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Establishing the Nairobi City County Air Quality Monitoring Network

Procurement Guidelines for Acquisition of Low-cost Air Quality Monitors

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Air Quality Systems East Africa

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Executive Summary

Nairobi City County (NCC), with the support of the Clean Air Fund (CAF) under the Breathe Cities initiative, is undertaking the procurement of low-cost particulate matter ($PM_{2.5}$) sensors to establish a comprehensive and real-time air quality monitoring network across the city. This strategic initiative aims to address the growing concern of air pollution and its detrimental impact on public health of city residents. To inform the selection of suitable technology for this network, this report provides a detailed comparative analysis of various low-cost $PM_{2.5}$ sensors. The analysis focuses on critical factors influencing their operational effectiveness, data accessibility, and overall cost-efficiency. These factors include the specific air pollutants each monitor can measure, their unit price, communication and data logging functionalities, power requirements, the necessity of a data platform subscription, among other relevant features. A comprehensive list of low cost air quality monitoring devices was developed from a selection of products tested by AQMD's AQ-SPEC program and Afri-SET project, ensuring a foundation of reliable performance data.

Purpose of Procurement

NCC intends to utilize the low-cost $PM_{2.5}$ sensors, supported by CAF, for the following key purposes:

1. Establishment of a comprehensive air quality monitoring network through deployment of at least 50 $PM_{2.5}$ sensors across designated locations in all the wards. This network will enable real-time monitoring of $PM_{2.5}$ levels and identification of pollution hotspots across the county.
2. Generate data for evidence-based policy and intervention that will inform the development and implementation of effective air quality management policies and targeted interventions to reduce pollution.
3. Improve public awareness and engagement by providing accessible air quality information to the public. Real time information from the low cost sensors will enhance citizens awareness of pollution levels and empowering residents to take protective measures.
4. Data generated by the sensors will support the development, implementation, and enforcement of air quality regulations and action plans aimed at achieving long-term air quality improvements and reducing health impacts.
5. Training and capacity building for relevant NCC officials on the effective deployment, operation, maintenance and management of low cost air quality sensor network.

Rationale

To develop a comprehensive procurement guide, the analysis considered several factors including cost of LCS ownership, parameters measured, communication and connectiviety and data logging capabilities. Information about all the 17 LCS manufacturers considered in this anlysis is summarised under Table A of the Appendices section. Data on additional LCS manufacturers not considered in this report can be accessed on the AQMD's AQ-SPEC program and Afri-SET evaluation pages.

In line with the project objectives and budget, the total cost of ownership for each LCS, including not only the initial purchase price but also associated expenses for essential ancillary accessories was considered an essential procurement factor. Ancilliary accessories to be specified and provided by LCS manufacturers include; mounting hardware, power solutions such as solar panels, and data collection and transmission components like GSM/WiFi modules and potential data acess or API subscription fees. This holistic approach revealed a significant price range among the evaluated LCS manufacturers, ranging from approximately $200 to $10,000.

Beyond price, a notable diversity in features was considered. While some advanced monitors offer real-time measurements for a wide array of air pollutants, others are designed to focus on specific parameters. For the purpose of this analysis, however, particulate matter (PM2.5) was prioritized as the primary pollutant of interest, aligning with the project's immediate objectives.

Connectivity options offered by different manufactures also vary considerably. Certain monitors offer integrated Wi-Fi and cellular capabilities for seamless and continuous data transmission to remote servers. In contrast, others rely on local data storage solutions, such as SD cards, requiring manual data retrieval.

Data logging capabilities and the accessibility of collected data were identified as critical differentiating factors. Some manufacturers require a subscription to their cloud-based data platform to access realtime and historical data, advanced analytical tools, and visualization features. Conversely, other manufacturers provide options for local data storage or alternative methods for data access. Furthermore, the availability of user-friendly mobile applications for real-time data visualization and analysis varied across the evaluated devices.

Finally, LCS deployment history or experience in Nairobi and its environs was considered. Table B of the Appendices section details some of the already deployed networks in Nairobi showcasing application of different LCS options. This analysis was limited to only the known projects and options of LCS that have been deployed and operational in Nairobi for at least one year.

Mandatory sensor requirements for deployment in Nairobi

The low-cost air quality monitors under consideration must fulfill the following essential requirements:

- **Solar powered:** The devices must be equipped with solar panels to harness energy from the sun, enabling them to operate autonomously and sustainably without reliance on external power sources.
- **Cellular connectivity/GSM communication:** The monitors should incorporate cellular connectivity or GSM communication modules to transmit data wirelessly over cellular networks. This feature is important since all deployments are on remote outdoor settings with no access to wireless communication with WiFi.
- **No annual subscription costs:** The monitors must not incur any recurring annual subscription fees for data access or usage, ensuring cost-effectiveness and long-term affordability.
- **Open data access through API:** The collected air quality data should be accessible through an open application programming interface (API). This facilitates data sharing and integration with Nairobi County digital platforms, OpenAQ and enables researchers, developers, and the public to utilize the data for various purposes.
- **Particulate matter:** The monitors must be capable of measuring and monitoring particulate matter (PM) levels in the air.

Recommendations and Guidelines for Procurement

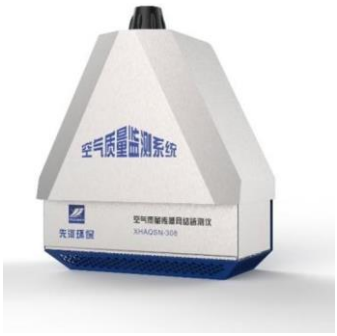
The list below shows the low-cost monitors deployed by different stakeholders in Nairobi and meet all the mandatory requirements listed above. Besides, this list has omitted devices that cost above $3000.

Table 1 Recommended Monitors for Procurement

KEY:

Affordable
Medium cost
High cost

Device	Origin	Parameters	Price	Additional Information
AirVisual Outdoor IQAIR	Germany	PM2.5, PM10, CO2, TVOC, temperature, and humidity 	$1000 - $5000	Mains powered (solar option available at additional cost), real-time PM2.5, PM10, CO2, TVOC, temperature, and humidity readings, Wi-Fi connectivity (GSM option available at an additional cost), mobile app, air quality platform, outdoor enclosure, electrochemical sensors, laser particle counter. • **UNEP/Stockholm Environment Institute (SEI) Network**
Binos Monitor AirQo	Uganda	PM2.5, PM10, temperature, and humidity 	$500-$1000	Solar-powered, real-time PM2.5, PM10, temperature, and humidity readings, GSM cellular connectivity, cloud-based data platform, Mobile App, API, outdoor enclosure, optical sensors. • **AIRQO Network**

Modulair QuantAQ	US	PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, and humidity 	$1000 - $5000 including $500/unit / year for cloud access	Mains powered (solar option available at additional cost), real-time PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, and humidity readings, Ethernet, Wi-Fi, and cellular connectivity, cloud-based data platform, outdoor enclosure, electrochemical and optical sensors. • **GEOHealth Hub Kenya Network**
XHAQSN-308 Hebei Sailhero	China	PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC, temperature, and humidity 	$1000 - $5000	Solar powered, real-time PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC, temperature, and humidity readings, GSM and LoRaWAN connectivity, cloud-based data platform, robust outdoor enclosure, electrochemical sensors. **UNEP/Stockholm Environment Institute (SEI) Network**

Procurement Guidelines

Given the project's requirements and budget constraints, the procurement of 50 low-cost air quality monitors necessitates careful consideration of both cost and functionality. The following options are recommended, each with their own advantages and disadvantages:

A. Exclusive procurement of AirQo monitors

This option involves the purchase of up to **50 AirQo monitors**, exclusively designed for

particulate matter measurement.

Advantages

- Cost-effective to procure because AirQo monitors fall within the acceptable price range, ensuring that the project stays within budget.
- Streamlined integration due to ease of using a single monitor type. AirQo has already integrated data on the county website and this simplifies data integration and management on the city's platform to be developed.
- Uniform maintenance and availability of technical support. AirQo's local presence and experience in the region will streamline maintenance processes and technical support.

Disadvantages

- Limited pollutant measurement since AirQo monitors only measure particulate matter, excluding other potentially relevant pollutants.

B. Combined Procurement of AirQo and AirVisual Pro Monitors

This option involves procuring a mix of **25 AirQo monitors** for particulate matter and **10 AirVisual Pro** monitors for particulate matter and VOC/gaseous pollutant measurement.

Advantages

- Expanded pollutant measurement through the inclusion of AirVisual Pro monitors which allows for the measurement of VOCs and other gaseous pollutants such CO and CO2, providing a more comprehensive air quality assessment.
- Targeted deployment of AirQo monitors in areas prone to dust and AirVisual Pro monitors can be strategically deployed in areas with potential VOC or gaseous pollutant concerns.

Disadvantages

- Increased complexity in managing two different monitor types data integration, maintenance, and technical support.
- Potential cost variations associated with changes in shipping costs, maintenance costs, and technical support availability. The cost of shipping and customs clearance will be higher for devices shipped from Europe. Delayed shipment of one of the brands would affect project delivery timelines.

C. Multi-brand procurement

This option involves procuring a mix of **10 AirQo Binos Air Monitors, 10 IQAir AirVisual Pro,** and **5 Sailhero** monitors.

Advantages

- Diverse data collection will be possible through utilizing multiple brands offering a wider range of data collection capabilities and features.
- Comparative analysis of different brands for monitor performance and data accuracy calibration.

Disadvantages

- Logistical challenges will arrive from managing four different suppliers in terms of shipping, integration, and support. The cost of shipping and customs clearance will be higher for devices shipped from Europe and China. Delayed shipment of one of the brands would affect project delivery timelines.
- Cost and maintenance variability due to varying requirements between the different brands, potentially leading to budget overdrafts and logistical complications.
- Integrating data from four different APIs into the Nairobi City County's platform could be technically challenging and time- consuming.

Additional Considerations

- The availability and cost of long-term maintenance and technical support to be factored into the decision-making process.
- Ensuring data quality and comparability across different monitor brands is essential for accurate air quality assessment and analysis.
- The chosen procurement option should be scalable to accommodate future expansion of the air quality monitoring network in Nairobi.

Conclusion

In conclusion, this comprehensive analysis focused on various low-cost PM2.5 sensor technologies to be considered in response to the Procurement and deployment of a comprehensive city-owned low-cost sensor AQ monitoring network project commissioned by CAF for NCC. The analysis and guildeline provides the critical information needed to make informed procurement decisions. By considering the total cost of ownership, key performance features, connectivity options, data accessibility, and demonstrated deployment success within Nairobi, this report guides the selection of sensors that align with the project's objectives, budget, and mandatory technical requirements. The emphasis on solar power, cellular connectivity, open data access via API, and the measurement of particulate matter ensures the chosen sensors will contribute effectively to establishing a sustainable and impactful air quality monitoring network across selected locations in the city's 85 wards, ultimately supporting evidence-based action towards cleaner air and improved public health. Three procurement options were proposed for consideration, highlighting pros and cons of each alternative. Finally, the **exclusive procurement of AirQo monitors (Option A)** option is recommended because it offers the most cost-effective and streamlined solution for measuring particulate matter across Nairobi City County.

Appendices

Table A: Comprehensive comparison of various low-cost air quality monitors

KEY:

Affordable
Medium cost
High cost

Device	Origin	Parameters	Price	Data Logging	Subscription	Features
PurpleAir PA-II	UK	PM2.5, PM10	$500-$1000	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time PM2.5 readings, Wi-Fi connectivity, mobile app, outdoor enclosure, laser particle counter, temperature and humidity sensors.
AirVisual Outdoor	Germany	PM2.5, PM10, CO2, TVOC, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time PM2.5, PM10, CO2, TVOC, temperature, and humidity readings, Wi-Fi connectivity, mobile app, air quality history, outdoor enclosure, electrochemical sensors, laser particle counter.
Dylos DC1700	USA	PM2.5, PM10	$10,000+	Local storage (SD card)	No	Real-time PM2.5 and PM10 readings, USB connectivity, data

						logging, laser particle counter.
Shinyei PPD42NS	Japan	PM1.0, PM2.5, PM10	$10,000+	Cloud-based, local storage	No	Real-time PM1.0, PM2.5, and PM10 readings, UART connectivity requires external data logger, laser particle counter, API integration.
AQ Mesh	UK	CO, NO, NO2, O3, SO2, PM2.5, PM10, VOCs, temperature, humidity	$5000 - $10000+	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time NO, NO2, O3, CO, SO2, H2S, TVOC and CO2, PM1, PM2.5, PM10, TPC and TSP (0.3 to 30 microns), temperature, humidity, and noise readings, Wi-Fi and Bluetooth connectivity, and cloud-based data platform, mobile app, indoor use.
Aeroqual AQY100	USA/New Zealand	PM2.5, PM10, CO, NO2, O3, temperature, humidity	$10,000+	Cloud-based, local storage (SD card), API, Mobile	No	Real-time PM2.5, PM10, CO, NO2, O3, temperature, and humidity readings, Ethernet connectivity,

				App		data logging, outdoor enclosure, electrochemical sensors.
AirGradient	Thailand	PM2.5, PM10, CO2, TVOC, temperature, humidity, barometric pressure	$500-$1000	API, Local storage (SD card)	No	Real-time PM2.5, PM10, CO2, TVOC, temperature, humidity, and barometric pressure readings, Wi- Fi connectivity, mobile app, open- source hardware and software.
AirQo	Uganda	PM2.5, PM10	<$500	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time PM2.5 and PM10 readings, GSM and Wi-Fi connectivity, cloud-based data platform, outdoor enclosure, laser particle counter.
Modulair QuantAQ	USA	PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	Paid subscription required	Real-time PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, and humidity readings, Ethernet, Wi-Fi, and cellular connectivity, cloud- based

						data platform, outdoor enclosure, electrochemical and optical sensors.
Clarity Node S	USA	PM2.5, PM10, NO2, CO, O3, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	Paid subscription required	Real-time PM2.5, PM10, NO2, CO, O3, temperature, and humidity readings, Wi-Fi, Ethernet, and cellular connectivity, cloud-based data platform, outdoor enclosure, electrochemical sensors.
Kunak Air Pro/Lite	Spain	PM2.5, PM10, CO, NO2, TVOC, temperature, humidity, noise	$5000 - $10000 +	Cloud-based, local storage (SD card), API, Mobile App	Paid subscription required	Real-time PM2.5, PM10, CO, NO2, TVOC, temperature, humidity, and noise readings, Wi-Fi and Bluetooth connectivity, cloud-based data platform, mobile app, indoor use.
South Coast Science Praxis/Ur	USA	NO, NO2, PM1, PM2.5, PM10,	$5000 - $10000 +	Cloud-based, local storage	Paid subscription required	Real-time NO, NO2, PM1, PM2.5, PM10,

ba n		Temperature, Humidity, Atmospheric pressure		(SD card), API, Mobile App		temperature, humidity, and atmospheric pressure readings, Ethernet, GSM, and Wi-Fi connectivity, cloud-based data platform, outdoor enclosure, electrochemical and optical sensors.
Airly	Poland	PM1, PM2.5, PM10, NO2, O3, SO2, CO, temperature, humidity, pressure	$1000 - $5000+	Cloud-based, API, Mobile App	Paid subscription required	Real-time PM1, PM2.5, PM10, NO2, O3, SO2, CO, temperature, humidity, and pressure readings, Wi-Fi and Ethernet connectivity, cloud-based data platform, outdoor enclosure, laser particle counter, and electrochemical sensors.
XHAQSN-308 - Hebei Sailhero	China	PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC,temperature, and humidity readings, GSM and LoRaWAN connectivity,

						cloud-based data platform, outdoor enclosure, electrochemical sensors.
Air Quality Egg	USA	PM2.5, PM10	$10,000+	Cloud-based, local storage (SD card), API, Mobile App	No	Real-time PM2.5 and PM10 readings, Wi-Fi connectivity, cloud- based data platform, mobile app, indoor and outdoor use, laser particle counter.
Airbeam3	USA	PM2.5, PM10	$10,000+	Cloud-based, local storage	No	Real-time PM2.5 and PM10 readings, Bluetooth connectivity, cloud-based data platform, mobile app, personal exposure monitoring, laser particle counter.
BlueSky 8145	USA	CO, NO, NO2, O3, SO2, PM2.5, PM10, VOCs, temperature, humidity	$10,000+	Local storage, data output via API	No	Real-time CO, NO, NO2, O3, SO2, PM2.5, PM10, VOCs, temperature, and humidity readings, Ethernet connectivity, data output via API, outdoor

						enclosure, electrochemical and optical sensors.

Table B: LCS deployed in Nairobi City County

KEY:

Affordable
Medium cost
High cost

Device	Parameters	Price	Data Logging	Subscription	Features
AirVisual Outdoor	PM2.5, PM10, CO2, TVOC, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	No	Mains powered (solar option available at additional cost), real- time PM2.5, PM10, CO2, TVOC, temperature, and humidity readings, Wi-Fi connectivity (GSM option available at an additional cost), mobile app, air quality platform, outdoor enclosure, electrochemical sensors, laser particle counter. • **UNEP/Stockholm Environment Institute (SEI) Network**
AirQo	PM2.5, PM10	$500-$1000	Cloud-based, local storage (SD card), API, Mobile App	No	Solar-powered, real-time PM2.5, PM10, temperature, and humidity readings, GSM cellular connectivity, cloud-based data platform, Mobile App, API, outdoor enclosure, optical sensors. **AirQo Network**

Modulair QuantAQ	PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	Paid and free tiers available	Mains powered (solar option available at additional cost), real- time PM2.5, PM10, NO2, O3, CO, SO2, VOCs, temperature, and humidity readings, Ethernet, Wi-Fi, and cellular connectivity, cloud- based data platform, outdoor enclosure, electrochemical and optical sensors. **GEOHealth Hub Kenya Network**
Kunak Air Pro	PM2.5, PM10, CO, NO2, TVOC, temperature, humidity, noise	$5000 - $10000 +	Cloud-based, local storage (SD card), API, Mobile App	Paid and free tiers available	Real-time PM2.5, PM10, CO, NO2, TVOC, temperature, humidity, and noise readings, Wi-Fi and Bluetooth connectivity, cloud-based data platform, mobile app, indoor use. **UNEP Network**
South Coast Science Praxis/Urb a n	NO, NO2, PM1, PM2.5, PM10, Temperature, Humidity, Atmospheric pressure	$5000 - $10000 +	Cloud-based, local storage (SD card), API, Mobile App	Paid subscription required	Real-time NO, NO2, PM1, PM2.5, PM10, temperature, humidity, and atmospheric pressure readings, Ethernet, GSM, and Wi-Fi connectivity, cloud-based data platform, outdoor enclosure, electrochemical and optical sensors. **UNEP Network**

XHAQSN-308 - Hebei Sailhero	PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC, temperature, humidity	$1000 - $5000+	Cloud-based, local storage (SD card), API, Mobile App	No	Solar powered, real-time PM2.5, PM10, NO2, CO, O3, SO2, H2S, NH3, TVOC, temperature, and humidity readings, GSM and LoRaWAN connectivity, cloud- based data platform, robust outdoor enclosure, and electrochemical sensors. **UNEP/Stockholm Environment Institute (SEI) Network**