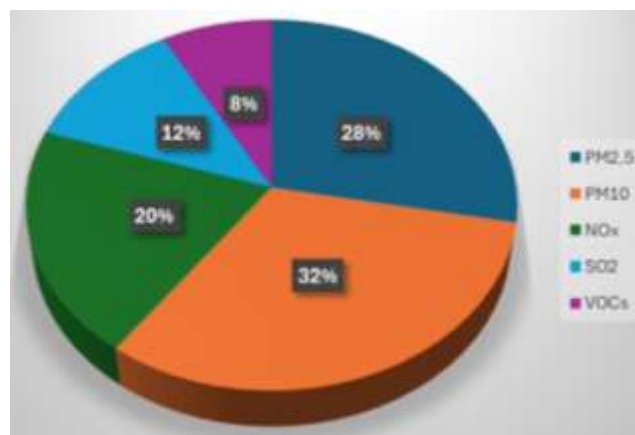


Figure 1. Major pollutants distribution in Sub-Saharan Africa.

From the analysis of specific countries and based on the reported and published studies, Nigeria emerges as one of the most affected countries, with high percentages of its urban areas exceeding WHO limits for almost all the pollutants. South Africa comes second, followed by Kenya, Ghana and Ethiopia being the least polluted of the considered countries, as highlighted in Figure 2.

The above statistics reveal severe air pollution issues in urban areas of Sub-Saharan Africa, particularly in Nigeria, South Africa, Kenya, Ghana, and Ethiopia. Key contributors to this pollution include the burning of biomass such as wood and charcoal for cooking and heating, vehicles using low-quality fuel without emission controls, and industrial activities such as manufacturing and mining. [102, 105, 106]. The same studies revealed some major diseases linked with air pollution in Sub-Saharan Africa, specifically among the urban populations. Figure 3 shows the approximate prevalence of most identified diseases in the region. About 10-15% of people living in cities have asthma, 8-12% have COPD, and up to 20-30% of children get acute respiratory infections (ARIs). Cardiovascular diseases are also common, with 5-10% of the population suffering from ischemic heart diseases (IHD) and 15-20% of the population having hypertension. Furthermore, 2-5% and 5-8% of the population, respectively, receive a lung cancer and type 2 diabetes diagnosis [102, 107, 108].

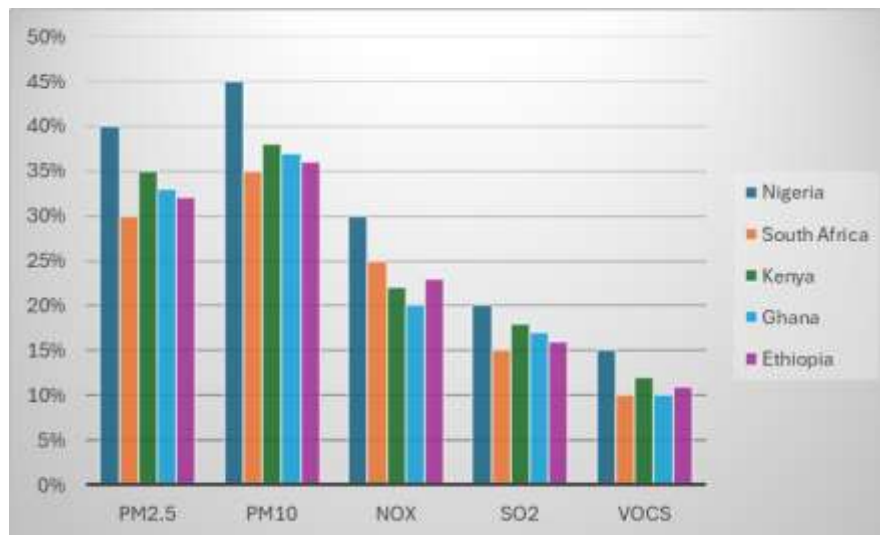


Figure 2. Areas of exceeding WHO limits per country.

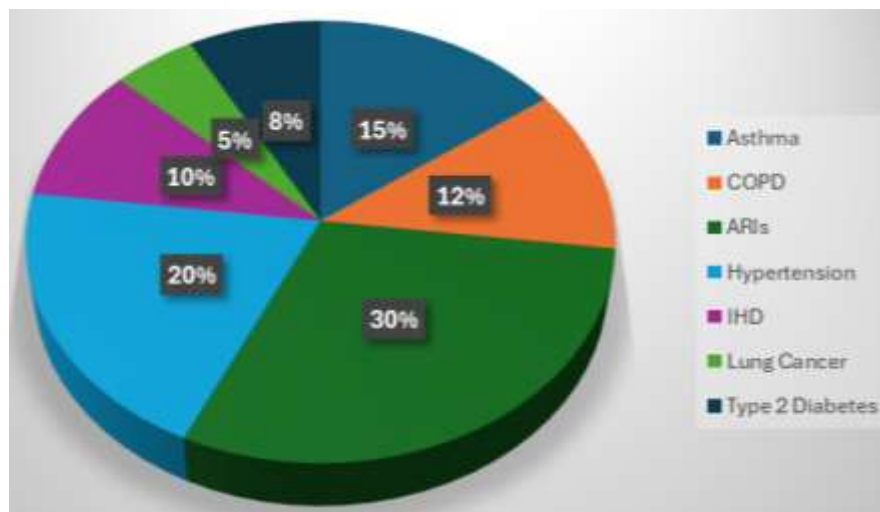


Figure 3. Major air pollution caused diseases.

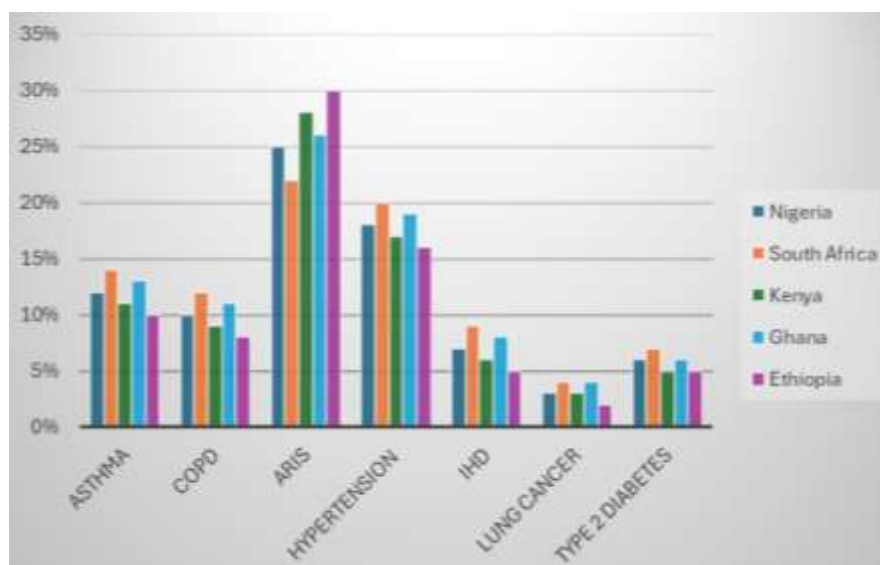


Figure 4. Diseases prevalences per country.

The differences in prevalence rates in the five studied countries are presented in [Figure 4](#). The highest rates of IHD, lung cancer, type 2 diabetes, asthma, COPD, hypertension, and other conditions are found in South Africa, while Ethiopia comes as the country with the lowest rates except for ARIs in children where the country has the highest prevalence while South Africa has the lowest. Other countries such as Nigeria, Kenya, and Ghana show intermediate prevalence rates, with Nigeria reporting 12% for asthma, 10% for COPD, 18% for hypertension, and 25% for ARIs in children. Kenya and Ghana have similar patterns, with notable rates of ARIs in children (28% and 26%, respectively) and hypertension (17% and 19%, respectively) [\[102, 107\]](#).

The observed trends can be attributed to several factors. South Africa's higher prevalence rates may be due to its advanced industrial activities, higher urbanization levels, and increased vehicle emissions, which contribute to greater air pollution. Ethiopia's lower rates for most diseases, except ARIs in children, may result from less industrialization and lower vehicle emissions, although dust storms significantly impact children's respiratory health. Additionally, variations in healthcare access, regulatory enforcement, and socioeconomic conditions across these countries also play a crucial role in these health outcomes.

However, despite the crucial insights provided by existing research on air pollution and NCDs in Sub-Saharan Africa, several data gaps and inconsistencies limit the general understanding of the full impact of air pollution on health in this region. One major issue is the limited geographic coverage of studies. Most research has been concentrated in a few major cities such as Nairobi, Accra, and Johannesburg, which leaves a significant portion of the region under-represented. This concentration of studies in specific urban areas restricts the generalizability of findings to other urban and rural settings that may have different pollution profiles and health outcomes [\[113\]](#).

Another significant problem is the inconsistency in measurement techniques used across studies. Variations in how air pollution and health outcomes are measured make it challenging to compare results and draw definitive conclusions. Different studies often use varied methodologies for air quality monitoring and health impact assessment, leading to discrepancies in the findings. Standardized measurement techniques are necessary to ensure consistency and reliability, facilitating more accurate comparisons and comprehensive understanding [\[107\]](#). Furthermore, there is a notable lack of longitudinal studies in the region while the majority of existing research consists of cross-sectional studies, which provide only a snapshot of the health impacts of air pollution at a single point in time. Longitudinal studies, which track health outcomes over an extended period, are essential for understanding the long-term effects of chronic exposure to air pollution on NCDs. Such studies would provide more robust evidence of causality and the progressive

impact of pollution on health [\[105\]](#).

Furthermore, the lack of detailed data on a broader range of pollutants limits a comprehensive understanding of the health impacts of air pollution [\[106\]](#). While most studies concentrate on commonly monitored pollutants such as PM_{2.5} and PM₁₀, there is a notable gap in research concerning the health effects of other critical pollutants, including NO, SO₂, and VOCs [\[114\]](#). These pollutants are also prevalent in urban environments and have been shown to have adverse health effects, highlighting the need for more inclusive research [\[108\]](#).

Socioeconomic and demographic factors are another area that has not been fully explored in current research [\[115\]](#). Understanding how factors such as socioeconomic status, age, gender, and other demographic variables influence the relationship between air pollution and NCDs is crucial. These factors can affect exposure levels, vulnerability, and health outcomes, and thus, their interactions must be studied to develop targeted and effective public health interventions [\[116\]](#). Therefore, there is a need for collective efforts to improve air quality monitoring, standardize research procedures, and carry out extensive investigations in a variety of Sub-Saharan African settings in order to address the above data gaps and inconsistencies.

7. Comparative Analysis with Other Regions

In low and middleincome countries, air pollution from vehicle emissions, industrial activities, and biomass burning significantly impacts public health by exacerbating NCDs [\[117\]](#). The association between air pollution and respiratory conditions like COPD and asthma is well-documented, with exposure to pollutants causing increased respiratory symptoms and decreased lung function [\[118\]](#). Similarly, air pollution is consistently linked to cardiovascular diseases, including heart attacks, strokes, and hypertension, through mechanisms involving inflammation, oxidative stress, and vascular damage [\[119\]](#). Certain carcinogenic pollutants, such as benzene and formaldehyde, are associated with increased risks of lung and other respiratory cancers in regions with high levels of air pollution [\[120\]](#). Additionally, there are regional differences in the sources of pollution [\[121\]](#). However, in some low- and middle-income countries, indoor air pollution from cooking with solid fuels significantly contributes to respiratory conditions, while outdoor pollution from vehicles and industries is more prominent elsewhere [\[122\]](#). According to Yu & Morotomi, (2022) differences in healthcare infrastructure and access to services influence the outcomes of NCDs linked to air pollution exposure. Some countries have improved air quality and health outcomes through strict regulations, while others struggle with enforcing policies [\[123\]](#). Analyzing and comparing different regions can provide valuable insights into lessons learned and best practices that

can be applied to improve various aspects of a particular region. This includes comparing how other regions have managed their economic development strategies, such as attracting investments, supporting entrepreneurship, and fostering innovation. Identify successful models and approaches that could be adapted to boost economic growth in the target region [124]. Guo et al (2020), asserted that examining how other regions have invested in infrastructure projects to improve transportation, utilities, and connectivity, while learning from their experiences in planning and implementing infrastructure projects effectively to drive sustainable development [125]. Furthermore, study social policies implemented in other regions to address pressing issues such as healthcare, education, poverty alleviation, and social welfare. Identify policies that have shown positive outcomes and consider their applicability in the target region [126].

Exploring best practices in environmental conservation, renewable energy adoption, and climate change mitigation from other regions can help the target region address environmental challenges and ensure long-term resilience by adopting sustainable practices [127]. Governance and public administration play a pivotal role in enhancing the effectiveness of decision-making and service delivery by analyzing governance structures, transparency mechanisms, and public administration systems in other regions [128]. Implementing good governance practices can significantly boost accountability and efficiency in the target region [129]. Luongo and colleagues (2023) asserted that one crucial aspect is fostering collaborations and knowledge sharing with other regions to promote cultural exchange, tourism, and trade [130]. Analysing and comparing different regions can provide valuable insights into lessons learned and best practices that can be applied to improve various aspects of the target region [131]. Bello-Bravo & Lutomia, (2020) stated that examining how other regions have managed their economic development strategies such as attracting investments, supporting entrepreneurship, and fostering innovation, one can identify successful models and approaches to boost economic growth in the target region [132]. Furthermore, studying how other regions have invested in infrastructure projects to improve transportation, utilities, and connectivity allows for learning from their experiences in planning and implementing infrastructure projects effectively to drive sustainable development [133].

Additionally, examining social policies implemented in other regions to address issues such as healthcare, education, poverty alleviation, and social welfare can help identify policies that have shown positive outcomes and consider their applicability in the target region [134]. Exploring best practices in environmental conservation, renewable energy adoption, and climate change mitigation from other regions can help the target region address environmental challenges and ensure long-term resilience [135]. Fostering collaborations and knowledge sharing with other regions can

also enrich the cultural fabric of the target region and create opportunities for growth and development. Moreover, studying how other regions have leveraged technology and innovation to drive economic transformation, improve public services, and enhance competitiveness is crucial [136]. Mızrak, (2023) asserted that embracing digitalization and innovation can propel the target region into the digital age and harness the power of technology for development [137].

Therefore, conducting a comparative analysis with other regions enables policymakers and stakeholders to gain valuable insights, learn from successful practices, and adapt strategies to advance the development agenda of their region. It is essential to tailor these lessons to the specific context and needs of the target region to achieve sustainable and inclusive growth.

8. Policy and Public Health Implications

Air pollution is a major public health concern in Sub-Saharan Africa [138]. According to Abaje et al (2020), policies and regulations, such as national air quality standards, aim to control pollutants like PM, SO₂, NO₂, and CO [134, 139]. Key measures include enforcing vehicle emission standards and promoting clean cooking initiatives [140]. Addressing this issue requires collaboration among governments, industries, communities, and international partners. Effective implementation and enforcement of these policies can improve air quality and protect public health in the region [141]. Similarly, interventions targeting NCDs have significant policy and public health implications [142]. Governments play a crucial role in promoting healthy behaviors and environments through regulations on tobacco control, alcohol consumption, unhealthy food marketing, and physical activity promotion [143]. Public health programs aim to educate individuals on NCDs risks and promote healthy lifestyles [144]. Access to preventive healthcare services, including screening programs, vaccination campaigns, and primary care, is essential for early detection and management of NCDs [145]. Community-based interventions targeting specific populations can effectively address NCDs risk factors [146]. Collaboration across multiple sectors, including healthcare, education, urban planning, and agriculture, is necessary [147]. Policies that promote cross-sectoral partnerships can lead to more comprehensive and sustainable interventions. Regular monitoring and evaluation of NCD interventions are critical for assessing effectiveness and making informed policy decisions [148]. Data collection on NCD risk factors, morbidity, and mortality can help track progress and identify areas for improvement [149]. Considering these policy and public health implications, stakeholders can develop and implement interventions to effectively target NCDs, improve population health, and reduce the economic burden of these chronic conditions [150]. Furthermore, a number of general recommendations can help policymakers, healthcare providers, and researchers

effectively address the public health challenges associated with air pollution and NCDs. Below are some key recommendations:

Policymakers:

- 1) Implement and enforce strict air quality standards to reduce pollution levels and protect public health.
- 2) Invest in clean energy initiatives and sustainable transportation to reduce emissions and improve air quality.
- 3) Develop urban planning policies that prioritize green spaces and pedestrian-friendly infrastructure to mitigate the impact of air pollution on NCDs.
- 4) Allocate resources for research and monitoring programs to better understand the link between air pollution and NCDs and inform evidence-based policy decisions.
- 5) Provide funding and support for public health campaigns to raise awareness about the health risks associated with air pollution and promote preventive measures.

Healthcare Providers:

- 1) Include air pollution exposure history as part of routine patient assessments and screenings.
- 2) Educate patients about the health effects of air pollution and provide guidance on reducing exposure, such as staying indoors on high pollution days and using air purifiers.
- 3) Collaborate with public health agencies and policymakers to advocate for policies that prioritize clean air and public health.
- 4) Conduct research on the local impact of air pollution on NCDs to better tailor prevention and treatment strategies for at-risk populations.
- 5) Advocate for increased funding and resources for healthcare services to address the growing burden of NCDs linked to air pollution.

Researchers:

- 1) Conduct longitudinal studies to further investigate the long-term effects of air pollution exposure on the development and progression of NCDs.
- 2) Explore potential biomarkers and mechanisms underlying the relationship between air pollution and NCDs for targeted interventions.
- 3) Collaborate with interdisciplinary teams to assess the economic and social implications of air pollution-related NCDs.
- 4) Evaluate the effectiveness of policy interventions and public health initiatives in reducing the burden of NCDs associated with air pollution.
- 5) Share findings and best practices through peer-reviewed publications and conferences to inform evidence-based strategies for addressing the public health impact of air pollution on NCDs.

Implementing these recommendations, policymakers, healthcare providers, and researchers can work together to

mitigate the impact of air pollution on NCDs and promote a healthier environment for all.

9. Challenges and Limitations

Studying the impact of air pollution on NCDs in Sub-Saharan Africa presents several methodological challenges [151]. Lyer and colleagues, (2021) asserted that these include accurately measuring individual exposure to pollutants, accounting for confounding factors like lifestyle and genetics, managing the long latency periods of diseases, ensuring data quality in resource-poor settings, conducting costly cohort studies, addressing ethical considerations, and applying findings across diverse populations [152]. Overcoming these challenges requires interdisciplinary collaboration, advanced data collection methods, and a deep understanding of the interaction between air pollution and NCDs to develop effective public health interventions for Sub-Saharan Africa [153]. Data availability and quality issues in Sub-Saharan Africa also hinder data analysis. These include incomplete data, inaccuracies from limited monitoring infrastructure, biases in data collection, privacy concerns, and historical data gaps [154]. According to Cinnamon, (2020) these issues can compromise the reliability of results and obstruct evidence-based decision-making essential for public health [155]. To address these challenges, robust data governance practices, rigorous data quality assessments, effective data cleaning techniques, integration of diverse data sources, and validation of data are necessary to improve reliability and reduce biases.

Additionally, reviews within the Sub-Saharan Africa context face limitations such as local perspective biases, small sample sizes due to logistical constraints, misaligned review timing with local health priorities, cultural influences on subjective interpretations, lack of regional health expertise, potential biases in sponsored content, and variations in user experiences due to digital access disparities [156]. It is important to recognize and address these limitations when using reviews to inform decision-making processes tailored to Sub-Saharan Africa's unique health challenges.

10. Future Research Directions

1) Long-Term Exposure and Vulnerable Populations

Future research on the relationship between air pollution and NCDs in Sub-Saharan Africa should prioritize long-term exposure studies. These studies should assess the impacts of air pollution on cardiovascular diseases and cancer. Additionally, researchers should focus on identifying the susceptibility of vulnerable populations and specific sources of air pollution, such as industrial emissions and household practices. Enhanced air quality monitoring systems, evaluations of intervention and policy effectiveness,

interdisciplinary collaborations, community engagement, and studies on the interactions between air pollution, climate change, and NCDs are essential. These efforts aim to develop evidence-based strategies to mitigate health risks in Sub-Saharan Africa.

2) Interdisciplinary and International Collaborations

Future research should also emphasize the potential for interdisciplinary and international collaborations. Partnerships among public health experts, environmental scientists, policymakers, and community stakeholders can provide diverse perspectives and expertise, enhancing the research quality. International collaborations can facilitate knowledge exchange, capacity building, and the implementation of best practices across regions. Interdisciplinary efforts can yield comprehensive insights into the complex interactions between air pollution and NCDs, leading to effective mitigation strategies tailored to Sub-Saharan Africa's specific challenges. By fostering these collaborations, researchers can address critical research gaps, drive innovation, and improve public health outcomes in the region.

3) Innovations in Monitoring and Mitigating Air Pollution

Innovations in monitoring and mitigating air pollution can significantly benefit future research in Sub-Saharan Africa. Advances in low-cost sensor technologies and remote sensing capabilities could enable widespread, real-time air quality monitoring, facilitating data-driven interventions and policy decisions. Implementing strategies like mobile monitoring platforms or citizen science initiatives can fill existing data gaps and enhance understanding of air pollution sources and exposure patterns. Exploring novel approaches such as nature-based solutions, green infrastructure, and sustainable urban planning offers cost-effective methods to reduce pollutant levels and improve public health outcomes in Sub-Saharan Africa. Embracing these innovations can drive progress in addressing the complex relationship between air pollution and NCDs, leading to more effective interventions and policies to protect human health in the region.

11. Conclusion

The review reveals the significant effects of air pollution on NCDs in Sub-Saharan Africa, linking pollution from biomass burning, vehicular emissions, industrial activities, and dust to high rates of respiratory diseases, cardiovascular diseases, cancer, and diabetes in urban areas. Specifically, asthma affects 10-15% of the urban population, COPD impacts 8-12% of adults, and acute respiratory infections occur in 20-30% of children. Cardiovascular diseases such as hypertension and ischemic heart disease affect 15-20% and 5-10% of the population, respectively, while lung cancer and type 2 diabetes affect 2-5% and 5-8% of the population, respectively. Addressing air pollution is essential for improving public health in Sub-Saharan Africa. Reducing pollution can significantly decrease the incidence of these

diseases, improve quality of life, and lower healthcare costs. Effective measures include switching to cleaner energy sources, improving vehicle emission standards, enforcing industrial regulations, and enhancing air quality monitoring. Public awareness campaigns and education on the health impacts of air pollution can also promote community-level action and support for policy measures. A collective effort from stakeholders are crucial. Governments need to prioritize air quality management in national health strategies, policy-makers should enforce and strengthen environmental regulations, and international organizations and donor agencies can provide funding and technical assistance. Researchers and public health professionals must continue studying the health impacts of air pollution and advocating for evidence-based interventions. Communities and civil society organizations can help raise awareness and demand cleaner air. By working together, stakeholders can create healthier urban environments and reduce the negative health impacts of air pollution in Sub-Saharan Africa.

Abbreviations

ARIs	Acute Respiratory Infections
CVD	Cardiovascular Disease
CVDs	Cardiovascular Diseases
CH ₄	Methane
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
DRC	Democratic Republic of Congo
DLEU1	Deleted in Lymphocytic Leukemia 1
HDI	Human Development Index
HS3ST3B1	Heparan Sulfate-Glucosamine 3-O-Sulfotransferase 3B1
IHD	Ischemic Heart Disease miR-99b – microRNA-99b
N ₂ O	Nitrous Oxide
NH ₃	Ammonia
NO	Nitric Oxide
NO ₂	Nitrogen Dioxide
NO _x	Nitrogen Oxides
NCDs	Non-Communicable Diseases
NOS	Newcastle-Ottawa Scale
PM	Particulate Matter
PM _{2.5} / PM ₁₀	Particulate Matter with aerodynamic diameter ≤2.5 μm / ≤10 μm
VOCs	Volatile Organic Compounds
SO ₂	Sulfur Dioxide
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
VOCs	Volatile Organic Compounds
WHO	World Health Organization
μg/m ³	Micrograms per cubic meter

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Author Contributions

Kalala Elisée Kabuya: Conceived the study, conducted the literature review, and drafted the manuscript. Responsible for the overall project management and coordination of all aspects of the research and writing process.

Maxwell Katambwa Mwelwa: Contributed to the development of the study framework, conducted data analysis, and reviewed and revised the manuscript. Provided critical insights and suggestions for improving the quality and depth of the review.

Charline Mukasa Sangany: Contributed to the development of the study framework, and performed editing, proofreading, reviewing, and revision of the manuscript to enhance its structure, quality, and depth.

Conflicts of Interest

The authors declare no conflicts of interest.

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