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Review Article

Systematic Review of Air Quality Management in Urban Environments: Planning for Healthy Cities Using the One Health Approach

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Abstract

Background: Air Quality Management in urban environments is a planned and interdisplinary practice expected at follow up, regulatory, and decreasing air contamination to keep community well-being and the atmosphere. Through fast development, people growing, and urban motor traffic growth, numerous municipalities particularly in Global south countries expression thoughtful air quality encounters. The aim review evaluates air quality management in urban environments with emphasis on planning for healthy cities. *Methodology*: The systematic review observes global compositions evaluating air quality administration methods, through an emphasis happening controlling contexts, wellbeing influences, checking systems, and city development policies. Databases containing PubMed, Web of science, and Google Scholar remained used to identify peer-reviewed articles, official reports, and case studies. After applying inclusion and exclusion criteria, 55 documents were selected for thematic analysis. Important themes included pollution sources, health and environmental impacts, urban planning strategies, technological innovations, and policy frameworks. *Results:* Results show that though industrialized countries require applied organized air quality administration methods reinforced through law for instance the U.S. Clean Air Act and EU Air Quality Directives, where unindustrialized nations fight through split strategies, inadequate statistical records, and inadequate official capability. Progressive tackles for example low-cost sensors, digital urban twins, and real-time pollution forecasting are existence progressively accepted to increase policymaking. Municipalities that combined air quality administration with city forecasting established better wellbeing results, counting compact respiratory and cardiovascular diseases. Though, important obstacles persist, for instance inadequate finance, administrative resolve, and community commitment. *Conclusions:* Operative city air quality managing is vital to design for healthy metropolises. The evaluation highlights that effective air quality controlling needs robust authority, consistent facts, innovative skills, and lively investment participation. Metropolises obligation implant air quality deliberations into wider ecological and growth rules to accomplish permanent developments. City air pollution finished complete and comprehensive policies should be serious intended for protection community wellbeing, attaining weather objectives, and making strong city surroundings.

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Keywords

Air Quality Management, Urban Environments, Air Pollutants

1. Introduction

Air quality management (AQM) in urban environments is a planned, interdisciplinary, and adaptive process aimed at monitoring, regulating, and reducing air pollution to protect human health and the environments [1]. Clean air is a basic human right; however, air pollution remains a critical global issue contributing to non-communicable diseases such as heart attacks strokes, and respiratory conditions while also threatening ecosystems [2].

The world health organization reports that air responsible for approximately 7 millon premature deaths annually, mainly due to outdoor and household air contaminants [3, 4]. Over half of these deaths occur in low and middle income countries, where poor air quality is linked to increased respiratory illnesses, cardiovascular diseases, and reduced life expectancy [4].

Rapid industrialization and the rise in motor vehicle use have worsened urban air pollution especially in the Global South, where urban growth often outpaces environmental regulation and infrastructure development [4]. Urban air pollution originates from multiple sources, including traffic emissions, industrial activities, construction dust, and open burning of waste and biomass [5]. These challenges not only endanger public health but also contribute to climate change and economic productivity losses [6].

A growing number of countries are adopting integrated strategies combining environmental monitoring, policy enforcement, urban planning, and technology. Tools such s real time air quality sensors, Geographic Information systems (GIS), and digital urban twins are transforming how cities assess and manage pollution [4].

From a one health approach perspective air pollution affects not only humans but also animals and ecosystems. Pollutants harm both domestic and wild animals and contribute to environmental degradation, increasing the risk of zoonotic diseases. Therefore, incorporating one health in AQM encourages cross sector collaboration linking human animal and environmental health to support sustainable urban development. This review aims to evaluate the current landscape of urban AQM, with a focus on designing healthier cities and drawing from global and regional best practice including the one health approach.

2. Methodology

This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) rules to guarantee inclusive, clear, and consistent method to classifying, choosing, and producing related research. The objective of review evaluates and synthesizes current research on urban air quality management, with a focus on planning strategies for healthier cities globally. The review must be passed four vital steps selecting screening, fitness, and presence. A Comprehensive review explore was showed crossways numerous databases, containing Google Scholar, PubMed, and Web of Science, to determine peer-reviewed articles, government reports, and publications from international organizations. The examination methods engaged particular key terms: air quality management, urban environments, healthy cities, urban planning, urban air pollution, and policy interventions, capturing both historical and recent publications.

2.1. Inclusion Criteria

The standards concentrated on studies investigative urban air quality management universal, predominantly those tackling community fitness effects, controlling structures, or design tackles. Acceptable sources included peer-reviewed articles, guidelines, official reports, and publications with clearly defined methodologies and results. Studies were excepted if the full text was inaccessible or if they were not published in English. Completely retrieved articles were bringing into the EndNote reference manager, and duplicates were removed. Full PDF texts of hypothetically relevant articles were assessed.

The concluding synthesis included studies categorized into thematic areas for example air quality management; pollution sources, health and environmental impacts, planning strategies, technologies, and policy frameworks. Records were extracted using a consistent form to ensure uniformity. Extracted information included study objectives, design, location, sample characteristics, pollutants measured, monitoring methods, health or environmental results, air quality standards applied and policy recommendations. Results were synthesized using a narrative approach, importance key trends, knowledge gaps, and policy implications.

2.2. Research Design

The evaluation working a combined approach to identify, chooses, and investigates studies on urban air quality management. It attentive on peer-reviewed articles, official reports, and guidelines that met the inclusion criteria. Inclusive exploration was accompanied crossways numerous databases to detention completely possibly applicable literature. The assessment developments elaborate showing labels, summaries, and complete manuscripts for importance to the investigation inquiries. Data from the certain studies were extracted and prepared into key thematic areas, including pollution sources, health and environmental impacts, urban planning strategies, technological innovations, and policy frameworks. A description synthesis was used to review the results and highlight key trends, gaps, and future research directions.

3. Result

The flow of documents complete the evaluation is revealed in the PRISMA diagram. Overall of 444 records were recognized through database, internet, and journal searches. After eliminating duplicates, 177 titles and abstracts were screened. Total 272 complete articles were evaluated for fitness. Finally, 55 documents were included in the study (Show Figure 1).

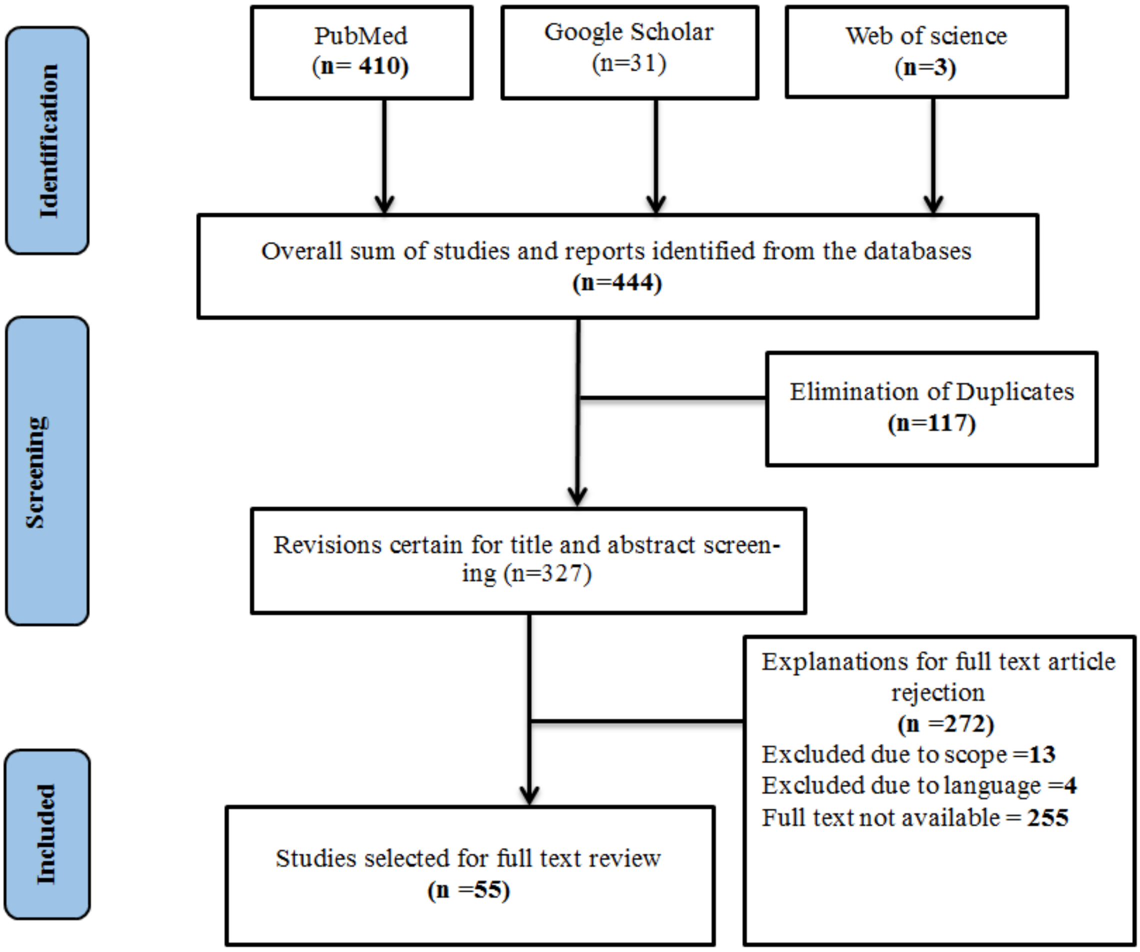

Figure 1. Flow of documents through the review, following PRISMA reporting style.

4. Air Quality Management in Urban Environments

4.1. Urban Air Quality

Air condition in city states to the situation of the surrounding in towns, recognized by the consideration of chemicals damaging to human health and the environments [6]. The characteristically evaluated by measuring the level of major pollutants like particulate matter (PM2.5 and PM10), Nitrogen dioxide(NO_2), Sulfur dioxide(SO2), carbon monoxide(CO) Ozone(O_3) and Volatile organic compounds(VOCs) [6]. Clean air is essential for community health, environmental integrity, and weather constancy. Polluted air contributes to a wide range of health problems, including respiratory and cardiovascular diseases, reduced productivity, and premature mortality, particularly in densely populated urban areas [7].

City surroundings are specifically life-threatening in air quality studies because of high demographic density; manufacturing activities, transportation related emissions, and power using all major contributors to pollution [8]. Fast development in many Global south nations has exaggerated air contamination weights, turning towns into hotspots for environmental health risks [9]. Furthermore, the undesirable effects of air pollution extend outside human health, unclean air damages ecologies, decrease farming crops, and damages built heritage [10]. Even though international efforts are ongoing to decrease pollutant productions and greenhouse gases, the pace of manufacturing expansion and vehicle expansion, especially in low and middle income countries, remains to increase city contamination points [11].

Greenhouse gases such as carbon dioxide, methane, and ozone mainly emitted in urban areas are also related to weather alteration, although they are often preserved distinctly from local air contaminants due to their universal effects [12]. Consequently, considerate urban air quality is vital for developing sustainable community health strategies, urban planning strategies, and climate actions. This review explores key pollution sources, their impacts, monitoring tools, and policy approaches, with particular focus on Africa, including Ethiopia (*Show Table 1*).

Table 1. *Description of air quality management in urban environment.*

Definition of air quality management in urban environments
Air Quality administration in city surroundings is a planned, interdisplinary process that goals to assess, monitor, control, and reduce air pollution in cities to safeguard public health, ensure environmental protection, and support sustainable urban development. It includes coordinated actions counting air pollution source identification, regulatory policy development, and implementation of control measures, stakeholder engagement, and continual evaluation of air quality standards [13].
City air quality administration is organized procedure that includes assessing air pollution levels, recognizing pollution causes, location principles, and developing and implementing rules to decrease discharges and protect community wellbeing in urban settings [6].
Air quality management in towns contains combined approaches for checking, policy-making, and controlling implementation to decrease contaminant levels, particularly from transportation, energy, and manufacturing sectors, thereby ensuring a healthier city environment [45].
Real city air quality administration needs joining systematic tools, recognized capacities, financial tools, and community commitment to decrease discharges, predominantly in rapidly urbanizing areas of developing countries.
Urban air quality administration refers to a systematic method used by towns to assess air pollution problems, recognize causes, set air quality goals, and implement regulator policies using both methodological tools and official actions [77].
Air quality administration in city areas includes a suite of strategies, guidelines, checking systems, and action plans aimed at improving air quality in line with national and EU standards, particularly in high-exposure zones such as cities [39].

4.2. Sources of Urban Air Pollution

City air pollution is mainly influenced driven by anthropogenic activities and fast urban development, with main causes counting traffic related emissions, manufacturing processes, household energy consumption, and infrastructure development. In numerous towns, transportation emissions are the primary cause, particularly from outdated, poorly retained automobiles working under overcrowded traffic situations [13]. Industrial actions that trust on coal, oil, and natural gas and lack effective pollution management technology emit large quantities of PM, NO_2, SO_2, and VOCs [6]. Furthermore, residential use of solid biomass fuels for food preparation and thermal conditioning families in low-income urban areas leads to both indoor and outdoor air pollution [14]. Building and destruction activities also release large quantities of dust and fine particulates, deteriorating city air quality, particularly in rapidly developing countries [15]. These causes can largely be classified into mobile, stationary, and area sources, each playing a role in varying degrees to general pollution levels. In African cities such as Addis Ababa, city air pollution is increased by older vehicle fleets, uncontrolled small-scale manufacturing, and extensive dependence on biomass fuels for household energy [16].

The World Bank (2016) emphasizes that in Sub-Saharan region home fuel combustion alone is responsible for a significant share of fine particulate pollution, obstacle exacerbated by poor city development and feeble implementation of environmental regulations. In city zones, indoor air pollutants contain contaminants from indoor sources such as cooking and tobacco smoking, as well as those that infiltrate from outdoors, counting particulate matter (PM) and carbon monoxide from nearby traffic. Streets represent another distinct and critical microenvironment, often characterized by pollution hotspots due to traffic or manufacturing emissions [17, 18].

The comparative significance of diverse microenvironments varies universal, contingent on how people allocate their time, the design and quality of buildings, the distribution of pollution causes, and the implementation of air quality administration actions [18]. Cooperatively, these various and overlapping causes make urban air pollution a multifaceted, comprehensive matter that needs combined and context-specific policy responses (*Show Table 2*).

Table 2. *Sources of air pollution in urban environments.*

Microenvironment	Sources	Pollutants
Home	Meal preparation room heating, smoking, household products, pets, gnawing animals, and insects	PM, CO, NO_x, VOCs Allergens
Transport settings	Transport and industrial emission, dust from road surfaces, smoking	PM, CO, NO_x, O3, VOCs, Aeroallergens, carcinogens
Streets	Vehicle emissions, &road dust	PM, CO, NO_x, O3, VOCs, Carcinogens, lead
Work environments	Manufacturing processes, &smoking, ambient pollution	PM, CO, VOCs, NO_x, Carcinogens
Entertaining surroundings	Meal preparation and Thermal energy production	PM, VOCs, carcinogens

CO= carbon monoxide; NO_x: nitrogen oxides; O: ozone. Source [6]

4.3. Health and Environmental Impacts

Urban air pollution presents significant risks to both human health and the environment, contact to key pollutants for instance PM2.5 and PM10, NO_x, SO_2, O_3, CO, and VOCs is related to extensive variety of negative health effect, such as pulmonary diseases, circulatory system disorders, brain attack, and early death [6, 19]. Fine particulate matter, especially PM2.5, can infiltrate deeply into the pulmonary system and circulatory system, worsening asthma, chronic bronchitis, and heart disease. Surface-level ozone continues to decrease pulmonary function and aggravates respiratory problem, especially among high risk population populations like pediatric and geriatric [20].

Clear evidence shows causal associations between PM2.5 exposure and all-cause mortality, chronic obstructive pulmonary disease (COPD), ischemic heart disease, stroke, lung cancer, and lower respiratory infections [19, 21]. Current studies also recommend associations between air pollution and type II diabetes, newborn death, and underweight at birth, as well as nervous system disorders such as Alzheimer's dementia [21-23]. Extremely, air pollution ranks among the top five global health risks for cause disease, rivaling unhealthy diets and tobacco use [24].

To illustrate, NO_2 alone has been attributed to 13% of global pediatric asthma cases [25]. Apart from health, air contamination significantly degrades the environment, contaminants like SO_2 and NO_x lead to acid rain, which harms vegetation, acidifies water bodies, and degrades soil quality [26-28]. Furthermore, black carbon and methane act as short-lived climate pollutants, intensifying global warming and associating air quality directly to climate change [3, 29-31].

The financial consequences are additional significance, in globally as reported by the World Bank (2016), exposure to PM2.5 alone resulted in US$143 billion in lost labor income and US$3.55 trillion in losses in global well-being. These expenses are sustained through both direct health care expenditures and indirect losses in productivity. In developing countries, welfare losses equaled 1% of Gross Domestic Product (GDP), while in high-income, non- Organization for Economic Co-operation and Development (OECD) countries, they reached up to 5% [17].

Utilizing the One health approach which recognizes the interconnection between people, animals, and their shared environment enables integrated strategies for monitoring and reducing air pollution [3, 32]. This multidisciplinary framework is increasingly vital in mitigating the complex challenges, climate change, and public health threats.

Furthermore, air pollution reduces agricultural productivity, corrodes buildings and infrastructure, and escalates the cost of climate mitigation and adaptation. In summary, urban air pollution represents the single largest environmental health threat worldwide, contributing to millions of deaths annually, reducing quality of life, harming ecosystems, and placing a massive burden on national economies. These impacts underscore the urgent need for effective air quality management, policy enforcement, and international cooperation (*Show the Figure 2*).

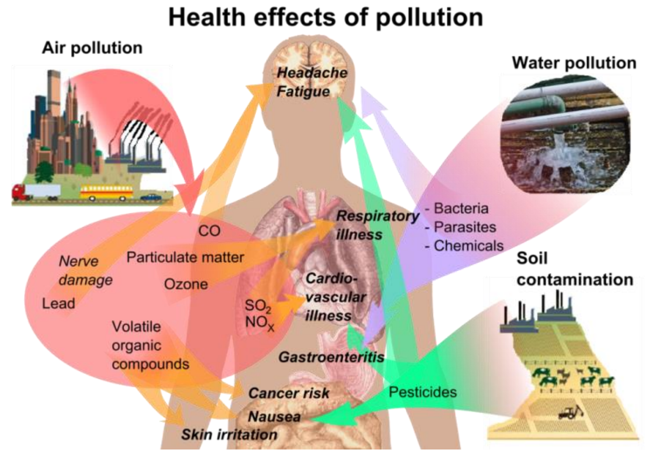

Figure 2*. Health and Environmental Impacts of Urban Air Pollution [4].*

4.4. Management Strategies and Policy Frameworks

Active directing of urban air quality needs holistic framework combining regulatory, planning, technological, and behavioral strategies [3]. Worldwide, regulatory strategies including emission standards, zoning laws, and environmental impact assessments (EIA) have been instrumental in reducing emissions from transport and industrial sectors [1, 6]. For example, the European Union implements stringent air quality directives that mandate threshold limits for PM2.5, NOx, and ozone [33]. In the United States, the clean air act empowers the Environmental Protection Agency (EPA) to set national ambient air quality standards (NAAQS) and control industrial emissions using best available control technology [34]. In urban planning, the incorporation of green infrastructure, such as parks and tree corridors, alongside compact city designs and smart city technologies, has shown potential for reducing pollution exposure [35]. These measures are being adopted in fast growing urban areas, including parts of Asia and Latin America [36]. Technological solutions, such as transitioning to electric vehicles (EVs), using cleaner fuels, and installing emission control devices like scrubbers, catalytic converters on vehicles and factories, are increasingly promoted in both developed and developing countries [36].

In Africa, however, air quality regulation often suffers from weak enforcement and outdated regulatory systems. Countries like South Africa and Nigeria have started implementing air quality control plans, but progress remains uneven [26, 37]. In Ethiopia, urban air pollution is addressed under the environmental pollution control proclamation (No. 300/2002), which mandates EIAs and emission controls, but enforcement is limited due to institutional and financial constraints [16]. Therefore, to be effective, policy frameworks in low- and middle-income countries must combine regulatory tools with capacity-building, public engagement, and localized technology solutions. Urban air contamination control practices are nation exact and according to established priorities for specific air quality regulation regions to keep tolerable ambient air quality [13].

In below table three various developed and developing countries have implemented their own legislative laws on UAQM [38]. A fundamental components of city air quality administration development for well-being city include air quality objectives, tracking, emission inventories, prediction and forecasting tools, control strategies, and community contribution [13]. Every component has an important function in enhancing the effectiveness of UAQMP and thereby reducing pollutant concentrations. Nevertheless, the efficient and effective operation of urban air quality management in developing countries remains a major challenge for air quality managers due to factors such as lack of government commitment and stakeholder involvement, weaknesses in policies, standards, and regulations, and the absence of real-time air quality data and comprehensive emission inventories [13].

The research finding Indonesia shows that the urban air pollution is probably the most severe ecological problem, mainly in rapid development of the manufacturing and transportation sectors [13]. Systems based methodology was developed for urban air quality management, this approach includes: Recognition of major pollutants and sources, establishment of an air quality monitoring network, development of an emission inventory, ranking of pollution sources, design of mitigation plans, and creation of a decision-making tool (*Show Table 3)*.

Table 3*. Key legislative actions and policy measures of different countries.*

Countries	Legislative laws	Action
United States [38]	Air pollution control act Amended: Foundational air pollution legislation. National Ambient Air Quality Standards	Automotive emission Power generation facility standards State implementation plans Air pollution warning systems for at risk populations
United Kingdom [42]	Environment Act Basis for Local Air Quality Management (1995). Air quality strategy revises pollution reduction goals	Ultra low emission zones in London. Air pollution warning system for at risk population

Countries	Legislative laws	Action
Germany [80]	National emission regulation act	Emission control zone in urban center Progression of sustainable public transportation and cycling facility
Japan [81]	Air quality protection act 1968	Traffic adjacent pollution monitoring stations Rigorous controls on factory emission and vehicle fuel economy
South Africa [82]	National Environmental Management: Air Quality Act Core legislation for air quality regulation	Development of nationwide and regional air quality monitoring systems Air quality management plans for metros and provinces.
Kenya [83]	County government to monitor and regulate air quality	Pilot air quality sensors in Nairobi and Kisumu. Encouragement of walking, cycling and urban greening initiatives
Nigeria [84]	NESREA establishes the environmental enforcement agency Act (2007). Air Quality Control Regulations defines pollutant limits and monitoring rules	Nationwide air pollution monitoring stations. Public awareness initiatives to curb open waste burning and generator dependence
Ghana [85]	The Ghana standards authority establishes national ambient air quality	Motor vehicle emissions testing Awareness programs on the origins of pollution Prohibition of two stroke engine use and open waste burning in Accra
Ethiopia [86]	Environmental Pollution Control Proclamation Climate Resilient Green Economy Strategy	Promotion of clean cook stoves and electric in Addis Ababa Enclosure of air quality in climate adaptation plans

4.4.1. Air Quality Standards

City air quality standards are crucial for protection of community health in fast growing and tightly occupied towns [1, 6]. From a global perspective, the issues air quality standards that serve as benchmarks for acceptable concentrations of major pollutants, including $PM_{2.5}$ and PM_{10}, NO_2, SO_2, O_3, and CO the update, World Health Organization guideline shows that a significantly tightened recommended limits based on new scientific evidence, setting the annual mean $PM_{2.5}$ standard at just 5 μg/m ³; reflecting increased awareness of health consequence at all small contamination points (*Show the below Table 4)* [6].

Table 4. *WHO 2021, Recommended Standard level of air pollutant and their health effects*

Pollutant	High health risk (IT-1)	Elevated but less severe(IT-2)	Moderate risk(IT-3)	Low risk(IT-4)	Minimal health risk
$PM_{2.5}$ (Annual mean)	35	25	15	10	5
$PM_{2.5}$ (24-hr/mean	75	50	37.5	25	15
PM_{10} (Annual mean)	70	50	30	20	15
PM_{10} (24-hr/mean	150	100	75	50	45
NO_2 (Annual mean)	40	30	20	-	10
NO_2 (24-hr/mean)	120	50	-	-	25
O_3 (Peak season)	100	70	-	-	60
O_3 (8 hr)	160	120	-	-	100

Pollutant	High health risk (IT-1)	Elevated but less severe(IT-2)	Moderate risk(IT-3)	Low risk(IT-4)	Minimal health risk
SO_2 (24-hr/m)	125	50	-	-	40
CO (24-hr/m)	7	-	-	-	4

Regionally the European Union (EU) implements compulsory air quality guideline across member states, mandating urban areas to monitor and regulate pollutant concentration but specifically, the EU sets a legal annual limit of 25 µg/m ³ for $PM_{2.5}$, which is more lenient than the WHO guideline but legally binding [39]. Based on the European Environment Agency's 2023 report, although urban air quality has improved in many cities, an important portion of the population remains exposed to pollution levels exceeding both EU and WHO recommendations [39].

Countrywide and city level standards show how countries understand and apply these global and local standards, the United States, the Environmental Protection Agency (EPA) launches the National Ambient Air Quality Standards (NAAQS), setting an annual $PM_{2.5}$ limit of 12 µg/m ³[40]. On other hand, heavily polluted urban areas such as Delhi, India, follow national standards that often diverge from WHO recommendations due to economic and policy constraints, up till now still face continued air quality problems, subsequently, numerous cities have implemented emergency response plan and traffic management strategies to mitigate severe pollution events and while guided by international scientific research, urban air quality standards should be customized to the particular social economic and environmental condition of each city [41].

In the U.S, air quality regulations are divided into ambient and hazardous categories, the ambient standards fall under NAAQS and cover six criteria pollutants: O_3, CO, SO_2, NO_2, PM_{10}, and $PM_{2.5}$ [40]. In the United Kingdom, guidelines are aligned with the ecosystems capacity limits, while UAQMP policies specify a timeline within which authorities must meet these targets [42]. In low and middle income country, have set their own air quality guideline, though certain countries and directly follow WHO guidelines [43].

4.4.2. Methods for Monitoring

Tracking and evaluating urban air pollution are crucial for analyzing pollution patterns, assessing health risks, and guiding effective policy interventions. Internationally, ground-based monitoring stations remain the highly accurate approach to pollutant measurement for instance $PM_{2.5}$, NO_2, SO_2, O_3, CO, and lead, contribution high-resolution, real-time data that supports compliance with air quality standards [6].

However, given the significant expenses for setup and maintenance covers commonly underutilized in developing countries. To mitigate these challenge, satellite remote sensing technologies such as NASA's MODIS and ESA's Sentinel-5P serve as critical tools for regional and national air quality monitoring, providing data on aerosol optical depth (AOD) and trace gases, which show strong association with surface level pollutant concentration [44]. Air Quality Indices (AQIs) are extensively adopted by global and national institutions to translate intricate datasets into understandable health risk insights for the general population [45].

Furthermore, dispersion model such as AERMOD and CALPUFF assist in simulating the transport and transformation of contaminants, support predictive analyses and underpin emission policies [46]. On the nationwide level, real air quality checking depends on the design of robust monitoring networks associated with particular environmental objectives [47]. Planned a network in Fulton County, Georgia, focused on non-reactive contaminants [48]. In Saudi Arabia, a multiple criteria approach was employed to optimize the network design in Riyadh [49]. In the United States, the environmental protection agency operates a nationwide network through the office of air quality planning and standards, with forecasts for over 300 cities [53].

The United Kingdom operates over 300 monitoring stations provide hourly data and European union member states coordinate their efforts through the European environment agency [48, 51]. China's CNEMC oversees more than 2,000 monitoring stations across 113 cities while, Hong kong operates 14 continuous monitoring station managed by the environmental protection department, with additional collaboration through the pearl river delta regional network has been extensively studied [52].

In India, the national ambient air quality monitoring network comprises 342 stations across 127 cities and reinforced by state pollution regulator boards and targeted monitoring program, for instance: Delhi operated by the Indian institute of tropical meteorology [53]. In South Africa operates 94 monitoring stations to ensure regulatory compliance and most low income and middle-income countries organize their network primarily aimed at fulfilling legal obligation, despite facing resource and infrastructure limitations [54]. Together, the coordination of ground level monitoring systems, satellite technologies, air quality indices, and modeling tools significantly enhances global and national capacities for environmental monitoring, evaluate, and effectively manage urban air quality. The table below presents the countries and the methods they use for monitoring air quality (*Show table 5*).

Table 5. *Countries implement air quality monitoring networks.*

Countries	Air quality monitoring network	Automatic/ Manual	Pollutants
European union [33]	Grouped according to policy compliance risk assessment real time monitoring	Both	NO_x, NO_2, SO_2, O_3, CO, PM(PM_{10} and $PM_{2.5}$) Benzene
Australia [87]	City level and regional according to population density > 25000. Screening studies have shown that specific pollutant level consistently remains below the national ambient air quality standards	Both	CO, NO_2, O_3, SO_2, PM_{10} and $PM_{2.5}$
South Africa [88]	South Africa's national air quality database	Manual	CO, NO_2, PM_{10}, SO_2

4.4.3. Source Apportionment

Pollution source identification is integral the part of global urban air quality management. It provides the scientific basis for empirically supported policymaking under urban air quality management programs (UAQMP). Source apportionment studies are routinely performed using two approaches: morphological and chemical analysis of contaminants, among these, chemical characterization is preferred for large-scale studies due to its numerically accuracy and process includes identifying the chemical components of particulate matter which differ based on the emission source and its strength [55].

Source apportionment techniques like chemical mass balance (CMB) and Positive Matrix Factorization (PMF) models are commonly used to quantify pollutant concentrations based on ambient air quality data. An essential element of receptor modeling use source profiles contains metals such as Al, Si, Ti, and Ca are indicative of crustal or soil sources; Ni and V suggest fuel oil combustion; Zn and Cr indicate refuse burning; and Zn, Cr, Pb, and Cu are commonly linked to vehicular emissions [55].

Bimolecular markers are also employed for their high source specificity levoglucosan for wood burning, hopanes and steranes for mobile sources, and polycyclic aromatic hydrocarbons (PAHs) for distinguishing between gasoline and diesel exhaust [56]. Various modeling techniques are used to support these analyses, including time series analysis, principal component analysis, species series analysis, and multi-linear engine (ME) analysis [40, 57].

Most source apportionment studies rely on receptor modeling, a few have also employed dispersion modeling approaches [58]. Recent research conducted in the United States and Europe has shown that $PM_{2.5}$ concentrations are mainly influenced by metal industries, motor exhaust, and crustal emissions [59]. These efforts not only guide urban air pollution mitigation measures but also contribute to the development of comprehensive emission inventories are crucial for effective long term air quality planning.

4.4.4. Emission Inventory

A detailed inventory of emissions is essential component of the urban air quality management offering detailed information on the types, amounts, and origin of air pollutants released in a specific area during a set timeframe, usually emission is classified by major sectors such as transportation, industry, residential fuel use, power generation, and open burning, detailed emission inventory is considered the first step in developing effective emission control strategies for key pollutants and is an essential component of any UAQMP [13].

In economically advanced country, several models and tools have been implemented to facilitate reliable inventory development, such as, in the United States, the environmental protection agency has developed several emission inventory models including MOVES, MOBILE6, and NMIM vehicular emissions were assessed across different scenarios to evaluate emission level of CO and NOx using mobile 6.2 and moves in Southeast Texas, concluding that mobile 6.2 produced more accurate results in that context [64].

Most EU countries utilize COPERT to estimate emissions from motorized vehicles, although countries like Germany and Switzerland also employ the and book of Emission Factors [60]. Multiple research efforts in India have contributed to establishing emission factors: the Indian Institute of Petroleum estimated emission factors for two-wheelers and cars based on the Indian driving cycle and the Automotive Research Association of India (ARAI), in collaboration with the Central Pollution Control Board (CPCB), developed emission factors for all motorized vehicle types using standard driving cycles and average speed data [61]. In South Africa, emission rates are calculated using simple multiplication of emission factors and traffic volume [62]. Ultimately, emission inventories act as essential tools in urban air quality management program across both developed and developing countries, supporting the development of focused, economically viable and evidence based air quality solution.

4.4.5. Air Quality Modeling

Air quality modeling is essential for developing effective air pollution control strategies and guiding management strategies through scientific insights for efficient air quality planning and the main goal of air quality modeling is to estimate the ambient level of a given pollutant [63]. In economically advanced countries, especially in the United States, several regulatory models are recommended by the U.S. environmental protection agency use AERMOD, a steady-state dispersion model and an advanced version of ISC3, is widely used for regulatory applications [63]. For Trans boundary movement of pollutants (source-receptor distances of 50 km to several hundred kilometers), the CALPUFF model is favored as it can stimulate emissions originating from point, volume, area and line sources [64]. To address vehicular emissions from highways in urban areas and rural areas, the CALINE-4 model is commonly used (Benson, 1984). In addition, the CMAQ (Community Multiscale Air Quality) model is used for evaluating regional air quality [65, 66].

The ADMS urban model is commonly applied in the United Kingdom to evaluate urban ambient air quality [66]. In europe and worldwide, the practice of coupling air quality models with GIS is gaining momentum to better support spatial analysis and exposure demonstrate the usefulness of GIS-based modeling in urban environments [67, 68]. Integrating GIS enables high resolution spatial and temporal forecasting, scenario mapping and benchmarking against air quality standards. This approach can also integrate socio-economic data at the receptor level, aiding health and exposure assessments and thereby improving the effectiveness of UAQMPs [69]. A major challenge in developing country is the scarcity of accurate and high resolution input data [68]. Nonetheless, advancements are underway; South Africa has developed the AirQuis modeling system and implemented as part of the UAQMP in the city of eThekwini [70]. In Mexico City a distinct approach is employed; the WRF-Chem model, which couple meteorological and photochemical processes, is mainly used to forecast air pollutant concentration [41, 71]. Overall, although modeling capabilities and data access varies between regions, air quality modeling remains an indispensable tool in both developed and developing countries. When combined with GIS and socio-economic data, it greatly improves the effectiveness of urban air quality management program by facilitating scenario planning, exposure assessment, and evaluation of health impact.

4.4.6. Public Participation

Public involvement entails meaningful engagement of citizens and stakeholders in defining urban air quality objective and outlined methods for effectively communicating urban air quality information to the public through mobile applications, street displays, and mass media channels [72, 73]. The most Europe union countries share air quality data via official government and publication and the United States utilizes AIRNow to deliver real- time and forecasted air quality index information for over 300 cities [50, 74]. Furthermore, the window to My environment is an online tool that provides detailed environmental data from federal, state and local source for specific U.S. location [40]. India and china have effectively communicated urban air quality conditions to the public through the strategic deployment of mass media, electronic platform, street displays, and online tools [53, 75].

Across Africa and especially South Africa air quality data is shared with the public via government websites, newsletters, official report, and mass media outreach [76]. Although structured public engagement mechanisms are still evolving across much of the continent, efforts to raise awareness and involve communities in air quality management are growing, especially in urban centers with deteriorating air quality. Public access to air quality data and environmental education initiatives are being increasingly recognized as vital tools for citizen involvement in environmental governance.

5. Challenges and Gaps

Multiple challenge and gaps continue to obstruct effective urban air quality administration and mitigation efforts and a major challenge is the scarcity of dependable air quality data, particularly in low and middle income countries with limited or aging monitoring infrastructure [6]. In Africa few maintain continuous air quality monitoring station the foundation for data driven policy decisions [45]. Poor enforcement of environmental laws worsens air pollution issues, while limited institutional capacity and corruption frequently hinder the application of existing standards [77]. Furthermore, swift urban growth and rising vehicle use strain infrastructure and lead to higher emissions from transport and informal sectors [78]. Moreover, socioeconomic inequality results in low income community bearing the highest pollution exposure, given their closeness to emission sources and limited access to healthcare and clean technology [79, 87]. Together, these overlapping challenges highlight the critical necessity for enhanced monitoring stronger enforcement of regulation and fair urban planning to safeguard public health and promote environmental justice.

6. Planning Strategies

Enhancing urban air quality in the future will necessitate the integration of advanced technology, innovative policies, and active community engagement, crucial strategy involves leveraging artificial intelligence and big data to enhance real time air quality monitoring and enabling responsive and targeted intervention, instruments improve pollution prediction models, enhance traffic flow, and provision timely community health advisories. Combination air quality initiatives with climate change strategies like encouraging renewable energy sustainable transport, and energy efficient constriction can deliver important co-benefit for environment health and human well-being [26]. Real control of city air quality demands intersectoral collaboration, incorporating transportation energy well-being and city design strategies inside combined agenda [77]. Additionally, community involvement and national discipline creativities are increasing with reasonable devices enabling people to track air pollution levels and provision air quality administration efforts and by consuming mobile application, public associates can gather air quality data and push for enhancements at the local level an method predominantly advantageous in low and middle income countries with constrained controlling and practical funds [89].

7. Conclusion

Generally the effective urban air quality managements are central to design for healthy cities. The criticism highlights that effective air quality management needs strong control, consistent data, progressive skills, and lively investor participation. Air quality administration in city surroundings is a vital element of maintainable growth, given the increasing health and ecological threats posed by increasing pollution levels. This review recognized the major causes of city air contamination including vehicular emissions, industrial discharges, and household fuel use as well as the major pollutants of concern such as $PM_{2.5}$, NO_x, SO_2, and VOCs. The health effects, reaching from pulmonary diseases to early mortality, are predominantly severe in overcrowded population and fast urbanizing areas of unindustrialized countries.

Tracking and evaluation methods for instance satellite remote sensing, air quality indices, and dispersion models are progressively used but frequently continue underutilized in developing country due to inadequate groundwork. Additionally, data limits, feeble strategy for implementation, and socioeconomic disparities remain to hinder real air quality administration, predominantly in developing countries, primarily located in Africa, Latin America, Asia, and Oceania commonly referred to as the Global South.

Specified these challenges, the weight must shift toward all-inclusive and maintainable air quality administration policies that incorporate scientific novelty, cross-sector partnership, and climate-smart city planning. Upcoming efforts should also prioritize public commitment and citizen science to bond data gaps and shape community attentiveness. Finally, management city air quality efficiently needs not only technical involvements but also comprehensive control and long-term strategy commitment at both local and international levels.

Abbreviations

PM2.5	Particulate Matter
PM10	Particulate Matter
NO_2	Nitrogen Dioxide
No_x	Nitrogen Dioxide or Nitrogen Monoxide
SO_2	Sulfur Dioxide
CO	Carbon Monoxide
O_3	Ozone
(VOCs)	Volatile Organic Compounds

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Conflicts of Interest

The authors declare no conflicts of interest.

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