AQS/NA/25/1

Establishing the Nairobi City County Air Quality Monitoring Network

Needs Assessment Report

February 2025

Air Quality Systems East Africa

PREPARED FOR THE CLEAN AIR FUND AND NAIROBI CITY COUNTY UNDER PROJECT NO. 001609

Contents

Executive Summary

Nairobi City County epitomizes the challenges of a rapidly urbanizing metropolis and its adverse effects on the environment and, by extension, the well-being of its residents. This report assesses the need for an air quality monitoring network in Nairobi City as part of the Procurement and deployment of a comprehensive city-owned low-cost sensor AQ monitoring network project.

Currently, Nairobi City lacks a systematic approach to monitoring its air quality, hindering its ability to understand pollution levels, identify sources, and implement effective mitigation strategies. The assessment also reveals a reliance on data from over 70 stations managed by various stakeholders due to the lack of a city-owned continuous monitoring network. By reviewing past air quality studies in Nairobi and projects with continuous monitoring, we identified the monitoring gaps and regions to prioritise for deployment of low-cost sensors.

The assessment recommends adoption of a more comprehensive and targeted approach to air quality monitoring, with specific interventions based on observed pollution trends and spatial heterogeneity. The document recommends prioritizing the monitoring of particulate matter across all regions of the county. The county's expansion strategy to consider inclusion of additional reference monitoring stations for development of localised calibration models especially for low cost sensors deployed across southern and eastern regions of the county.

1.0 Introduction

Air pollution continues to be a pressing concern across Nairobi City with levels exceeding the World Health Organisation (WHO) threshold[1] attributing to over 400 premature deaths in 2021[2]. Developing a robust air quality monitoring network and capacity building for sustainable management of the infrastructure are essential strategies stipulated in the Nairobi City County Air Quality Action Plan (2019-2023) particularly the objective related to building scientific evidence for policy, legislative and regulatory interventions (Objective I)[3].

For a comprehensive overview of the air quality network needs, it is important to understand the factors contributing to the state of air pollution in Nairobi County. The first section provides an overview of the factors contributing to pollution in Nairobi County as a basis for understanding the different monitoring needs across the city. The second section extends the general outlook of air quality network and capacity development needs based on existing baseline research conducted in Nairobi. The final section summarises the key findings and provides recommendations for the development of a comprehensive air quality network and capacity development needs.

1.1 Nairobi City County: An Overview

The city of Nairobi, the capital of Kenya, originated from the construction of the Uganda Railway acting as a construction depot and colonial administrative camp. Nairobi was gazetted as a township in April 1900 covering an area of 18 km^2. Today, the city is home to over 4.4 million residents[4] and the population is growing at a rate of over 4% annually. Currently, the population density is approximately 6318 residents/km^2. The highest population density is in Embakasi, Kasarani and Kibera sub counties.

By 1995, Nairobi had approximately 134 informal settlements with 77,589 structures with a combined population of 1,886,166 inhabitants[5]. According to the 2009 population census report, Nairobi had a population of 3.1 million with an estimated 60% living around 200 informal settlements[6]. Most of the population resides in the eastern regions of the county, which doubles as the industrial hub of the city with most of the informal settlements and unplanned housing projects. High population density in these low-income areas of Nairobi has contributed to mushrooming of pollution hotspots. For instance, illegal dumpsites, open burning waste and underdeveloped infrastructure are some of the characteristics of informal settlements across Nairobi.

[1] Pope, F. D., Gatari, M., Ng'ang'a, D., Poynter, A., & Blake, R. (2018). Airborne particulate matter monitoring in Kenya using calibrated low-cost sensors. *Atmospheric Chemistry and Physics*, 18(20), 15403-15418, https://doi.org/10.5194/acp-18-15403-2018.

[2] Oguge, O., Nyamondo, J., Adera, N., Okolla, L., Okoth, B., Anyango, S., ... & Berhane, K. (2024). Fine particulate matter air pollution and health implications for Nairobi, Kenya. *Environmental Epidemiology*, 8(3), e307.

[3] Nairobi Air Quality Action Plan (2019-2023) https://www.eci-africa.org/wp-content/uploads/2019/05/Nairobi-Air-Quality-Action-Plan_Final_ECI_31.12.2018.pdf.

[4] Kenya National Bureau of Statistics. 2019 Kenya Population and Housing Census . Nairobi, Kenya: Kenya National Bureau of Statistics; 2019. https://www.knbs.or.ke/

[5] Chirisa, I. PERI-URBAN DWELLING AND SOCIAL TRANSFORMATION IN AFRICA. *The Political Economy of Poverty and Social Transformations of the Global South*, 181.

[6] Guerrero García, F. J. (2015). *Impact of a value chain approach on the sustainability of solid waste management in Mukuru Kwa njenga informal settlements Nairobi, Kenya* (Doctoral dissertation, CITDH).

Figures 1a) and 1b) below shows the distribution of informal settlements and distribution of illegal in Nairobi

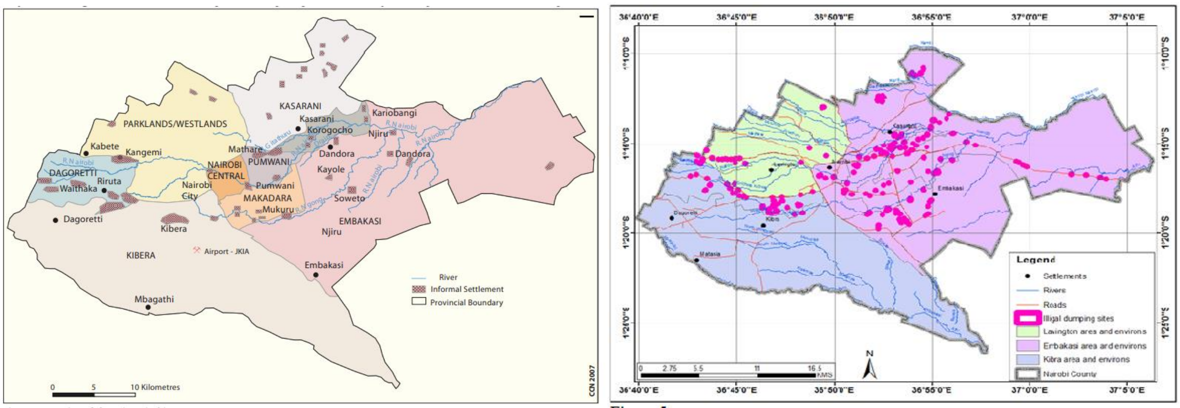

Figure 1: Distribution of settlements and dumpsites in Embakasi, Kibera and Lavington or Westlands a) Informal settlements. b) Distribution of illegal dumpsites

It is however unfortunate that most of the content of the illegal dumpsites found in informal settlements and slums originate from middle- and high-income areas because the inhabitants of these settlements tend to sort and recycle waste, reuse most of their household items and can only discard leftover waste[7].

1.1.1 Land use, terrain and topography

City planning issues in Nairobi are based on the problem of land speculations that originated from the notion of "no man's land" that was effectively used by the colonial settlers to acquire large tracts of land[8]. Most of the land in the northern and western ridges of Nairobi County where they constructed private residential homes or leased land marking the beginning of land use segregation. The eastern part of the county was stratified and left for Africans to develop spontaneously. European zones in the west and north of the city were carefully planned with layout and aesthetics that conformed to acceptable standards and densities. Five decades after independence, Nairobi County still hosts British urban planning and architecture with the problem of land speculations persisting to date but now divided based on status quo with low-income zones in the eastern parts experiencing poor planning, poor infrastructure, and rampant air pollution.

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[7] Ibid

[8] Banyikwa, W. F. (1990). Signatures of four generations of urban planning in Nairobi, Kenya. Journal of Eastern African Research & Development, 186-201.

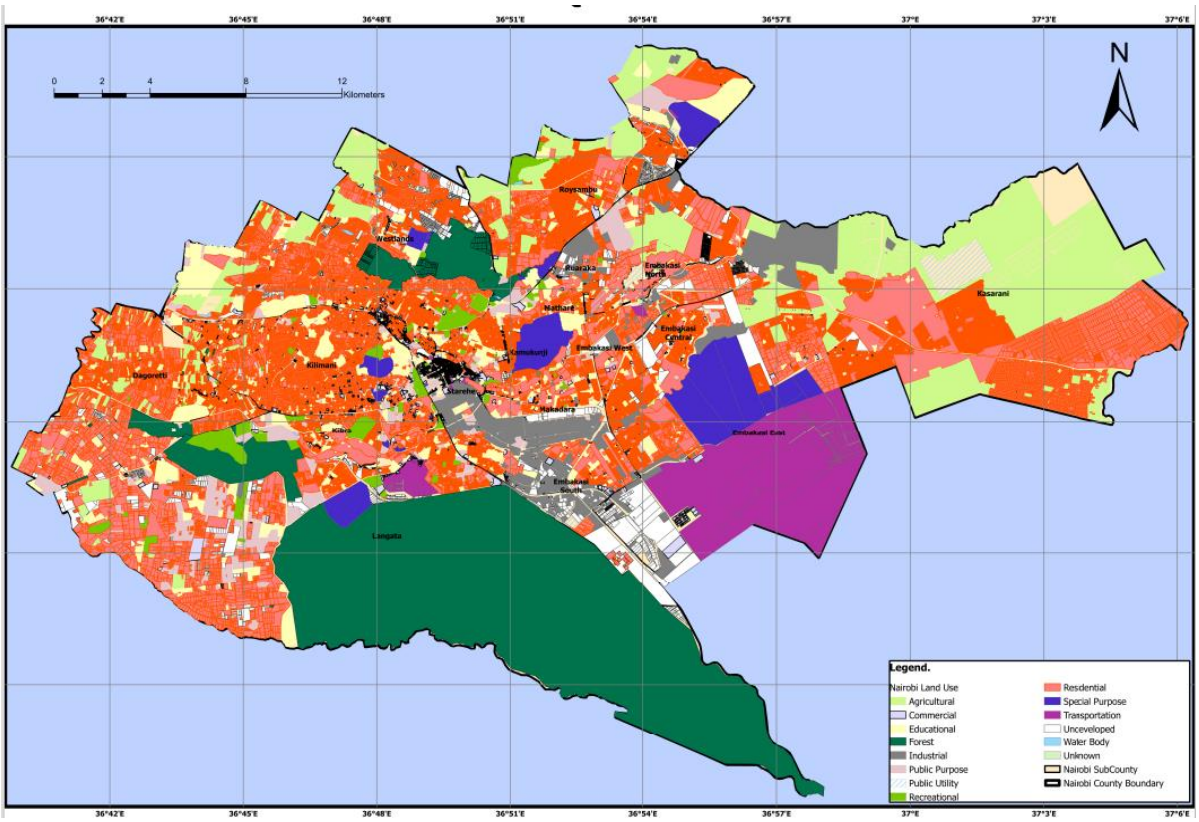


Figure 2: Land use characteristics

Other than the historical definition of land use, Nairobi County is characterised by residential areas with over 80% of the residents renting out spaces. As illustrated above, the population per square kilometre varies significantly across the county from extremely high in the Central and slums such as Kibera to very low in the high-income residential areas such as Muthaiga. Sections in the west and north of the city are utilised for agriculture with forest zones in the south and north of the county.

The highest side of the county is in the western region, which generally has a rugged topography. The lower side situated in the eastern part, is characterised as flat. The northwestern part of the county is green due to the spread of the indigenous Karura forest. Nairobi, Ngong, and Mathare rivers traverse numerous neighbourhoods. The highest side to the west of the city borders the Ngong hills with the highest mountain.

1.1.2 Other considerations for air quality network development

Across the year, most of the wind comes from the eastern and northeastern direction. Wind direction of Nairobi is heavily influenced by South East Trade Winds coming from the Indian Ocean. Other minor sources would be fine particulate matter coming from construction sites and road repairs, as well as open burning taking place, particularly in areas that have little to no proper garbage disposal or collection, such as low-income districts.

Traffic in Nairobi is concentrated around the central business district. Other busy roads experience heavy traffic during peak hours. Within the central business district and busy roads, air pollution is heightened by emissions from old, motorised transport including cars, motorbikes, trucks, and other heavy-duty vehicles such as lorries and buses running on older diesel engines.

2.0 Methods

We utilized a mixed-methods approach, incorporating a literature review to examine existing air quality data from analogous research conducted in Nairobi and stakeholder consultations with institutions and projects contributing to the data infrastructure in Nairobi. These consultations focused on perceived air quality issues and potential pollution sources. Additionally, the assessment included preliminary air quality sampling and data analysis to provide an initial evaluation of air pollution levels, identify hotspots, and prioritize areas for long-term monitoring.

From the methods, three steps were established for establishing the existing monitoring gaps, map out pollution trends across the Nairobi City County and propose potential regions for deployment of a comprehensive network of low cost sensors. The 3-step process involved participatory data collection, AI modelling for site classification and fused analysis of datasets for advanced site recommendations and satellite data analysis as described below.

Step 1: Literature review and participatory data collection

This step involved a review of literature on air quality monitoring projects that involved network deployments in Nairobi, monitoring needs guided by the actions outlined on the Air Quality Action Plan 2019-2023 and insights from projects managing continuous monitoring networks in Nairobi.

Step 2: Automated site categories from an integrated AI model using the OpenStreetMap data

We developed an integrated Python model that utilised OpenStreetMap data and large language models to automate siting taking into consideration OpenStreetMap data categories and land use patterns. This led to identification of over 140 sites including the mandatory sites with third party monitors and those recommended by city stakeholders. Network optimisation using basic Python models will be incorporated into the capacity-building workshop for NCCG officials on design of air quality monitoring networks. Elements of this automated modelling will be included in the deployment map documentation for additional context.

Step 3: Satellite data collection and analysis

Using Google Earth Engine open access resources, we developed data mining models that pre-processed and analysed data for prospective sites. Prospective sites identified in steps 1 and 2 above served as the basis for data collection from Sentinel 5P satellite used in this step. For development of the pollution baseline of Nairobi, we considered the Copernicus Sentinel-5 Precursor (S5P) mission atmospheric data. Level 3 Near Real-Time (NRTI) S5P data corresponding to the preselected site coordinates within Nairobi was extracted from the satellite images provided by Google Earth Engine. Only the tropospheric column density band providing insights on anthropogenic pollution was considered. The images below represent the spatial distribution of pollutants from January 1, 2022 to October 31, 2024 as captured by the S5P satellite imagery.

A deep dive on the data mining, pre-processing, visualisation and application of fused datasets for pollution forecasting will be presented in the third capacity-building workshop. The relevance of fused networks for air quality monitoring including dense ground monitoring stations and satellite data will be best understood after the network is deployed and baseline datasets are available.

3.0 Findings

3.1 Literature Review and Participatory Data Collection

Over the years, Nairobi City County has developed a robust framework to inform the development of a comprehensive city-owned air quality monitoring network. As part of the framework, the Climate Action Plan (2020-2050)[9] is a blueprint for sustainable and climate change resilient Nairobi while the Air Quality Act of 2022 provides a legislative foundation for managing air pollution and recommends incorporation of monitoring devices for premises to prevent unlicensed discharge of pollutants[10].

A key element of this framework has been the Air Quality Action Plan 2019-2023 that, under Objective I, explicitly outlines development of a robust air quality monitoring network, baseline data and capacity building for county officials. Actions towards realising the ambitious plan have been implemented under the Green Nairobi Sector where one of the core functions of the Environment sub sector is defined as control of air pollution, noise pollution and other public nuisances. As of 2023, the county had realised some of the actions stipulated in the plan including establishment of an air quality unit within the NCCG Green Nairobi Sector[11], the development of Air Quality Policy (Air Quality Act, 2022), capacity training for city officials and established budgetary allocations to air quality management among others.

3.1.1 Research-based network deployment

Central to the NCCG air quality management framework is data. However, the city is yet to establish its own network of equipment for continuous air pollution monitoring to support the data-driven interventions as stipulated in the existing framework. As such, the data ecosystem for the county has been based on an intricate network involving various stakeholders, technologies, and processes providing short and long-term insights into the pollution trends across the county. Most of the ad hoc air quality monitoring performed in Nairobi over the years have been short term and with limited scope.

Table 1 below gives a summary of some of the air quality studies that involved setting up a network within Nairobi City in the past 10 years.

Table 1: Summary of recent air quality monitoring studies in Nairobi

[9] Nairobi City County Climate Action Plan 2020-2050, https://cdn.nation.co.ke/downloads/Nairobi-City-Climate-Action-2021.pdf
[10] The Nairobi City County Air Quality Act, 2022, https://nairobiassembly.go.ke/ncca/wp-content/uploads/act/2023/Air-QualityAct.pdf
[11] Public-Private Partnership on Air Quality Monitoring: A Case Study of Nairobi City County. https://cepei.org/wp-content/uploads/2024/12/Nairobi-County-Case-Study.pdf

Study	Network size and type of equipment	Parameters monitored	Duration
Oguge et al., 2024	2 RGM (BAM-1022 and Teledyne T640)	$PM_{2.5}$	2019-2022 (36 months)
Matara et al., 2024	3 LCS (Open-Seneca Sensors)	PM_{10}, $PM_{2.5}$, NO_X, TVOC, CO	2024 (<1 month)
Mutua, 2022	9 sites (MiniVol tactical air sampler)	PM_{10}, $PM_{2.5}$	2022 (3 days)
Chepkorir et al., 2022	6 LCS	$PM_{2.5}$	2022 (6 months)
Priyanka N deSouza et al., 2021	8 LCS (Open Seneca Sensirion SPS30)	PM_{10}, $PM_{2.5}$, PM_1	2020 (2 months)
Singh et al., 2021	1 LCS (Alphasense Optical Particle Counter (OPC-N2))	$PM_{2.5}$	2018 (<1 month)
West et al., 2020	3 LCS (Dylos 1700)	$PM_{2.5}$	2015
Pope et al., 2018	2 LCS (AlphaSense OPC-N2 ran with a Raspberry Pi)	PM_{10}, $PM_{2.5}$, PM_1	2017 (1 month)
Mukaria et al. 2017	4 LCS	$PM_{2.5}$	2016 (<1 month)

Priyanka, et al., 2017	6 LCS (Alphasense OPC-N2 , Alphasense A-series electrochemical (amperometric) gas sensors: NO2-A43F, SO2-A4, NO-A4)	PM_{10}, $PM_{2.5}$, NO_X, SO_2	2016-2017 (8-9 months)
Engondi et al. 2016	4 LCS	PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO, BC, O_3	2015 (<1 month)

3.1.2 Air Quality Monitoring Infrastructure

To date, there is no city owned AQ monitoring network designed, deployed and managed by NCC. However, several projects have been continuously monitoring pollution across the city collectively forming a hybrid network of over 100 air quality monitors. However, NCC can only access data from less than 30% of all the locations with continuous datasets. Notably, two reference stations equipped with regulatory-grade BAM1022 monitors have been established in collaboration with WRI, and are currently serving as the city's primary colocation sites. The table 2 below outlines some of the projects and institutions contributing to the monitoring ecosystem in Nairobi City County.

Table 2: Projects and institutions contributing to the continuous air quality monitoring

Institution/ Project	Network size and type of equipment	Parameters monitored	Active duration	Open Data Access by NCCG
Clean Air Catalyst - WRI	2 RGM (BAM1022) 2 LCS (microAeth mA200)	$PM_{2.5}$, BC	2024 to date	Yes

AirQo	30+ LCS (Binos Air Monitors)	PM_{10}, $PM_{2.5}$	2022 to date	Yes
US Embassy	1 RGM (Teledyne T640)	$PM_{2.5}$	2019 to date	Yes
GEOHealth Hub	1 RGM (BAM-1022) 3+ E-samplers 10+ LCS (QuantAQ Modulair)	PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO, O_3	2019 to date	No
UNEP/SEI	1 RGM (BAM-1022) 20+ LCS (IQAir AirVisual Outdoor, Sailhero, Kunak, Clarity, Praxis)	PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO, BC, O_3	2020 to date	No
sensors.Africa	10+ LCS	PM_{10}, $PM_{2.5}$	2019 to date	No
NEMA	ECOTECH Serinus, GRIMM, Gas Chromatography (GC), Mobile Air Monitoring Laboratory	PM_{10},$PM_{2.5}$, NO_X, SO_2, CO, CO_2,BTEX, O_3,	unknown	No
Kenya Meteorological Department (KMD)	3 Regional Global Atmosphere Watch (GAW) stations, Mobile Air Monitoring Laboratory	PM_{10},$PM_{2.5}$, NO_X, SO_2, CO, CO_2,VOCs, O_3	unknown	No

Institute of Nuclear Science and Technology - University of Nairobi	1 RGM (BAM-1020) 10+ LCS (Clarity, PurpleAir)	PM_1, PM_{10},$PM_{2.5}$, NO_X, SO_2, CO, O_3	2019 to date	No
Clean Air Africa - KEMRI	Gravimetric lab 10+ LCS (PurpleAir, UPAS, LASCAR Easy EL-USB-CO, microAeth mA200)	PM_{10}, $PM_{2.5}$, NO_X, CO, O_3	2022 to date	Partial
Kenyatta University	1 RGM (TEOM) 5+ LCS(American Ecotech Serinus 40, Clarity Node-S, PurpleAir)	PM_{10}, $PM_{2.5}$, NO_X	2022 to date	Partial

3.1.2.1 Open data access projects

i) UNEP/SEI

UNEP in partnership with the Stockholm Environment Institute deployed a hybrid network across over 15 locations in Nairobi. The network consisted of a reference monitor (BAM 1022) and low cost sensors measuring several parameters. Data is shared through a third-party digital platform managed by IQAir.

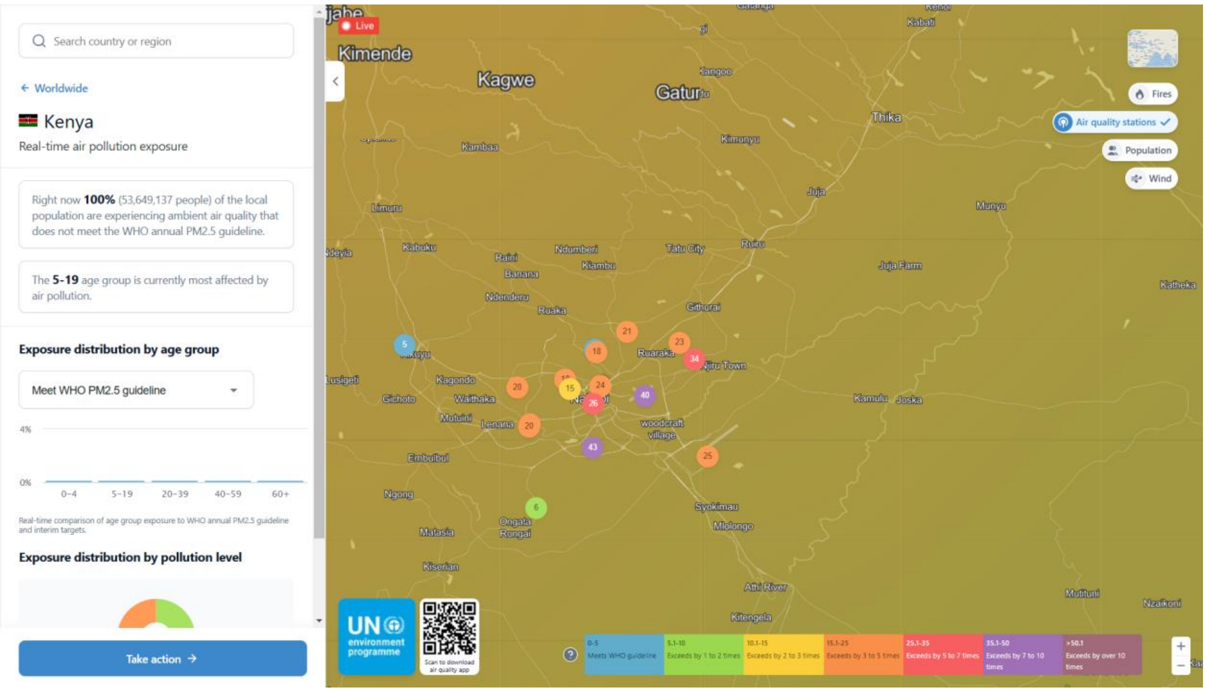


Figure 3: UNEP digital platform in collaboration with IQAir. Real time pollution data accessed on the platform and IQAir mobile app.

ii) AirQo (Makerere University)

AirQo has deployed over 30 low cost sensors across Nairobi since 2022. Data from this network including US Embassy reference monitor data is shared on the official NCCG Website. Besides, the data can be accessed through AirQo digital platforms including the web analytics page, API and the AirQo mobile app.

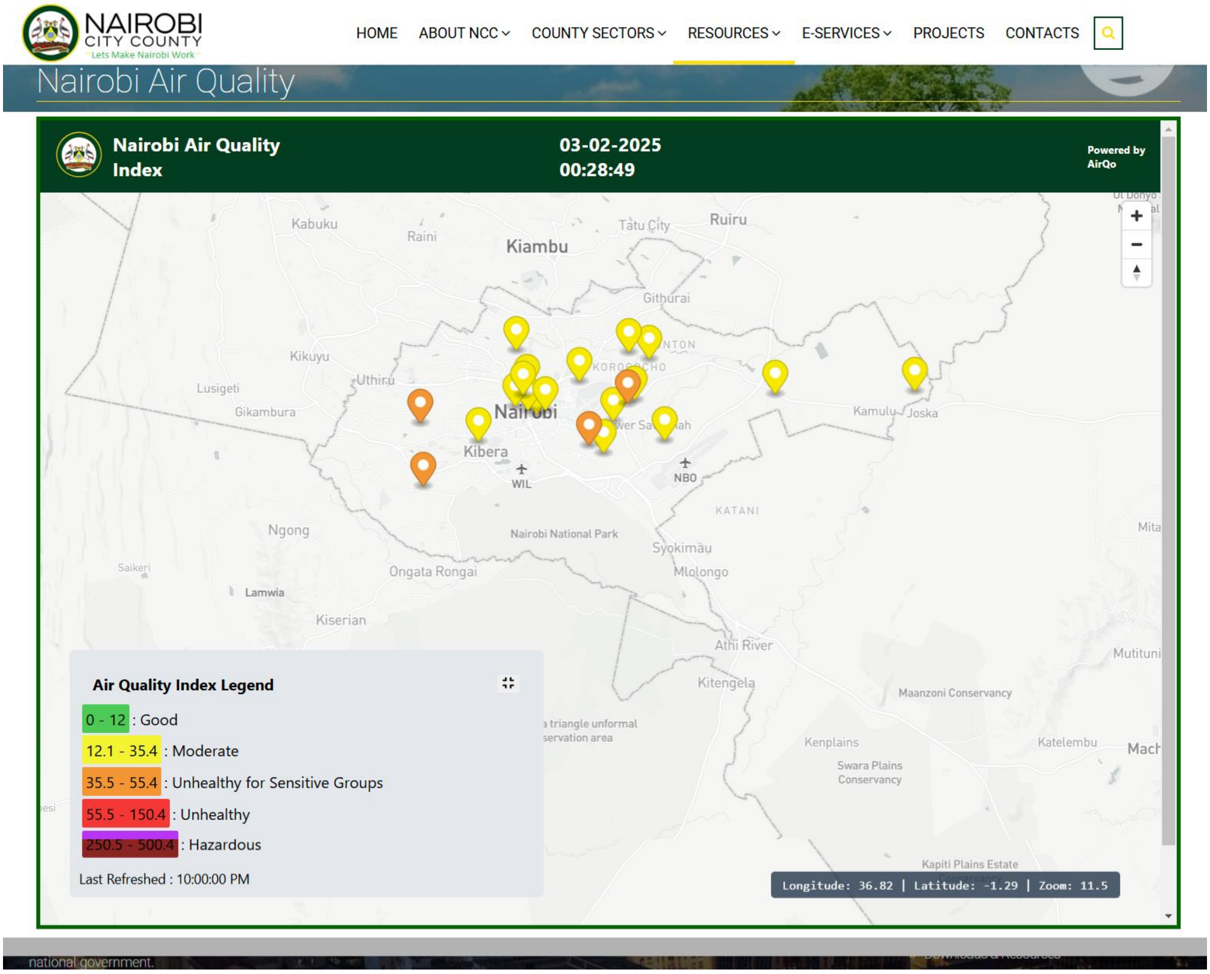


Figure 4: AirQo network powering the air quality web platform for Nairobi County. Real time data accessed on the NCCG website and AirQo digital platforms.

iii) US Department of State

The US Embassy in Nairobi has been providing open access to particulate matter data as reported by the Teledyne T640 reference monitor.

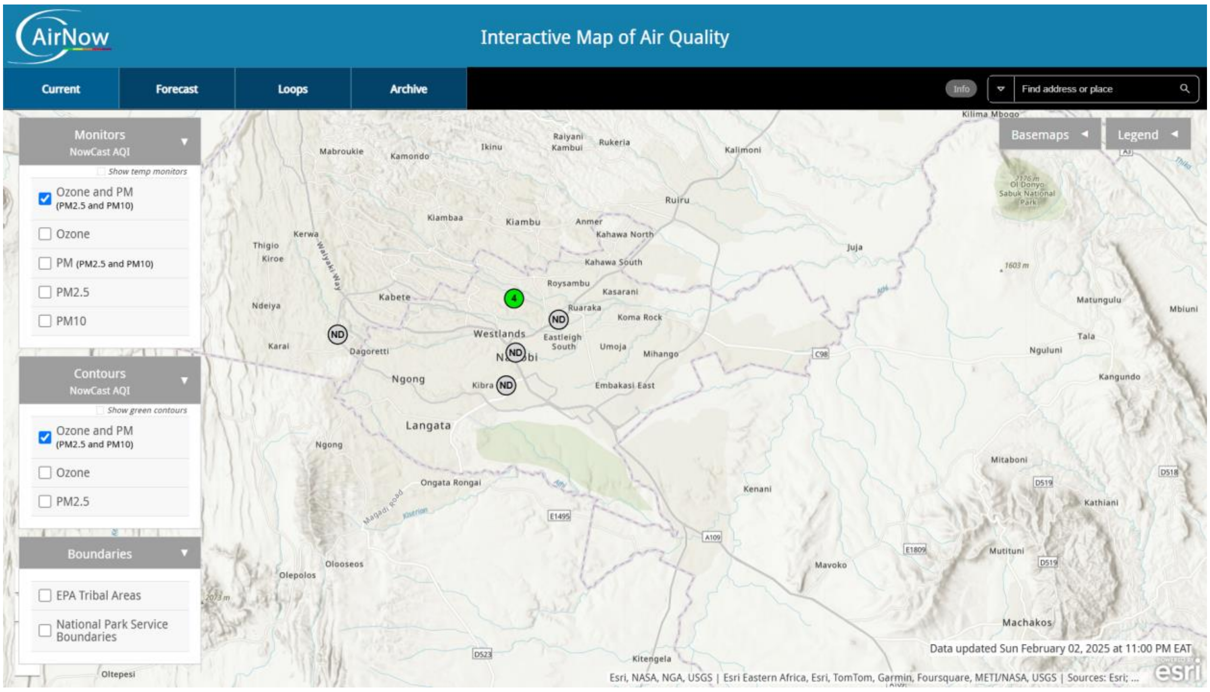
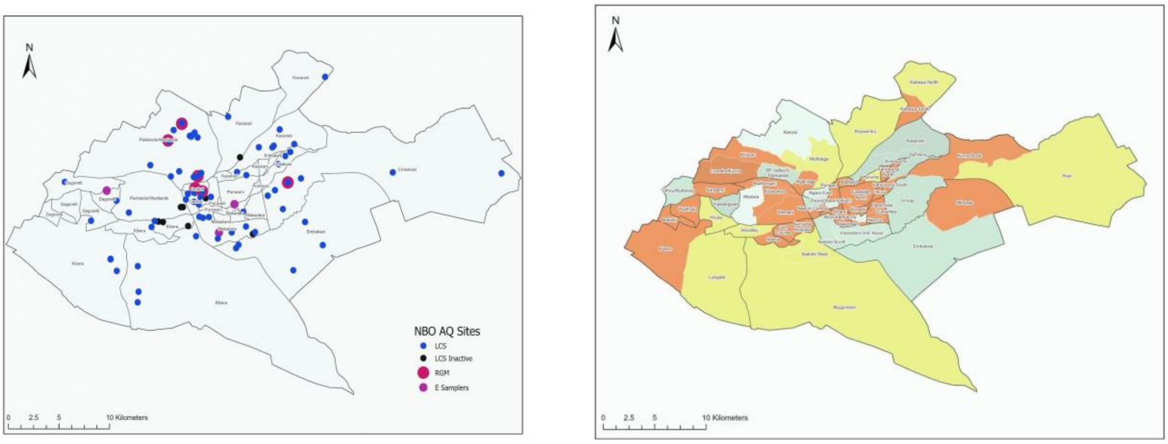


Figure 5: US Embassy T640 reference monitor providing open data access through the AirNow platform.

3.1.3 Status of Air Quality Monitoring in Nairobi

From the literature review and consultation with institutions managing air quality networks, a map of the existing infrastructure was developed. Figure 6 below illustrates the existing air quality monitoring network in Nairobi City County, Kenya. The network comprises a hybrid of over 70 monitors, including reference stations and low-cost monitors, deployed across the city by various institutions. This map only comprises locations with data shared on open digital platforms or the network administrators provide information about their locations.



a) Air quality monitoring stations

b) Status of monitoring

Figure 6: Distribution of air quality monitoring stations and status of monitoring across Nairobi County

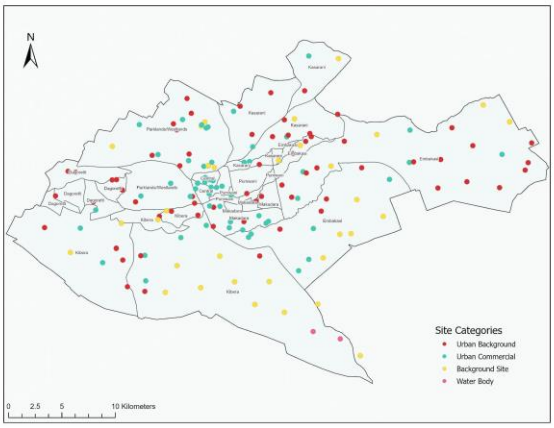
The map in Figure 6 a) above shows a dense distribution of monitoring stations in central Nairobi. Eastern wards in Embakasi and southern wards in Kibera, Lang'ata and Dagoretti South have sparsely distributed stations with no reference monitors deployed in any of those regions. However, from the overview of Nairobi County, the concentration of monitoring stations is aligned with many of the emission drivers such as population distribution and land use characteristics. Figure 6 b) maps out the status of monitoring at ward and sub county level. Orange represents wards with no active stations, while lime green for limited monitoring and green for wards with more dense distribution of stations. Embakasi East, Embakasi Central, Kamukunji, Makadara, Westlands and Dagoretti have the least air quality monitoring stations.

3.2 Site characteristics

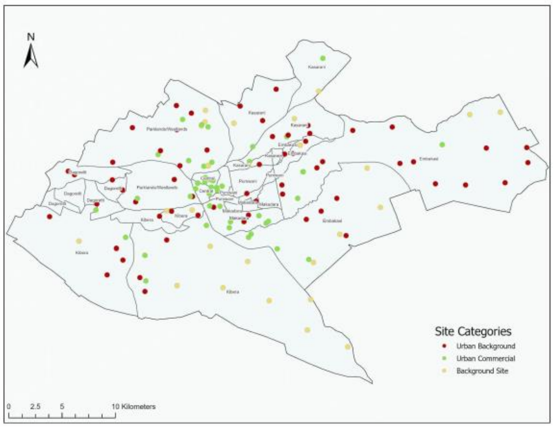
The map on figure 6 above illustrated the network gaps across the subcounties indicating dense distribution of monitors in the central Nairobi ward. However, the analysis was based on the known stations across the county and did not factor in the characteristics of each of the sites to inform the objectives of monitoring. From the literature review considered and active projects in Nairobi summarised on table 1 and table 2 respectively, particulate matter, specifically $PM_{2.5}$ is the predominant pollutant monitored across Nairobi. However, the distributed nature of monitoring in Nairobi presents the risk of replication and also monitoring gaps in other parts of the city.

3.2.1 Site categories using OpenStreetMap data

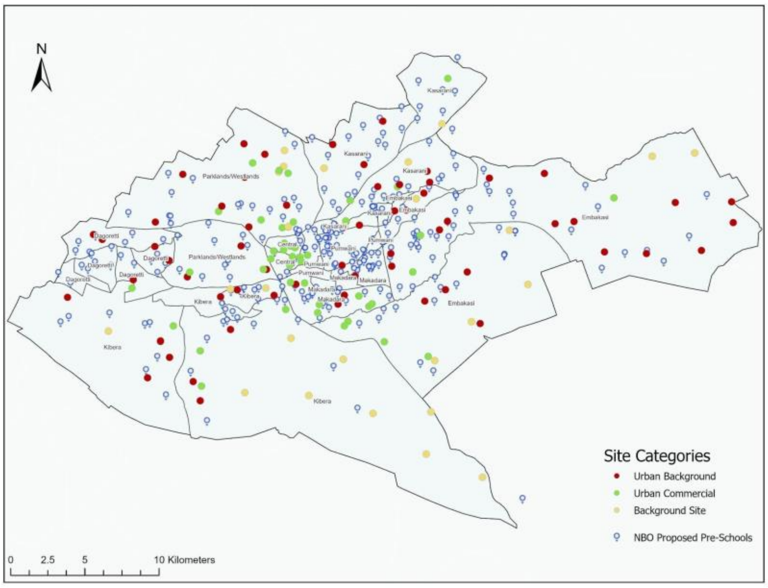
We developed an algorithm for automated mapping of the existing network with inclusion of recommended sites by NCCG. The figure below shows the comprehensive map of the existing network alongside proposed sites for expansion.



a) Site categorisation including water bodies



b) Automated site categorisation



c) Algorithm recommendations of potential monitoring sites overlaid by proposed NCCG facilities for network expansion.

Figure 7: Automated Site Categories Developed Using an Integrated Model Using the OpenStreetMap Data.

The integrated model developed using OpenStreetMap data was designed to optimally map the 82 known monitoring nodes, distribute 60 new unknown sites to the network and categorise all the nodes for understanding the characteristic of each ward site. Minimum distance between sites was set to 0.5km with definition of hotspots as areas classified using OpenStreetMap categories. Sites are clustered according to land use type and emissions into urban background, urban commercial and background sites.

Background sites were defined as locations with background emissions not influenced by any single source or street, but rather by contribution from all sources within the region. These sites are therefore characterised by large open spaces and parks with trees where no single source of emission is predominant. On the other hand, urban background and urban commercial were considered to be locations such as high and low density residential and commercial areas of the city with buildings, big streets. The three categories were used to define the density of monitoring required where urban sites require denser network distribution for measuring air quality representative of a few km^2.

Figure 7a) and 7b) above shows that the selection algorithm and already deployed networks prioritised urban commercial and urban background sites. The overlaid plot represented by figure 7c) also shows preferential distribution of amenities closer to urban commercial and urban background sites indicating dense distribution of population, buildings, roads, recreational facilities and other infrastructure. The algorithm, however, failed to account for protected areas, forest, parks and facilities such as airports with restricted access. Network expansion nodes were optimally distributed in areas like the Nairobi National Park, JKIA, Karura Forest and other background sites. Besides, this method provided no information about the types of parameters to be monitored and the nodes require individual marching with the closest county facilities for development of a deployment map.

3.3 Understanding pollution trends

The choice of pollutants to prioritise is informed by the concentration trends as observed by researchers and guided by existing sources of open datasets. Several studies conducted in Nairobi emphasize the need for continuous monitoring of background and pollution hotspots resulting from the major sources; transport or vehicular emissions, industrial activity, biomass burning, open burning of solid waste[12]. Highly congested areas of the city including the central business district, informal settlements, industrial zones (e.g. Viwandani) and major highways with high traffic volumes have been identified in previous studies[13] as pollution hotspots with monitoring stations recording the highest concentrations.

3.3.1 Satellite data analysis

Analysis of satellite imagery data provided a crucial foundation for understanding spatial and temporal distribution of pollutants and mapping out pollution trends and monitoring needs. Since most studies and continuous monitoring projects focused on particulate matter monitoring, basic understanding of pollution trends is crucial. Figure 8 below shows the aerosol distribution across Nairobi and its metropolitan area on

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[12] deSouza, P., Nthusi, V., Klopp, J. M., Shaw, B. E., Ho, W. O., Saffell, J., ... & Ratti, C. (2017). Research article A Nairobi experiment in using low cost air quality monitors. *Clean Air Journal*, 27(2), 12.

[13] Kiai C, Kanali C, Sang J, Gatari M. Spatial Extent and Distribution of Ambient Airborne Particulate Matter (PM2.5) in Selected Land Use Sites in Nairobi, Kenya. *J Environ Public Health*. 2021 Nov 13;2021:4258816. doi: 10.1155/2021/4258816. PMID: 34812262; PMCID: PMC8605910.

Sentinel 5P data extracted by the EarthObserver App based on the Google Earth Engine framework.

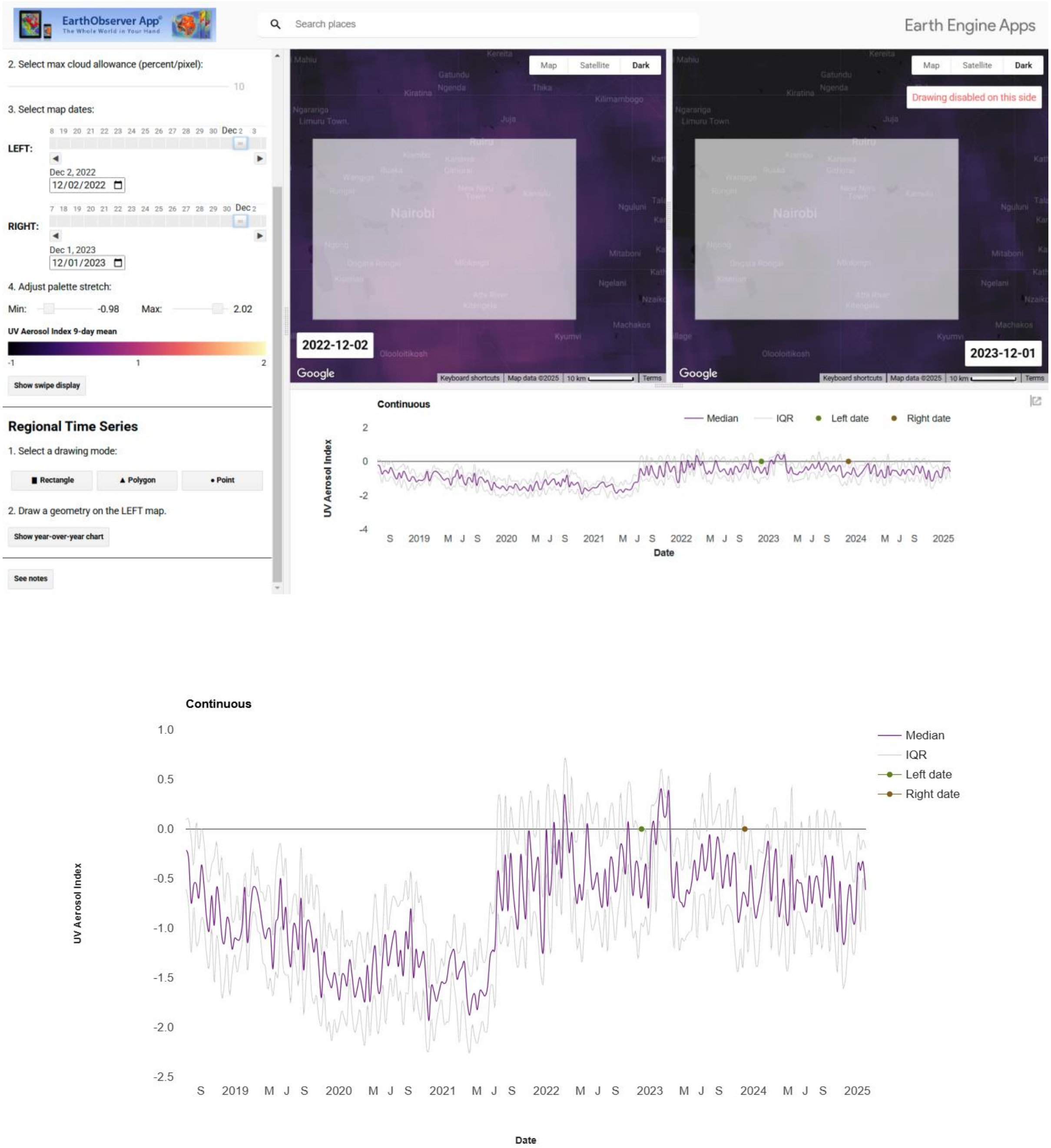
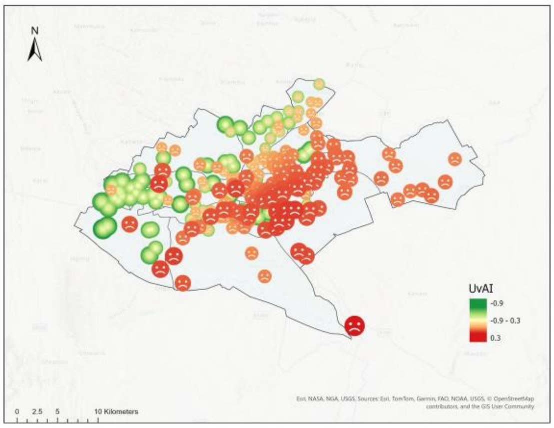
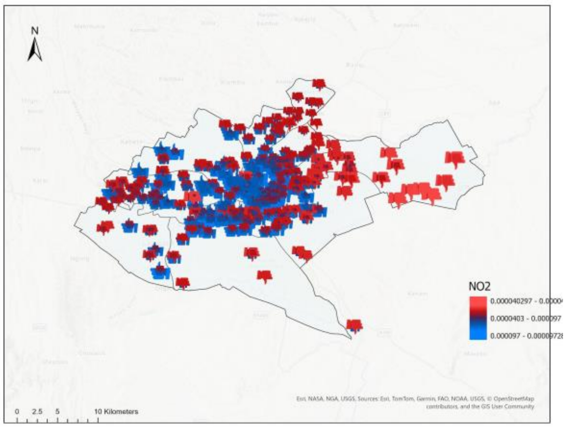


Figure 8: Aerosol distribution across Nairobi and its metropolitan area. Data based on Sentinel 5P mission visualised on the EarthObserver App

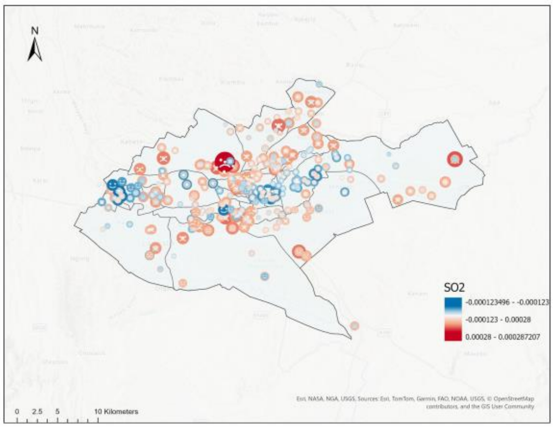
Further analysis was conducted using Sentinel 5P data product on Google Earth Engine extracted and pre-processed on Google Colab IDE. ArcGIS Pro was utilised for visualization as presented in the figure 9 below.



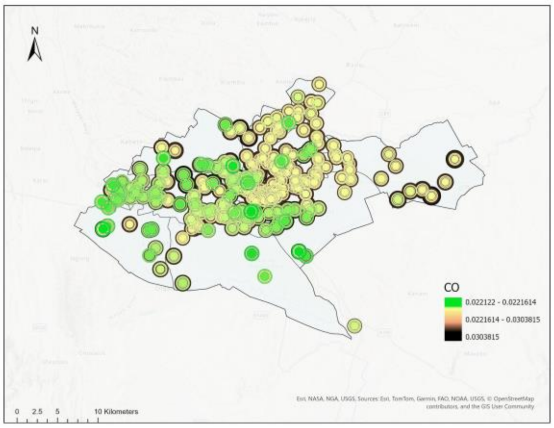
a) UvAerosolIndex_absorbing_aerosol_index



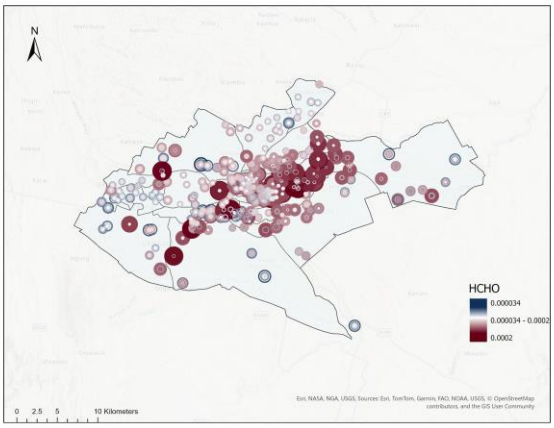
b) NitrogenDioxide_NO2_column_number_density



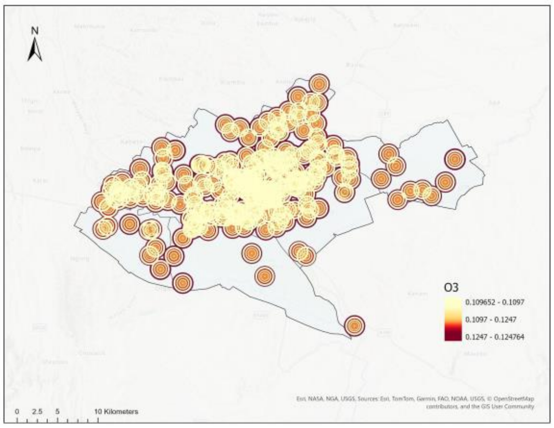
c) SulphurDioxide_SO2_column_number_density



d) CarbonMonoxide_CO_column_number_density



e) Formaldehyde_tropospheric_HCHO_column_number_density 2022-2024



f) Ozone_O3_column_number_density

Figure 9: Pollution trends from 2022-2024 across 142 selected nodes as observed by the TROPOMI instrument on board the Sentinel 5p mission

Figure 9a) above show higher concentrations of particulate matter, indicated by the ultra violet aerosol index (UvAI), were predominantly observed in sub counties adjacent to the central business district (Starehe, Kamukunji, Makadara) and within the south eastern regions of Embakasi. Studies conducted on the spatial distribution of particulate matter in Nairobi attributed higher concentrations across sites within central regions of the city to vehicular emissions[14][15].

Nitrogen dioxide concentration was observed to be higher across monitoring nodes in the central and western regions of the county where motorised transport is more prevalent. Sulphur dioxide pollution trends revealed two specific hotspots located towards the eastern side of the county (Kamulu and Athi) and northwestern regions of Parklands or Westlands, which might be associated with industrial facilities or plants close to those nodes. According to figures 9 d) and 9 e), elevated levels of formaldehyde and carbon monoxide were detected in eastern wards such as Dandora, Eastleigh, and Komarock, as well as south-western wards in Lang'ata and Karen sub counties, a trend similar to that observed for particulate matter.

The findings from the satellite data analysis highlight the spatial heterogeneity of pollution across Nairobi County and emphasize the need for targeted pollution control measures. Prioritized interventions by allocating sensors measuring specific parameters is an effective approach to development of a comprehensive network.

[14] Shilenje, Z. W., Thiong'o, K., Ongoma, V., Phillip, S. O., Nguru, P., & Ondimu, K. (2016). Roadside air pollutants along elected roads in Nairobi city, Kenya. *Journal of Geology & Geophysics,* 5(5), 1-10.
[15] Mukaria, S. M., Wahome, R. G., Gatari, M., Thenya, T., & Karatu, K. (2017). Particulate matter from motor vehicles in Nairobi Road Junctions Kenya. *Journal of Atmospheric Pollution*, 5(2), 62-8.

4.0 Summary

The needs assessment highlights the distributed air quality monitoring efforts across Nairobi County. By fostering public-private partnerships, Nairobi's data agenda has accelerated the county's progress in improving air quality monitoring network development and management. Collaborations with multiple stakeholders has enabled access to essential resources, expertise, and technology, helping the county to address both data collection and action on air quality.

Even though stakeholders managing networks in Nairobi have focused on diverse categories of sites, distributed efforts have led to redundant monitoring for wards with higher monitoring interests. Through diverse stakeholders involvement in monitoring, the county can effectively develop comprehensive networks with diverse priorities but similar objectives. However, without centralization of air quality monitoring networks, the infrastructure development is so far counterproductive.

This assessment also revealed monitoring network coverage gaps with over 20 wards having no known stations. Limited monitoring was noted in Kamukunji, Makadara and Westlands sub counties but the mapping of pollution trends indicated high concentration of pollutants in these highly populated urban commercial and background settings.

4.1 Conclusion and recommendations

From this needs assessment for procurement and deployment of a comprehensive city-owned low-cost sensor AQ monitoring network, we recommend the following:

- Scaling spatial and temporal coverage through **deployment of dense air quality networks** across all wards. A city-owned network will provide a broader and more accurate picture of air quality and facilitate targeted interventions in the most affected areas. For this project, a targeted deployment of at least 40 low cost sensors for particulate matter starting with the over 20 wards without any known stations will ensure a density of at least one monitoring station for every 50,000 residents.
- Design and development of a **centralised, open-access repository** for the city to strengthen the air quality data banks and access to information. For establishing a comprehensive air quality monitoring program for Nairobi County, beyond implementing a network of strategically located air quality monitoring stations to continuously measure key pollutants, NCCG needs to integrate data from the existing networks onto a city owned platform for effective monitoring and consolidated mitigation. As such, a data management and analysis platform will enhance capabilities for collecting, analysing, and reporting air quality data to track trends and inform policy decisions. Research based on the data repository will strengthen the capacity of county officials to adopt data-driven approaches to policymaking.
- Building the **capacity of the county government to design, deploy and**

manage air quality networks. Continuous and long-term training of Nairobi County personnel involved in air quality monitoring and management will guarantee project sustainability. This effort should involve multiple partners with interest in providing expertise and data to the city.

- Development of a comprehensive **air quality management plan** outlining the strategies for network expansion, emission inventory development and data needs.
- Hotspot monitoring for gaseous pollutants is required to broaden the monitoring scope and develop targeted interventions and mitigation strategies to reduce pollution. Future expansion should prioritise other criteria pollutants including gases and volatile organic compounds. Monitoring of sulphur dioxide in at least two sub counties, and nitrogen dioxide, carbon monoxide and VOCs across the central and eastern Nairobi wards. However, challenges of managing a network of gaseous sensors such as cost and frequency of sensor replacement, high power demand and failure rate, limited reference equipment for calibration and expensive calibration needs should be considered.
- Strengthen baseline data collection the southern and western sub counties by **increasing the number of reference grade monitors**. Variation in pollution trends across regions in Nairobi requires more localised baseline datasets for development of regional calibration models.