Considerations when deploying an air quality network

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kunak
SENSING ANYWHERE

www.kunakair.com

HOW TO CHOSE A SENSOR SYSTEM?

Take into account:

1. **What is the performance of the sensor system?**

2. What are the general features of the Air Quality Sensor System?

3. Which is the maintenance I need to carry out once they are deployed in field?

Sensor Limitations and Challenges

- Environmental conditions effects
- Cross-sensitivities
- Baseline and span drift

Lewis, A., Peltier, W. R., & von Schneidemesser, E. (2018). Low-cost sensors for the measurement of atmospheric composition: overview of topic and future applications.

1. Performance of the Air Quality Sensor Systems

United States Environmental Protection Agency

- Target Pollutant
- Measurement Range
- Detection Limit
- Sensor Accuracy
- Response Time
- **Calibration and data correction**

Making the invisible visible:

A guide for mapping hyperlocal air pollution to drive clean air action

SELECTING MONITORING EQUIPMENT

The monitor sensors you choose to add to your network will depend on:

- the pollutant(s) you want to measure
- the data quality
- the budget you can devote to purchase and maintain the equipment.

Clements, A., R. Duvall, D. Greene, AND T. Dye. The Enhanced Air Sensor Guidebook. U.S. Environmental Protection Agency, Washington, DC, 2022.

Craft, E.., Nowlan, A., Rickenbacker, H., Uennatornwaranggoon, F. Making the invisible visible. Environmental Deferense Fund, 2019.

1. Performance of the Air Quality Sensor Systems

- Target Pollutant
- Measurement Range
- Detection Limit
- Response Time

Pollutant	Sources	Typical Concentration
CO	Fuel combustion in cars or trucks, small engines, stoves,...	0 to 0.3 ppm
CO_2	Deforestation and the burning of fossil fuels	350 to 600 ppm
NO	Automotive engines and the burning of coal, oil, diesel fuel, and natural gas	0 to 60 ppb
NO_2	Combustion of fossil fuels	0 to 50 ppb
O_3	The result of the atmospheric reaction of a number of precursor pollutants	0 to 125 ppb
H_2S	Natural origin by the organic matter decomposition. Anthropically, in industrial activities (pulp manufacturing, oil refining, WWTP, and textile industry)	0 to 20 ppm
SO_2	Combustion of coal or fossil fuels, in metallurgy and volcanic eruptions	0 to 100 ppb
NH_3	Agriculture, livestock, and, waste and water management (slurries, composting and landfills).	0 to 3 ppm
VOCs	Fuel combustion (wood, coal, gasoline etc.)	0 to 5 ppm
PM	Road transport and industrial combustion plants and processes, commercial and residential combustion and power plants.	0 to 100 µg/m3

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https://www.kunakair.com/doc/External/Kunak_Smart_Environment_EN_low.pdf

Sensor Accuracy

USES CASES - Belgium

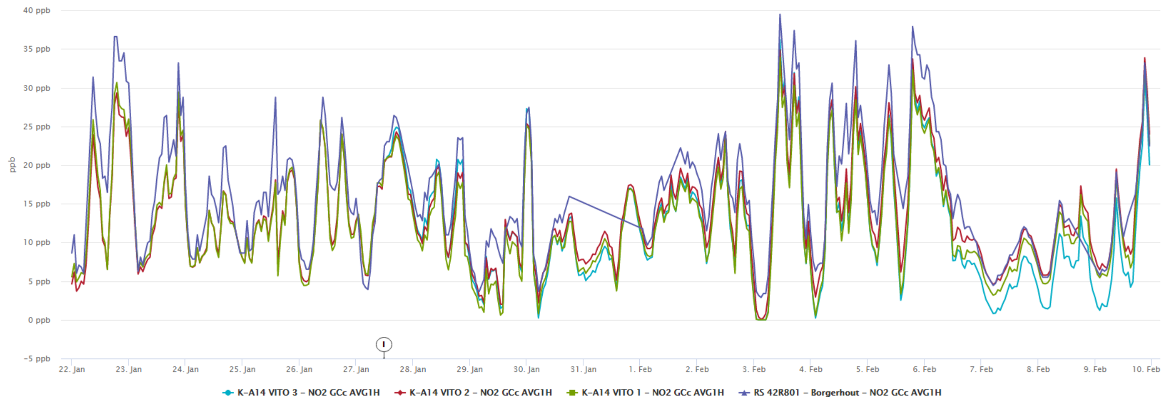
Devices: 3 Kunak AIR stations

Measurement parameters:
- NO_2, NO, O_3,CO and particles (PM1, PM2.5 and PM10)
- Temperature, relative humidity and atmospheric pressure.

CHALLENGES	SOLUTIONS
• Humidity >80%	• Kunak temp/RH correction algorithm
• Electrical network not fully accessible	• Kunak calibration (NOT Machine Learning based) – baseline adjustment from season to season.
• Deployment for 1 year	• Autonomy through solar panel
• 3 different locations	

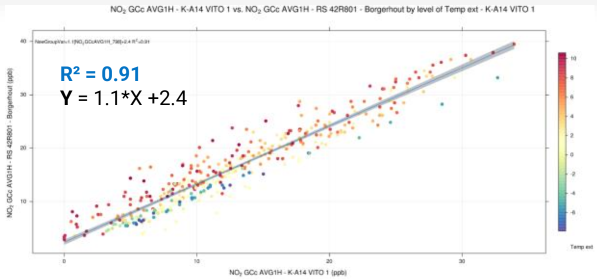
1. Antwerp
2. Kampenhout
3. Saint Niklaas

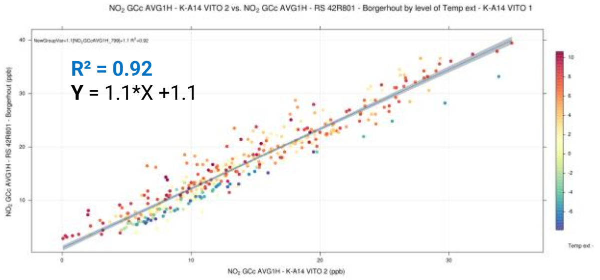
Sensor Accuracy

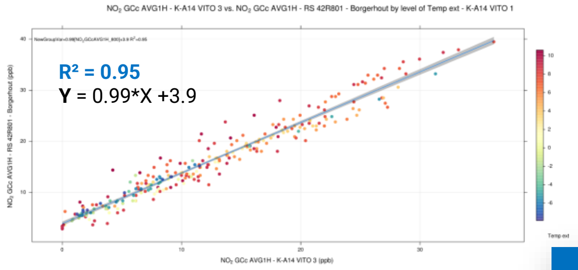


	R^2	Mean Absolute Error (ppb)	U(exp) (<25%)
#1	0.91	3.62	17.13%
#2	0.92	2.81	5.99%
#3	0.95	3.80	9.99%

U(exp): Data Quality Objetive expressed as the Expanded Uncertainity in the Limit Value







HOW TO CHOSE A SENSOR SYSTEM?

Take into account:

1. What is the performance of the sensor system?

2. **What are the general features of the Air Quality Sensor System?**

3. Which is the maintenance I need to carry out once they are deployed in field?

2. General features of Air Quality Sensor Systems

United States Environmental Protection Agency

AIRLAB SOLUTIONS POUR NOTRE AIR

- Durability
- Enclosure
- Ease-of-Use
- Power
- Display
- Data Transmission
- Data Access
- Data Handling
- Cost

- ✓ Usability → easy of use, reduced maintenance
- ✓ Portability → autonomy, mass and volume (Form factor)

Clements, A., R. Duvall, D. Greene, AND T. Dye. The Enhanced Air Sensor Guidebook. U.S. Environmental Protection Agency, Washington, DC, 2022.

2. General features of Air Quality Sensor Systems

Durability	Robust for harsh environments
Enclosure	IP65
Ease-of-Use	Final user
Power	Mains vs Solar Size of the solar panel
Display	For field deployments
Data Transmission	LORA, Cellular, Wifi
Data Access	Cloud, Modbus
Data Handling	Final Private vs Public
Cost	100$ to 5,000$

HOW TO CHOSE A SENSOR SYSTEM?

Take into account:

1. What is the performance of the sensor system?

2. What are the general features of the Air Quality Sensor System?

3. **Which is the maintenance I need to carry out once they are deployed in field?**

3. Maintenance of Air Quality Network

Short reminder….

Sensor Limitations and Challenges

- Environmental conditions effects
- Cross-sensitivities
- Baseline and span drift

WORLD METEOROLOGICAL ORGANIZATION

Lewis, A., Peltier, W. R., & von Schneidemesser, E. (2018). Low-cost sensors for the measurement of atmospheric composition: overview of topic and future applications.

3. Maintenance of Air Quality Network

Correct installation and **maintenance** to ensure the proper performance of the devices and the quality of the data.

WORLD
METEOROLOGICAL
ORGANIZATION

Quality Assurance (QA) - appropriate calibration ensures that data monitored are robust and accurate.

Quality Control (QC) - monitoring the long-term performance to ensure it **remains calibrated** and **help notify the user** when it needs to be corrected, removed or re-calibrated.

Snyder et al., 2013 "Data of poor of unknown quality is less useful than no data since it can lead to wrong decisions".

Calibration and Corrections

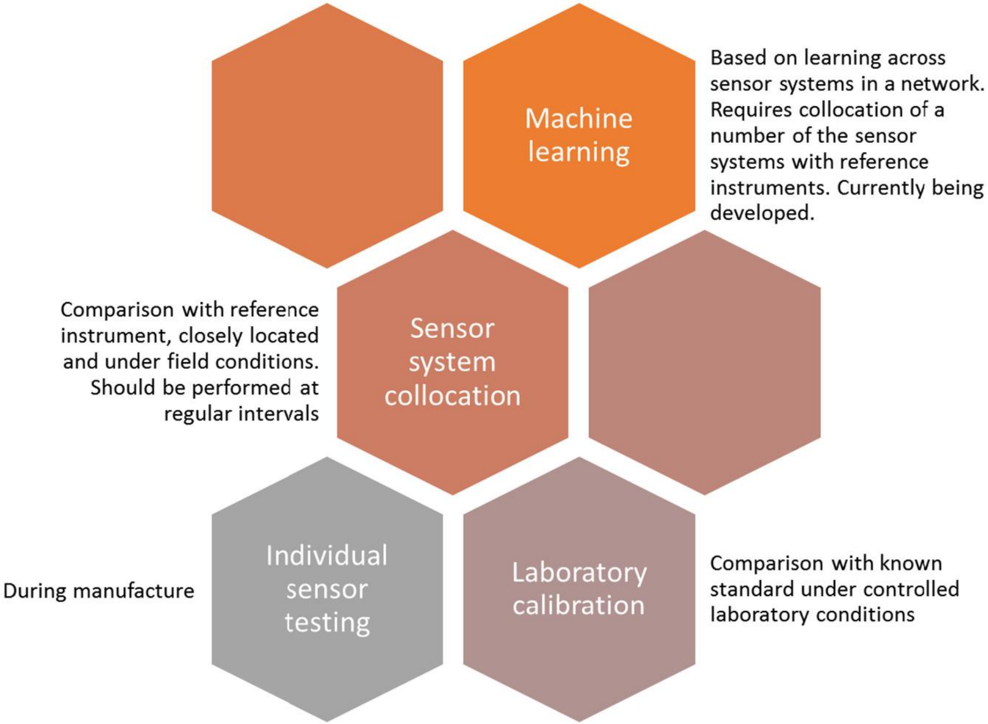


Fig. 2. Alternative methods available for calibration of low-cost sensor systems.

Ripoll, Anna, et al. "Testing the performance of sensors for ozone pollution monitoring in a citizen science approach." Science of the total environment 651 (2019): 1166-1179.

Calibration and Corrections: Deterministic Algorithms

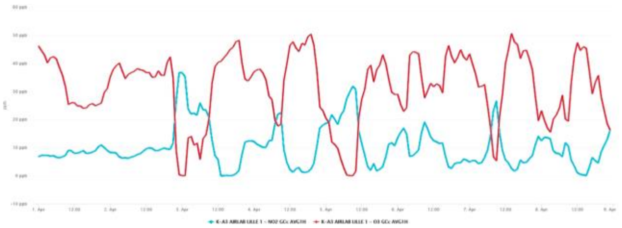
RAW Low-cost sensor data

Meteo parameters (Temp / RH)

~~Reference data~~

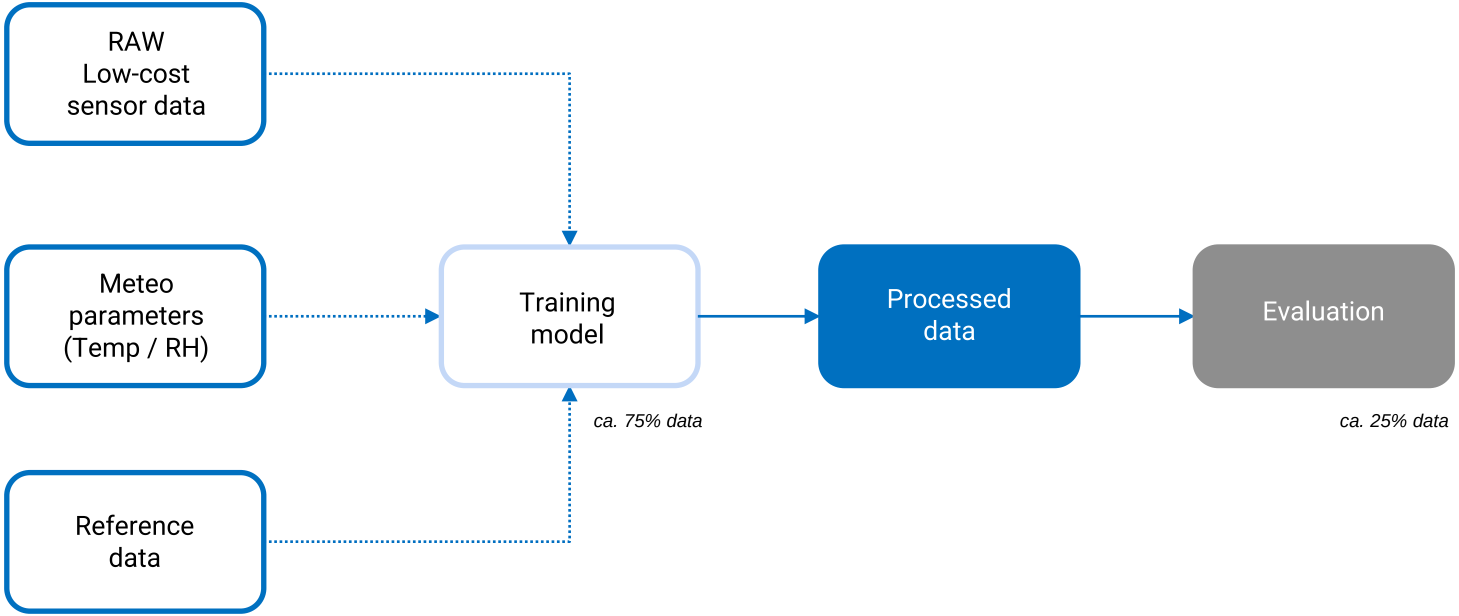
Deterministic Algorithm

Concentration values (ppb or ug/m^3)



- Corrects effects of ambient conditions
- Cross-sensitivities
- Baseline/Span Drift

Calibration and Corrections: Machine Learning



3. Maintenance of Air Quality Network

Air quality platform

- **Visualize the operation** of the equipment and the data obtained → to monitor the health of the network and the status of the devices.
- **Detect errors and anomalies** in the devices and data **immediately**, consult them, and invalidate the data if needed.
- **Detect** that the gas and particle sensors need **calibration** and allow the **calibration remotely**.
- Availability of a validation tool for **validating and invalidating the data remotely**, to have reliable data for advanced analysis.
- **Availability of raw data** (non-processed data) and **flags** **(Temporal, Valid/Invalid, Corrected)** to assure traceability.
- A **Computer-based Maintenance Management System** → to facilitate network maintenance.
    - maintenance tasks
    - uploading of images and documents
    - access to configuration history, logbook, etc.

CONSIDERATIONS - AQ NETWORK

USES CASES - Spain

Devices: 10 Kunak AIR Pro stations + sound level meters + information screens

Measurement parameters:
- SO_2 ,NO_x, O_3,CO and particles (PM1, PM2.5 and PM10)
- Noise level.
- Temperature, relative humidity and atmospheric pressure.
- Wind speed and direction.

CHALLENGES

- AQ data diffusion to citizens
- Civil engineering work. Poles installation.
- Public electrical network spots
- Lack of concern about the O&M of the network
- Public tender – fixed price

SOLUTIONS

- AQ data accessible from web portal and screens.
- National Project
- Powered by public electric bikes chargers
- Operation and Maintenance Service in remote
- Price not adaptable for improvements

Unión Europea

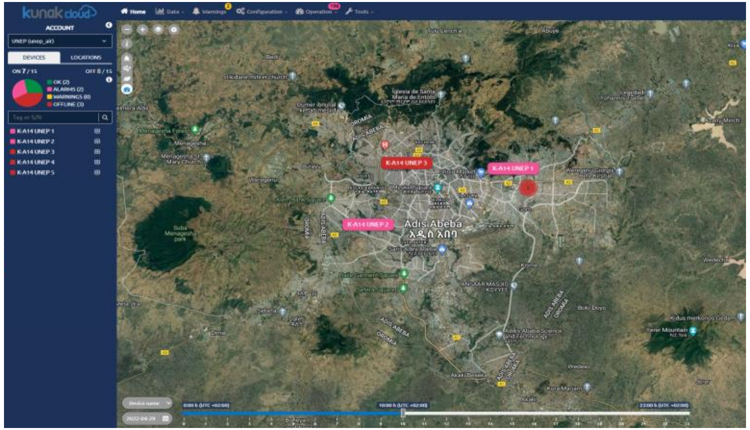
EDUSI ALBACETE

CONSIDERATIONS - AQ NETWORK

USES CASES - Ethiopia

Devices: 5 Kunak AIR A14 stations

Measurement parameters:
- NO_2, O_3 and particles (PM1, PM2.5 and PM10)
- Temperature, relative humidity and atmospheric pressure.
- Wind speed and direction.



CHALLENGES	SOLUTIONS
• Not Official Reference Stations	• Factory calibration against reference standards
• High temperature and humidity conditions	• Remote baseline and sensitivity correction
• Low budget	• Kunak temp/RH correction algorithm
	• Automatic maintenance of the network (not technician hours)

UN environment
United Nations Environment Programme

CONCLUSIONS

- When developing an air quality sensor-system, must be considered →

  the **climatic conditions**

  the **facilities** when installing the sensors

  possibilities of **calibration & maintenance** of the sensor system.

- The air quality sensor system must have a **well-known QA&QC procedure** →

  the temperature and humidity effects, well corrected, independently of the final location.

  the sensor-system proper installation, maintenance and calibration to **provide reliable and accurate air quality data effortless**.

  Air quality platform user friendly that allows a proper maintenance of the network

CONSIDERATIONS WHEN DEPLOYING AN AIR QUALITY NETWORK

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Final