ACCEPTED MANUSCRIPT

Technical Sciences

Title: Mobile air quality monitoring station - a solution for better pollution control

Authors: Seweryn Lipiński1, Jarosław Piotrowski, Tomasz Olkowski

To appear in: Technical Sciences

Received 6 June 2025;

Accepted 27 October 2025;

Available online 5 December 2025.

MOBILE AIR QUALITY MONITORING STATION - A SOLUTION FOR BETTER POLLUTION CONTROL

Seweryn Lipiński[1,], Jarosław Piotrowski, Tomasz Olkowski[2]*
[1] ORCID: 0000-0001-9771-6897
[2] ORCID: 0000-0003-3783-1281
Faculty of Technical Sciences, University of Warmia and Mazury in Olsztyn, Poland
**correspondence: seweryn.lipinski@uwm.edu.pl*

Abstract

The paper presents the design of a mobile air quality monitoring station. Its mobility is defined by a lightweight and compact structure, allowing easy transportation and use without additional equipment. To enhance user convenience, a system for storing and analysing the collected data was implemented on an internet server, connected to a web application. The device includes a PM1.0/PM2.5/PM10 sensor, a barometer and hygrometer both with built-in temperature sensors, and two gas sensors. A GPS module provides precise location data, and a GSM module enables wireless transmission of results. The system is powered by Li-Ion batteries, with extended operation time thanks to a photovoltaic panel. The system was tested by comparing its measurements with air quality data from airly.eu, ensuring time and location consistency. The comparison confirmed the device's accuracy while further tests in mobile mode, i.e., walking, cycling, and driving showed that the system's mobility increases the number of measurement points, enhancing local air pollution monitoring. Mobile stations could be beneficial, especially in areas with a low density of monitoring stations, e.g. by using vehicles on fixed routes, such as public transport. This would allow effective air quality control and localization of point-source pollution.

Keywords: air quality monitoring; localized pollution detection; environmental sensors; portable microcontroller devices; environmental data collection

Introduction

Civilization and technology are advancing at a rapid pace. One of the obvious negative consequences of industrial progress is the increase in air pollution. Higher production levels and a consumer-driven culture contribute to the generation of various pollutants, including those affecting air quality. The adverse effects of poor air quality can be detrimental to human health and life, as well as to the surrounding environment (Dziubiński et al., 2025; Mitchell and Chapman, 2025; Ngutuka Kinzunga et al., 2024).

The demands of human society have reached such a scale that the planet is no longer capable of fully regenerating its resources. This results in the phenomenon of "ecological debt," which refers to the number of days remaining in the year after the planet has exhausted its regenerative capacity. This day, known as Earth Overshoot Day, has shown an increasing trend since the 1970s. In 2024 this day occurred on August 1 (Earth Overshoot Day, 2025).

However, there is also a growing awareness among people about these issues, which has led to the development of various regulatory frameworks and monitoring systems aimed at controlling resource consumption and pollution production. Air quality monitoring systems can now be found in most major cities. Due to the high costs of traditional solutions, the establishment of stationary monitoring stations is expensive, resulting in limited coverage and monitoring of small, localized areas (Chen et al., 2024; Kirešová and Guzan, 2022).

A potential solution to the insufficient number of monitoring points is the creation of a system based on low-cost mobile monitoring stations. These stations, equipped with GPS modules, can conduct air quality measurements while considering the exact location, enabling more widespread and dynamic monitoring (World Meteorological Organization, 2025; Zhu et al., 2021).

The above analysis was our inspiration for the design of such a mobile air quality monitoring station, offering a cost-effective, flexible alternative to stationary systems. The device's mobility allows for broader geographic coverage and more detailed data on air pollution, especially in areas where monitoring infrastructure is limited (Shiva Nagendra et al., 2019; Wu et al., 2024).

The paper presents its design. The term "mobile" refers to the lightweight and compact construction of the device, which enables easy transport and operation without the need for additional equipment. To enhance user convenience, a system has been implemented to store and analyse the collected data, hosted on a web server and connected to a user interface in the form of a web application (Purkayastha et al.,2021; Şahin et al., 2017).

The device includes a dust/air quality sensor (PM1.0/PM2.5/PM10), a barometer, and a hygrometer, both equipped with temperature sensors. Additionally, it features two gas sensors: the first detects ammonia, hydrogen sulfide, ethanol, and toluene, while the second detects ammonia, alcohol, smoke, carbon dioxide, nitrogen oxides, and benzene. A GPS module allows for precise location tracking of the measurements, and the GSM module ensures wireless transmission of the results. The system is powered by a rechargeable Li-Ion battery, with extended operation time provided by a photovoltaic panel.

The designed system has been tested, and the measured air quality parameters were compared with data obtained from the airly.eu portal, ensuring alignment of measurement time and location. The comparison demonstrated the device's accurate performance, with the results being closely aligned.

Subsequent tests were conducted to evaluate the device's performance in a mobile mode, with measurements taken at various movement speeds—on foot, by bicycle, and by car. The results showed that the mobility of the system enables an increased number of measurement points, leading to a better understanding of air pollution, particularly localized sources.

Project of the mobile air quality monitoring station

Block diagram and sensors used in the project

The measuring station comprises a control system, measuring modules, sensors, GSM and GPS modules, and a power supply. All components are enclosed in a housing that features a roof to protect against atmospheric precipitation while ensuring adequate air circulation. These elements are interconnected on a custom-designed PCB.

The individual components of the measuring station are illustrated in the diagram shown in Fig. 1.

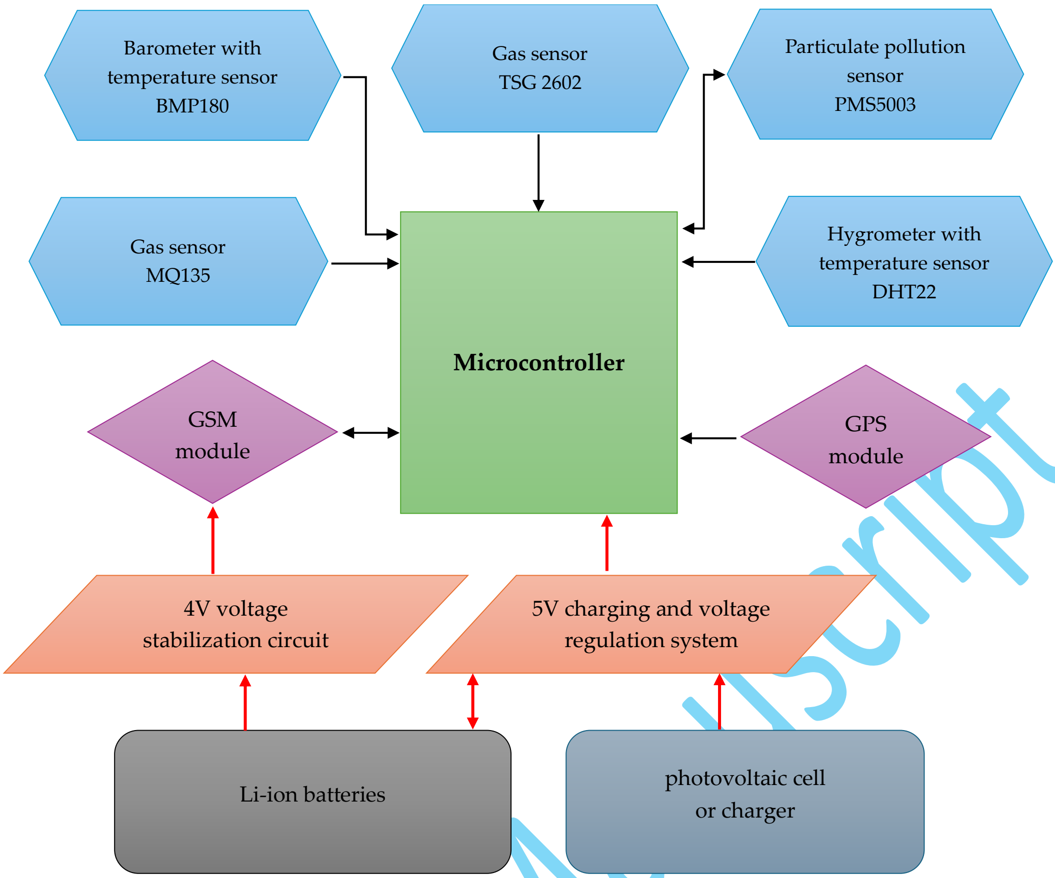


Fig. 1. Connection block diagram of the mobile air quality monitoring station (arrows show the direction of information/power flow).

The control system is built around the classic Arduino Uno rev 3 board, an open-source electronics platform. Its user-friendly software and hardware make it popular and versatile. The affordability and capabilities of Arduino made it the optimal choice for this project.

To measure the specified environmental parameters, the system utilizes digital sensors: PMS5003 for particulate matter (PM1.0, PM2.5, PM10) (Kaur and Kelly, 2023), BMP180 for atmospheric pressure and temperature (Ioannou et al., 2021; Mobaraki et al. 2022), and DHT22 (Mobaraki et al. 2022) for humidity and temperature. In addition, the station is equipped with analog gas sensors: MQ135 (Hassan et al., 2024, Mane et al., 2022), which detects ammonia (NH_3), nitrogen oxides (NO_x), alcohol, benzene, smoke, and carbon dioxide (CO_2), and TGS2602 (Mane et al., 2022), which responds to volatile organic compounds (VOCs) such as ammonia, hydrogen sulfide (H_2S), ethanol (C_2H_5OH), and toluene ($C_6H_5CH_3$).

Communication

After activation, the device initiates a 5-minute stabilization period before sequentially performing the following measurements:

- ambient temperature and humidity,
- atmospheric pressure and temperature,
- particulate matter concentrations (PM1.0, PM2.5, PM10),
- concentrations of hydrogen sulfide (H_2S) and ammonia (NH_3),
- concentrations of nitrogen oxides (NO_x), carbon dioxide (CO_2), and volatile organic compounds (VOCs).

Subsequently, the device determines its current geographic location using GPS signals and compiles all measurement data into a JSON object. This object is then transmitted via the HTTP POST method using the GSM/GPRS communication module to a REST API hosted on a remote web server. Following device authentication, the data is stored in a backend database. The NEO-6M GPS module and the SIM800L GSM/GPRS module were used to facilitate geolocation and data transmission, respectively.

Power supply

In line with the project's assumptions, the device was designed to be mobile and therefore required to operate on battery power. The selected battery had to be compact, lightweight, and offer high energy capacity.

Choosing the appropriate battery also necessitated the selection of a compatible charging module and DC-DC converters to provide stable operating voltages for the system components. Most of the modules and sensors, as well as the main control board, require a supply voltage close to 5 V. There are, however, specific exceptions: the BMP180 pressure sensor and the SIM800L GSM/GPRS module. The BMP180 operates at 3.3 V, which is supplied via a dedicated output on the Arduino board's internal voltage regulator. The SIM800L module operates within a voltage range of 3.4-4.4 V but demonstrates unreliable network connectivity at voltages below or near 3.8 V. The optimal operating voltage for stable performance of this module is 4 V.

A lithium-ion battery was selected due to its favourable energy density and compact form factor (Zubi et al., 2018). The design employs Samsung 18650 Li-ion cells with a capacity of 2800 mAh.

The measurement station is powered using a dedicated shield for 18650 batteries. This shield boosts the nominal 3.7 V from the batteries to provide regulated 5 V and 3 V outputs, which are used to power the control board and peripherals requiring these voltages. The power system also incorporates a charging module with built-in protection against overcharging and deep discharge. The shield supports two 18650 batteries and includes four LEDs to indicate the current battery charge level.

To achieve the required 4 V output for the SIM800L module, an LM2596 step-down converter was used.

Prototype development

Based on the outlined assumptions and selected components, the final design of the device was developed. The complete mobile monitoring unit, comprising the enclosure, sensors, lithium-ion power supply, and solar panel, weighs approximately 550 g. The following figures present the elements of the system:

- A detailed schematic of the system is presented in Fig. 2;
- Fig. 3 illustrates the design and fabrication of the printed circuit board (PCB), which implements the schematic shown in Fig. 2;
- Fig. 4 shows the interior of the assembled prototype;
- Fig. 5 presents the three-dimensional model of the device housing, along with the completed enclosure. The photovoltaic panel, mounted on the top, is clearly visible. As mentioned earlier, the housing was designed to allow unobstructed air access for accurate measurements while ensuring resistance to adverse weather conditions;
- Fig. 6 presents an exemplary screenshot of the web application integrated with the mobile air quality monitoring station.

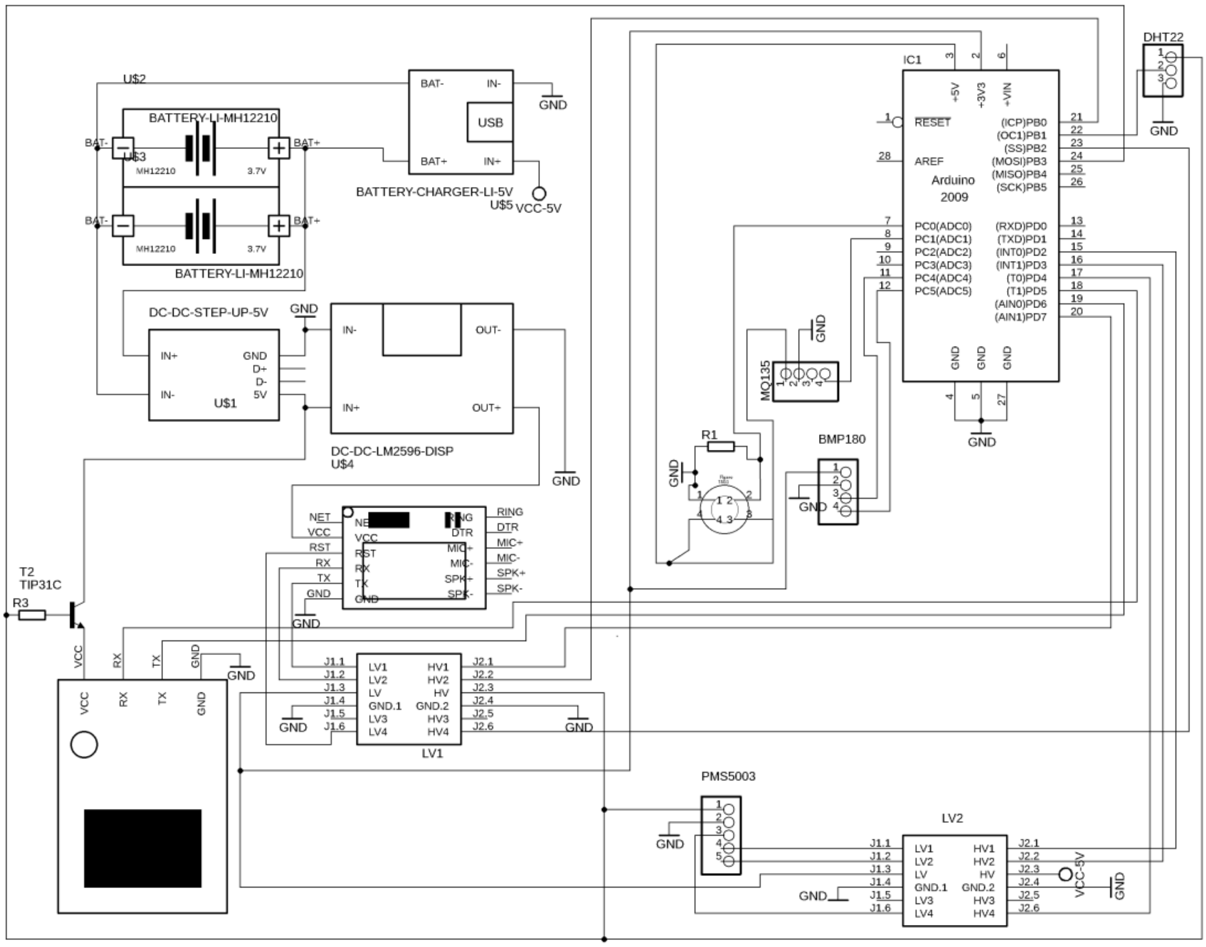


Fig. 2. Detailed connection design of the mobile air quality monitoring station.

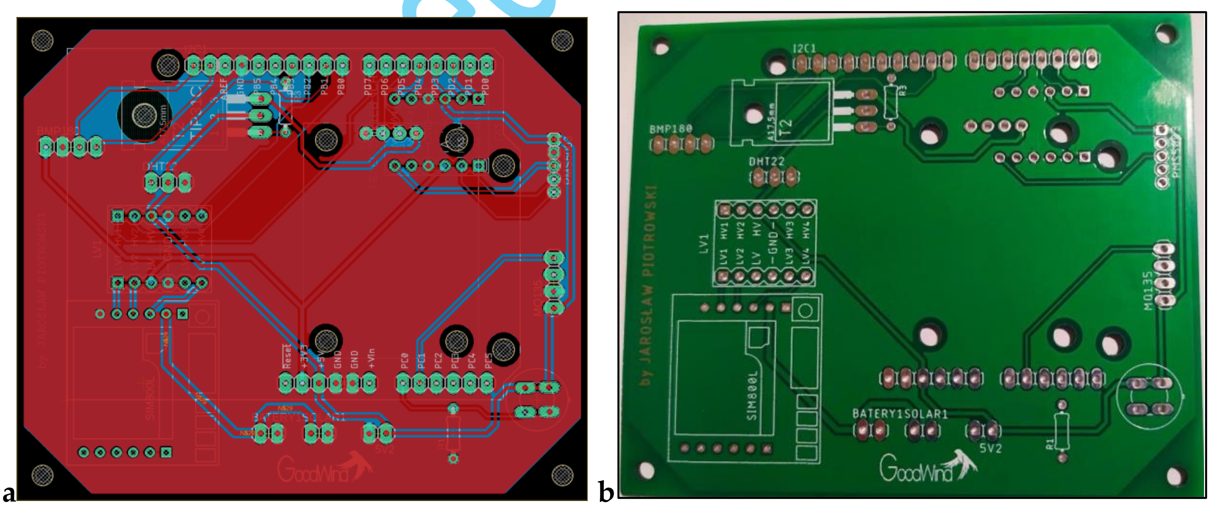


Fig. 3. Project (a) and photo of the fabricated PCB (b) that implements the schematic presented in Fig. 2.

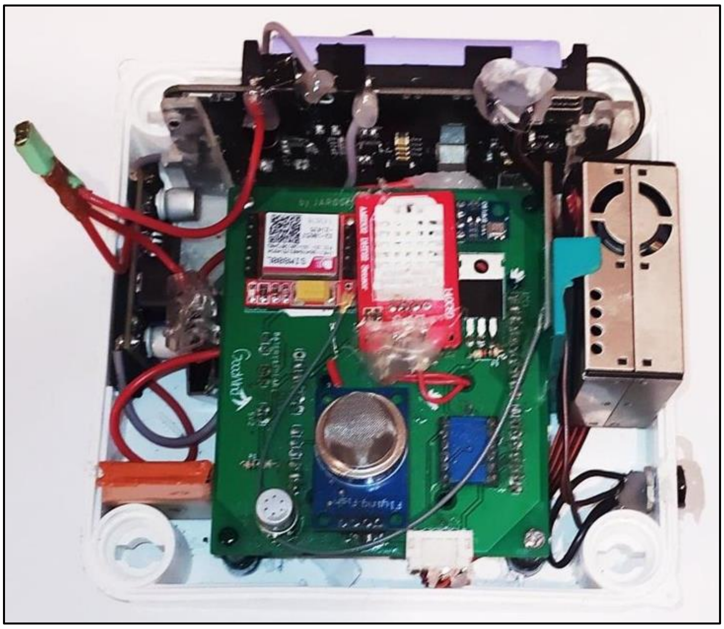


Fig. 4. Interior of the assembled prototype of the mobile air quality monitoring station.

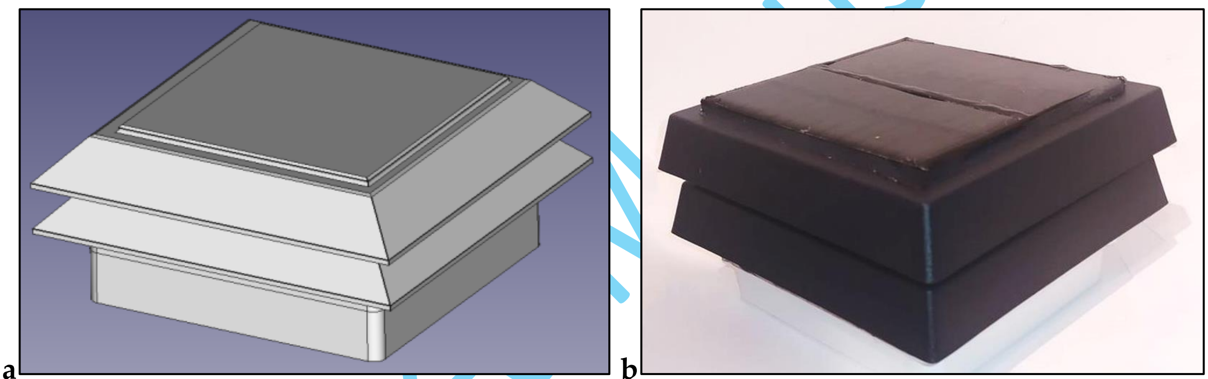


Fig. 5. 3D model of the mobile air quality monitoring station housing (a) and a photo of the assembled device (b) - a photovoltaic panel is visible on the top of the enclosure.

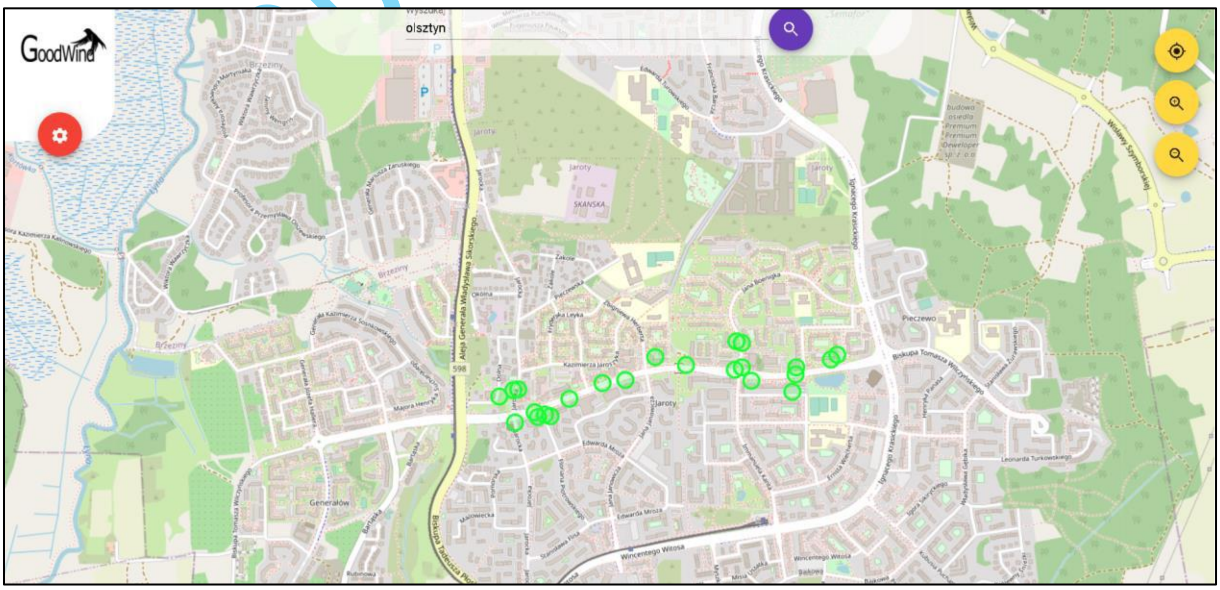


Fig. 6. Exemplary screenshot of the web application integrated with the mobile air quality monitoring station, showing distribution of measurements obtained during a walk.

Results

Comparison of the measurement results obtained with the designed mobile air quality monitoring station and data from the stationary monitoring network

The primary objective of this research was to evaluate the effectiveness and reliability of air quality measurements conducted using a custom-developed mobile monitoring system. The measurements took place in Poland, specifically in northern Mazovia (mainly in Przasnysz) and the city of Olsztyn.

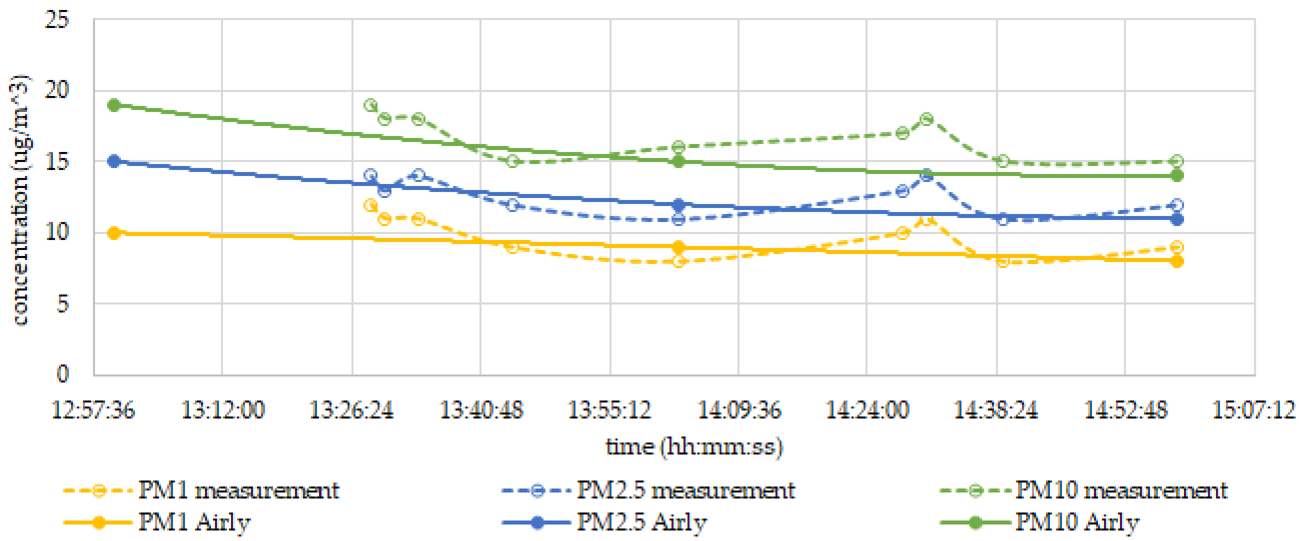
The study aimed to assess the level of agreement between the mobile system's results and those provided by publicly available stationary monitoring stations (Airly platform [airly.org]). It also examined the potential advantages of the mobile system in terms of spatial coverage and measurement frequency.

Measurements were carried out using the previously described mobile air quality monitoring unit. The device was mounted on a vehicle (either a bicycle or a car) or carried by hand. While in motion, it continuously collected and transmitted data to the system's central database. Measurements were performed across different seasons and under various weather conditions. Each location was revisited three to five times to ensure repeated measurements at different times of day and in diverse environmental contexts.

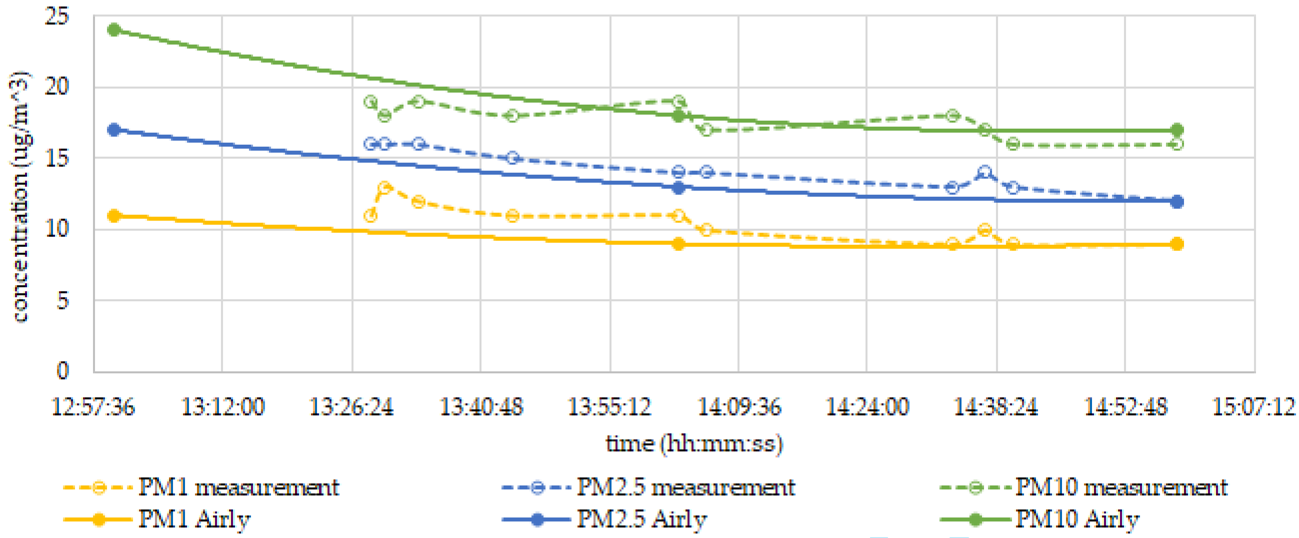
For each measurement scenario, three repetitions were performed to verify data consistency. Additionally, selected tests were conducted in the presence of potentially interfering factors, such as operating lawn mowers or outdoor grills, to assess their impact on measurement accuracy. In total, approximately 750 individual measurements were recorded using the mobile station, with all data stored in the project's integrated database system.

Fig. 7 presents three sample measurement series of PM1.0, PM2.5, and PM10 from three locations in Przasnysz, compared with pollution levels retrieved from the Airly platform. As shown in the Fig., the results obtained with the mobile station are consistent with those from the Airly platform. Moreover, the high temporal resolution of the mobile measurements allows for the detection of short-term pollutant spikes - such as the one observed around 2:30 PM in Fig. 7a - which might be missed by systems with lower sampling frequencies.

a



b



c

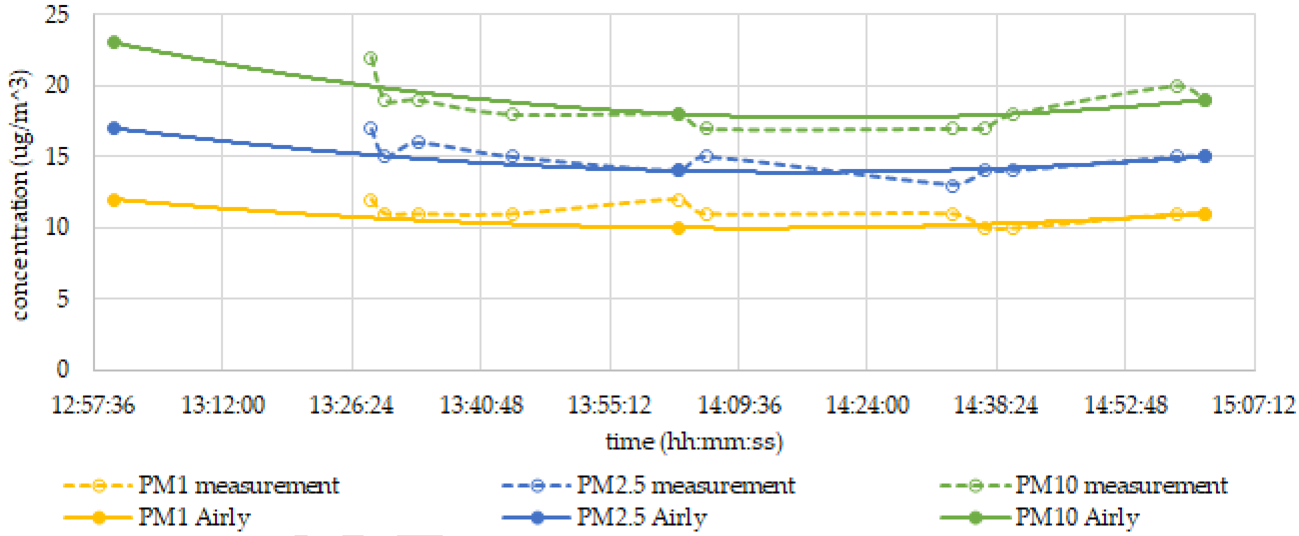


Fig. 7. Comparison of three series of PM1.0, PM2.5, and PM10 measurements (in three locations in Przasnysz, i.e. Marii Dąbrowskiej (a), Lipowa (b), and Kilińskiego (c) streets) with measurements from the Airly Portal.

Exemplary results and observations from field testing of the device

The first example presents results from a test conducted during an 8 km bicycle ride with the monitoring device mounted on the bike (Fig. 8b), carried out in the city of Przasnysz (Poland). These results were compared with data simultaneously recorded by nearby stationary monitoring stations (Fig. 8a). As shown, there are only a few such stations in the city, all located near the city center. Consequently, in the case of localized pollution, monitoring based solely on these stations would fail to detect the significant pollution observed along the mobile route (red circle). This demonstrates the potential value of mobile monitoring, particularly in areas with sparse stationary coverage. Regularly moving vehicles, such as public transport, appear to be a practical platform for deploying such devices.

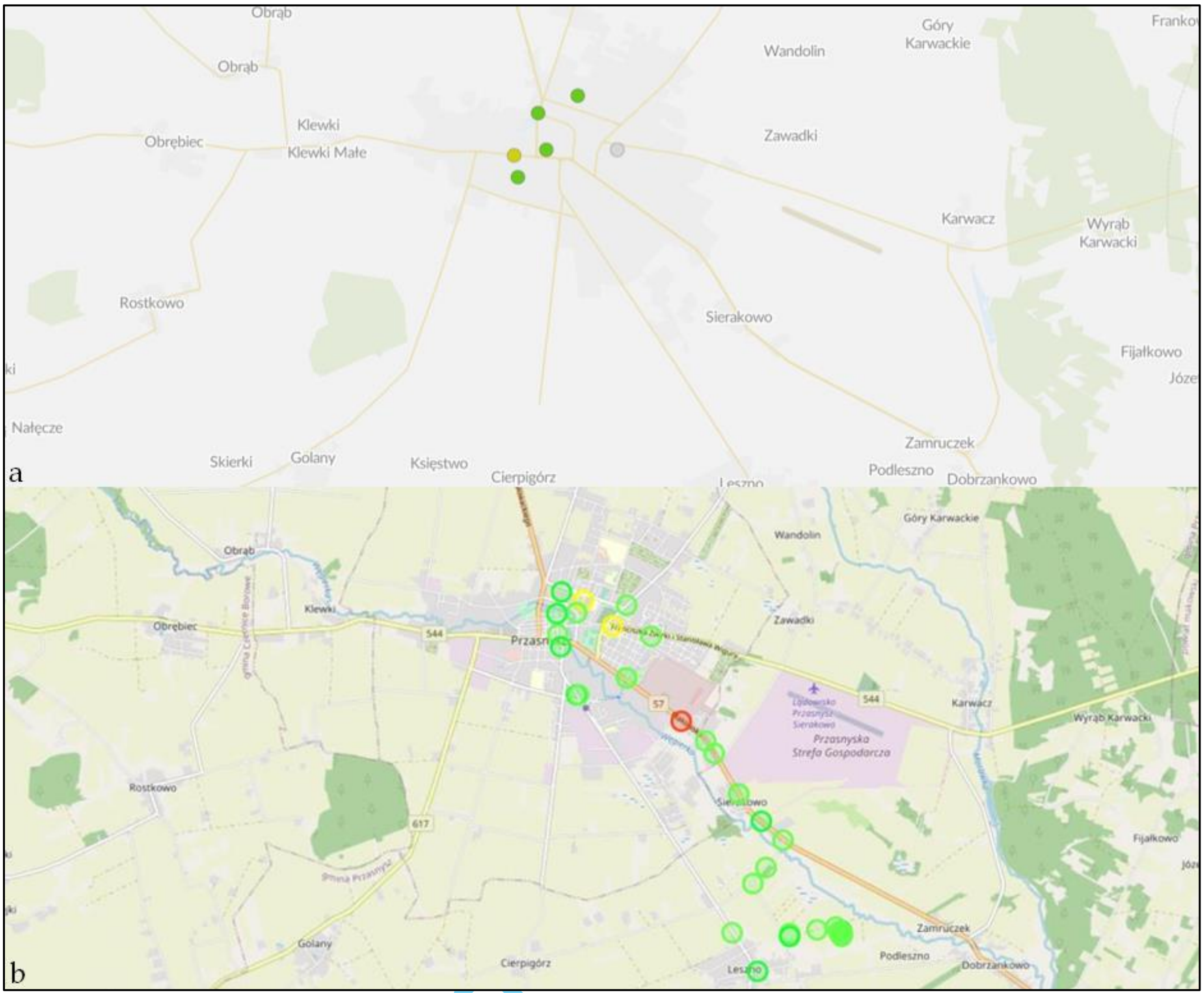


Fig. 8. Comparison of air pollution measurements from a mobile monitoring station during an 8 km bicycle route in Przasnysz (b) with data from nearby stationary monitoring stations (a).

The following examples demonstrate how proximity to two pollution sources influences measurement results. The first case involves measurements taken near a petrol-powered lawn mower. Using the mobile monitoring station, data were collected before, during, and between close encounters (within 2–5 meters) with the lawn mower's exhaust emissions. Fig. 9 presents the mapped measurement locations, as well as recorded levels of PM1.0, PM2.5, and PM10, along with CO_2 and VOC concentrations. The data clearly show that the lawn mower significantly impacted the recorded pollutant levels.

Fig. 10 presents analogous results recorded in a proximity of a lit charcoal grill.

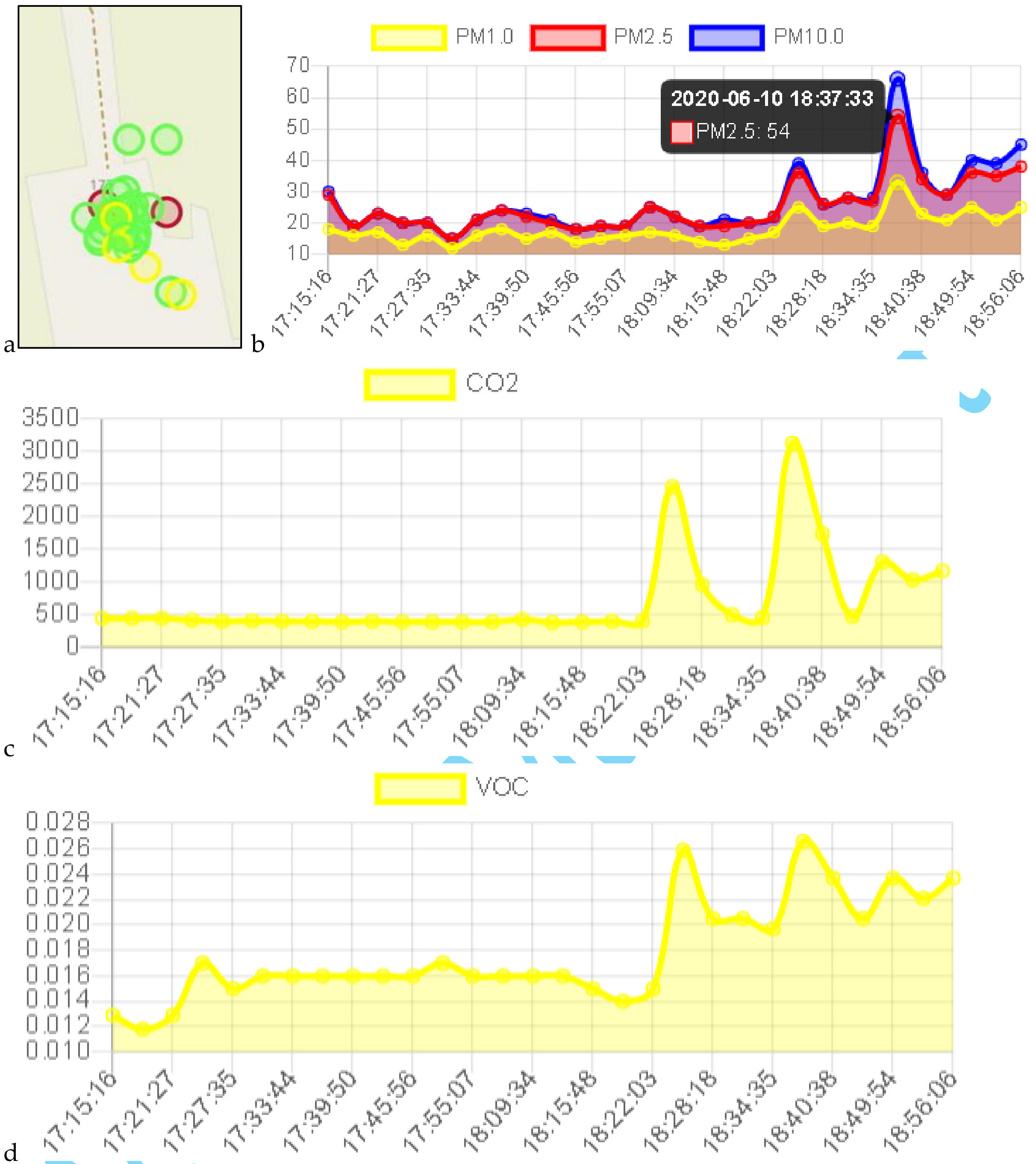


Fig. 9. The map showing the measurement points (a), and measurements of PM1.0/PM2.5/PM10 (b), CO_2(c), and VOC(d) levels before, during, and after close contact with a petrol-powered lawn mower.

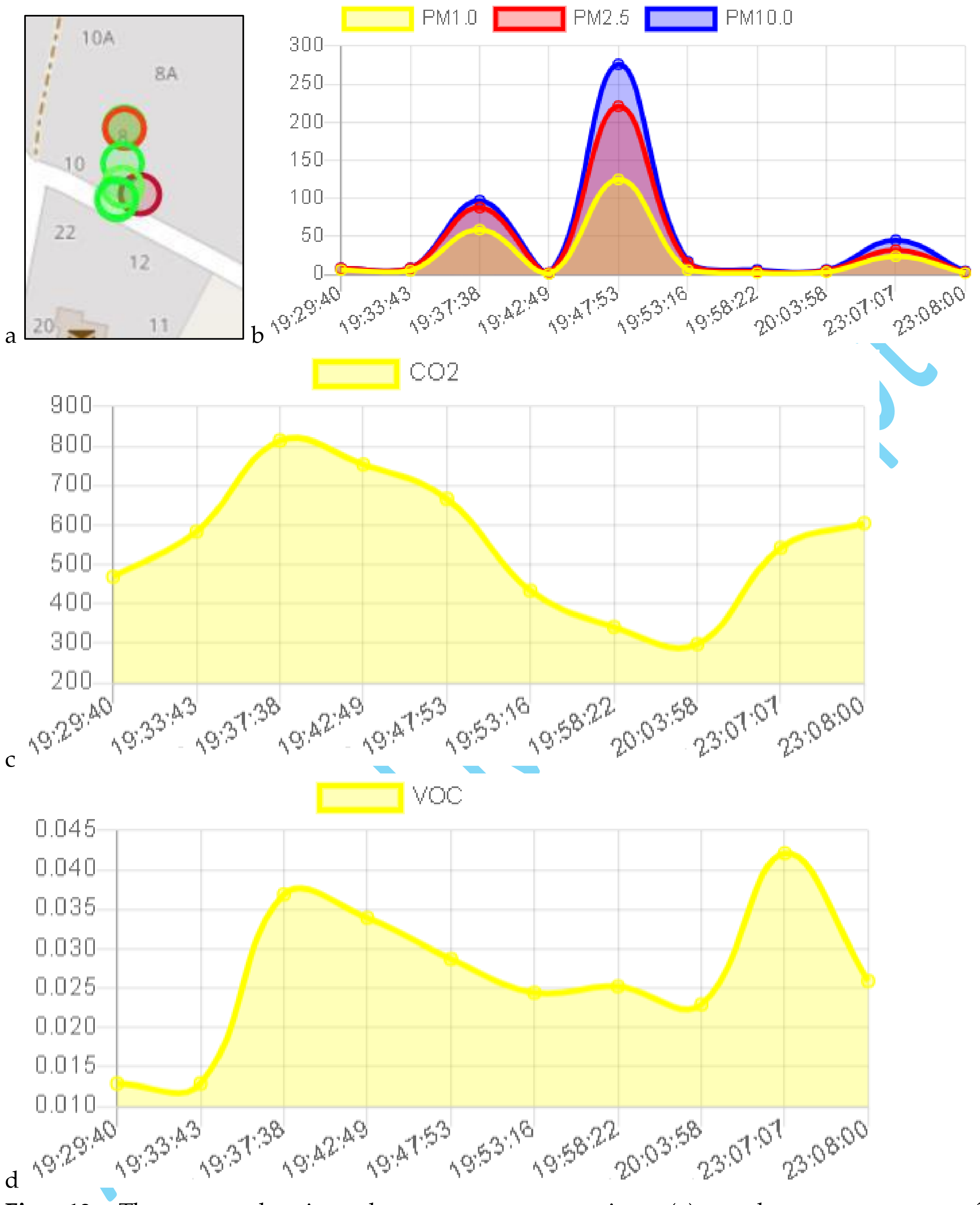


Fig. 10. The map showing the measurement points (a), and measurements of PM1.0/PM2.5/PM10 (b), CO_2(c), and VOC(d) levels in a proximity of a lit charcoal grill.

As shown, both a lawn mower and a lit charcoal grill have a noticeable impact on air quality parameter readings. While such results might be dismissed as measurement disturbances, they also highlight the legitimate environmental concerns associated with these pollution sources (Priest et al., 2000; Brienza et al., 2015).

Discussion

Within the scope of the project presented in this paper, a mobile air quality monitoring station was designed and built, including the implementation of a communication and data storage system, and the creation of a user interface. The use of small-sized sensors, a GPS module, a GSM/GPRS communication module, and high-capacity Li-ion batteries makes the monitoring station mobile, thereby increasing the area covered. The ability to move the device and its relatively low construction cost make it a cheaper and potentially more effective solution than stationary monitoring stations. The implemented system fully meets its objectives. Data transmitted via the HTTP protocol from the station is stored in a database after device verification. This protocol is also used for communication with the user interface in the form of a web application. Additionally, the created API can be used to expand the system, for example, with a mobile application for smartphones and tablets, or for communication with purpose-built receiving stations based on microcontrollers like Arduino or NodeMCU.

In our opinion, mobile air quality monitoring stations have several promising applications, like e.g.:

- Identification of pollution hotspots – mobile monitoring facilitates the detection of localized pollution sources and real-time air quality tracking, supporting public health initiatives aimed at reducing exposure to harmful pollutants (Brienza et al., 2015, Whitehill et al., 2024);
- Integration with smart city infrastructure – incorporating mobile air quality monitoring stations into smart city systems allows for real-time data collection to inform urban planning and management decisions, such as traffic regulation and industrial zoning (Mihăiţă et al., 2019);
- Agricultural applications – monitoring air quality in rural and agricultural areas helps assess the effects of air pollutants on crops and livestock, leading to improved farm management practices and higher productivity (Shahid et al., 2025);
- Emergency response – in cases of environmental emergencies, such as wildfires or chemical spills, mobile stations can be quickly deployed to evaluate air quality and support effective emergency response strategies (Whitehill et al., 2024);
- Research – mobile stations provide valuable data for research projects focused on the spatial and temporal dynamics of air pollution (Aini et al., 2025; Hart et al., 2020);
- Public engagement and awareness – by making air quality data publicly available through web-based applications, communities can become more informed and proactive in addressing pollution issues, for example by reporting local emissions to relevant authorities (Brienza et al., 2015, Shahid et al., 2025).

These applications demonstrate the potential of mobile air quality monitoring stations, highlighting the relevance and practical value of our research.

Conclusions

During the design, construction, and testing phases of the monitoring device and its associated system, the following conclusions were drawn:

- The research confirmed the higher versatility and comparable accuracy of mobile air quality monitoring stations relative to stationary units;

- Mounting the monitoring stations on vehicles such as buses, trams, taxis, or public bicycles enhances measurement coverage and effectiveness. In our opinion, it can be particularly effective for their deployment on city buses or trams, which operate on fixed routes and schedules. The use of GPS, standardly installed in such vehicles, enables high-resolution spatial mapping of air quality;
- Performed experiments demonstrated that localized pollution sources, such as grill smoke or exhaust fumes from lawnmowers, can have a significant influence on measurement results;
- The PMS5003 sensor used in the project showed that compact laser-based particulate sensors can deliver fast and reliable air quality measurements. Their small form factor makes them suitable for both stationary and portable applications;
- The use of lithium-ion batteries significantly reduced the size and weight of the mobile unit while maintaining a high energy capacity, what is particularly useful in combination with photovoltaic power supply;
- The GSM/GPRS Sim800L module proved that GPRS communication technology is sufficient for projects requiring low data transmission volumes at infrequent intervals. These modules are cost-effective compared to 3G and 4G alternatives, and their transmission speed (30–80 kbps) is adequate for most microcontroller-based systems;
- Implementing API-based software on an internet server for storing data from microcontroller devices proved to be simple, scalable, and effective. Microcontrollers equipped with GSM/GPRS, 3G/LTE modems, Wi-Fi, or Ethernet modules can communicate with the server using standard HTTP methods such as GET, POST, and PUT. This enables integration with various applications, including web, mobile, desktop, and embedded systems;
- The API-based data exchange ensures data security. Transmitting information in JSON format using HTTP methods minimizes the risk of injection attacks, as data is processed through defined endpoints. Functions for saving, retrieving, and editing data are protected and constrained to accept only predefined, validated inputs.

In conclusion, the designed and constructed mobile air quality monitoring station, along with its integrated system, met all functional expectations. The device is portable and fully capable of communicating with the server from virtually any appropriately chosen location. The accompanying web application, equipped with a real-time measurement map, performs its intended role effectively and reliably.

References

AINI, Q.; MANONGGA, D.; RAHARDJA, U.; SEMBIRING, I.; LI, Y.M. *Understanding behavioral intention to use of air quality monitoring solutions with emphasis on technology readiness*. International Journal of Human–Computer Interaction **2025**, 41(8), 5079-5099.

Air Quality Map - Check air pollution in your area. Available online: https://airly.org/map/en/ (accessed on 08 May 2025).

BRIENZA, S.; GALLI, A.; ANASTASI, G.; BRUSCHI, P. *A low-cost sensing system for cooperative air quality monitoring in urban areas*. Sensors **2015**, 15(6), 12242-12259.

CHEN, F.; ZHANG, W.; MFARREJ, M.F.B.; SALEEM, M.H.; KHAN, K.A.; MA, J., RAPOSO, A.; HAN, H. *Breathing in danger: Understanding the multifaceted impact of air pollution on health impacts*. Ecotoxicology and Environmental Safety **2024**, 280, 116532.

DZIUBIŃSKI, Ł.; LIPIŃSKI, S.; CHWIETCZUK, P. *Adaptive microclimate control system to regulate conditions in a living-space. Technical Sciences* **2025**, 28, 5-18

Earth Overshoot Day. Available online: https://www.genevaenvironmentnetwork.org/resources/updates/earth-overshoot-day/ (accessed on 08 May 2025).

GENG, S.; DORLING, K.C.; PRENZEL, T.M.; ALBRECHT, S. *Grill and chill: a comprehensive analysis of the environmental impacts of private household barbecuing in Germany*. Sustainability **2024**, 16(3), 1041.

HART, R.; LIANG, L.; DONG, P. *Monitoring, mapping, and modeling spatial - temporal patterns of PM2.5 for improved understanding of air pollution dynamics using portable sensing technologies*. International Journal of Environmental Research and Public Health **2020**, 17(14), 4914.

HASSAN, A.K., SARAYA, M.S.; ALI-ELDIN, A M.; ABDELSALAM, M.M. *Low-cost iot air quality monitoring station using cloud platform and blockchain technology*. Applied Sciences **2024**, 14(13), 5774.

IOANNOU, K.; KARAMPATZAKIS, D.; AMANATIDIS, P.; AGGELOPOULOS, V.; KARMIRIS, I. *Low-cost automatic weather stations in the internet of things*. Information **2021**, 12(4), 146.

KAUR, K.; KELLY, K.E. *Laboratory evaluation of the Alphasense OPC-N3, and the Plantower PMS5003 and PMS6003 sensors.* Journal of Aerosol Science **2023**, 171, 106181.

KIREŠOVÁ, S.; GUZAN, M. *Determining the correlation between particulate matter PM10 and meteorological factors*. Eng **2022**, 3(3), 343-363.

MANE, S.A.; NADARGI, D.Y.; NADARGI, J.D.; ALDOSSARY, O.M.; S. TAMBOLI, M.; DHULAP, V.P. *Design, development and validation of a portable gas sensor module: A facile approach for monitoring greenhouse gases*. Coatings **2020**, 10(12), 1148.

MIHĂIŢĂ, A.S.; DUPONT, L.; CHERY, O.; CAMARGO, M.; CAI, C. *Evaluating air quality by combining stationary, smart mobile pollution monitoring and data-driven modelling*. Journal of Cleaner Production **2019**, 221, 398-418.

MITCHELL, A.L.; CHAPMAN, K.A. *Estimating the Impact of PM2. 5 on Hospital Burden from Respiratory and Cardiovascular Conditions in Southern Oregon: A Case-Crossover Analysis*. Air **2025**, 3(2), 13.

MOBARAKI, B.; KOMARIZADEHASL, S.; CASTILLA PASCUAL, F.J.; LOZANO-GALANT, J.A. *Application of low-cost sensors for accurate ambient temperature monitoring*. Buildings **2022**, 12(9), 1411.

NGUTUKA KINZUNGA, M.; WESTERVELT, D.M.; MATONDO MASISA, D.; BANGELESA, F.; KASEREKA ISEVULAMBIRE, P.; TANGOU TABOU, T.; KABENGELE OBEL B.; KIYOMBO MBELA G.; KAYEMBE NTUMBA, J. M. *Assessment of Respiratory Health Impacts of PM2.5 by AirQ+ Software in a Sub-Saharan African Urban Setting*. Atmosphere **2024**, 15(12), 1518.

PRIEST, M.W.; WILLIAMS, D.J.; BRIDGMAN, H.A. *Emissions from in-use lawn-mowers in Australia*. Atmospheric Environment **2000**, 34(4), 657-664.

PURKAYASTHA, K.D.; MISHRA, R.K.; SHIL, A.; PRADHAN, S.N. *IoT based design of air quality monitoring system web server for android platform*. Wireless Personal Communication **2021**, 118(4), 2921-2940.

ŞAHIN, K., IŞIKDAĞ, U. *A web api and web application development for dissemination of air quality information*. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences **2017**, 4, 373-378.

SHAHID, S.; BROWN, D.J.; WRIGHT, P.; KHASAWNEH, A. M.; TAYLOR, B.; KAIWARTYA, O. *Innovations in Air Quality Monitoring: Sensors, IoT and Future Research*. Sensors **2025**, 25(7), 2070.

SHIVA NAGENDRA, S.N.; YASA, P.R.; NARAYANA M.V.; KHADIRNAIKAR, S.; RANI, P. *Mobile monitoring of air pollution using low cost sensors to visualize spatio-temporal variation of pollutants at urban hotspots*. Sustainable Cities and Society **2019**, 44, 520-535.

WHITEHILL, A.R.; LUNDEN, M.; LAFRANCHI, B.; KAUSHIK, S.; SOLOMON, P.A. *Mobile air quality monitoring and comparison to fixed monitoring sites for instrument performance assessment*. Atmospheric Measurement Techniques **2024**, 17(9), 2991-3009.

World Meteorological Organization. Available online: https://wmo.int/news/media-centre/low-cost-sensors-can-improve-air-quality-monitoring-and-peoples-health (accessed on 08 May 2025).

WU, W.; LIU, R.; TANG, Y. *Study on Mapping and Identifying Risk Areas for Multiple Particulate Matter Pollution at the Block Scale Based on Local Climate Zones*. Atmosphere **2024**, 15(7), 794.

ZHU, Z.; CHEN, B.; ZHAO, Y.; JI, Y. *Multi-sensing paradigm based urban air quality monitoring and hazardous gas source analyzing: a review*. Journal of Safety Science and Resilience **2021**, 2(3), 131-145.

ZUBI, G.; DUFO-LÓPEZ, R.; CARVALHO, M.; PASAOGLU, G. *The lithium-ion battery: State of the art and future perspectives*. Renewable and Sustainable Energy Reviews **2018**, 89, 292-308.