Implementation of a Mobile Pollution Monitoring Station: A Case Study for the City of Mohammédia

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Abstract. This study promotes the development of automated air quality measurement devices in Mohammédia and Ben Slimane. The aim is to address air pollution, which mainly consists of fine particles (PM2.5, PM10) and polluting gases (NO_2, CO, CO_2). These gases are regularly found in concentrations that are hazardous to public health. The lack of pollution measurements by stations means that pollution in the region is not managed efficiently or actively. This calls for active, structured management of the problem. The primary aim of this project is to set up a real-time air quality measurement system using measuring equipment. Morocco, as co-host of the 2030 World Cup, is in a strategic position to carry out the project in Mohammédia and Ben Slimane. These are large cities with large areas. Internationally, the region will be impacted during the cup. During the matches, pollution management will be essential to balancing pollution levels and protecting people's health. This will help ensure that the events run smoothly and have a positive impact. The expected results include the establishment of a network of mobile stations to monitor air pollution at several strategic locations. This data will be crucial for shaping public health and environmental planning policies. The objective is to inform the local population and international visitors to areas of high air pollution about related issues, particularly during major international events. This will encourage more responsible environmental management.
Keywords: Air pollution, Air quality, Mobile station, Pollution monitoring, Pollution sensors, AQI (Air Quality Index), City buses, Urban management, Pollution mapping, Real-time monitoring, Environmental awareness, Environmental technology, 2030 World Cup, Global events.

1 Introduction

Air pollution is one of the most significant environmental challenges modern cities face. In densely populated areas like Mohammédia and its surroundings, air quality is deteriorating rapidly due to the emissions of harmful gases and particulates (PM2.5 and PM10) from transportation, industry, and anthropogenic activities. Prolonged exposure to these pollutants,

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as reported by the WHO, poses serious public health problems, including respiratory and cardiovascular diseases and increased premature mortality [1],[2].
Air quality management is critical in relation to the health of the spectators and the athletes, as well as Morocco's vision of supporting sustainable development in the frame of the upcoming significant international event - the 2030 World cup. Mohammédia will be at the center of these activities as it is adjacent to the large stadium in Ben Slimane. Therefore, enhancing air pollution monitoring serves to both fulfill the immediate requirements of the world event and equip the city to face environmental challenges in the years to come [3],[4].
This project involves creating a mobile station integrated into urban vehicles for monitoring air pollution, particularly on buses in the city of Mohammédia. This innovative approach could enable real-time pollution measurements and provide valuable information on air quality over a period of one year and across a large geographical area [5]. Unlike fixed stations, this mobile solution is not limited to one city, but offers flexible coverage that can be adapted to the needs of the city of Mohammédia and its surroundings [6].
The mobile station is equipped with an ESP32 microcontroller for data processing with state-of-the-art air quality sensors [7], as well as a real-time transmission system via Wi-Fi or GSM [8]. It is designed to produce a dynamic map of air pollution and its evolution over time in order to inform the authorities, but also the inhabitants, for appropriate public health decisions [9].
In this context, this project is part of a framework of sustainable development and participatory science, helping to manage pollution during the 2030 World Cup and also providing local, lasting solutions to foster a healthier and greener future for the population of Mohammédia and Ben Slimane [10],[11].

2 Project Context

Related works

The objective of this project is to design a mobile air pollution monitoring station capable of measuring and processing pollution in real time in the city of Mohammédia and its surroundings, including the city of Ben Slimane. Given the geographical proximity of these two cities to the large stadium that will host the 2030 World Cup matches, they will face major challenges in managing air pollution before and during the event, and, to some extent, after the competition.

Several initiatives around the world have already explored the use of mobile measuring stations to overcome the limitations of fixed stations. In Europe and North America, for example, buses and some municipal vehicles have been equipped with sensors for dynamic pollution mapping in cities. These experiments show that mobility is a major asset for quickly covering large areas and collecting representative data in real time [12],[13].

Another relevant line of work is the use of low-cost sensors combined with artificial intelligence techniques. These particular sensors are much cheaper than traditional stations and allow for better coverage of the monitoring network. Raw data, which is often biased and uncertain, can be improved by machine learning algorithms that increase the accuracy and confidence of metrics [14]. Several international studies also confirm the value of these approaches for urban monitoring, highlighting their ability to improve predictive modeling and increase the reliability of measurements [15],[16]. This combination of technologies is a

promising approach for large-scale projects with high international visibility, such as the World Cup.

Finally, new studies have highlighted the need for inter-system interoperability, real-time data acquisition, and processing of relevant environmental information. The incorporation of IoT (Internet of Things) platforms not only consolidates measurements obtained from disparate sensors, but also enriches data with predictive machine learning and Big Data modeling. This technological convergence helps with the proactive detection of pollution episodes, the automated optimization of urban traffic configuration, and the rapid development of response scenarios [17],[18]. Similarly, recent research has shown that new-generation sensors enable accurate estimation of hourly concentrations of PM2.5 fine particles across an entire urban area, paving the way for automated and self-adaptive air quality control [19].

Project Objectives

The aim of this project is to design a mobile air pollution monitoring station with real-time air pollution measurement and processing capabilities in the city of Mohammédia and its suburbs, including the city of Ben Slimane. Given the geographical proximity of the two cities to the large venue that will host the 2030 World Cup matches, they will face major challenges in managing air pollution before and during the event and, to some extent, after the competition.
The specific objectives of this project are as follows:

- ✓ Develop a mobile station mounted on urban buses in Mohammédia to monitor air pollution in real time.
- ✓ Measure key air pollutants such as PM2.5 and PM10 fine particles, NO2, CO, VOCs, CO2, temperature, and humidity in order to develop a relevant air pollution measurement index.
- ✓ Offer a mobile solution that allows for broad and significant geographical flexibility adapted to the dynamics of a city, resulting in cost savings compared to fixed measuring stations.
- ✓ Assist in delivering real-time data useful for local-level decision-making for pollution management and public health policy.
- ✓ Support educating individuals on air pollution by directly granting them access to information on air quality, especially in the lead-up to the 2030 World Cup.

Project justification

Air quality management in cities is important for controlling health risks to urban populations, while comparing variations in air quality. Airports, as well as television and radio stations, are subject to conventional monitoring, but their high cost and fixed nature distinguish them from other places of urban interest such as the 2030 World Cup stadiums and others. Their restricted and peripheral access prevents citizens from responding effectively to pollution crises in their environment. The option we propose, which is to build a mobile station, meets several objectives:

- ✓ Follow bus routes throughout the city and pass by all places of interest. In this way, the mobile station collects data at various times of the day, thus complementing the fixed station.
- ✓ Mobile stations are both more convenient and less expensive than fixed stations. Not only are these infrastructures less costly, but they are also easier to install.

- ✓ Impact local: Integrating this station into the urban transit system will enable the collection of pertinent air quality information before and during the 2030 World Cup. This will be important for safeguarding the health of visitors and citizens.
- ✓ Civic engagement: This project enhances the participatory approach to governance as it empowers citizens with real-time data on air quality, thereby actively engaging the public in managing pollution in the context of a science-informed environment.

In short, this project will contribute to sustainable development. It aligns with the Morocco's environmental objectives and could be a significant step, in the long-term, in the sustainable management of air pollution, while having a direct and positive impact on the quality of life of the residents of Mohammédia and Ben Slimane.

3 System Components and Architecture

3.1 System Components

The mobile surveillance station for air pollution monitoring works as a system composed of multiple components that enables efficient and real-time data collection, processing, and transmission. Each component has a specific range for its reliability, accuracy, and its integration within the system. The following are the main components of the system:

3.1.1 Air Pollution Sensors

- PMS5003: It is used for measuring particulate matter PM2.5 and PM10. These particles are a measurement of air pollution and are a good indicator of the atmospheric pollution level, where they are mostly found around the urbanized areas.
- MQ-135: The sensor is used for measuring pollutants such as nitrogen dioxide NO_2, carbon monoxide CO and other toxic atmospheric gases. This sensor is important for monitoring the harmful gas emissions from vehicles, from energy generation, and from other related activities.
- MQ-7: He is a specialist for the monitoring of the carbon monoxide gas (CO). This gas is extremely dangerous as it is odorless and can build up in enclosed spaces thus posing a serious health risk.
- MH-Z19C: This sensor is dedicated to measuring carbon dioxide (CO_2) which is important in the context of monitoring air quality because it can have indirect health effects by influencing ventilation in enclosed areas.
- CCS811: This sensor measures volatile organic compound (VOCs) which are pollutants associated with consumer products, paints, and construction materials. VOCs are associated with a number of undesirable health impacts.
- BME280: This sensor measures temperature, humidity, and atmospheric pressure. These data are critical for adjusting the measurements made by other sensors since temperature and humidity may affect the accuracy of measuring gases and particulate matter.

3.1.2 ESP32 microcontroller

- The microcontroller ESP32 serves as the system's backbone. It collects data from the sensors, processes the information in real time, and disseminates it through a wireless network. ESP32 has several advantages:

- Wi-Fi and GSM connectivity: It enables real time transmission of the collected data to a central database, which can be accessed by local authorities or through a mobile application by citizens.
- Calcul local des indices de qualité de l'air (AQI): Le microcontrôleur calcule l'Air Quality Index (AQI) à partir des données des capteurs, permettant ainsi de fournir une mesure simple et compréhensible de la pollution.
- Low energy consumption: L'ESP32 is designed to be energy efficient, which is critically important for a mobile station powered by rechargeable batteries or the bus's power supply.

Power supply

Power supply: a rechargeable battery or a 12V connector via the bus can power the station. The power supply is stable and sufficient for all the components to function uninterrupted for several hours.

3.2 System architecture

The pollution monitoring system is organized around the three key functions of data collection, data processing, and data transmission. Here is how each function is structured:

Data collection

The sensors monitor air quality parameters for particulate matter, gases, temperature, humidity, and pressure continuously. These parameters are collected at predefined intervals of 30 seconds to 1 minute.

Data processing

Data is collected and sent to the ESP32 microcontroller for processing. The microcontroller carries out some real-time processing, like converting measurements to AQI indices, to provide an instantaneous and easily interpretable evaluation of air quality.

Data transmission

After processing, data is sent over Wi-Fi or via the GSM modem to the central database where it can be accessed in real-time by local authorities and citizens through a mobile application. The data is also saved locally on an SD card to enable access later in the event of a disconnection.

User interface

A basic user interface is provided through a two by sixteen (2x16) LCD screen which displays information such as AQI, PM2.5 and PM10 levels as well as temperature in real time. This gives a snapshot view of the air quality for the passengers and the bus operators.

Architecture of the pollution monitoring system

The presented architecture (Fig. 1) illustrates the general structure of the air pollution monitoring system. It is based on a set of heterogeneous sensors allowing the simultaneous measurement of several environmental parameters (see Fig. 1)**.**

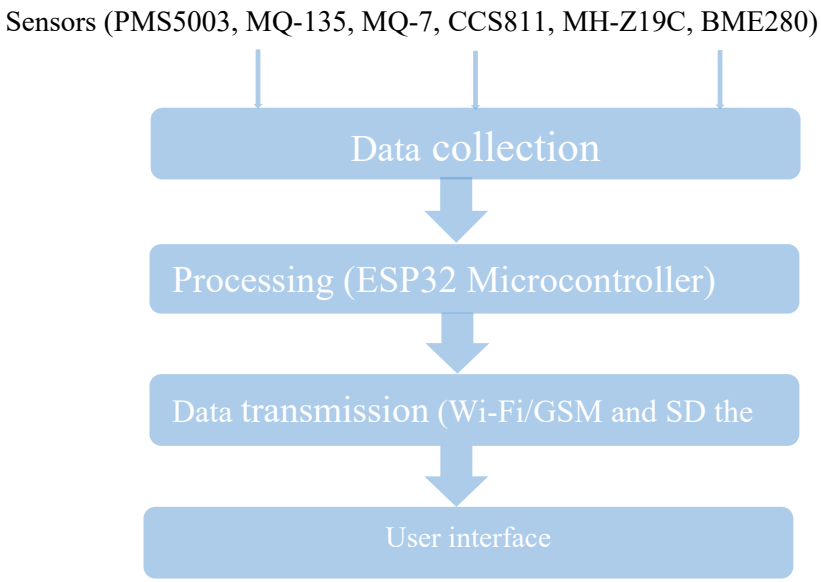

Fig. 1. Architecture of the pollution monitoring system

Fritzing Schematic

Here is a basic Fritzing diagram for the air pollution monitoring station (see Fig. 2).

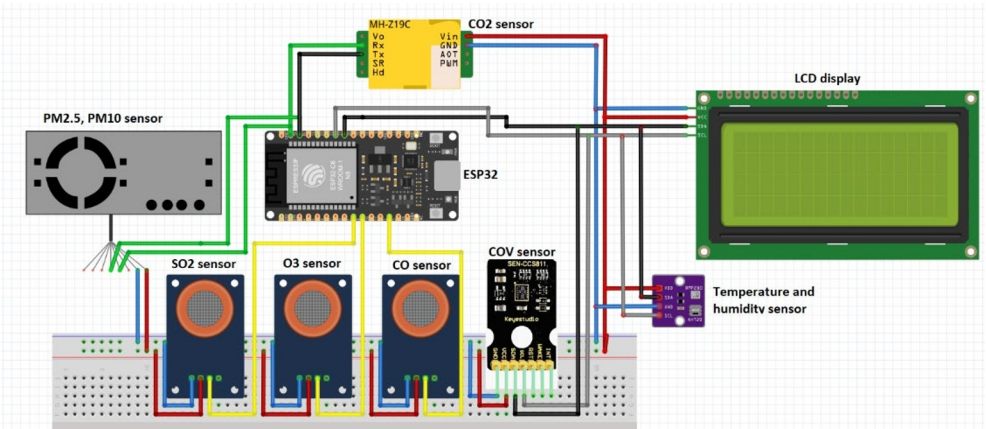

Fig. 2. Electronic diagram of the box components designed on (Fritzing).

- Each sensor is connected to an ESP32.

- The PMS5003, MQ-135, MQ-7, MH-Z19C, CCS811, and BME280 sensors will be connected to the ESP32 pins for reading data.
- The LCD 2x16 is connected to the ESP32 through I2C interface.

4 Box Design and Component Impregnation

4.1 Box Design

The box that houses the components of the mobile station surveillance system for air pollution is the box, which has the requirements of protection, durability, accessibility, and ventilation. It has to be robust enough to endure the dust, humidity, and vibration, but still, be lightweight and compact enough to sit on the buses.

Distribution of sensors inside

Optimal sensor placement: Fine particle and gas sensors (PMS5003, MQ-135, MQ-7, CCS811, MH-Z19C) should be placed so that they are exposed to the maximum amount of ambient air. Gas and VOC sensors should face air inlets, and the particle sensor should be placed in an area where air can circulate freely.
Air management: Air force: sensors should be placed approximately 5 cm from openings to ensure good air circulation and prevent blockages.

Sensor separation: Gas and particle sensors should be spaced slightly apart to prevent interference between measurements from different units. Sensors should be sealed inside the housing but easily accessible for maintenance or replacement (see Fig. 3).

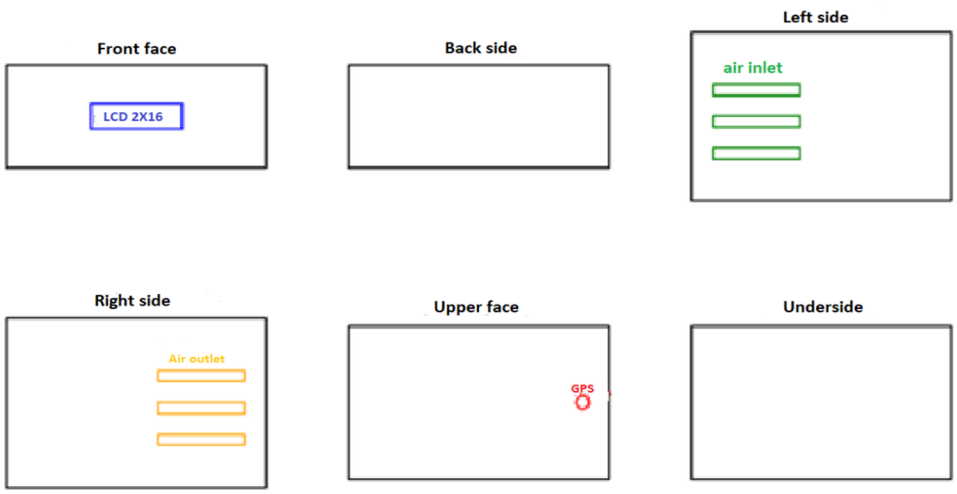

Fig. 3. Detailed 2D plan of the 6 sides of the box

Modular design that allows for quick installation on a vehicle (bus)

Modular fastening system: The enclosure is designed for easy installation on the roof. Adjustable brackets provide ease of installation on any type of bus and provide custom fit. The station can be secured with bolts and screws.

Easy to maintain: The enclosure is configured to provide quick access to the internal components for tasks like sensor replacement, battery recharges, and system level maintenance.

Heat dissipation and moisture control

Thermal heat dissipation: Electronic components like the microcontroller ESP32 and sensors can produce heat with the electronic bus's system. The enclosure has ventilation slots on the sides to allow warm air to escape bus systems and dissipate heat that has built up internally. Aluminum plates can also be added to assist with the absorption of heat and to prevent overheating of the components.
Humidity Management: An anti-condensation film, or hermetic plugs for the openings, aids in protecting the inside of the casing from humidity. The casing also has to be waterproof to prevent water from entering in the event of rain or condensation (see Fig.4).

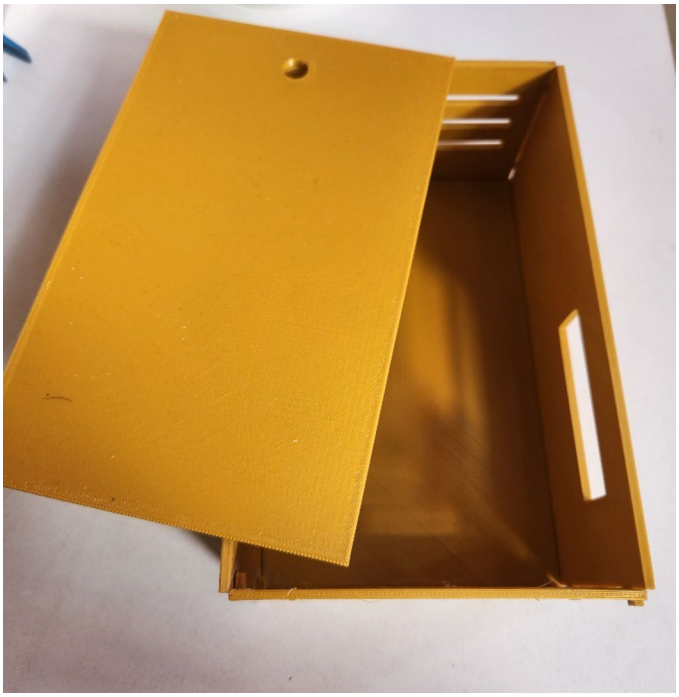

Fig. 4. Actual photo of the box after 3D printing

Exterior view of the printed ABS case, showing the openings for ventilation, internal supports, and the modular mounting system.

Ventilation and Air Flow

Air circulation is essential for the proper functioning of the sensors. Particle and gas sensors (PMS5003, MQ-135, MQ-7) must have access to an undisturbed air sample to ensure reliable measurements.

Openings for gas and particle sensors

Air inlets: Ambient air is introduced through 40 mm * 5 mm slots located on the left side of the device, where the gas sensors are located. The openings are arranged to minimize dust ingress while ensuring optimal airflow for measurement.
Air outlets: 40 mm * 5 mm slots are also present on the right side of the housing so that air flows through the housing, is measured by the fine particle sensor (PMS5003), and then expelled.
Airflow optimization: The positioning of the openings on opposite sides optimizes air circulation, commonly referred to as crossflow. This flow is necessary for measuring particles and gases. It also ensures that the data collected by the sensors is as accurate as possible.

5 Implementation and Testing

5.1 Communication between Sensors and the ESP32 Microcontroller

The reliability and accuracy of the system depend on optimal communication between the sensors and the ESP32. Each sensor communicates according to a specific protocol:

Table 1: Sensor communication protocol

Sensor	Setting	Protocol	Data type
PMS5003	PM2.5, PM10	UART	Digital
MH-Z19C	CO_2	UART	Digital
BME280	Temp, Humidity, Press.	I^2C	Digital
CCS811	COV	I^2C	Digital
MQ-135, MQ-7	NO_2, CO	ADC	Analog

5.2 Sensor calibration

PMS5003 (PM2.5, PM10)

Raw data is multiplied by a calibration factor to obtain the concentration in µg/m³.

$$Concentration = Raw\ Value \times Calibration\ Factor \quad (1)$$

MH-Z19C (CO_2)

Raw data is adjusted with an offset and calibration factor to obtain the concentration in ppm.

$$CO2\ (ppm) = \frac{Raw\ value - offset}{calibration\ factor} \quad (2)$$

BME280 (Temperature, Humidity, Pressure)

Raw values are directly converted into real units (°C, %, hPa) using calibration coefficients provided by the manufacturer.

$$Temperature = \frac{Raw\ Value\ x\ Factor}{100} \quad (3)$$

$$Humidity = \frac{Raw\ Value\ x\ Factor}{100} \quad (4)$$

$$Pressure = \frac{Raw\ Value\ x\ Factor}{100} \quad (5)$$

CCS811 (VOC, CO_2)

Uses an internal algorithm to calculate VOC and CO_2. Raw data is converted to ppb and ppm based on the calibration factors provided.

$$COV\ (ppb) = \frac{Raw\ Value}{VOC\ calibration\ factor} \quad (6)$$

$$CO2\ (ppm) = \frac{Raw\ Value}{CO2\ calibration\ factor} \quad (7)$$

MQ-135 and MQ-7 (NO_2, CO)

Analog values are converted to ppm using a calibrated resistor and a calibration curve.

$$Concentration\ (ppm) = \frac{Analog\ Value}{\boldsymbol{R}cal} \quad (8)$$

5.3 System Development and Implementation

In order to validate the developed concept, a functional prototype was created and tested. The figure below illustrates the pollution calculation and monitoring system in its real version (see Fig. 5).

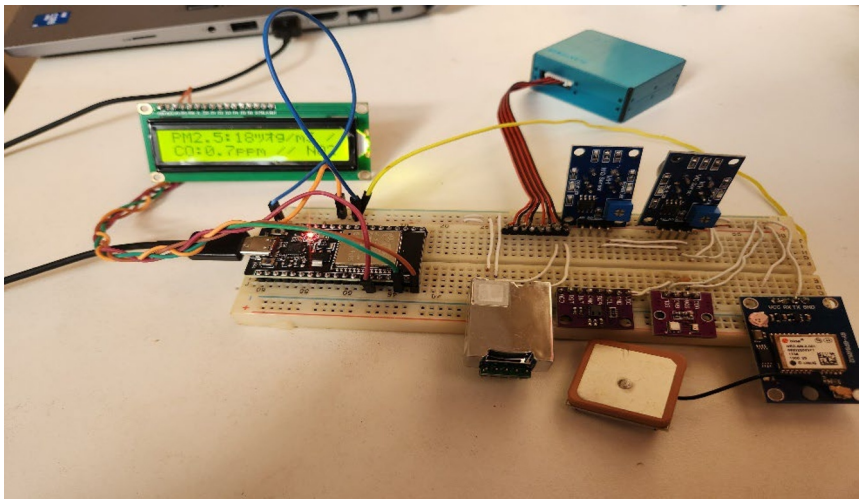

Fig. 5. Prototype of the pollution calculation system

This prototype integrates measurement sensors (CO_2, PM2.5, temperature, humidity, etc.) and the ESP32 microcontroller. It has been tested to assess its reliability in a real-world environment.

Field Test Values

The first tests carried out in real conditions (typical urban traffic) validated the system's operation. Here is a representative example of the values obtained during a test:

Table 2: Results table

Hour	PM 1.0 (µg/m³)	PM 2.5 (µg/m³)	PM10 (µg/m³)	CO (ppm)	CO_2 (ppm)	NO_2 (ppm)	TVOC (ppb)	Temp (°C)	Humidity (%)	Pressure (hPa)	Latitude	Longitude
00:00	12	18	25	0.4	420	0.02	150	22	70	1012	33.68	-7.419
03:00	10	15	22	0.3	415	0.01	120	21	72	1013	33.68	-7.419
06:00	18	25	35	0.5	430	0.03	200	20	75	1014	33.68	-7.419
09:00	30	45	60	0.7	450	0.05	250	24	60	1012	33.68	-7.419
12:00	35	55	70	0.8	460	0.06	300	27	55	1010	33.68	-7.419
15:00	40	60	80	0.9	470	0.07	350	28	50	1008	33.68	-7.419
18:00	45	70	90	1.0	480	0.08	400	26	55	1009	33.68	-7.419
21:00	25	40	55	0.6	440	0.04	220	24	65	1011	33.68	-7.419
23:00	15	25	35	0.5	430	0.03	180	23	68	1012	33.68	-7.419

5.4 Problems encountered

Communication issues

Some connectivity issues may arise, especially in areas with poor network coverage. In these cases, solutions are put in place, such as using GSM for areas not covered by Wi-Fi, or storing data locally on the SD card until the connection is restored.

Sensor calibration

Sensor calibration can be challenging, particularly for gas sensors, which require specific conditions to function optimally. Regular calibration procedures are in place to ensure measurement accuracy.

Power management

Another issue encountered is power management during long journeys. Sometimes the battery can discharge faster than expected. Energy consumption optimization strategies are implemented to improve the station's autonomy, in particular by activating standby modes during periods of inactivity.

6 Conclusion

This project has enabled considerable progress in air quality monitoring. The described device is installed in mobile urban bus units. As a result, the cities of Mohammédia and Ben Slimane have received a mobile air pollution monitoring station. Its application provides real-time data on air quality throughout the city with appropriate measurement accuracy. In addition, the system proved incredibly convenient and easy to deploy, as demonstrated by field tests.

Future applications of your project appear to offer strong potential for improving pollution control. The addition of predictive analytical algorithms could help predict events leading to pollution spikes. This would mean that air quality could be managed proactively, and pollution control needs could be anticipated much more quickly and effectively. This system could even be extended to other cities. It offers the opportunity to expand data collection nationwide and beyond. As such, it could inspire other developing countries to implement similar solutions to combat air pollution.

Finally, it will encourage greater collaboration between local governments, public health organizations, and educational institutions. By integrating more areas of public policy, the impact of the project can be maximized for the environment and health. This project paves the way for better air quality management and a healthier future in cities.

References

1. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. Frontiers in Public Health, 8.
2. Mannucci, P., Harari, S., Martinelli, I., & Franchini, M. (2015). Effects on health of air pollution: a narrative review. Internal and Emergency Medicine, 10, 657-662.
3. Hemamalini, R., Vinodhini, R., Shanthini, B., Partheeban, P., Charumathy, M., & Cornelius, K. (2022). Air Quality Monitoring and Forecasting using Smart Drones and Recurrent Neural Network for Sustainable Development in Chennai City. Sustainable Cities and Society.
4. Rafaj, P., Kiesewetter, G., Gül, T., Schöpp, W., Cofala, J., Klimont, Z., Purohit, P., Heyes, C., Amann, M., Borken-Kleefeld, J., & Cozzi, L. (2018). Outlook for clean air in the context of sustainable development goals. Global Environmental Change.
5. Idrees, Z., & Zheng, L. (2020). Low cost air pollution monitoring systems: A review of protocols and enabling technologies. J. Ind. Inf. Integr., 17, 100123.
6. Dhingra, S., Madda, R., Gandomi, A., Patan, R., & Daneshmand, M. (2019). Internet of Things Mobile–Air Pollution Monitoring System (IoT-Mobair). IEEE Internet of Things Journal, 6, 5577-5584.
7. Moharana, B., Anand, P., Kumar, S., & Kodali, P. (2020). Development of an IoT-based Real-Time Air Quality Monitoring Device. 2020 International Conference on Communication and Signal Processing (ICCSP), 191-194.
8. Janaki, K., Eapen, M., Meera, M., Bhendale, M., Arun, S., & Krishnamoorthy, R. (2024). Enhancing Environmental Safety: Design and Development of IoT based Air Quality Monitoring System. 2024 5th International Conference on Image Processing and Capsule Networks (ICIPCN), 845-850.

9. Khan, A., Khan, M., Hasan, M., Zakri, W., Alhazmi, W., & Islam, T. (2022). An Efficient Wireless Sensor Network Based on the ESP-MESH Protocol for Indoor and Outdoor Air Quality Monitoring. Sustainability.
10. Manshur, T., Luiu, C., Avis, W., Bukachi, V., Gatari, M., Mulligan, J., Ng'an'ga, D., Radcliffe, J., Singh, A., Waiguru, E., Wandera, A., & Pope, F. (2023). A Citizen Science Approach for Air Quality Monitoring in a Kenyan Informal Development. City and Environment Interactions.
11. Commodore, A., Wilson, S., Muhammad, O., Svendsen, E., & Pearce, J. (2017). Community-based participatory research for the study of air pollution: a review of motivations, approaches, and outcomes. Environmental Monitoring and Assessment, 189, 1-30.
12. El Khaili, M., Bakkoury, J., Khiat, A., & Alloubane, A. (2018). Crowdsourcing by IoT using LabVIEW for measuring the air quality. ACM International Conference Proceeding Series.
13. Jiao, W., Hagler, G., Williams, R., Sharpe, R., Brown, R., Garver, D., & Rice, J. (2016). Community Air Sensor Network (CAIRSENSE) project: evaluation of low-cost sensor performance in a suburban environment in the southeastern United States. Atmospheric Measurement Techniques, 9(11), 5281–5292.
14. El Arfaoui, A., Nhaila, H., & El Khaili, M. (2025). Developing a real-time atmospheric pollutant monitoring method with high accuracy and wide measurement range. 2025 5th International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET).
15. Castell, N., Dauge, F. R., Schneider, P., Vogt, M., Lerner, U., Fishbain, B., & Bartonova, A. (2017). Can commercial low-cost sensor platforms contribute to air quality monitoring and exposure estimates? Environment International, 99, 293–302.
16. Rai, A. C., Kumar, P., Pilla, F., Skouloudis, A. N., Di Sabatino, S., Ratti, C., & Yasar, A. (2017). End-user perspective of low-cost sensors for outdoor air pollution monitoring. Science of The Total Environment, 607-608, 691–705.
17. Essamlali, I., Nhaila, H., & Khaili, M. E. (2025). Impact of urban block shape on traffic and air quality: A SUMO-based comparative study of rectangular, radial, and triangular forms. Transportation Research Interdisciplinary Perspectives, 31, 101413.
18. Kumar, P., Skouloudis, A. N., Bell, M., Viana, M., Carotta, M. C., Biskos, G., & Morawska, L. (2020). Real-time sensors for indoor air monitoring and challenges ahead in deploying them to urban buildings. Science of The Total Environment, 751, 141803.
19. Zikova, N., Masiol, M., Chalupa, D. C., Rich, D. Q., Ferro, A. R., Hopke, P. K., & Utell, M. J. (2017). Estimating hourly concentrations of PM2.5 across a metropolitan area using low-cost particle monitors. Sensors, 17(9), 1922.