



## OPEN ACCESS

## EDITED BY

Sourangsu Chowdhury,  
Centre for International Climate and  
Environmental Research (CICERO), Norway

## REVIEWED BY

Gaetano Settimo,  
Istituto Superiore di Sanità, Italy  
Bakhat Rawat,  
University of Wollongong, Australia  
Navdeep Agrawal,  
Indian Institute of Technology Kanpur, India

## \*CORRESPONDENCE

Humphrey Agevi  
✉ agevihum@yahoo.com

RECEIVED 26 November 2024

ACCEPTED 13 June 2025

PUBLISHED 04 August 2025

## CITATION

Kanyangi W, Atela J, Mwaniki G, Randa T,  
Agevi H and Akinyi E (2025) Political economy  
of the air quality management of Nairobi city.  
Front. Environ. Health 4:1534700.  
doi: 10.3389/fenvh.2025.1534700

## COPYRIGHT

© 2025 Kanyangi, Atela, Mwaniki, Randa, Agevi  
and Akinyi. This is an open-access article  
distributed under the terms of the [Creative  
Commons Attribution License \(CC BY\)](#). The  
use, distribution or reproduction in other  
forums is permitted, provided the original  
author(s) and the copyright owner(s) are  
credited and that the original publication in  
this journal is cited, in accordance with  
accepted academic practice. No use,  
distribution or reproduction is permitted  
which does not comply with these terms.

# Political economy of the air quality management of Nairobi city

Washington Kanyangi<sup>1</sup>, Joanes Atela<sup>1</sup>, George Mwaniki<sup>2</sup>,  
Tom Randa<sup>3</sup>, Humphrey Agevi<sup>1,4\*</sup> and Eurallyah Akinyi<sup>1</sup>

<sup>1</sup>Africa Research and Impact Network (ARIN), Nairobi, Kenya, <sup>2</sup>World Resources Institute (WRI), Nairobi, Kenya, <sup>3</sup>Power Shift Africa, Nairobi, Kenya, <sup>4</sup>Biological Sciences, Masinde Muliro University of Science and Technology (MMUST), Nairobi, Kenya

Poor urban air quality is a growing global concern due to its far-reaching environmental, social, and health impacts. Nairobi City's rapid urbanization—characterized by rising human and vehicular populations, industrial expansion, and commercial activities—has significantly deteriorated air quality. Despite the existence of international, national, and county-level policies on air quality management, their implementation remains weak due to overlapping mandates, unclear institutional roles, and limited capacity. This study analyzed Nairobi's sectoral sources of air pollution, governance structures, and strategic entry points for gender-responsive air quality management. Using a mixed-methods approach, in addition to the policy analysis and urban diagnostics, the study finds that air pollution in Nairobi is driven by multiple interconnected sectors, necessitating a coordinated and cross-sectoral approach. While existing institutions play key roles, an integrated Nairobi Air Quality Working Group is essential for harmonizing policy efforts, strengthening enforcement, and fostering inclusive governance. The findings highlight the need for a streamlined regulatory framework, enhanced institutional coordination, and targeted capacity-building programs to address air pollution effectively and equitably.

## KEYWORDS

air quality, well-being, integrated approach, urbanization, pollution

## Introduction

The quality of air has a significant direct impact on human life (1–3). Poor urban air quality is a major and increasing concern as around 55% of the global population now live in cities, which is projected to increase to 68% by 2050 (2, 4–6). In Africa, PM<sub>2.5</sub> exposure levels surpass the World Health Organization (WHO) 24 h health guidelines of 15 µgm<sup>-3</sup>, and the situation is projected to deteriorate further, particularly in the rapidly growing cities where there is also increasing populations (7). This projected increase in urban population will in-turn results to global rapid urbanization which poses significant environmental, social, and health risks with multiple cascading impacts across sectors and social groups (3, 8, 9). These claims have been affirmed by the World Health Organization (WHO), stating that more than 90% of people living in urban areas are exposed to air pollution levels that exceed the 2005 recommended health-based air quality guidelines hence posing threats to lives, productivity, and economies (10). This is in addition to one out of every 9 deaths globally (11). The exposure levels stem from large-scale construction, increased energy use, vehicular emissions and industrialization (12–14).

Nairobi city, the capital city of Kenya is one of the fastest-growing cities in the developing world (15). However, the city's urbanisation growth is marred by challenges including: inadequate formal housing that results in expanding informal settlements, unplanned housing estates, and lack of coordinated planning and poor enforcement of zoning rules and regulations (4, 15–17). These challenges are a result of increasing trends in human population, vehicle population, industrial and commercial activities. To put this into perspective, the city's rapid urbanization has seen the population grow from 4.3 million in 2018 to 5.2 million in 2022, an average annual growth rate of 3.9%. This is projected to increase to about 6 million in 2030 (18). This has led to an increase in waste generation, fumes and pollutants from combustion engines all of which play a critical role as the major city's air pollution sources (19). Further, the US Environmental Protection Agency (EPA) states that the Nairobi air quality index (AQI) along roadside locations is at an unhealthy level (20, 21) primarily due to the high vehicular population compounded by poor transport infrastructure. Kirago et al. (22) reported that "black carbon emissions from traffic are a key stressor for air quality in Nairobi. Kiai et al. (23) reported that "highest 24-hour average concentration of  $PM_{10}$  and  $PM_{2.5}$  was observed in Viwandani, an industrial area ( $111.87 \mu\text{g}/\text{m}^3$ ), and the lowest concentration at Karura ( $21.25 \mu\text{g}/\text{m}^3$ ), a forested area. In addition, efforts to monitor and mitigate pollution don't match the rate at which the city is developing despite the sources contributing independently to air quality (24).

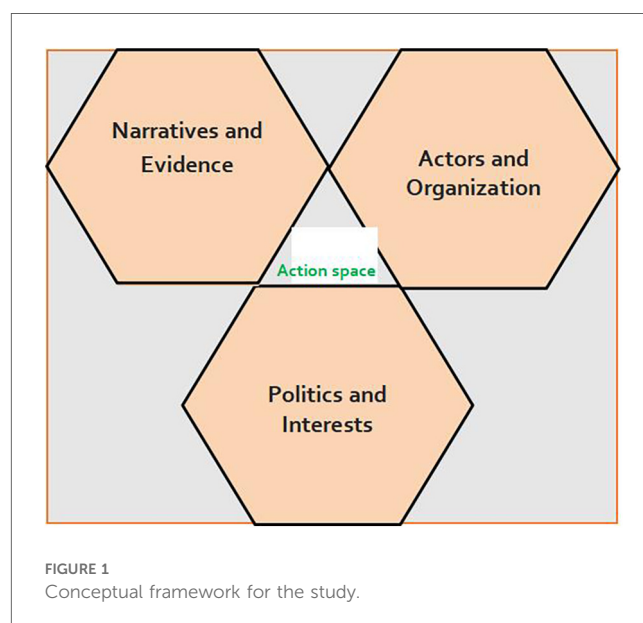
Therefore there is an increasing need to understand the local air quality management ecosystem and to establish an integrated coordination platform or system to profile ongoing activities, track their impact and measure their contributions to mitigating the city's air pollution. In addition, the need to understand the inter-sectoral linkages of air pollution sources to best manage and improve the city's air quality is of great significance. This suggests that concerted efforts must be holistic and inclusive in improving air quality, people's health and well-being by addressing the root causes of environmental pollution (25). Achieving this requires a coordinated cross-cutting approach spanning diverse policy domains.

To this end, the study aimed to understand the major sources of air pollution, actors within the air pollution space, the governance process, and the narratives underpinning this process. This was guided by the following specific objectives: (1) examine sectoral sources of air pollution in Nairobi city and unpacking the interlinkages among the sectors; (2) understand the governance processes underpinning air quality management including challenges and opportunities; and (3) explore strategic intervening niches that could promote effective, equitable and gender-responsive air quality management systems in Nairobi. This study is critical since the findings will contribute greatly to the air quality interventions, measurement and monitoring. Further, the information could be used to refine and update databases for air quality numerical simulations, increasing the reliability and precision of any analysis and widening the possible application of modelling for urban policy improvement.

## Materials and methods

The study employed the policy process analytical framework described by Keeley and Scoones (26), combining analysis of narratives/discourses, actors/networks, and politics/interests to analyse the political economy of the Nairobi Air quality. The framework was developed based on case studies of African environmental policy-making processes (18, 26). The policy process framework acknowledges how interests and politics shape power relations, and how these relate to the politics of resource access and use (Figure 1). Based on the conceptual framework, the study employed a mixed methods study approach that employed qualitative and quantitative methods complementarily. Further, the urban diagnostics approach by Bryson et al. (27) to analyse the Nairobi air quality landscape and institutional governance, highlighting some of the challenges. The study was conducted from November 2022, to December, 2022 for the field work while 3 months for planning, data coding and analysis processes.

Focused Group Discussions (FGDs) and Key informants Interviews (KIIs) were used to interrogate the targeted stakeholders and actors within the air quality landscape in Nairobi. Participants were purposely selected considering their roles, responsibilities and expertise to contribute to the issue of air quality improvement in Nairobi (70). The participants engaged in the FGD and KIIs were both from government and non-governmental entities directly and or indirectly connected to Nairobi's air quality management as service users, regulators, citizens and civil societies. The participants were drawn from the National Environmental and Management Authority (NEMA), the Kenya Association of Manufacturers (KMA), Kenya Alliance of Resident Association, Ministry of Energy, Nairobi County Government departments of Environment and Air Quality monitoring, World Research Institute (WRI), Academia, National Gender Equality Commission and the Ministry of transport. A total of 1 FGD and 7 KIIs were conducted during the period of study.



The FGD workshop had a total of 14 participants strategically drawn from the thematic sectors of transport, energy, industry, and waste management. Discussions were held through an open dialogue format guided by a series of thematic questions. This encouraged participants to share their insights, and experiences while unpacking cross-cutting issues ailing the city's air quality management. Qualitative data collected from the session was thematically analysed enabling the identification of actionable insights relevant to the study's objectives. The KIIs played a significant role in generating additional qualitative data to fill in gaps that were not comprehensively addressed during the FGD discussions. It helped to understand the in-depth challenges faced in the process of implementing air quality policies in respective sectors, the decision-making and power relation dynamics, the critical actors who aren't adequately engaged, gender dynamics and the intervention pathways to disrupt the common and dominant narratives in air quality management.

Additionally, a desktop scoping review was leveraged to understand the existing institutional, policy, and legal framework of Air Quality Management in Nairobi city. In addition, the desk review played a significant role in examining the dynamics of how each sector affects the city's air quality and its implications on the general population. Further, mapping of stakeholders from various databases and a comprehensive understanding of the air quality management and sectoral contributions in the city was undertaken.

## Targeted consultative dialogues

Online consultative discussions were conducted and targeted the sector representatives, key decision makers in the city regarding air pollution reduction, and gender experts to fill in the missing gaps and challenge dominant narratives in air pollution sources and their reduction, governance, and intervention pathways from the previous methodological steps.

## Synthesis and analysis

The gathered information from all the methodological steps above was collated and synthesized through expert analytical steps employing a narrative analysis method. The narrative analysis method allowed the review of the information gathered from the interviews and discussions and restated them into context by analyzing the structure of the narrative, the argumentation, the description, and the key message which further informed the reporting.

## Limitation of the methodological framework

The limitations related to the short study duration and small sample size are acknowledged, and these are identified as areas

for further research. Future studies could expand on these preliminary findings by employing a larger and more diverse sample over an extended period.

## Results and discussions

### Legal and institutional governance landscape of Nairobi air quality

Nairobi's air quality policies reflect a convergence of national and county-level efforts. The national government established air quality regulations in 2014, setting standards for pollutants. In response, Nairobi City County enacted the Air quality policy in 2020 and the Air Quality Bill in 2021, aiming to address local pollution sources and enhance monitoring. This alignment ensures a unified approach to air quality management, integrating national standards with localized strategies. The management of the city's air quality is localized but anchored on the local, national and international legal framework. At county level, Nairobi has advanced air quality management through policies like the Air Quality Action Plan 2019–2023 (28), Nairobi City County Climate Action Plan, 2020–2025 (29), the Breathe Nairobi Strategy, improved monitoring systems, international collaborations, and research initiatives, creating a strong foundation for future action (Figure 2).

At National level, the laws and regulations developed hinges on the Constitution of Kenya, 2010, part II, section 3 (30, 31) and the global World Health Organization guidelines as the international legal framework for air quality management. This provides recommendations on air quality guideline levels as well as interim targets for six key pollutants (32). However, Nairobi's air quality management faces challenges including inadequate monitoring networks, limited data for policy development, reliance on unclean cooking fuels, improper waste management, and highly-polluting small-scale industries, particularly in informal settlements. Figure 2 below shows the major legal and institutional establishments for the city's air quality governance.

### International air quality legal and institutional governance

The World Health Organization has established the Global Air Quality Guidelines (AQGs), which are based on evidence of the impacts of pollutants on human health (11). These guidelines offer a regulatory framework that nations are using to understand their air quality status, determine the impacts of their intervention efforts, determine the level of pollution for various pollutants, and reference their air quality against the global community and standards. Researchers also rely on the same to determine the levels of concentration of different pollutants from various sources and sectors (33). These guidelines include values that do not bind states to particular actions but rather reflect a high degree of scientific consensus, giving them global authority. The guidelines recommend air pollutants concentration levels for 6 major pollutants including – particulate matter (PM), ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>) sulfur dioxide (SO<sub>2</sub>), and carbon

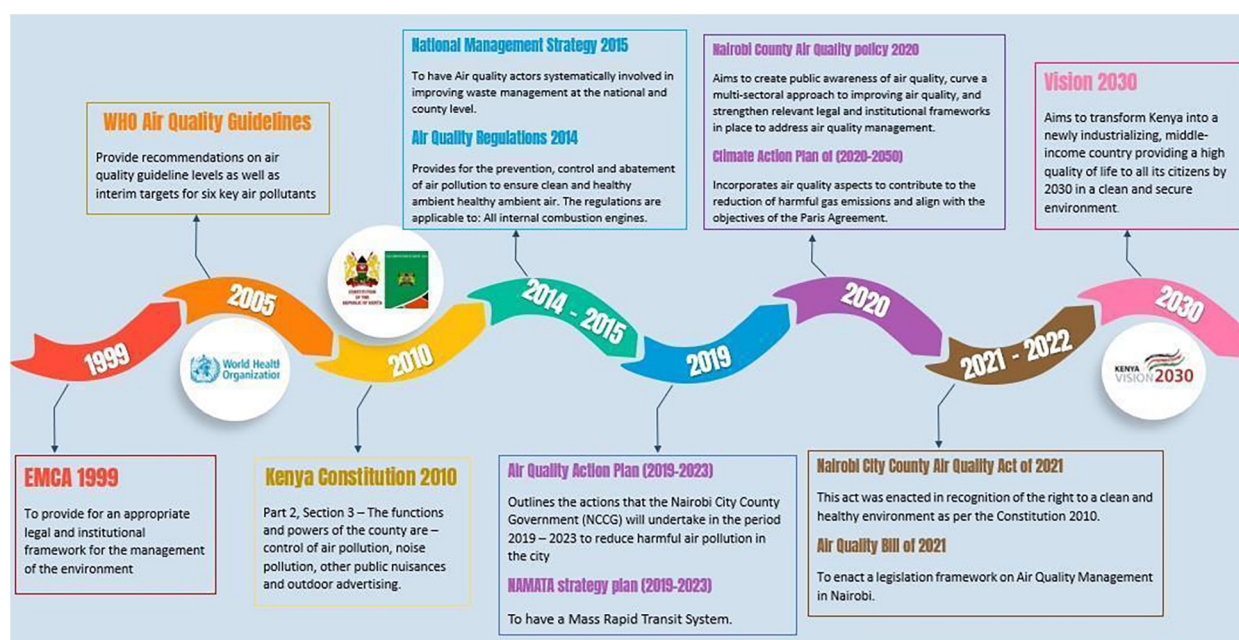


FIGURE 2  
Legal and institutional framework for the Nairobi City's air quality governance.

TABLE 1 Air quality guidelines (AQG) and interim targets.

Pollutant	Averaging time	Interim target 1	Interim target 2	Interim target 3	Interim target 4	AQG level
PM <sub>2.5</sub> , µg/m <sup>3</sup>	Annual	35	25	15	10	5
	24-hour <sup>a</sup>	75	50	37.5	25	15
PM <sub>10</sub> , µg/m <sup>3</sup>	Annual	70	50	30	20	15
	24-hour <sup>a</sup>	150	100	75	50	45
O <sub>3</sub> , µg/m <sup>3</sup>	Peak season <sup>b</sup>	100	70	–	–	60
	8-hour <sup>c</sup>	160	120	–	–	100
NO <sub>2</sub> , µg/m <sup>3</sup>	Annual	40	30	20	–	10
	24-hour <sup>a</sup>	120	50	–	–	25
SO <sub>2</sub> , µg/m <sup>3</sup>	24-hour <sup>a</sup>	125	50	–	–	40
CO, mg/m <sup>3</sup>	24-hour <sup>a</sup>	7	–	–	–	4

<sup>a</sup>Distance from the Central Business District (CBD) of Nairobi.

<sup>b</sup>Recorded using PurpleAir low-cost sensors.

<sup>c</sup>Located in informal settlements.

monoxide (CO). The average annual concentration and the 24-hour average concentration levels for each of the pollutants (Table 1).

Findings from the study indicate that the WHO guidelines are yet to be adequately integrated into the national air quality and management guidelines in Kenya. Similarly, there are no dedicated platforms by the city government or procedures through which international programs being deployed into the city or being implemented elsewhere, are engaged, verified, and directed for impacts. Instead, most projects are deployed through local partnerships that sometimes are ad-hoc and designed for the sake of the project goals. In these, many useful international initiatives are not niche-targeted, and most, therefore, end up leaving no or little sustainable impacts in the city (34). Most governments have opted to formulate pro-air quality policies

according to the dynamics existing in their jurisdictions even in their broader environmental and livelihood ecosystems. As such, air quality laws and regulations have been designed by countries in an attempt to fit their local context and address the regional challenges in air quality management.

Besides the WHO guidelines, there are also various institutions and global programs working in Nairobi to support air quality management through either research, policy support, or community support. These international programs are mainly established by international actors in partnership with local institutions or governments among other stakeholders to deploy air quality management interventions. The approaches used in deploying programs, in this case, are widely project-based, where either research or action projects are designed, funded, and implemented through local collaborations. Some of these



TABLE 2 International programmes in Air quality.

Organization	Program	Partners	Objectives
National Institute For Food and Agriculture	Grants program	CENRS Air Quality Research Subcommittee, National Atmospheric Deposition Program	To fund air quality research on emission control technologies that will minimize pollutants from agricultural production facilities. This will in turn help regulatory authorities design permits for agricultural facilities.
World Resources Institute (WRI) and Environmental Defense Fund (EDF)	Clean Air Catalyst program	National and local governments, Non-governmental organizations	Develop data-driven solutions to air quality problems to equip stakeholders with knowledge on developing realistic and implementable policies.
World Bank (WB)	Pollution Management and Environmental Health Program	Stakeholders across low and middle-income countries	To provide technical assistance on pollution management, facilitate knowledge generation and sharing with relevant stakeholders, and raise awareness on the impacts of pollution on health systems.
United Nations Environment Program (UNEP)	Global Environment Monitoring System for Air	Governments in Developing countries	To build capacity in developing country governments to improve the air quality in their jurisdictions through science and technology.

international programs include; the Grant program by the National Institute for Food and Agriculture, the Clean Air Catalyst program by the World Resources Institute (WRI) and Environmental Defense Fund (EDF), the Pollution Management and Environmental Health Program by the World Bank, and the Global Environment Monitoring System for Air by United Nations Environment program (Table 2).

### National air quality legal and institutional governance

The Kenyan Constitution 2010 is the supreme law that provides the legal framework for all laws and regulations on air pollution to enhance air quality management and governance (31). Article 10 entrenches the principle of sustainability as one

of the national values and principles of governance. Article 42 guarantees every Kenyan the right to a clean and healthy environment, including the right to protect the environment for the benefit of present and future generations. Further, article 69 and 70 of the constitution give rise to the obligations of the state and citizens to ensure that the environment for which air is fundamental component remains in a stable state. The constitution also envisions the right to clean and healthy air and provides the overarching legal framework. The Environmental Management and Coordination Act (EMCA) 1999 (35), is the main national legal Framework governing environmental pollution prevention. Some sections have since been repealed under the 2015 (36) amendment to align it with the current Kenyan 2010 constitution. Among other things, EMCA provides a legal framework for the establishment of various institutions that are central to the environment and thus air quality governance in Kenya (36). The institutions include the National Environment Management Authority, Public Complaints Committee, National Environment Tribunal, National Environment Action Plan Committees, and the County Environment Committees. The National Environmental Management Authority (NEMA) is the principal institution mandated to implement Government policies on the environment and exercise general supervision and coordination over all matters relating to the environment (Table 3).

Kenya developed the Environmental Management and Coordination (Air Quality) Regulations in 2014 to operationalize the aspirations of the Kenyan constitution. The regulation was developed based on a comparison of countries with similar characteristics like Kenya since there was no baseline data (37). The regulations provide for the prevention, control, and abatement of air pollution for clean, healthy, and ambient air (38, 39). The approval of the regulations on air quality management in 2014 highlights the national government's commitment to addressing urban air pollution (40).

The regulations, therefore, form the most recent national attempts to strengthen air quality management in Kenya. Before this period, other policies related to air quality and the environment were disjointed and did not reflect local realities as shown in (Table 3) (2). Kenya is also a party to the Sustainable Development Goals (SDG) by the objectives set in its Vision 2023 blueprint for development. Goal 3 talks about good health and well-being of people while target 7 mentions of the enhanced use of clean energy. Notably, SDG 7 aims to ensure access to affordable, reliable, sustainable and modern energy (41). In addition, SDGs 3, and 11 are targeted at taking holistic, evidence-based policy actions with improving urban air quality being integral to sustainable development (42, 43).

Despite these multiple policies, there were enforcement challenges, alongside ongoing population and economic growth resulting in continued high ambient and household air pollution levels (44). According to Singh et al. (2), this is due to the fact that there is a lack of air quality data to forecast scenarios and inform evidence-based air quality control measures. Their implementation also still needs more socio-political structural strengthening, institutional alignments, and capacity

TABLE 3 Summary of institutions engaged during the workshop.

Institution	Typology	Roles
National Environmental Management Authority (NEMA)	Parastatal	Principal institution mandated to implement Government policies on the environment.
National Environment Tribunal	National Government	It is a Quasi-judicial body that checks the excess powers of NEMA by resolving appeals from the general public.
Nairobi City County Government (NCCG)	Local Government	Responsible for environmental management in the Nairobi City
Ministry of Energy	National Government	To formulate, implement and influence policies, regulations and foster practices that are crucial for air quality management.
Ministry of Transport	National Government	To implement policies tailored to regulate vehicle emissions, importation of energy efficient vehicles, and invests in sustainable transport infrastructure for mass transit for urban mobility.
Kenya Association of Manufacturers (KAM)	Private sector	A representative of the manufacturers and processing industries in Kenya.
National Environment Action Plan Committees	National Government	The committee is mandated to coordinate and oversee environmental planning and management across Kenya.
County Environment Committees (CECs)	Local Government	The CECs ensures various county and national environmental policies and regulations are adhered to by the public and entities within their jurisdictions. they collaborate with various stakeholders in addressing environmental challenges such as; pollution and waste management.
Public Complaints Committee	National Government	To address environmental public grievances through investigation, mediation and policy recommendations.

strengthening. Generally, the national legal and institutional arrangements for air quality management are progressive as there are efforts to not only scale up the legal framework for air pollution reduction but also devolve the same through the county governments. The progressiveness of air quality management in Kenya is therefore in terms of the increasing political will that has paved the way for the establishment of various environmental policies and laws (Table 4). However, According to DeSouza (45), despite having an air pollution governance framework, the Kenyan government has been effective in taking action to improve air quality. This is attributed to the fact that there are multiple organizations with overlapping jurisdictions in their mandated roles of managing air pollution. This contributes to challenges in coordination and thus effective policy enforcement.

### Nairobi city county air quality legal and institutional governance

The Nairobi City County government was established through the Kenyan Constitution (30) alongside other 46 counties in Kenya. Article 186 of the constitution clearly outlines the functions and

TABLE 4 Key environmental policies related to air quality in Kenya (17, 25, 42).

S/N	Key environmental policies	Year
1	Air Quality Regulations	2014
2	Environmental Policy 2013	2013
3	Occupational health and safety Act	2007
4	Public Health Act, Cap 242	2012
5	National transport and safety Act	2012
6	Energy Act	2006

powers of the national government and those of the county governments including that of the Nairobi City government. The Fourth Schedule of the Constitution of Kenya 2010, Part 2, and Section 3 outlines the specific functions and mandates of the county governments which among them is to control air pollution, noise pollution, other public nuisances, and outdoor advertising within their jurisdiction. The County Government Act, No.17 of 2012 as amended by Act No. 7 of 2016 further outlines the roles of the County government in general. Section 2 of this Act stipulates that a county government shall be responsible for, inter alia, functions provided for in Article 186 and assigned in the Fourth Schedule of the Constitution, without prejudice to the generality of the first subsection (30).

The City government in partnership with the United Nations Environmental Program and the Environmental Compliance Institute developed the Air Quality Action Plan 2019 to 2023 (12). The action plan is aimed at aiding the city County government in developing better air quality management strategies. The action plan forms the basis of various strategic actions of the City County in legislation, enforcement, and gathering scientific evidence to support critical decision-making in air pollution reduction. The development of an action plan highlights the importance of bringing governance closer to the people including the development of a systems approach to air quality management (25). However, the plan needs to be updated in order tandem with current dynamics and scenarios of the prevailing air quality.

Building on the action plan, the city County government developed the Nairobi City County Air Quality Policy 2021 in response to the third objective of the action plan. The policy aims to provide a legal framework and form the foundation for developing relevant legislative frameworks for effective air quality management in the city of Nairobi. The Act advocates for an integrated approach toward air quality management by all relevant sector players in Nairobi (29). Key to the provision of the policy is the inclusion and participation of various stakeholders in the city air quality management from the identified sectors. The policy clearly states the various policy statements and actions to be taken by the County government. Specifically, the policy outlines the need to update the pre-existing air quality standards and strengthen the enforcement capacity. The key sectors identified in the policy for prioritization of air pollution reduction include transport, waste management, industry, energy, construction, Housing, and agriculture. The policy acknowledges the existing gap in coordination and governance that needs to either be realigned or be established where they don't exist (46).

## Sectoral air quality analysis in Nairobi city

### Industrial sector

The industrial sector in Nairobi is mainly composed of small to medium enterprises and a thriving less regulated informal sector commonly referred to as the “Jua Kali”. A large portion of the small to medium enterprises is in the manufacturing and processing sectors. While Nairobi City boasts of being the largest contributor to the national gross domestic product at about 21.7%, the city’s industrial sector is believed to contribute a larger share of this percentage (19). In as much as the Nairobi City County policy highlights various measures to help manage and reduce air pollution in the city from the industrial sector, various institutions, most of which are national entities, play a critical role in industrial pollution management. The National Ministry of Industrialization has the key role of promoting national industrial transformation and is thus keen on industrial development and performance.

The Ministry of Environment, Climate Change, and Forestry champions environmental protection and conservation by advocating for environmental governance. environmental issues. The Kenya Industrial Property Institute is a government parastatal dealing with intellectual property rights and thus plays a minimal but promotes large-scale production of goods by industries (47). The Kenya Bureau of Standards (KBS) is a national parastatal in charge of standards and quality checks of products and appliances. All these state agencies play a role in air pollution reduction efforts in the sector either directly or indirectly. There are few multi-government forums to coordinate and align these roles in complementary and impactful ways. The Kenya Industrial Research and Institute Development (KIRDI) has also made efforts to realize the circular economy among industries to conserve the environment mainly by deterring open burning of recyclable waste materials. KIRDI, through its Center of Environmental Sustainability and Climate Change Research is keen on researching efficient energy use and green manufacturing processes in the industrial sector. The adoption of these green manufacturing processes by industries and manufacturers will lead to less carbon footprint hence enhancing the quality of air in the city. The Kenya Association of Manufacturers, which is a representative of manufacturing and value-added industries in Kenya plays a critical role in linking all manufacturers and creating awareness and crosscutting actions. While keen to promote the growth of businesses in the industrial sector, the association can be used as an avenue to push for the implementation of some by-laws and policies to reduce air pollution from the sector.

The County city government has stipulated in its policy documents and legislation the strategic areas of intervention to reduce air pollution in the industrial sector. Ranging from establishing emission monitoring systems to continually enforcing compliance regulations and tough measures for non-complying industries. In controlling outdoor air pollution by industries, the National and Nairobi County Governments, through the National Climate Change Action Plan 2018–2022, are looking forward to enhancing the circular economy among industries.

One of the proposed policy measures for industries to adopt green energy is to design and lobby economic incentives for industrial firms to invest in more efficient and environmentally friendly processing technologies. The policy further explores strategies to move industries away from residential areas to limit adverse effects on the immediate population. Despite these efforts, air pollution from the sector has been on the rise in the recent past due to a continued growing industrial sector with a lean regulatory framework focusing mainly on stack emissions and compliance. NEMA as the regulating Authority, therefore, has a major challenge in monitoring and enforcing regulations on fugitive emissions. According to Air Quality Regulations 2014, sanction measures are only issued against stack emission reports from industries. NEMA’s inadequate capacity in tracing and quantifying fugitive emissions complicates its efforts to effectively regulate air pollution in the city from the industrial sector alongside the emissions from the less regulated informal sector. However, industries are required to formulate fugitive emission control plans and reduction measures for purposes of self-regulation (38).

Overall, the industrial sector air quality management remains complex with various actors and contributors. Managing and balancing the economic interest which is strongly linked to the industrialization efforts against environmental sustainability efforts is proving difficult when it comes to reducing air pollution in the sector. The economic growth and livelihood contribution from large industries that pollute more may override the regulatory recommendations as the political influence on high-level decision-making takes preeminence in most cases. To effectively manage the sector, the County government, NEMA, and the Association must thus work collaboratively with all other stakeholders, if any tangible progress has to be made concerning air pollution reduction in the sector.

### Transport sector

The transport sector in Nairobi comprises the large and small locomotive engines operating or passing through the city’s jurisdiction. Various studies have shown that pollution levels are mostly high in road junctions and along major roads in the city (48). The sector has continued to grow with the growing human population with a vehicular population expected to hit a record high of about 1.4 million by 2030. The rising vehicular population can be attributed to the importation of second-hand vehicles from overseas not more than 8 years old. The rise in two and three-wheeled locomotives has been on the rise in Kenya and indeed Nairobi city has been attributed to their affordability and ability to maneuver the traffic congestions in the city. With this new development, fossil fuel consumption is increasing and more pollution is noted as the engines become older and inefficient. According to Nairobi’s Climate Action plan for 2020–2050, the transport sector contributed 45% of the total Green House Gas (GHG) emissions in the city in 2016. Numerous studies have shown that road traffic emissions significantly affect the air quality of urban environments by contributing to the ambient particulate matter (PM<sub>2.5</sub>) levels

(49–54, 71). Sing et al. (2) and Kirago et al. (22) among others found out that vehicle emissions were a key source of air pollution in Nairobi, accounting for an estimated 47.5% and 48.1% of the total PM loading in the PM<sub>2.5</sub> and PM<sub>10</sub> size fractions respectively at roadsides. These levels have increased by 30% between 2017 and 2019 (55). According to (13), these levels have been increasing by 1.4% per year.

There are various institutions involved in the transport sector in the city. The key stakeholder includes the National Transport and Safety Authority which is central in the vehicle inspection and licensing of locomotive engines, the Kenya Police which enforces the traffic laws and regulations, the city County government which has a traffic department to enforce compliance with its bylaws, the Matatu Owners Association who coordinate the Matatu public transport investment and operations, the Association of bus operators Kenya (ABOK), and the *boda boda* safety association who coordinates the two-wheeled motorcycles. The sector players are keen on their mandate, especially on enforcing their operational compliance but less on the environment and more so on air pollution elements. The rapidly growing city population and the need for efficient and effective transport have increased pressure on the existing transport systems and the situation may worsen soon unless radical strategic measures are taken. The traffic congestion in the city has led to the loss of productivity of up to Ksh.100 billion annually (NAMATA strategy plan 2019–2023). The Kenya Institute for Public Policy Research and Analysis (56) reported that traffic congestion is mostly caused by private vehicle owners as they account for 64% of motor vehicles in traffic jams carrying only 22% of the total passengers. Public motor vehicles account for 27% of vehicles on the road while carrying only 29% of commuters.

Since Nairobi County is a motorized city, there is a need to have a policy that will stop/minimize the importation of diesel engine vehicles as its emissions which mostly contain sulfur have severe health effects. The gap is to be filled with the importation of electric vehicles which are environment friendly. Formulation and implementation of the relevant policy to this effect should involve all stakeholders in the sector, especially the Matatu Owners Association (MOA) as they are the primary transport providers in the city. Induction of the association into the policy is vital as it employs over 80,000 men and women living in the city who are further depended on by their immediate and extended family members. Further, the sector contributes majorly in revenue for both the National and County governments, insurance firms, and spare part shops (57). The sector also presents a complexity in balancing the environmental desire with the much politicized and conspicuous socio-economic gains in sustainability growth. Strategic and radical air pollution interventions in the sector, therefore, require a multilevel and multi stakeholder approach and efforts to implement. The creation of elaborate cycling and pedestrian pathways will encourage non-motorized means of transport as envisioned in the Nairobi County Non-Motorized Transport Policy 2017 (12). The Policy advocates for an increase in budgetary allocations for the construction of non-motorized transport lanes. Successful

implementation of these measures will significantly reduce the number of motor vehicles on the road hence reducing the number of emissions released into the atmosphere.

Besides Matatu being the city's major transport provider, there are *Boda bodas* that provide general transport, especially during traffic congestion as they can easily maneuver through. Despite being a vital part of the transport system in the city, it has been noted that *Boda bodas* emit more hydrocarbons compared to vehicles (58). Therefore there's a need for urgent strategic intervention in the sub-sector as the population of two-wheelers is rapidly increasing in the city and is mostly used for commercial transportation. There are increasing calls to introduce and promote electric motorbikes in the city to reduce air pollution. This comes with its fair share of challenges due to the inadequate infrastructural and policy systems to support the shift besides the affordability and economic constraints. The existing *bodaboda* engines are already high and what happens to them? How do you incentivize the sub-sector to shift to electric bikes? How do you gradually face the fossil fuel-dependent engines and introduce the electric ones without disrupting the socio-economic fabrics of the sub-sector? What would be the possible impacts and how do you manage the politics around the sector? These are the hard questions the interventions in the sector would grapple with and work to address the complexities.

The interventions in the transport sector in the city, therefore, require the active and good political will of the national government, the city government, the development partners, and the general public. The reduction of air pollution from the sector, therefore, requires strategic infrastructural development, policy development, and implementation, embracing cleaner technology and enhanced stakeholders and public awareness and capacity support. It is indeed a complex and resource-intensive sector but a progressive plan can be drawn and implemented to reduce air pollution from the sector in the long run.

## Waste management sector

The waste management sector in Nairobi City comprises waste production units that include households, and industrial and commercial units. Collection, transportation disposal, and processing of different wastes are outlined in the Nairobi City County Solid Waste Act 2015. This role is done by the city-county government alongside the private sector commercial players and privately managed households' collectors and industrial collectors with a few city cleaners and collectors designated in most public spaces in the city (59). Key stakeholders in the waste management sector in Nairobi city include the city County government, NEMA, Private waste collectors, designated community-based organizations, City industries, the Kenya Association of Manufacturers, households, commercial enterprises, and waste-to-product processors.

One of the major challenges in the waste management sector in the city is the inadequate and inefficient collection of wastes from the generation sources and their transportation to the designated dumping sites. This has led to the emergence of illegal dumpsites in residential areas, underdeveloped lands, and open green spaces including rivers and informal settlements. Most



community-based organizations dealing with waste management have only the capacity to collect household waste (which is mostly biodegradable) and set them at designated zones for collection and transportation to the designated dumping site (60). The inadequacy and inefficiency in the waste collection from these designated collection points have seen some turned into illegal dumpsites with a majority opting to open burning and dumping in illegal sites.

The sector is also suffering from an overdependence on private waste collectors and transporters. While the sector is under the City county government, the licensed private collectors seem to enjoy some level of monopoly and political support beyond the city government. Some of the private waste collectors have been reported to expand their profit margin by dumping waste in illegal and undesignated sites to avoid paying the NEMA and city County levies for handling and dumping wastes at the designated Dandora dumping site. In the plight of this, the county government set up mechanisms to monitor the private waste collectors after granting them operation licenses (28). This involves reviewing and monitoring tonnage records at the weighbridge at Dandora dumpsite or at other recycling facilities where the disposal has taken place. To ensure accuracy at the tonnage weighbridge, the site is manned by county officers for the safekeeping of the tonnage registers. The private waste collectors who irregularly frequent the dumpsite are often quarried where they dispose of the collected waste materials. Despite this monitoring system in place, there are still incidences of illegal disposal of waste.

There are also challenges in waste segregation at the source. Most of the household wastes are mixed and thus the menace of illegal dumping promotes segregation during transportation and only the less useful wastes are demoed in the Dandora site. Waste segregation at the source would promote the efficiency required as the collectors and transporters would know what waste compositions to pick when and transport to the designated processing facilities. This would leave a few tonnes of garbage to be transported to Dandora, where an incineration facility or waste-to-energy facility could be set to handle the waste. This entire value chain system thinking and intervention would greatly reduce air pollution from the source, transportation, and processing and thus significantly contribute to the creation of decent jobs and livelihood support systems. Waste management in the city is therefore a complex system issue that requires a system mainstreaming approach that incorporates the inculcation of waste segregation at the source, efficient and adequate collection, and transportation to the designated waste processing facilities (61). The adequacy and efficiency, though require much political goodwill, human and financial resources, and capacity support to effectively address.

Despite the identified complexities and challenges in the waste management sector in Nairobi city, there are quick starting points identified for action to reduce air pollution from the sector. Promoting public awareness of waste segregation at the source level and supporting the capacity to do so would enable its adoption and practice. The County government working with its partners can then move in to streamline the sector in terms of

adequate and efficient waste collection and transportation in the city. This means the adequate number of trucks assigned to a specific region as per the waste tonnage generated. Working with private processing, material recovery, and recycling facilities would help reduce the tonnage dumped (62). Initiatives such as the city government partnering with private development partners such as Sanergy to process organic wastes and produce animal feeds are examples of waste-to-product initiatives that can be rolled around the city and cover all organic waste generated and segregated at source. The initiative can be incentivized to promote waste segregation and delivery to the processing facilities. For the Dandora dumpsite, a good starting point would be to incinerate waste that has already been segregated and that no one has an interest in at the dump site. The incineration process reduces waste volume by up to 90%. Which is vital in reclaiming land as well as managing air pollution.

While it may sound as if the city is in direct control of the waste management, it becomes complex as more and more tonnes of waste is generated in the city and this translates into a whole new realm of commercial engagement for the private sector with a controlled environment, making it a bit difficult to understand and penetrate. The complexity is dynamic with additional wastes generated, Dandora dumpsite getting overfilled, and attempts to relocate it proving futile with lots of resistance and periodic changes in the city governments and key decision makers. The power dynamics in the sector are not well documented and its discussion at the city level spurs mixed discussions comprised of unclear political influence and controlled sector with some level of informally instituted levies on collection, transportation, and disposal.

This study has therefore established that the sector is strongly controlled politically and informal groupings have been set to control the sector at various political and operational levels. These informal arrangements make it difficult to strategically intervene in terms of air pollution from the sector unless the focus is shifted to source waste segregation and prioritizing recycling or waste-to-product processing by partnering with private developers and investors. This reduces the tonnage dumped in Dandora which can be further processed through waste-to-energy initiatives or incineration processes. For the sector to improve and have a meaningful intervention realized, strategic and radical measures may have to be put in place with the support of both the national and county governments in discussion with the strategic private sector stakeholders. The government may be forced to take up the full and direct operation of the waste management sector to streamline it before handing it back to the private sector partners or collaboratively agree on the streamlining journey through public-private partnership modalities to enhance efficiency and adequacy.

## Energy sector

The energy sector includes all the combustion fuel sourcing, processing, productive use, and sustainability with a coverage of the fuels used in combustion engines, energy transformation processes such as electricity generation, and their use in industries, transport, and household sectors among others.

Generally, the sector covers both the electricity and cooking sectors. However, the study is cognizant of the fact that the Energy sector is not fully devolved to the counties and a majority of key decision-makers are at the national government through its Ministry of Energy and the semi-autonomous institutions (34). For instance, on issues of regulations and licensing in the energy sector, the Energy and Petroleum Regulatory Authority has the full mandate, and for electricity distribution, the Kenya Power and Lighting Company is in charge. In this regard, the city largely relies on national agencies to manage the sector and has a minimal role, therefore, it regulates or even reduces air pollution from the sector. This then leaves the city government to largely focus on the cooking energy sub-sector to reduce air pollution. The focus of this report is therefore skewed toward indoor air pollution and more specifically on household air pollution (HAP) with a light touch on the outdoor pollution from engine combustion on locomotives and industries using fossil fuels.

The promotion of clean cooking in Kenya and indeed Nairobi city has been real in the past decade with attention shifting from biomass to the exploration of other available clean cooking options. Historically, the promotion of clean cooking has focused on clean cookstoves with special attention to stoves that could reduce the amount of biomass being used and later those that reduce emissions (63). Electrification programs have been promoted to increase electric access with Nairobi city benefiting from such programs the most. The use of cleaner cooking fuels such as the use of Liquefied Petroleum Gas, Biogas, biofuels, and electricity has been on the rise and this is because of the increased supply chain with incentives to regulate the prices and associated appliances. Most households in Nairobi, therefore, use LPG as the primary cooking fuel. This is however not the case in most informal settlements where the use of charcoal, paraffin, and wood fuels is still common. Cooking fuel stacking is a common practice and most households' cooking fuel includes biomass fuels. Household air pollution is therefore rampant and reported every year with over 265 deaths reported annually in Kenya.

The national government through the Ministry of Energy and Petroleum has set an ambitious target to achieve universal access to clean cooking by 2028. Various efforts are being paced toward this goal and thus provide an opportunity for the County government to initiate programs and activities that will support the journey to achieving the set goal (64). The Bioenergy Strategy 2020–2027 aims to support the achievement of the set goal through; capacity development, financing mechanisms, designing an effective policy regulation, and lobbying for political goodwill. Besides, the Energy and Petroleum Regulatory Authority (EPRA) is also a strategic stakeholder in the energy sector. It is an agency established under section 9 of the Energy Act, 2019 whose main mandate is to collect and maintain energy data, and energy pricing and analyze the energy policies such as the National Energy Policy 2018 which is reviewed every 5 years (63).

Through the Petroleum Act No. 2 of 2019, section 101, the Energy and Petroleum Regulatory Authority (EPRA) has a critical role in determining the prices of petroleum and

petroleum products. The Authority's mandate directly affects the transport sector, especially public vehicles whereby bus fares are adjusted depending on petroleum prices. In Nairobi, when petroleum prices are adjusted upwards, private vehicle owners often opt to use public transport to cut their monthly transport costs by spending less the petrol stations. This move tends to reduce traffic congestion as fewer vehicles will be on the road hence a reduction in PM<sub>2.5</sub> concentration levels from exhaust emissions. Besides this, an upward review of fuel prices by EPRA has prompted car buyers to opt for fuel-efficient vehicles as they are conscious of cost saving (72) hence an improvement of the city's air quality.

Besides the transport sector, EPRA's upward review of petroleum has increased production costs in the industry sector as most of them run on fossil fuels hence prompting price increases of food, goods, and services. For instance, according to the research done by Ngare et al. (65), an increase in fuel prices has directly imparted negatively food prices especially perishable goods as they need fast transportation to the market. He noted that prices of cabbage and potatoes tend to rise by 13.9% and 7.9% respectively when fuel prices hike, unlike maize and beans. Due to the ever-rising fuel prices in the country, some industries have now resorted to investing in clean and cheap energy to make their production cost sustainable. For instance, East Africa Breweries Limited (EABL) has invested a total of 22 billion shillings in solar energy. It aims to shift from the National Electricity Grid and fuel by 2030. With this investment, the company aims to generate at least a total of 117MW (Promoting the Use of Solar Energy in the Manufacturing Sector in Kenya (56). Further, in an effort for EPRA to protect the consumer's interest, it is always in consultation with the Kenya Bureau of Standards (KEBS) to ensure only energy-efficient appliances are allowed into the country.

The Clean Cooking Association of Kenya (CCAK) is one of the major associations in this sector. It plays a key role in advocating for Government budgetary allocation towards research on viable clean cooking technologies and seeks improvement on regulatory provisions on clean cooking. For instance, when the Government re-introduced the 16% VAT on LPG in July 2021 (66), CCAK released a report on analysis of the implications of the added tax on access to clean cooking energy. It noted that the decision would be a setback as many households would fall back to the use of highly polluting biomass fuels such as charcoal and kerosene due to the high prices of the LPG and other cleaner cooking options.

In terms of decision-making processes, most of the decisions are made through the Ministry of Energy at the national level. The decisions made affect the city, its leadership, and its residents just like any other part of Kenya. In this regard, the Cabinet Secretary of the Ministry of Energy and Petroleum makes key decisions on matters of energy as per the Energy Act 2019. For instance, he/she is responsible for reviewing the National Energy Policy every 5 years in consultation with relevant stakeholders in the sector and also publishing a report on the status of implementation of the policy within 3 months after the end of a financial year (67). However, the County government of Nairobi has the chance to

determine and shape up its ambitions in reducing household air pollution. In this space, the County government has the key decision-making powers and lobbies for the support of the County Assembly to allocate adequate resources for the sub-sector. Besides, the City government has the chance to partner with non-state actors and development partners to promote clean cooking in the city as a climate action pathway to enhance the achievement of SDG 7 and support the national government in the attainment of universal access to clean cooking by 2028.

## Gender analysis of the air pollution in Nairobi city

Gender concepts and dimensions come into play in air quality management in numerous ways including the historically socially constructed roles and responsibilities that adversely define the exposure and vulnerabilities to air pollution, the disproportionate impacts, inequalities in key decision-making, and thus the overall air quality management (68). Gender dimensions are therefore very critical in air pollution reduction efforts, strategies, and intervention designs. With the increasing urbanization and city growth, the increasing air pollution impacts are disproportionately felt by the various gender groups. This project established that society has constructed the prevailing norms in the main sectors identified for air pollution and thus constructed the gender inequalities when it comes to exposure and vulnerabilities to air pollution and its adverse impacts. There are minimal efforts to mainstream gender in the mainstream sectors and if there are such efforts, they are less integrated and have a linear focus as evident in the Ministry of energy where the gender policy is skewed only to energy matters and not a single focus on pollution.

In addition, this gap is evident with the lack of comprehensive sex and gender-segregated data and impacts research evidence to redefine and refocus intervention designs in Nairobi city (19). For instance, the city's transport system is designed with less gender sensitivity, and many a time, those with disabilities, expectant women, and the young struggle while using the dominant public transport system in the city. While men and boys are likely to access jobs and livelihood sources from the transport sector, women and ladies are likely to create jobs and livelihood sources through small-scale commercial support businesses to the sector such as food vending. It is therefore difficult to attribute exposure to air pollution from the transport sector as both men and women, boys and girls are exposed in different ways.

Overall, it is perceived that more men and boys are exposed to air pollution from the transport sector than women and girls because they operate more in the transport sector. However, the safety risks are likely to be more for women and children in the use of public transport in the city. The transport sector dynamic is set to change progressively with continued advocacy for non-motorized transport systems and expansion and improvement of public transport. As such, it's a prime opportunity to advocate for the establishment of gender-sensitive infrastructures and systems in Nairobi city and this requires a dedicated and

transformative gender working group as will later be proposed by this study.

In the energy sector, different gender groups are exposed to and thus affected differently due to socially constructed roles and responsibilities. While outdoor air pollution affects all gender groups almost equally, indoor air pollution, the focus of this report energy sector, has a disproportionate exposure and impact levels on the gender groups. Indoor air pollution is mostly caused by the over reliance on biomass cooking fuels. In most households in Kenya and indeed Nairobi, women and girls are the main cooks and thus exposed more to air pollution from the sub-sector and thus more vulnerable to indoor air pollution than men and boys (69). This is because of the socially constructed role of cooking assigned to women and girls. The exposure and vulnerabilities are further made worse in low-income households, where the women and girls are less empowered to make key decisions even in the kitchen and thus have less control over the fuels being used. It's unfortunate that in some households in the Nairobi informal settlements, the men decide on the household investment in cooking fuels without understanding the impacts it has on the other gender groups. Overall, women and girls are affected by air pollution from the energy sector silently and their wish and power to change the narrative and make key decisions even to adopt clean cooking options are met with socio-economic challenges.

In an attempt to change the narrative of women being sidelined in policy intervention in the energy sector and to implement Sustainable Goal 7, the Ministry of Energy has launched the first-ever Gender policy to implement its National Energy Policy of 2018 effectively. The Gender Policy seeks to enhance access to clean energy sources for cooking by availing of efficient cooking technologies to low-income households. However, the formulation and design of the gender policy didn't have air pollution in mind and the priority was just to promote energy access. With the realization of the gap, the ministry is seeking to include the air pollution goals in the clean cooking strategy being developed. This provides an opportunity for the city government to partner with the Ministry of Energy of the National government to promote clean cooking for the double effect of attaining the clean cooking universal access goal by 2028 but also reducing the exposure, vulnerabilities, and thus mortalities due to air pollution.

The industrial sector is full of dynamics and gender still comes into play. Men dominate the informal sector and are thus more exposed to air pollution from the sub-sector. However, in small, medium, and large manufacturing and processing firms, the men are exposed directly to emissions coming from the hard tasks in industrial processing. The hard tasks such as managing the industrial boilers and operating heating units are reserved for men in most cases. This is because they are believed to be masculine and tough to accommodate the tasks. Women are mostly assigned light and formal duties in such industries. While the exposure to direct emissions may be more for men, the fugitive emissions still affect both gender groups. The exposure levels and thus vulnerabilities to the consequential impacts of air pollution thus vary from one gender group to the other and may

depend on the number of gender groups in the industries. Beyond the industrial premises, the emissions from the sector are usually carried down by the prevailing wind pattern and affect those living in the vicinity of the industries and thus the city dwellers at large. With the lack of gender-segregated data and research evidence, it is somehow impossible to pinpoint the gender-specific impacts of air pollution from this sector in the city (43).

The waste management sector with its complexities also presents a case for gender analysis. Waste collection, transportation, and processing seem to be defined by society for specific gender groups. While waste generation is universal to all groups, its collection from the point of generation and transportation is largely done by men and boys in Nairobi. The segregation and processing are also largely done by women and girls in collection points and at the Dandora dumpsite. This is because the collection from the generation points and transportation is societally perceived to be a hard and dirty task that only men and boys can handle. The segregation of recyclable wastes is largely done by women and girls as it's perceived as a light duty in the waste management value chain. The exposure and vulnerabilities, therefore, vary across the board with most men and boys participating in the waste burning and thus directly affected by the emissions. However, the women and girls are also exposed as they either work or operate within the vicinities of the waste-burning sites. The exposure and vulnerabilities are thus slightly high in men and boys but also affect women and women who suffer the most of the consequential respiratory illnesses and complications (61).

In terms of policies and institutional arrangements that affect the decision-making processes in air pollution reduction in the city, the study reveals that there is no sufficient gender-segregated data and research evidence to inform such policies and intervention design. The city is still struggling with general air pollution monitoring leave alone gender-specific data and information. With the evident struggles to mainstream gender in the existing policies and institutional arrangements, key stakeholders and decision-makers don't prioritize gender dimensions in their plans, actions, and frameworks. This can be attributed to the less capacity and understanding of gender concepts (68). In most cases, women's and men's representation have been confused to be gender mainstreaming and thus policy documents just mention gender without proper integration and mainstreaming in the implementation processes. The study, therefore, identifies the gap and proposes the establishment of a gender mainstreaming working group in the city drawn from various stakeholder groups to ensure substantial mainstreaming of gender concepts and enhance inclusivity in the air pollution reduction interventions for the city.

## Conclusions

Air quality management doesn't have a designated and single institutional arrangement. However, there are efforts from various institutions and actors under the prevailing laws and legal framework to reduce air pollution at the sectoral levels.

The air quality management in the city is therefore fragmented by the legal and institutional arrangements with the NEMA playing a central role in the process. The Nairobi City County government has also developed a policy guide and currently developing regulations to operationalize the air quality management in the city. For every sector, the analysis reveals that there are numerous challenges impeding the effective reduction of air pollution from the main sources. While the City county may have the desire to ultimately reduce air pollution from the identified sectors, the study shows that the city has much control and thus a greater opportunity to reduce air pollution from the waste management sector in the short term compared to the other sectors that are mostly controlled externally and the interventions are resource intensive or are highly politicized by a national government keen on economic growth and social benefits to the society than the environmental protection. The analysis also air pollution challenges which ranged from the legal and capacity gaps to inadequate resources and the dilemma of behavioral change, the lack of political goodwill among the key decision makers at the city and national governments tends to reduce air pollution less prioritized in most interventions. The prioritization of socio-economic pillars of sustainable development has seen the environmental pillar least considered and prioritized in various development agendas in the past. Even though the narrative is slowly changing with the intensified climate action and climate financing for sustainable developments, much still needs to be done to enhance the harmonious functioning of the various institutions and actors to reduce air pollution in the city. A starting point would be to have the key decision makers commit to working together and having a common goal set for reduced air pollution from the sector sources.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

## Author contributions

WK: Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. JA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. GM: Writing – review & editing, Supervision, Conceptualization, Project administration, Funding acquisition. TR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. HA: Formal analysis, Supervision, Writing – original draft, Writing – review & editing. EA: Writing – review & editing.



## Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was funded by the World Resources Institute (WRI).

## Acknowledgments

The authors acknowledge the immense work done by the stakeholders that contributed to providing key insights and information for this manuscript.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References

- World Health Organization. *Global status Report on Road Safety 2018*. Geneva: World Health Organization (2018).
- Singh A, Bakare H, Mazzeo A, Avis WR, Ng'ang'a D, Gatari M, et al. Urban diagnostics and a systems approach to air quality management: pathways towards sustainable economic development and a healthy Nairobi, Kenya. *Front Environ Sci*. (2022) 10:978002. doi: 10.3389/fenvs.2022.978002
- Saxena V. Water quality, air pollution, and climate change: investigating the environmental impacts of industrialization and urbanization. *Water Air Soil Pollut*. (2025) 236(2):1–40. doi: 10.1007/s11270-024-07702-4
- United Nations Human Settlements Programme (UN-Habitat). *UN-Habitat Annual Progress Report 2018: Working for a Better Urban Future*. Nairobi: UN-Habitat (2018).
- Jamal S, Atahar M, Ahmad WS. Resilience in urban ecosystems: interdisciplinary perspective, strategic blueprint, and innovative pathways for the cities of tomorrow. *GeoJournal*. (2025) 90(1):18. doi: 10.1007/s10708-024-11270-9
- Ruiz-Rudolph P, Johannessen K. Environment, cardiovascular health, and local and global inequities. In: Jensen SM, editor. *Global Challenges in Cardiovascular Prevention in Populations with Low Socioeconomic Status*. Cham: Springer Nature Switzerland (2025). p. 109–29.
- Kirago L, Gustafsson O, Andersson A, Haslett SL, Gatari MJ, Zhang W, et al. Dominant contribution of pyrogenic sources to PM<sub>2.5</sub>-bound polycyclic aromatic hydrocarbons in Nairobi, Kenya. *ACS ES&T Air*. (2025) 2(4):557–63. doi: 10.1021/acsestair.4c00283
- United Nations Environment Programme (UNEP). Actions on air quality: a global summary of policies and programmes to reduce air pollution (2021). Available online at: <https://www.unep.org/resources/actions-air-quality> (Accessed September 5, 2024).
- Saligari S, Nabukwangwa W, Mwitari J, de Cuevas RA, Clayton S, Nyongesa M, et al. Whose pollution, whose problem? Understanding perceptions of air pollution and implications for clean cooking (for health) in Nairobi schools. *Health Place*. (2025) 91:103398. doi: 10.1016/j.healthplace.2024.103398
- Health Effects Institute. *State of Global air 2019: A Special Report on Global Exposure to air Pollution and its Disease Burden*. Boston, MA: Health Effects Institute (2019). Available online at: [https://www.stateofglobalair.org/sites/default/files/soga\\_2019\\_report.pdf](https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf)
- World Health Organization (WHO). Global air quality guidelines: particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (2021). Available online at: <https://www.who.int/publications/i/item/9789240034228> (Accessed September 7, 2024).
- Rajé F, Tight M, Pope FD. Traffic pollution: a search for solutions for a city like Nairobi. *Cities*. (2018) 82:100–7. doi: 10.1016/j.cities.2018.05.008
- Singh A, Avis WR, Pope FD. Visibility as a proxy for air quality in east Africa. *Environ Res Lett*. (2020) 15:084002. doi: 10.1088/1748-9326/ab8b12
- Bera M, Das S, Garai S, Dutta S, Choudhury MR, Tripathi S, et al. Advancing energy efficiency: innovative technologies and strategic measures for achieving net zero emissions. *Carbon Footprints*. (2025) 4(1):70–9. doi: 10.20517/cf.2024.48
- Danquah M, Sen K, Gisselquist RM. Structural transformation: Domain report. Available at SSRN 5113156 (2025).
- Mwaniki MW, Moeller MS, Schellmann G A comparison of Landsat 8 (OLI) and Landsat 7 (ETM+) in mapping geology and visualising lineaments: a case study of central region Kenya. *Int Arch Photogramm Remote Sens Spatial Inf Sci*. (2015) XL-7/W3:897–903. doi: 10.5194/isprsarchives-XL-7-W3-897-2015
- Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the global burden of diseases study 2015. *Lancet*. (2017) 389:1907–18. doi: 10.1016/S0140-6736(17)30505-6
- Oluoch J, Bolo E, Randa T, Asarpota K. Strengthening local climate governance: insights from Nairobi's subnational government stocktake. *J City Clim Policy Econ*. (2025) 3(1):4–24. doi: 10.3138/jccpe-2024-0017
- Nairobi City County Government. State of the Environment Report 2020 (2021). Available online at: <https://nairobi-city.go.ke/download/state-of-environment-report-2020> (Accessed September 9, 2024).
- Simwela A, Xu B, Mekondjo SS, Morie S. Air quality concerns in Africa: a literature review. *Int J Sci Res Publ*. (2018) 8:588–94. doi: 10.29322/IJSRP.8.5.2018.p7776
- AirNow. Air quality index (AQI) basics. Office of air quality planning and standards (OAQPS), U.S. Environmental protection agency (2022). Available online at: <https://www.airnow.gov/aqi/aqi-basics> (Accessed January 23, 2022).
- Kirago L, Gatari MJ, Gustafsson O, Andersson A. Black carbon emissions from traffic contribute substantially to air pollution in Nairobi, Kenya. *Commun Earth Environ*. (2022) 3(1):74. doi: 10.1038/s43247-022-00400-1
- Kiai C, Kanali C, Sang J, Gatari M. Spatial extent and distribution of ambient airborne particulate matter (PM<sub>2.5</sub>) in selected land use sites in Nairobi, Kenya. *J Environ Public Health*. (2021) 2021:4258816. doi: 10.1155/2021/4258816
- Zeru R. Evaluation of Indicators' Potential to Assess Circularity in Waste Management: A case study on Nairobi's municipal solid waste management system (2025).
- Environmental Compliance Institute (ECI). Assessment of Nairobi's air quality policy (2021). Available online at: <https://www.environmentalcompliance.org/nairobi-air-policy> (Accessed September 11, 2024).
- Keeley J, Scoones I. *Understanding Environmental Policy Processes: Cases from Africa*. Nairobi: United Nations Human Settlements Programme (UN-Habitat) (2012). p. 1–224. doi: 10.4324/978184977362
- Bryson JR, Andres L, Mulhall R. *A Research Agenda for Regeneration Economies. Reading City-regions*. Nairobi: Edward Elgar Publishing (2018). p. c 208. doi: 10.4337/9781785360299

28. Nairobi City County. Air quality action plan 2019–2023 (2019). Available online at: <https://nairobi-city.go.ke/air-quality-action-plan> (Accessed September 13, 2024).
29. Nairobi City County. Air quality policy 2021 (2021). Available online at: <https://nairobi-city.go.ke/air-quality-policy> (Accessed September 15, 2024).
30. Government of Kenya. The constitution of Kenya (2010). Available online at: <https://www.klrc.go.ke/index.php/constitution-of-kenya> (Accessed September 17, 2024).
31. Government of Kenya. County Governments Act No. 17 of 2012 (2012). Available online at: [http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/CountyGovernmentsAct\\_No17of2012.pdf](http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/CountyGovernmentsAct_No17of2012.pdf) (Accessed September 19, 2024).
32. World Health Organization. Air quality guidelines for Europe. World Health Organization. Regional Office for Europe (2000).
33. World Health Organization (WHO). Global environment outlook: Nairobi focus (2021). Available online at: [https://www.who.int/environmental\\_health/nairobi](https://www.who.int/environmental_health/nairobi) (Accessed September 21, 2024).
34. Dianati K, Zimmermann N, Milner J, Muindi K, Ezech A, Chege M, et al. Household air pollution in Nairobi's slums: a long-term policy evaluation using participatory system dynamics. *Sci Total Environ.* (2019) 660:1108–34. doi: 10.1016/j.scitotenv.2018.12.430
35. Government of Kenya. Environmental Management and Coordination Act (1999). Available online at: <http://www.nema.go.ke/index.php/legislation-policies/344-environmental-act-emca1999> (Accessed November 11, 2015).
36. Government of Kenya. Environmental Management and Coordination (Amendment) Act (2015). Available online at: <http://www.nema.go.ke/index.php/legislation-policies/343-emca-am-act-2015> (Accessed November 11, 2015).
37. NGO. Policy Briefs on the Employment Retention and Promotion of Women Workers in the Public Road Transport Industry in Kenya. Flone Initiative (2018).
38. NEMA. Environmental management and coordination (air quality) regulations, 2014 (2014). Available online at: [https://www.nema.go.ke/images/Docs/Air\\_Quality\\_Regs\\_2014.pdf](https://www.nema.go.ke/images/Docs/Air_Quality_Regs_2014.pdf) (Accessed September 23, 2024).
39. NEMA. The environmental management and Co-ordination (air quality) regulations. National Environment Management Authority, Kenya (2014). Available online at: [https://www.nema.go.ke/index.php?option=com\\_content&view=article&id=31&Itemid=171](https://www.nema.go.ke/index.php?option=com_content&view=article&id=31&Itemid=171) (Accessed January 22, 2022).
40. NEMA. The environmental management and Coordination (air quality) regulations. National Environment Management Authority, Kenya (2014). Available online at: [https://www.nema.go.ke/index.php?option=com\\_content&view=article&id=31&Itemid=171](https://www.nema.go.ke/index.php?option=com_content&view=article&id=31&Itemid=171) (Accessed April 24, 2024).
41. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu N, et al. The lancet commission on pollution and health. *Lancet.* (2018) 391(10119):462–512. doi: 10.1016/s0140-6736(17)32345-0
42. Kenya National Bureau of Statistics. Kenya demographic and health survey 2020 (2020). Available online at: <https://www.knbs.or.ke> (Accessed September 25, 2024).
43. Amegah AK, Agyei-Mensah S. Urban air pollution in Sub-Saharan Africa: time for action. *Environ Pollut.* (2016) 220:738–43. doi: 10.1016/j.envpol.2016.09.042
44. Muindi K, Egondi T, Kimani-Murage EW, Rocklöv J, Ng N. “We are used to this”: a qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi. *BMC Public Health.* (2017) 14(1):226. doi: 10.1186/s12889-014-7533-9
45. deSouza P. Political economy of air pollution in Kenya. *Urban Forum.* (2022) 33(3):393–414. doi: 10.1007/s12132-022-09464-w
46. National Environment Management Authority (NEMA). Guidelines on waste segregation in Kenya (2020). Available online at: <https://www.nema.go.ke> (Accessed September 27, 2024).
47. Mudinyu B. *Challenges of Implementing Intellectual Property Protection for Entrepreneurial Innovations Among Selected Agencies in Kenya* (doctoral dissertation). University of Nairobi (2021).
48. Shilenje ZW, Thiong'o K, Ongoma V, Philip SO, Nguru P, Ondimu K. Roadside air pollutants along elected roads in Nairobi city, Kenya. *J Geol Geophys.* (2016) 5(5):253. doi: 10.4172/2381-8719.1000253
49. Giugliano M, Lonati G, Butelli P, Romele L, Tardivo R, Grosso M. Fine particulate (PM<sub>2.5</sub>–PM<sub>1</sub>) at urban sites with different traffic exposure. *Atmos Environ.* (2005) 39:2421–31. doi: 10.1016/j.atmosenv.2004.06.050
50. Borrego C, Tchepel O, Costa A, Martins H, Ferreira J, Miranda A. Traffic-related particulate air pollution exposure in urban areas. *Atmos Environ.* (2006) 40:7205–14. doi: 10.1016/j.atmosenv.2006.06.020
51. Pérez N, Pey J, Cusack M, Reche C, Querol X, Alastuey A, et al. Variability of particle number, black carbon, and PM<sub>10</sub>, PM<sub>2.5</sub>, and PM<sub>1</sub> levels and speciation: influence of road traffic emissions on urban air quality. *Aerosol Sci Technol.* (2010) 44:487–99. doi: 10.1080/02786821003758286
52. Kinney PL, Gichuru MG, Volavka-Close N, Ngo N, Ndiba PK, Law A, et al. Traffic impacts on PM<sub>2.5</sub> air quality in Nairobi, Kenya. *Environ Sci Policy.* (2011) 14:369–78. doi: 10.1016/j.envsci.2011.02.005
53. Kalisa E, Archer S, Nagato E, Bizuru E, Lee K, Tang N, et al. Chemical and biological components of urban aerosols in Africa: current status and knowledge gaps. *Int J Environ Res Public Health.* (2019) 16:941. doi: 10.3390/ijerph16060941
54. Singh A, Ng'ang'a D, Gatari MJ, Kidane AW, Alemu ZA, Derrick N, et al. Air quality assessment in three east African cities using calibrated low-cost sensors with a focus on road-based hotspots. *Environ Res Commun.* (2021) 3:075007. doi: 10.1088/2515-7620/ac0e0a
55. Pope FD, Gatari M, Ng'ang'a D, Poynter A, Blake R. Airborne particulate matter monitoring in Kenya using calibrated low-cost sensors. *Atmos Chem Phys.* (2018) 18:15403–18. doi: 10.5194/acp-18-15403-2018
56. Kenya Institute for Public Policy Research and Analysis (KIPPRA). Traffic congestion and economic costs in Nairobi (2020). Available online at: <https://kippra.or.ke> (Accessed October 1, 2024).
57. NAMATA. Strategy plan 2019–2023 (2019). Available online at: <https://namata.go.ke/strategy-2019-2023> (Accessed October 3, 2024).
58. Swiss Federal Office for Spatial Development. Erstellung des nationalen Personenverkehrsmodells für den öffentlichen und privaten Verkehr: Model Description. Swiss Federal Office for Spatial Development and Swiss Federal Department for Environment, Transport, Energy and Communication (2006).
59. Kasozi A. Solid Waste Management in Nairobi: A Situation Analysis. 59 (2010).
60. Nairobi Waste Management Coalition. Managing urban waste in Nairobi (2022). Available online at: <https://www.urbanwaste.or.ke> (Accessed October 5, 2024).
61. Njoroge BNK, Kimani M, Ndunge D. Review of Municipal Solid Waste Management: A Case Study of Nairobi, Kenya. 5 (2014).
62. Nairobi City County Government. Nairobi City County Transport Bill 2019. Nairobi City County Assembly (2019).
63. Clean Cooking Alliance. Clean cooking efforts in Kenya (2020). Available online at: <https://www.cleancookingalliance.org> (Accessed October 7, 2024).
64. Kenya Power and Lighting Company. Electricity access report (2021). Available online at: <https://www.kplc.co.ke> (Accessed October 9, 2024).
65. Ngare IO, Koske JK, Muriuki JN, Chitechi EW, Gathuku GN. Urban climate variability trend in the coastal region of Mombasa, Kenya. *Afr J Environ Sci Technol.* (2020) 14(8):214–21. doi: 10.5897/AJEST2020.2837
66. Finance Act 2020 (Kenya). Kenya Gazette Supplement (No. 104, Acts No. 8 of 2020). Available online at: [https://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/2020/TheFinanceAct\\_No.8of2020.pdf](https://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/2020/TheFinanceAct_No.8of2020.pdf) (Accessed June 30, 2020).
67. EPRA. Energy and petroleum statistics report (2022). Available online at: <https://www.epra.go.ke> (Accessed October 11, 2024).
68. Ministry of Energy. Kenya energy policy review (2021). Available online at: <https://energy.go.ke> (Accessed October 13, 2024).
69. Health Effects Institute. *Annual Report 2020: Valuing Science, Informing Decisions.* Boston, MA: Health Effects Institute (2020).
70. Robinson LW. Political ecology and resilience: an integration of human and ecological dynamics. *Ecol Soc.* (2014) 19(3):15.
71. Pant LP, Hambly-Odame H. Innovations systems in renewable natural resource management and sustainable agriculture: a literature review. *Afr J Sci Technol Innov Dev.* (2009) 1(1):103–35. Available online at: <https://hdl.handle.net/10520/EJC10492>
72. Soren T, Patra NK, Singh RK. Participatory natural resource management in tribal areas: a case study from Jharkhand, India. *Indian J Agric Econ.* (2011) 66(3):465–75.