Development of a Nairobi City-Owned Air Quality Data Management System and Public Access Portal

AIR QUALITY DATA AND ACCESSIBILITY NEEDS ASSESSMENT REPORT

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CENEX CONSULT LTD

PREPARED FOR THE CLEAN AIR FUND AND NAIROBI CITY COUNTY GOVERNMENT

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EXECUTIVE SUMMARY

Nairobi's air quality is deteriorating due to rapid urbanization, increasing vehicle emissions, and industrial activities—posing serious health and environmental risks, especially to vulnerable populations. Despite the presence of over 29 air monitoring stations operated by various actors (IQAir, Sailhero, AirNow, UNEP, U.S. Embassy, AirQO, University of Nairobi, and Nairobi City County), data systems are fragmented, uncoordinated, and largely inaccessible in real time.

To address this, the Nairobi City County Government, in collaboration with CENEX Consult Ltd and supported by the Clean Air Fund under the Breathe Cities Initiative, is developing a **City-Owned Air Quality Data Management System (AQDMS)** and a **Public Access Portal**. This initiative aims to centralize, validate, and harmonise air quality data, support evidence-based policymaking, and enhance public access and awareness. This move will lead to deployment of 50 more Air Quality Sensors across Nairobi City by NCCG supported by CAF. The deployment service will be done by AQS-EA.

A needs assessment conducted between February and May 2025 included extensive desktop review as well as internal county department consultations, a multi-stakeholder workshop, and engagement with civil society, academia, and community groups. Guided by a Joint Technical and Steering Committee, this process identified several critical gaps:

- **Fragmented systems** and a lack of city ownership undermine data control—**including secure, timely access and availability of data when required**—and limit effective use in decision-making.
- **Limited public access** prevents open and full public access, use and feedback for timely decision-making and civic engagement.
- **Technical needs** include role-based access, real-time alerts, visual dashboards, and system interoperability.

Key Recommendations

- Develop a centralized AQDMS with secure storage, automated data validation, and role-based access.
- Launch a real-time, mobile-responsive public portal featuring dashboards and historical trends.
- Ensure integration with national and regional platforms (e.g., AirQo, WHO, OpenAQ, AirQo, and EAC systems).
- Incorporate public feedback mechanisms and promote environmental literacy campaigns.
- Conduct regular system audits to maintain transparency and trust.

This project places Nairobi at the forefront of air quality innovation in Africa, setting a precedent for smart, data-driven environmental management and public health protection.

TECHNICAL TERMS AND ACRONYMS

AirQo:	An air quality monitoring initiative by Makerere University, Uganda, using low-cost sensors and public data platforms.
API:	Application Programming Interface—A set of tools that allows external systems to access and interact with the AQDMS data.
AQDMS:	Air Quality Data Management System centralized digital platform owned by the city that collects, validates, store, analyze, visualize, integrates and disseminates air with centralised digital platform owned by the city that collects, validates, stores, analyses and visualise.
CAF:	Clean Air Fund – A philanthropic initiative supporting clean air projects globally, including Nairobi's AQDMS.
CENEX:	CENEX Consult Ltd – The technical consultant appointed to lead the AQDMS development for Nairobi.
CO:	Carbon Monoxide – A colorless, odorless gas produced by incomplete combustion.
NEMA:	National Environment Management Authority – Kenya's agency responsible for enforcing environmental regulations.
NO_x:	Nitrogen Oxides – Pollutants primarily emitted from vehicle engines and industrial activity.
$PM_{2.5}$ / PM_{10}:	Particulate Matter – Fine particles with diameters less than 2.5 microns ($PM_{2.5}$) or 10 microns (PM_{10}), harmful to respiratory health.
SO_2:	Sulfur Dioxide – A toxic gas resulting from burning fossil fuels containing sulfur.
UNEP:	United Nations Environment Programme – Leads global environmental efforts, including air quality monitoring support.
USSD:	Unstructured Supplementary Service Data – A communications protocol used on mobile networks for interactive, text-based services.
VOCs:	Volatile Organic Compounds – Organic chemicals that easily evaporate and contribute to air pollution.
WHO:	World Health Organization – Sets global air quality guidelines.

1. INTRODUCTION

1.1 Background

Nairobi is undergoing rapid urbanization, with rising levels of motorization and industrial activity that have significantly contributed to worsening air quality. These conditions disproportionately impact vulnerable populations, including children, the elderly, and low-income communities.[1] The health and environmental consequences of air pollution are increasingly evident, yet the city's air quality monitoring infrastructure remains fragmented and inadequate.

Currently, data on Nairobi's air quality is collected by a variety of organizations—including IQAir, University of Nairobi, Sailhero, AirNow, the U.S. Embassy in Nairobi, UNEP, PurpleAir, and AirQo—across 29 monitoring stations.[2] However, these efforts are largely uncoordinated, resulting in data inconsistencies and limited public access to real-time, and historical data. This fragmentation inhibits effective policy development, reduces public awareness, and limits community-driven environmental action.[3]

To address these challenges, the Nairobi City County Government, with support from the Clean Air Fund under the Breathe Cities Initiative and in collaboration with CENEX Consult Ltd, has initiated the development of a City-Owned Air Quality Data Management System (AQDMS) and an interactive Public Access Portal. This system will unify data from multiple sources, standardize and validate information, and present it through accessible digital platforms. The goal is to enable evidence-based policymaking, enhance environmental accountability, and empower citizens with information to support healthier choices and sustainable behaviors.

This initiative is shaped by a wide range of stakeholder inputs, including government departments, civil society organizations, and local communities—to ensure the AQDMS reflects Nairobi's unique operational needs and long-term environmental goals.

1.2 Contextual Landscape: National, Regional, and International Perspectives on AQDMS

To better appreciate Nairobi's AQDMS development, it is essential to situate it within the broader national, regional, and international efforts shaping air quality management.

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[1] UNEP. (2022). *Air Pollution in African Cities: Trends and Opportunities*. United Nations Environment Programme.
[2] IQAir. (2025). *World Air Quality Report: Kenya – Nairobi Chapter*. https://www.iqair.com/
[3] Clean Air Fund. (2024). *Breathe Cities Program Overview*. https://www.cleanairfund.org/

1.2.1 National Context – Kenya

Kenya is making significant strides toward environmental sustainability and climate resilience through national legislation and policy frameworks:

Institutional and Legal Framework

- Nairobi City County Air Quality Act, 2022 provides the legal framework for air quality management at the county level.[4]
- Nairobi City County Climate change act, 2024 Nairobi City County Air quality policyNairobi City County Solid Waste Management Act, 2015, which outlines regulations for waste disposal and management.
- Nairobi City County Climate Action Plan (2020-2050) sets long-term strategies for climate resilience.
- Nairobi City County Sustainable Waste Management Act, 2022. This Act is another key piece of legislation aimed at promoting sustainable waste management practices.
- Nairobi City County Transport Act 2020. This Act is relevant to environmental management as it can address issues like emissions from vehicles and promote sustainable transportation.
- (NEMA-Kenya, 2024) The Environmental Management and Coordination Ambient Air Quality regulations 2024, implemented by NEMA, mandate emission control and ambient air monitoring.
- The National Environmental Management Authority (NEMA) has adopted WHO air quality guidelines and is increasingly working with county governments to decentralize monitoring. [5]
- The Kenya Clean Air Policy (Draft 2023) seeks to align national efforts with the African Union and SDG targets on air quality.The Climate Change Act (2016) and the National Climate Change Action Plan (NCCAP 2018–2022) emphasize integrated environmental data systems and air quality monitoring.[6]
- Smart Cities initiatives, led by the Ministry of ICT and the Digital Economy, promote digital environmental monitoring and data-driven governance. [7]

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[4] Nairobi City County. (2021). *Nairobi City County Air Quality Act*.

[5] NEMA. (2023). *Air Quality Guidelines and Implementation Progress*. National Environmental Management Authority.

[6] Government of Kenya. (2018). *National Climate Change Action Plan (2018–2022)*. Ministry of Environment and Forestry.

[7] MoICT. (2022). *Smart City Blueprint for Nairobi and Other Urban Centers*. Ministry of ICT, Kenya.

Existing Air Quality Monitoring and Data Management Initiatives in Kenya

- NEMA-Kenya operates a mobile, regulatory-grade air quality monitor in Nairobi and other cities; however, its deployment is limited and primarily driven by complaints, resulting in sparse coverage
- United Nations Environment Programme, Research institutions and NGOs, such as AirQO, Jomo Kenyatta University of Agriculture and Technology, Stockholm Environment Institute and University of Nairobi, have deployed low-cost sensors for community air monitoring.
- World Resources Institute co-owns two Reference Grade Monitors with Nairobi City County Government
- University of Nairobi owns 2 reference grade monitor BAM 1022 hosted by the East Africa GEOHealth Hub Program and the Institute of Nuclear Science and Technology

Breathe Nairobi Initiative launched in 2024 aims to support cities around the world to cut their air pollution and climate emissions. Despite these efforts, the national infrastructure for real-time, city-level air quality data remains yet to be properly developer or called reliable, making Nairobi's AQDMS a potential national model for urban environmental governance.

Challenges

- Fragmented data sources and lack of standardization.
- Limited rights on the existing data by the county authority affecting enforcement and compliance.
- Low public access to air quality data.
- Inadequate technical capacity for data analysis and interpretation.

1.2.2 Regional Context – East Africa

Across East Africa, cities are also embracing digital environmental monitoring solutions:

- AirQo, developed by Makerere University in Kampala, operates one of the region's largest networks of low-cost air quality sensors and provides real-time data access to the public. [8]
- Dar es Salaam and Kigali are piloting urban air quality projects with support from UNEP and UN-Habitat.[9]
- The East African Community (EAC) has initiated discussions on harmonizing air quality and climate monitoring across the region. [10]

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[8] AirQo. (2023). *Air Quality Monitoring in Africa: Scaling low-cost sensors*. Makerere University. https://airqo.net/

[9] UN-Habitat. (2022). *Smart Urban Air Monitoring Pilot Projects: East Africa Overview*.

[10] EAC. (2023). *East African Environmental Monitoring Strategy – Draft Policy Paper*.

1.2.3 Status of Air Quality Data Management in other African Cities

1.2.3.1 South Africa (Cape Town, Johannesburg)[11]

- Operates one of the most advanced AQDMS in Africa.
- The **South African Air Quality Information System (SAAQIS)** aggregates real-time data from regulatory-grade monitors and shares it online.
- Public access and integration into policy processes are well-established.

1.2.3.2 Nigeria (Lagos, Abuja)

- The **Nigerian Meteorological Agency (NiMet)** and **Federal Ministry of Environment** have pilot air quality monitoring programs.
- Data is not yet centralized or widely accessible.
- Lagos has partnered with **Airly and C40 Cities** to deploy low-cost sensors.

1.2.3.3 Ghana (Accra)

- Accra was a pilot city under the **WHO Urban Health Initiative**, deploying air quality monitors in collaboration with the EPA Ghana and Vital Strategies.Data feeds into health risk assessments and urban planning.
- Established in May 2019, the Ghana Urban Air Quality Project (GhanAQ) was initiated to address the country's limited air quality monitoring capabilities and the need for comprehensive data to inform public health policies. Recognizing the potential of emerging low-cost air quality sensors, GhanAQ aimed to complement existing reference monitoring systems and bridge data gaps across Ghana's urban areas. Since its inception, GhanAQ has successfully deployed over 60 low-cost air quality sensors in various communities within the Greater Accra Region
- Ghana Urban Air Quality Project (GHAir), through the Breathe Accra initiative with support from the Clean Air Fund, installed 65 Low-Cost Sensors (15 clarity nodes and 50 airnotes) in the 15 districts across three sub-metros and ten municipalities within the Greater Accra Metropolitan Area (GAMA), alongside a reference grade air monitoring device (BAM1022) installed in Central Business District of Accra. A web portal (https://breatheaccra.org/) was developed to host and share data from all deployed sensors.

Common Challenges of Air Quality Data Management in African Cities

- Limited funding and over-reliance on donor-supported sensors.
- Lack of actualised data.
- Weak policy uptake of available data.
- Poor data quality where data is available.

[11]SAAQIS. (2024). *South African Air Quality Information System*. https://saaqis.environment.gov.za

- Limited public dashboards or open data portals.

1.2.4 International Context

Globally, the push for open, real-time environmental data is gaining momentum:

- The World Health Organization (WHO) and UN Environment Programme (UNEP) lead global platforms such as the Global Air Quality Platform and Urban Air Action Platform, promoting public access to air pollution data.[12,13]
- The Breathe Cities Initiative, active in cities such as Jakarta, London, and Accra, promotes common benchmarks for air pollution measurement and management—often aligned with WHO guidelines—facilitates knowledge exchange, strengthens institutional capacity, and fosters global standards for air quality governance
- London, New Delhi, and Los Angeles have deployed advanced AQDMS platforms integrating government and citizen data to improve decision-making and urban health.[14]

1.2.5 Global Best Practices in Air Quality Data Management

South Africa's SAAQIS

The South African Air Quality Information System (SAAQIS) website provides real-time air quality data and information across South Africa. It serves as a resource for the public, researchers, and policymakers to access air quality monitoring data, reports, and educational materials.

United States (EPA's AirNow Program)[15]

- Centralized, real-time AQDMS that aggregates data from multiple sources.
- Provides public dashboards, mobile apps, and alerts.
- Informs regulatory decisions, health advisories, and urban planning.

European Union (Air Quality e-Reporting System)[16]

- Mandated under **Directive 2008/50/EC**.
- Standardized protocols for data collection, validation, and reporting.
- Public access via the **European Air Quality Index**.

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[12] WHO. (2021). *Air Quality Guidelines – Global Update 2021*. World Health Organization.
[13] UNEP. (2023). *Urban Air Action Platform*. https://urbanair.unep.org/
[14] C40 Cities. (2022). *Air Quality Data Platforms: Case Studies from Global Cities*. https://www.c40.org/

[15] US EPA. (2023). *AirNow Program*. https://www.airnow.gov

[16] European Environment Agency. (2023). *Air Quality in Europe — 2023 Report*. https://www.eea.europa.eu

China (National Air Quality Platform)

- Integrates data from over 1,500 cities.
- Real-time data shared on mobile apps and websites.
- Used for urban planning and traffic control.

India (SAFAR Program and CPCB Portal)

- SAFAR (System of Air Quality and Weather Forecasting and Research) combines monitoring and forecasting.
- Central Pollution Control Board (CPCB) aggregates and shares nationwide data.

1.2.6 Key Elements of a Functional AQDMS

Component	Description
Monitoring Infrastructure	Network of regulatory-grade and low-cost sensors.
Data Storage and Processing	A centralized, multi-layered system designed to collect, store, and refine real-time sensor data. It comprises: • **Database Management**: Central repository for structured/unstructured data with metadata tagging. • **Data Transformation**: ETL pipelines for cleaning, standardization, timestamp alignment, and spatial interpolation. • **Anomaly Detection**: Real-time monitoring to flag sensor drift, data outliers, or transmission faults.
Data Validation	A structured quality assurance process that applies standardised protocols—including routine calibration and scheduled maintenance—to ensure sensor data is accurate, consistent, and reliable before it enters downstream processing.
Analytics Tools	Visualization, trend analysis, source apportionment, forecasting.
Public Access	Online dashboards, APIs, SMS alerts, and mobile apps.
Policy Integration	Linkage with urban planning, transport, public health, and environmental laws.
Institutional Ownership	Managed by local or national governments for sustainability.
Integration with national and international platforms	(e.g., AirQo, WHO, EAC systems).

1.2.6.1 Monitoring Infrastructure

This component refers to the physical network of air quality sensors deployed across Nairobi. It includes:

- Types of sensors used—regulatory-grade (e.g., reference monitors) vs. low-cost sensors—and their technical capabilities.
- Maintenance and calibration protocols to ensure continuous accuracy and reliability.
- Cost, power, and connectivity considerations, especially in low-resource or informal settlements.

1.2.6.2 Data Aggregation

This involves the central collection and organization of air quality data in real time. Key aspects include:

- The technical architecture for centralizing data from disparate sensor types.
- Use of a universal schema for interoperable standards or a unified city/national platform.
- Mechanisms for data deduplication, synchronization, and timestamping.

1.2.6.3 Data Validation

Ensuring data quality is essential for credibility and usability. This includes:

- Adoption of standardized QA/QC protocols for air quality data.
- Use of automated validation tools that flag outliers and sensor drift.
- Processes for manual review or expert audits.
- Techniques for co-location calibration (e.g., aligning low-cost sensors with reference monitors).

1.2.6.4 Analytic Tools

These tools transform raw data into meaningful insights. Key elements:

- Dashboards and visualization platforms to interpret trends and anomalies.
- Trend and seasonal analysis (e.g., pollution spikes during dry or rainy seasons).
- Use of configured models for forecasting pollution levels or mapping exposure.

1.2.6.5 Public Access

Enabling access to air quality data for the public builds transparency and trust. Focus areas:

- User interfaces such as websites and web alerts.
- APIs for developers, researchers, and civic tech.
- Consideration of language, literacy, and digital accessibility.

1.2.6.6 Policy Integration

This component ensures that air quality data informs decision-making. Includes:

- Use of data to design or evaluate transport, health, and environmental policies.
- Integration into urban planning (e.g., zoning, traffic rerouting).
- Enforcement of emissions standards or industrial regulations.
- Cross-sectoral collaboration among departments (e.g., transport, health, environment).

1.2.6.7 Institutional Ownership

Sustainable AQDMS systems require strong institutional frameworks:

- Defined roles and responsibilities across government agencies.
- Capacity building and retention of technical staff.
- Budget allocations for operations, maintenance, and upgrades.
- Long-term governance models (e.g., municipal vs. national ownership).

1.2.6.8 Integration with National/International Platforms

Linking with broader systems enhances coordination and benchmarking:

- Adoption of common data formats and reporting standards (e.g., WHO Air Quality & NEMA Guidelines).
- Alignment with platforms like AirQo, EAC monitoring systems, etc.
- Enabling cross-border data comparisons, transboundary pollution tracking, and reporting.
- Promoting knowledge exchange through regional partnerships.

2. PROJECT OBJECTIVES

The overarching goal of this initiative is to establish a robust, city-owned system for managing and disseminating air quality data in Nairobi. The specific objectives are to:

i. **Centralize and harmonize air quality data** collected from diverse sources, including government agencies, third-party monitors, and sensor networks.
ii. **Develop a secure and scalable Air Quality Data Management System (AQDMS)** to ensure reliable data validation, storage, and integration.
iii. **Create a publicly accessible digital portal** to deliver real-time, interactive, and

user-friendly air quality information to the public, researchers, and policymakers.

iv. **Support evidence-based policymaking** and enforcement by providing timely, accurate air quality data to relevant government departments and institutions.

v. **Promote civic awareness and behavioral change** through accessible data, alerts, visualizations, and educational resources.

vi. **Facilitate interoperability** with national, regional, and international environmental monitoring platforms.

vii. **Ensure stakeholder inclusion and sustainability** through continuous feedback loops, capacity building, and system audits.

3. SITUATIONAL ANALYSIS OF NAIROBI CITY COUNTY'S AIR QUALITY DATA MANAGEMENT

Nairobi City County Government currently utilizes a cloned version of the AirQo Air Quality Data Management System, which has been integrated into the county's official website and can be accessed at https://nairobi.go.ke/nairobi-air-quality/. This platform was adopted to provide residents and stakeholders with access to real-time air quality information.

However, access to comprehensive data and periodic analytical reports remains limited due to existing access protocols. Additionally, while the system is publicly visible through the county's portal, it is fully owned, managed, and controlled by AirQo—an initiative based at Makerere University in Uganda. As such, the County Government has limited administrative control over the system's backend, customization options, and data governance.

This arrangement presents challenges in aligning the air quality data system with Nairobi's specific environmental priorities, reporting needs, and decision-making processes.

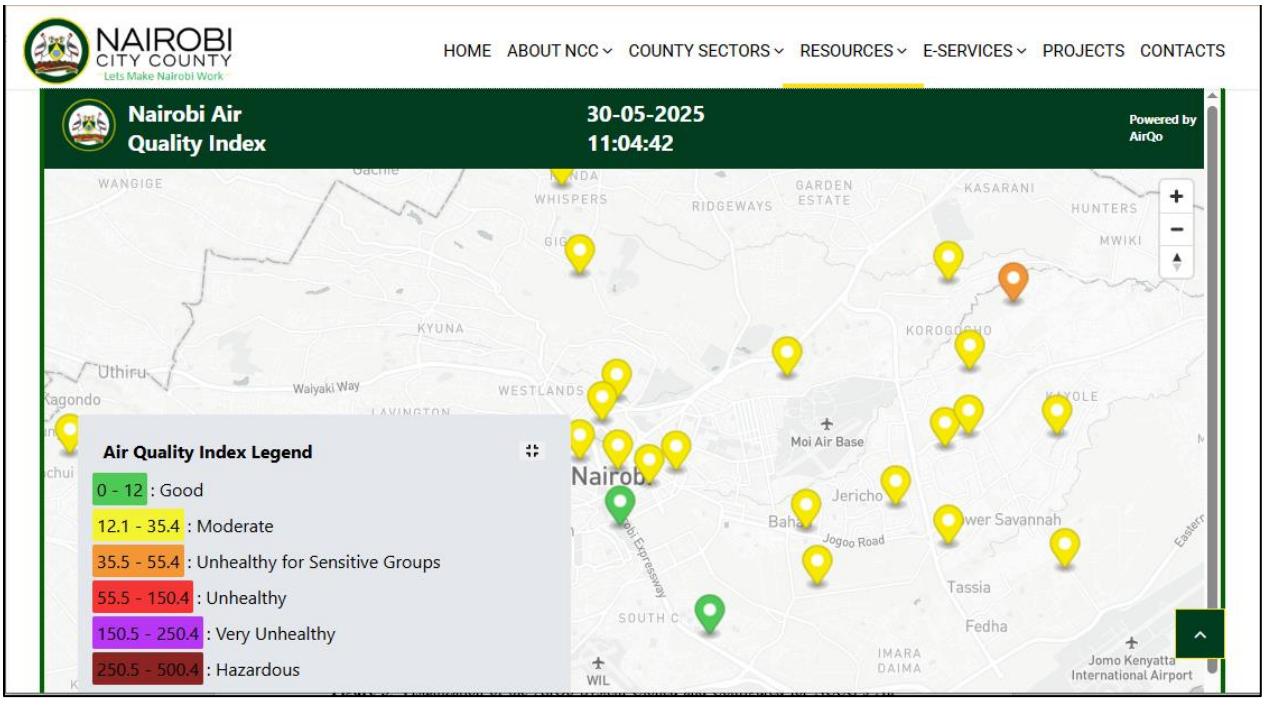

Figure 3: Visualization of the AirQo System Cloned and Configured for NCCG's Air Quality Data Management.[17]

Current Challenges Identified

a) Lack of City Ownership and Control

The existing air quality monitoring systems in Nairobi are not city-owned, limiting the County Government's autonomy in managing, accessing, and expanding the infrastructure. This lack of ownership restricts strategic oversight and sustainability.

b) Absence of Real-Time Reporting

Current systems are not equipped or authorized to provide real-time data access. As a result, information dissemination is delayed, and available reports are static, retrospective, and lack interactivity—hampering timely decision-making and public responsiveness.

c) Limited Public Accessibility and Usability

Air quality data is generally shared through periodic reports or simplified Air Quality Index (AQI) summaries on county government websites. However, these outputs are often infrequent, lack interactivity, and are presented in formats that are not user-friendly or easily interpretable by the general public. Moreover, the data is not openly licensed, limiting public rights to access, reuse, or analyze the underlying

[17] Nairobi City County Government. (n.d.). *Nairobi air quality*. Nairobi City County. https://nairobi.go.ke/nairobi-air-quality/

datasets. This restricts civic engagement, research collaboration, and community-driven innovation around environmental health.

d) Fragmented and Non-Integrated Systems

The data infrastructure across Nairobi is fragmented, with platforms operating in silos. There is little to no interoperability between environmental monitoring systems, public health databases, or emergency response tools—limiting the effectiveness of coordinated action and data-driven policy interventions.

Benefits of a City-Owned AQDMS

Establishing a **city-owned and city-managed Air Quality Data Management System (AQDMS)** would directly address the current challenges in Nairobi's air quality monitoring ecosystem. The following are the key benefits aligned with the specific issues identified:

a) Enhanced City Ownership and Strategic Oversight

By owning the AQDMS, Nairobi City County Government would gain full control over data collection, infrastructure deployment, and platform customisation. This ensures:

- Strategic alignment with local environmental priorities,
- Increased institutional accountability,
- Long-term sustainability through locally driven planning and budgeting.

b) Authority to Enable Real-Time Reporting

A city-owned system can be designed with built-in capabilities for **real-time data acquisition and reporting**, empowering the county to:

- Issue timely alerts to the public.
- Support rapid response actions during pollution spikes.
- Enable dynamic, up-to-date dashboards for both officials and citizens.

c) Improved Public Accessibility and Engagement

A tailored AQDMS would allow the county to deliver air quality data in **more user-friendly, accessible formats**, such as:

- Interactive maps and dashboards,
- Mobile-friendly apps and web alerts,
- Visual storytelling that enhances public understanding and risk awareness.

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d) System Integration and Interoperability

A city-managed platform could be built to integrate with other critical systems, including:

- **Public health databases**, to link pollution levels with disease trends,
- **Transport and urban planning systems** for emissions management,

e) **Disaster/emergency response tools**, enabling coordinated action during environmental crises.

4. METHODOLOGY

The needs assessment for Nairobi's Air Quality Data Management System (AQDMS) followed a participatory and evidence-informed approach, designed to capture a broad spectrum of technical requirements, user expectations, and policy considerations. An extensive review of relevant policies, technical reports, international best practices, air quality data portals, and literature on air quality data management systems. The assessment process also drew from multiple data engagement fora to ensure comprehensive stakeholder representation and input.

Key inputs were generated through deliberations of the Joint Technical and Steering Committee for the development of the AQDMS, which provided strategic direction and validated emerging priorities. These sessions were complemented by a series of internal and external stakeholder engagements involving Nairobi City County departments and national government sectors —such as ICT, Urban Planning, Health, Transport, Education and Environment—which offered insights into operational needs, data workflows, and institutional expectations.

In addition, an external stakeholder workshop was held on May 9th, 2025, at Weston Hotel, Nairobi. This workshop brought together representatives from civil society, academia, community-based organizations, and environmental NGOs. The event included plenary briefings, facilitated breakout discussions, and live polling to gather input on topics such as pollutant types, historical data needs, alert systems, and visualization preferences.

All inputs were systematically documented and analyzed using thematic analysis. Triangulation across sources—including committee deliberations, workshop transcripts, session summaries, and visual data—ensured that the findings were both credible and representative. This multi-layered approach forms the foundation for a robust, context-specific AQDMS design aligned with Nairobi's environmental and public health goals.

5. STAKEHOLDER-IDENTIFIED NEEDS

The design and development of the Air Quality Data Management System (AQDMS) were informed by extensive consultations with a broad range of stakeholders, including Nairobi City County departments, practitioners, academic institutions, civil society organizations, community-based groups, and environmental NGOs. These engagements were structured to capture user expectations, technical requirements, and functional priorities to ensure the system meets diverse operational and public needs.

During the consultations, stakeholders emphasized the importance of a system that is not only technically robust but also user-friendly, transparent, and inclusive. Their feedback was distilled into a set of core functional and technical needs that directly inform the AQDMS architecture, features, and governance structure.

Stakeholder Matrix for Nairobi County Air Quality Data Management System

The stakeholder matrix categorizes stakeholders based on their level of influence and interest in the air quality data management system, helping to prioritize engagement strategies.

Stakeholder Group	Type	Role/Impact	Engagement Strategy
Nairobi County Government	User/ Implementer	Key decision-maker, responsible for regulatory approval and enforcement	Collaborate through regular briefings and consultations
Joint Technical and Steering Committee	Representatives of various stakeholder groups working towards success of the NCCG-AQDMS	Charged with a responsibility of guiding and monitoring the development of the AQDMS	Evaluate the AQDMS process
National Environment Management Authority (NEMA)	Government Agency	Regulates environmental standards and enforces compliance	Collaborate through technical working groups and regular updates
Representative of Ministry of Health	Government Agency	Public health oversight, ensures health-related impacts are addressed	Consult during health impact assessments
Kenya Association of Manufacturers (KAM) representation	Industry Association	Represents businesses, concerned about economic impacts and compliance costs	Consult through industry-specific workshops and feedback sessions
ICT Professionals/ Experts/Practitioners e.g AirQO, Health Effects,	Private Sector	Represents diverse business interests, including those impacted by regulations	Inform and consult through sector meetings and forums

AQS, CENEX Consult Limited,			
Transport Sector (Matatu Owners Association, logistics firms)	Private Sector	Potentially impacted by vehicle emissions regulations	Consult during regulation development to gather input on compliance feasibility
Nairobi Air Quality working Group	Air Quality Experts Group	Focused on air quality improvement, mitigation, supports clean air initiatives	Collaborate in regulations development
Academia included- University of Nairobi, Kenyatta University, and Jomo Kenyatta Universiy, Makerere University	Academic and Research Institutions	Provides research and technical expertise on air quality	Collaborate in research, monitoring, and evaluation efforts
Media and Local Community Groups (e.g., KUSUDI cause Communication Trust), Groots Kenya, Slum Dwellers International**), Hewa Safi**	Media, Community and Civil Society	Report, Communicate and Most affected by air quality, concerned about public health and quality of life	Report, Communicate, Inform and consult through public forums, community meetings, and surveys
Civil Society Organizations e.g National Public Transport Alliance (NAPTA), ECI, SDI-K	Civil Society	Advocates for community well-being and cleaner environments	Inform and consult through workshops and public discussions
United Nations Environment Programme (UNEP)	International Organization	Provides global expertise on air quality regulations	Collaborate for technical expertise and best practices sharing
Health Effects Institute, World Resources Institute, Stockholm Environment Institute-Africa, C40 Cities, Clean Air Fund, World Bank	International Donors	Financial and technical support for environmental projects	Collaborate through project funding and strategic partnerships

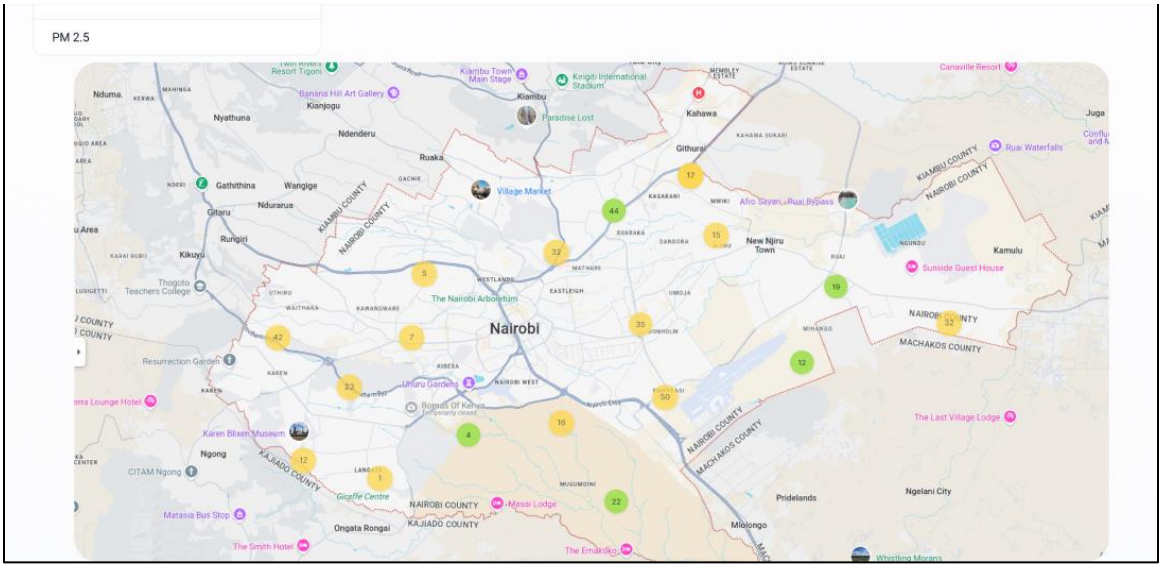
The table below summarizes the key needs identified across stakeholder groups, categorized by system function and accompanied by implications for system design:

Summary of Stakeholder-Identified Needs for AQDMS

Category	Stakeholder Needs	Implications for AQDMS Design	Stakeholder type /group
Pollutants Monitored	$PM_{2.5}$, PM_{10}, temperature, humidity (initial); CO, NO_x, SO_2, VOCs, heavy metals (future)	Flexible sensor integration to accommodate current and future parameters	Academia, practitioners, Civil Society representatives
Threshold Standards	Use WHO and NEMA guidelines; allow for localized thresholds	Configurable threshold settings and multi-standard compliance	NCCG, Joint Technical & Streering Committee, Nairobi Air Quality Working Group, and Academia,
Data Access	Real-time and historical data (minimum 3–5 years)	Time-series storage, retrieval tools, and trend analysis features	NCCG, Practitioners, Civil Society, Media and Academia
Alert Systems	Multi-level alerts (moderate to hazardous); delivery via SMS, email, USSD	Notification and multi-channel dissemination	All
Reporting Cadence	Weekly summaries; monthly and quarterly detailed reports	Customizable reporting templates and automated report generation	NCCG, Academia and Media
Visualization Tools	Dashboards, pollution maps, time-series graphs, hotspot tracking	Interactive and user-friendly portal with multiple data display formats	All
User Roles & Access	County admins, researchers, public users with role-based access	Secure role-based access control and data visibility management	NCCG, Practitioners and Academia
System Integration	Link to health, environment, emergency, and open data systems	API development and data interoperability protocols	NCCG, SPractitioners and Academia
Feedback Mechanism	Public comments, suggestions, and ratings on the portal	Embedded feedback loop and stakeholder engagement dashboard	All

These stakeholder inputs highlight the critical need for an adaptable or scalable, secure, and interoperable data platform that enables real-time monitoring, supports policy enforcement, enhances public engagement, and aligns with global best practices. Addressing these needs will ensure that the AQDMS delivers maximum value to both government institutions and the general public, while supporting long-term environmental sustainability and health outcomes in Nairobi.

Figure 4: Sample Portal Screenshot: Actual visual of air quality portal interface adapted from OpenAQ. [18]



[18] OpenAQ. *Global air quality measurements map* [Screenshot]. Retrieved May 27, 2025, from https://openaq.org

Figure 5: Graph Showing Workshop Participants' Prioritisation of AQDMS Features

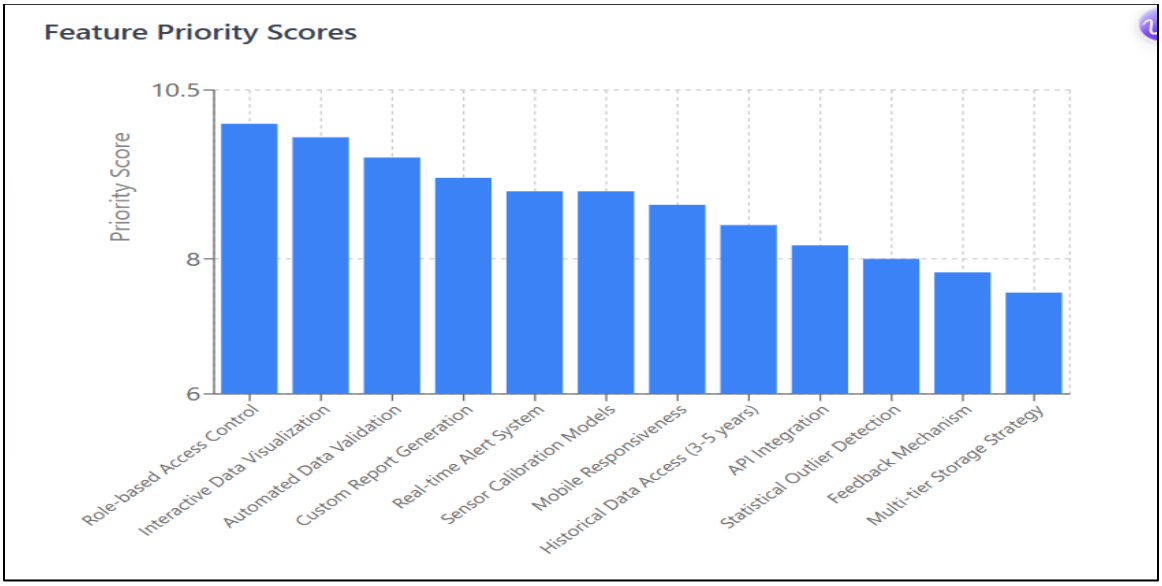


Figure 6: Summarized Expected Benefits

6. THE PROPOSED AIR QUALITY DATA MANAGEMENT SYSTEM (AQDMS) FOR NAIROBI

Technical Infrastructure

The proposed Air Quality Data Management System (AQDMS) for Nairobi will be built around two core components: a centralized data management platform and a publicly accessible digital portal. The data management system will collect, validate, integrate, and harmonize air quality data from various sources, including sensor networks and third-party monitoring tools. It will employ automated validation mechanisms to ensure data accuracy, detect anomalies and alert city's administrators, and maintain consistency across datasets.

This centralized infrastructure is designed to support interoperability; hence, it is intentionally built to integrate with external systems through common standards, data formats, and secure APIs. This allows it to function as part of a wider ecosystem of tools used by the county or its partners, such as the AirQO API, the public health sector, among others. It will also incorporate robust security protocols such as user authentication, access control, and encrypted data storage to protect sensitive information and ensure system integrity.

The public access portal will serve as the primary interface for data visualization and citizen engagement. It will feature real-time air quality indicators, interactive dashboards, and trend graphs. The public access portal will serve as the primary interface for data visualization and citizen engagement, featuring real-time air quality indicators such as $PM_{2.5}$, PM_{10}, NO_2, O_3, SO_2, and CO concentrations. These will be presented alongside an Air Quality Index (AQI), which translates pollutant data into an easy-to-understand, colour-coded scale, ranging from "Good" to "Hazardous". The portal will also include interactive maps, trend graphs, and live dashboards to allow users to explore pollution patterns over time and across neighbourhoods.

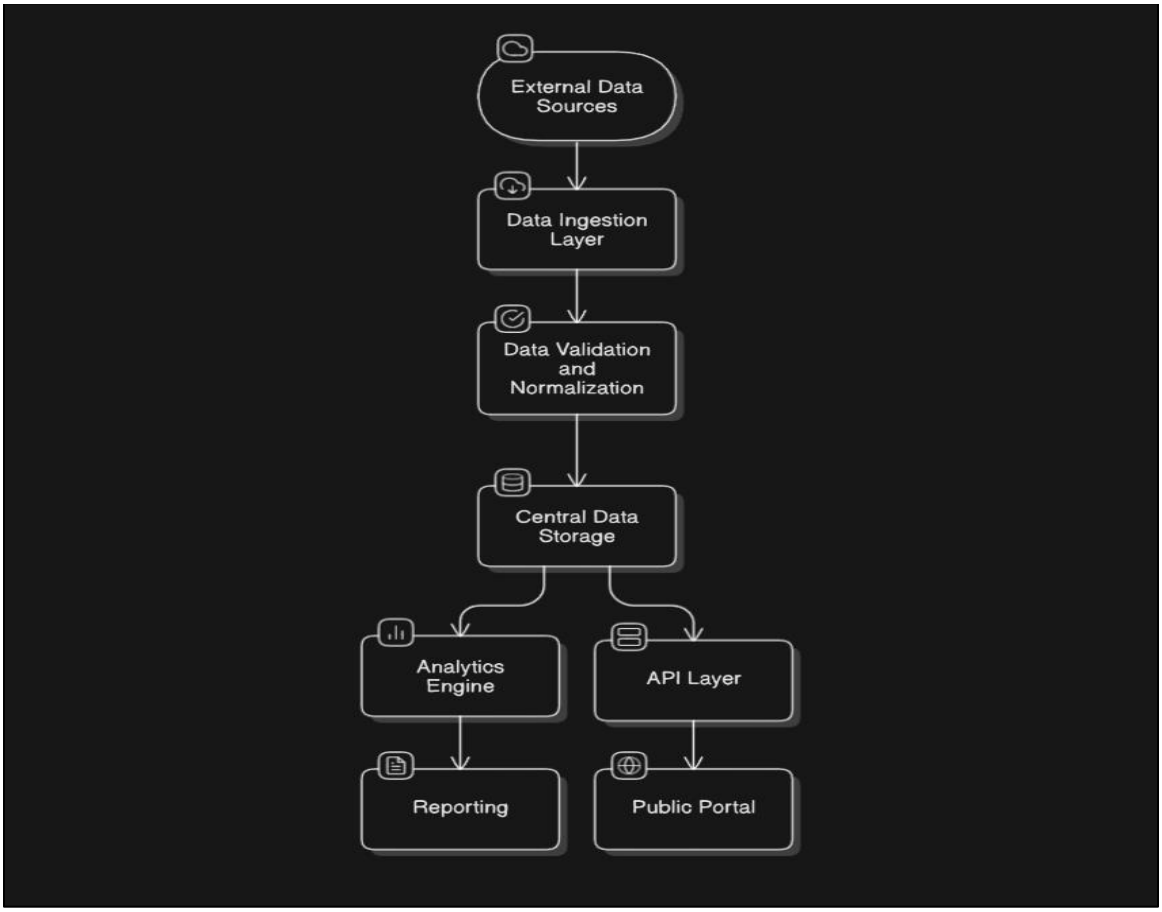
To enhance public responsiveness, the system will feature a built-in alert mechanism that notifies users when pollution levels reach harmful thresholds. These alerts—delivered via on-screen messages, push notifications, web alerts or email—may be accompanied by health advisories tailored to sensitive groups such as children, the elderly, or those with respiratory conditions. Together, these features will make air quality data both accessible and actionable, supporting informed daily decisions by residents.

Designed with mobile responsiveness and ease of use in mind, the portal aims to promote environmental awareness among the general public, researchers, and policymakers alike. Role-based access controls will govern data availability,

allowing different user groups to access data and features appropriate to their needs, from view-only public dashboards to advanced reporting tools for experts and administrators.

Together, these components will provide a scalable, transparent, and user-friendly infrastructure for managing and disseminating air quality data in Nairobi.

Figure 7: General high-level architecture of the Air Quality Data Management System.[19]



[19] U.S. Environmental Protection Agency. (2019). *Air sensor guidebook* (EPA/600/R-14/159). Office of Research and Development. https://www.epa.gov/air-sensor-toolbox

External Data Sources:

This layer includes various input channels from which air quality data is collected. Sources may include regulatory-grade sensors, low-cost monitoring devices, satellite feeds, meteorological stations, mobile sensors, and third-party contributors such as academic institutions, NGOs, or international platforms like AirQo or WHO databases.

Data Ingestion Layer:

The ingestion layer is responsible for collecting raw data from the external sources and transferring it into the system. It handles different data formats, protocols (e.g., MQTT, HTTP, FTP), and frequencies (real-time, hourly, batch). This layer ensures data is successfully captured and queued for processing.

Data Validation and Normalisation:

In this layer, raw data undergoes quality checks to identify and correct errors such as sensor drift, missing values, or outliers. Normalisation ensures that all data conforms to a standard format and unit of measurement, making it consistent and ready for downstream use.

Central Data Storage:

This is the core repository that stores all validated and normalised air quality data. It supports scalable, secure, and efficient storage for both historical and real-time datasets. The storage layer enables fast retrieval for analysis, reporting, and public access.

Analytics Engine:

The analytics engine processes stored data to generate insights. It performs tasks such as logical and informative analysis, pollution forecasting, and correlation with different kinds of data. This layer powers evidence-based decision-making and advanced reporting.

API Layer:

This layer provides structured access to the data through Application Programming Interfaces (APIs). It enables third-party systems (e.g., mobile apps, research platforms, and government dashboards) to query and consume air quality data programmatically, supporting interoperability.

Reporting:

This component generates routine and on-demand reports for stakeholders such as policymakers, environmental agencies, and the public. Reports may include charts, graphs, and narrative summaries and are often used in meetings, policy briefs, or public awareness campaigns.

Public Portal:

The public-facing component of the system, this portal displays real-time air quality indicators, historical trends, maps, alerts, and health advisories. It is designed for accessibility and engagement, empowering citizens with actionable environmental information.

7. IMPLEMENTATION ROADMAP

The implementation of Nairobi's Air Quality Data Management System (AQDMS) and Public Access Portal will follow a phased, structured approach designed to ensure technical rigor, stakeholder alignment, and long-term sustainability. The roadmap consists of five core phases as illustrated in details in Annex I and Fig 8 below:

Figure 8: Five core phases Explained

8. COMMUNICATION AND CAPACITY BUILDING

Capacity building is essential to ensuring the long-term success, usability, and sustainability of the Nairobi Air Quality Data Management System (AQDMS). This component of the project is designed to strengthen institutional readiness, foster public engagement, and promote widespread understanding and responsible use of air quality information.

Communication Strategy

As outlined in the Breathe Nairobi Communication Strategy (2024–2026),[20] the initiative seeks to enhance public awareness of air pollution and promote the adoption of the AQDMS portal across diverse user groups. These include government institutions, schools, civil society organizations, researchers, and the general public. The strategy emphasizes inclusive engagement by encouraging data-driven participation and fostering a culture of informed decision-making through accessible and targeted communication efforts.

Key elements include:

- **Public Awareness Campaigns**: Multi-channel outreach (radio, social media, community events) to promote understanding of air quality impacts and the value of the portal.
- **Targeted Messaging:** Tailored content for different user groups (e.g., alert notifications for residents, data dashboards for researchers, policy briefs for decision-makers).
- **User-Centered Portal Design:** Clear visuals, localized content, and mobile responsiveness to enhance public accessibility.
- **Feedback Integration:** Mechanisms for users to submit comments, suggestions, and ratings directly through the portal interface.

Capacity Building Initiatives

To ensure effective system adoption and long-term operational success, the project will invest in building the capacity of Nairobi City County Government (NCCG) staff and other key stakeholders through:

- **Technical Training:** Structured sessions for system administrators, IT personnel, and data analysts on system operation, maintenance, and troubleshooting.
- **Institutional Strengthening:** Support for inter-departmental coordination,

[20] **Breathe Nairobi Initiative.** (2024). *Communication Strategy 2024–2026.* Kusudi Cause Communication Trust. Retrieved from https://kusudicausecomms.org/wp-content/uploads/2025/03/Output-1.A_AQ-Communication-Strategy-_14-November-2024.pdf

data-sharing protocols, and integration with health, environment, and emergency response systems.

- **Sustainability Considerations**: To ensure ongoing relevance and ownership, the AQDMS project will include:
  - Routine refresher training and knowledge transfer programs.
  - Development of a "train-the-trainer" model to scale knowledge within county departments.
- **Technical Documentation and Toolkits**:
  - **Operation Manuals**: Step-by-step guides covering system use, from data acquisition to dashboard interaction.
  - **Maintenance Manuals**: Protocols for preventive care and corrective maintenance of sensor and server infrastructure.
  - **Troubleshooting Guides**: Diagnostic references to resolve common system errors and connectivity challenges.
  - **User Toolkits**: Role-specific checklists and templates for routine system tasks, stakeholder reporting, and data interpretation.

KEY RECOMMENDATIONS

Based on the findings of the needs assessment and multi-stakeholder consultations, the following strategic recommendations are proposed to guide the successful implementation, sustainability, and impact of Nairobi's Air Quality Data Management System (AQDMS) and Public Access Portal:

1. System Development and Technical Infrastructure

Develop a centralized, scalable AQDMS with automated data validation, secure data storage, and robust access controls.

Ensure interoperability with national health databases, emergency response platforms, environmental systems, and open-data initiatives after launch.

Integrate an API layer to enable third-party access and support research, mobile apps, and innovation.

2. Data Accessibility and Public Engagement

Launch a user-friendly public access portal with mobile responsiveness, real-time visualizations, and customizable data filters.

Include multilingual options and localized data thresholds to improve accessibility across diverse communities.

Establish a multi-channel alert system (SMS, email, USSD) for timely dissemination of air quality warnings.

3. Governance and Institutional Capacity

a) Appoint a dedicated AQDMS unit within the Nairobi City County Government to oversee system management, data governance, and interdepartmental coordination. Develop and implement standard operating procedures (SOPs) for data quality assurance, access control, and routine system audits.

b) Policy Support: The platform can generate automated policy briefs based on threshold exceedances and trends to aid rapid policy response.

To strengthen evidence-based governance, the Air Quality Data Management System (AQDMS) should include functionality to automatically generate policy briefs triggered by threshold exceedances or emerging air pollution trends. These automated briefs can summarize key data points, highlight specific areas of concern (e.g., sustained $PM_{2.5}$ levels above WHO or NEMA guidelines), and recommend actionable interventions.

By integrating this feature, the platform would enable real-time, data-driven decision-making for policymakers at both the county and national levels. It reduces reliance on manual data interpretation, accelerates response times during air quality incidents, and ensures that alerts are translated into timely institutional action. Briefs could be tailored for different stakeholders—such as the Ministry of Health, urban planners, and environmental enforcement units—ensuring relevance and clarity.

This functionality not only supports crisis response but also aids in long-term policy formulation by tracking patterns over weeks, months, or years. As such, it transforms the AQDMS from a passive data repository into an active decision-support system that continuously informs regulation, resource allocation, and public communication strategies.

4. Community Awareness and Feedback Mechanisms

Integrate environmental data literacy campaigns into public communication strategies and school curricula.

Establish ongoing feedback loops via the portal to collect user input, complaints, and improvement suggestions.

Partner with CBOs, schools, and health facilities to promote local ownership and behavioral change.

To promote knowledge transfer and cultivate the next generation of environmental stewards, the Nairobi AQDMS initiative should actively collaborate with universities and academic institutions. This collaboration could involve integrating real-time air quality data into academic curricula, research projects, and student-led innovation challenges.

Through partnerships with departments of environmental science, urban planning, data science, and public health, the AQDMS can serve as a live learning laboratory—providing students with direct access to authentic datasets for analysis, modeling, and policy exploration. These projects not only enhance educational outcomes but also generate valuable insights and potential system improvements from academic research.

Furthermore, formal linkages with universities can support long-term system sustainability by developing local expertise in air quality monitoring, data management, and citizen science. This academic integration also strengthens the feedback loop between scientific inquiry and urban governance, ensuring that policy and system development remain rooted in evidence and innovation.

c) **Governance Structure for the Air Quality Data Management System (AQDMS)**

To ensure the effective operationalization and long-term sustainability of the **Air Quality Data Management System (AQDMS)**, Nairobi City County Government (NCCG) is establishing a structured governance framework that defines clear roles, responsibilities, and mechanisms for interdepartmental collaboration.

At the apex, strategic oversight is provided by the **CECM for Environment & Climate Action** and the **CECM for Innovation and Digital Economy**, ensuring that environmental goals and digital transformation priorities are aligned. Reporting to them is the respective **County Chief Officers** responsible for Environment, ICT Infrastructure, Digital Economy, and Smart Nairobi.

Under these Chief Officers are the **Directors**—specifically the **Director for Environment**, **Director for ICT**, and **Director for ICT Infrastructure**—who will lead their technical teams in coordinating implementation efforts.

Co-Leadership and Functional Roles

The AQDMS will be co-led by the **Environment Sector** and the **County ICT Department**, operating under the following arrangement:

- **The Air Quality Unit** (within the Directorate of Environment) will be responsible for:
    - Air quality data collection, quality assurance, validation, and interpretation.
    - Oversight of air quality indicators, compliance monitoring, and reporting.
    - Providing technical and regulatory alignment on environmental standards.
- **The ICT and Smart Nairobi teams** will be responsible for:
    - Platform development, hosting, and digital infrastructure.
    - Cybersecurity, user access protocols, system integration, and long-term ICT support.
    - Maintenance of data pipelines, API development, and data visualization tools.

This dual-sectoral model ensures that **technical environmental expertise** is supported by **robust ICT infrastructure**, creating a **shared accountability structure** that improves resilience, enhances institutional ownership, and guarantees the continuity of system operations beyond project cycles.

Joint Governance Committee

To formalize coordination, a **Joint AQDMS Governance Committee** will be established. This committee will comprise representatives from:

- The Directorate of Environment
- The ICT Infrastructure Sub-Sector
- The Smart Nairobi Sub-Sector
- Other relevant county stakeholders

The Committee's mandate will include strategic guidance, policy alignment, risk management, resource planning, system upgrades, and ensuring interoperability with broader county digital platforms.

Implementation and Operations Team

A dedicated **AQDMS Implementation and Operations Team** will be tasked with day-to-day execution. This multidisciplinary team will include:

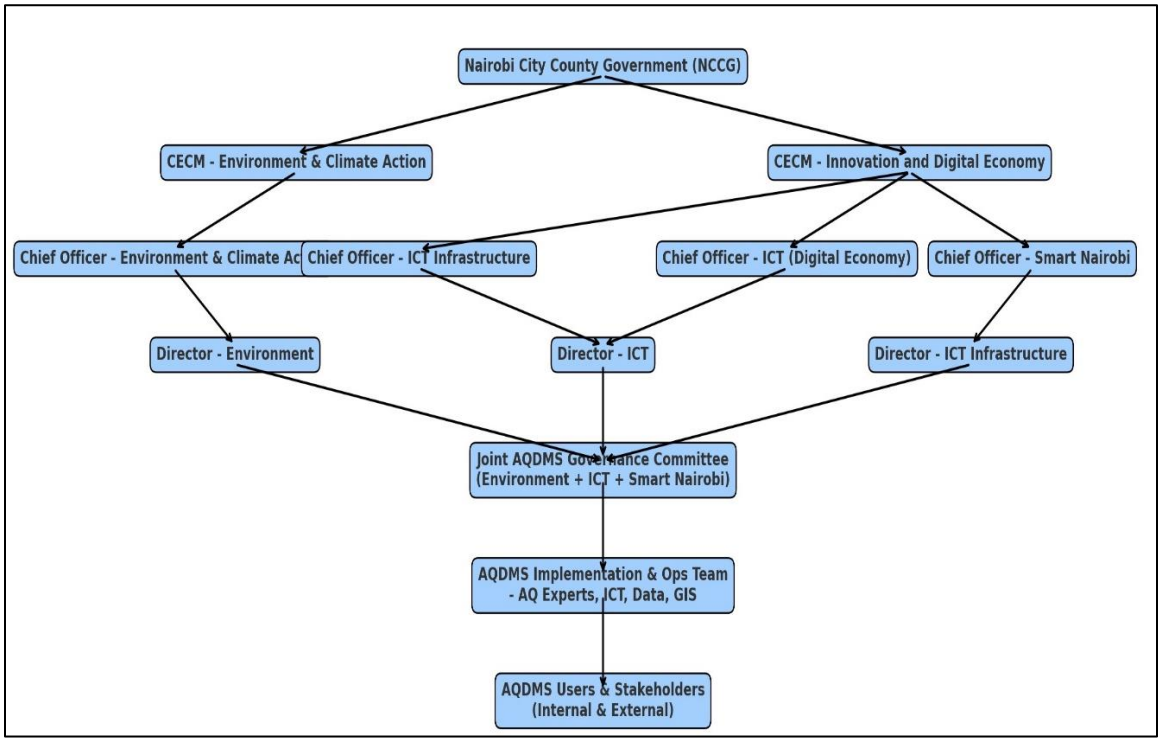
- Air quality experts
- ICT engineers and system developers
- Data analysts, GIS specialists, and platform administrators

The team will report to the Joint Committee and ensure continuous system improvement, stakeholder engagement, and user support.

Organogram

Below is the visual representation of the governance structure:

Figure 8: AQDMS Governance Structure



5. Sustainability and Impact Monitoring

Conduct regular system evaluations and publish public reports on air quality trends, platform usage, and public health linkages.

To ensure the long-term viability of the Air Quality Data Management System (AQDMS) beyond the donor-supported implementation phase, a clearly defined roadmap for financial sustainability is essential. This roadmap should outline phased strategies for transitioning from donor dependency to autonomous funding models anchored within Nairobi City County Government's operational frameworks.

Key components may include the integration of AQDMS-related costs into departmental budgets, establishment of public-private partnerships, and exploration of value-based revenue streams. For example, the system could offer premium data services or advanced analytics subscriptions to academic institutions, private sector

actors (e.g., insurance, transport, and logistics firms), or development partners seeking granular air quality insights for planning and compliance.

Additionally, collaboration with national-level agencies and global organizations may open avenues for performance-based funding or data-sharing agreements. Embedding this sustainability framework early in the project lifecycle will foster institutional ownership, protect against system decay or obsolescence, and enable continuous platform enhancement to keep pace with Nairobi's evolving environmental and technological landscape. Leverage regional and global partnerships (e.g., AirQo, WHO, UNEP) to remain aligned with emerging best practices and innovations.

6. Future Scalability Plans

The AQDMS should also be designed to support predictive analytics using AI algorithms to forecast pollution levels based on weather and traffic data.

To enhance the functionality and long-term relevance of the Air Quality Data Management System (AQDMS), it is recommended that predictive analytics capabilities be integrated into its architecture. Specifically, the AQDMS should utilize artificial intelligence (AI) and machine learning (ML) algorithms to forecast air pollution levels based on a range of real-time and historical variables, including meteorological data (e.g., wind speed, humidity, temperature) and traffic flow data (e.g., congestion patterns, vehicle counts, peak hours).

By leveraging AI models, the system can generate short-term (hourly to daily) and medium-term (weekly) pollution forecasts, allowing for proactive measures to be taken by city officials, emergency services, and health institutions. For example, predictive alerts can be issued during anticipated pollution spikes, enabling schools to restrict outdoor activities or hospitals to prepare for increased respiratory cases. Such forecasting also supports strategic urban planning by identifying future pollution hotspots based on traffic growth and weather cycles.

Moreover, integrating predictive analytics positions Nairobi's AQDMS as a forward-looking, smart-city tool aligned with global trends in data-driven environmental governance. It will not only improve response time and risk mitigation but also enhance public trust by demonstrating transparency, innovation, and a commitment to protecting public health through early warning systems.

Future Integration: Consideration should be given to integration with wearable health devices for personalized exposure monitoring.

As part of the long-term roadmap for enhancing the Air Quality Data Management System (AQDMS), strategic consideration should be given to integrating the platform with wearable health devices for personalized air pollution exposure monitoring. Wearable technology—such as smartwatches, fitness bands, and portable air quality sensors—can provide individuals with real-time feedback on their environmental exposure to pollutants like $PM_{2.5}$, NO_x, and VOCs.

By syncing data from these devices with the AQDMS, the system could offer personalized insights based on a user's location, activity level, and health profile. For instance, individuals with asthma, cardiovascular conditions, or other vulnerabilities could receive tailored alerts and exposure mitigation tips, enhancing their ability to make informed daily decisions such as route planning, time spent outdoors, or the use of protective measures.

On a broader scale, anonymized, aggregated data from wearables could feed back into the AQDMS to refine pollution models, identify micro-level hotspots, and support public health research. This integration aligns with global trends toward citizen-centered smart health solutions and promotes a more participatory, data-driven approach to urban air quality management.

9. SUMMARY

This report presents the findings of a comprehensive needs assessment conducted between February and May 2025 to inform the design and implementation of a City-Owned Air Quality Data Management System (AQDMS) and a Public Access Portal for Nairobi. Commissioned by the Nairobi City County Government (NCCG) in partnership with CENEX Consult Ltd and supported by the Clean Air Fund under the Breathe Cities Initiative, the assessment sought to ensure that the proposed system is context-specific, technically sound, and socially responsive.

In addition to assessing local needs, the report explores the broader landscape of air quality data management—examining the current state of AQDMS in Nairobi, across Kenya and Africa, and globally. It identifies prevailing challenges, emerging opportunities, and actionable recommendations to guide the development of a robust and sustainable air quality data infrastructure for the city.

The assessment identified major gaps in the current air quality monitoring landscape, including fragmented data sources, limited real-time access, and a lack of centralized infrastructure for managing and disseminating information. Through extensive stakeholder engagement—comprising technical departments, civil society organizations, community groups, and academic institutions—critical user needs were defined, spanning technical capabilities, accessibility, interoperability, and long-term sustainability.

The proposed AQDMS will address these challenges through a centralized, scalable platform that integrates and validates air quality data from various sources, supports role-based access, and provides real-time visualization via a mobile-friendly public portal. The system will also include alert mechanisms, customizable reporting, and integration with national and regional platforms to support evidence-based policymaking and citizen engagement.

In addition to the technical solution, the project emphasizes the importance of communication, capacity building, and stakeholder participation. Targeted awareness campaigns, user training, curriculum integration, and feedback loops are key to ensuring sustained use, trust, and impact.

Ultimately, the Nairobi AQDMS will serve as a model for urban air quality governance in Kenya and across the region. By improving data transparency, empowering communities, and enhancing institutional capacity, the system will contribute significantly to public health protection, environmental justice, and climate resilience in Nairobi.