AN AIR QUALITY MONITORING NETWORK USING LOW-COST SENSORS FOR THE MALTESE ARCHIPELAGO: CONCEPT AND IMPLEMENTATION

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ABSTRACT

Air pollution, especially airborne particulate matter (PM), poses significant risks to human health and the environment, yet air quality monitoring on the Maltese Archipelago remains spatially limited. This paper presents the concept and the gradual implementation of the first dense, low-cost PM monitoring network that covers Malta, Gozo and Comino, which utilises PurpleAir optical sensors capable of measuring $PM_{1.0}$, $PM_{2.5}$, and PM_{10} concentrations, apart from some other meteorological parameters. The sensors are strategically being deployed in urban, suburban, and rural environments to generate high-resolution spatial and temporal information on air quality (especially concerning PM concentration), complementing existing regulatory monitoring infrastructure and addressing gaps in sparsely monitored areas. The network design incorporates co-location with reference-grade instruments and meteorological sensors to support calibration, validation and accurate interpretation of PM concentration measurements under local atmospheric conditions. All stations transmit real-time data to a publicly accessible online platform, enabling researchers, policymakers and the general public to visualise air quality conditions and assess short- and long-term variability. Despite inherent limitations related to sensor calibration and long-term maintenance amongst others, the network demonstrates the feasibility of establishing a permanent, cost-effective and scientifically robust air quality monitoring system for small island environments. The network, which is currently under development, provides a foundation for future applications, including advanced data analysis, potential artificial intelligence-based PM forecasting and regional-scale air quality studies, contributing to improved understanding of air pollution dynamics and supporting evidence-based environmental management for the Maltese Archipelago.

Keywords: air quality monitoring, low-cost sensors, particulate matter, Maltese Archipelago.

1 INTRODUCTION

It is a well-established fact that exposure to air pollution is a leading contributor to global morbidity and mortality. As a significant environmental threat to human health, air pollution is estimated to be responsible for up to one in every five deaths worldwide [1], [2]. Consequently, effective air quality monitoring has become increasingly critical for safeguarding public health and protecting the environment.

Among the various atmospheric pollutants, airborne particulate matter (PM) remains one of the most concerning yet insufficiently characterised threats to human well-being. Along with volatile organic compounds (VOCs), PM pollution continues to pose substantial challenges for researchers and policymakers, underscoring the need for comprehensive monitoring solutions capable of capturing its complex behaviour, spatial variability, and wide-ranging impacts.

PM comprises fine airborne solid particles and liquid droplets capable of penetrating deep into the respiratory system [3]. Such exposure is known to heighten the risk of asthma, lung cancer, ischaemic heart disease, stroke, arterial thrombosis, as well as hypertension, and growing evidence also links PM to chronic obstructive pulmonary disease, type 2 diabetes, and dementia [4]–[8]. PM is conventionally classified as PM_{10}, $PM_{2.5}$ (fine particles), $PM_{1.0}$



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and $PM_{0.1}$ (ultrafine particles), corresponding to aerodynamic diameters smaller than 10 μm, 2.5 μm, 1.0 μm and 0.1 μm, respectively. $PM_{1.0}$, a sub-fraction of fine particles, has received increasing attention in air quality research due to its ability to penetrate more deeply into the respiratory tract than $PM_{2.5}$ [9], [10].

The health effects of PM are strongly associated with aerodynamic size and chemical composition, which together determine deposition patterns within the airways and subsequent biological responses [11], [12]. PM_{10} is predominantly deposited in the upper respiratory tract, whereas $PM_{2.5}$ can reach the bronchioles and, in some cases, the alveolar regions, contributing to impaired lung function. Both short- and long-term exposure to $PM_{2.5}$ has been associated with adverse cardiovascular effects and increased mortality [6], [7], [12], [13].

Emerging evidence suggests that $PM_{1.0}$ may pose greater health risks than $PM_{2.5}$ or PM_{10}. Owing to its small size, $PM_{1.0}$ can penetrate deep into the lungs, enter systemic circulation, and potentially cross the blood–brain barrier, enabling direct effects on the central nervous system [14]–[17]. Epidemiological studies link $PM_{1.0}$ exposure to higher risks of ischemic stroke and neurodegenerative disorders such as Alzheimer's and Parkinson's, and it often shows stronger associations with cardiopulmonary and metabolic outcomes compared to larger fractions [14], [18]–[23].

Ultrafine particles ($PM_{0.1}$) are abundant in the atmosphere and present additional concern due to their ability to cross the air–blood barrier efficiently. Once in the bloodstream, these particles can disperse throughout the body and accumulate in certain regions contributing to systemic toxic effects, as demonstrated in experimental and epidemiological studies [6], [24], [25].

PM originates from a range of natural and anthropogenic sources, including vehicle emissions, industrial processes, fossil fuel combustion, sea spray, and natural dust [26]. Beyond its impacts on human health, PM also contributes to material degradation, environmental harm, and reduced visibility [27]. Understanding the spatial and temporal patterns of this type of pollution is essential for designing effective mitigation strategies and informing evidence-based policy formulations.

Although regulatory-grade air quality monitoring stations provide accurate measurements, their considerable installation and maintenance costs restrict their number and spatial coverage. Consequently, many regions, including small yet densely populated areas, lack the monitoring resolution needed to capture local variations in pollutant concentrations, particularly those occurring near traffic corridors, intersections, or transport hubs. These limitations underscore the need for dense, cost-effective monitoring solutions capable of delivering detailed, real-time information on pollutant levels and sources [28]. To bridge the gap between expensive reference-grade stations and the demand for high-resolution air quality data, low-cost sensors are increasingly being deployed. Such sensors are relatively inexpensive, compact, easy to operate and run, and capable of providing rapid measurements with response times on the order of seconds to minutes [29], [30].

The Maltese Archipelago, comprising the islands of Malta, Gozo and the smaller island of Comino, presents an uncommon context in which high-resolution air quality monitoring is particularly important. The Maltese Archipelago is one of the most densely populated countries in the European Union, with substantial traffic congestion, limited land area, and a coastline exposed to marine aerosol and shipping emissions [31]. Despite these pressures, the current network of regulatory-grade monitoring stations is sparse and unable to resolve local-scale pollution variability across urban centres, residential zones and coastal regions [32]. Therefore, establishing a dense, low-cost (and hence affordable) air quality monitoring network, offers a practical and necessary approach to improving spatial coverage, enhancing

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public access to real-time air quality information, and supporting evidence-based environmental and health policies for the Maltese Archipelago.

2 AN OVERVIEW OF LOW-COST AIR QUALITY SENSORS (WITH EMPHASIS ON PM)

In recent years, low-cost air quality sensors have emerged as valuable tools for supplementing traditional reference-grade monitoring networks. In the case of PM, they are typically based on optical particle sensing technologies. They are compact and affordable instruments that provide fine-scale spatial and temporal information on PM concentrations [7], [33]. Although less accurate than regulatory monitors, the portability and ease of deployment of low-cost sensors make these instruments particularly useful in densely populated regions such as the Maltese Archipelago [28].

Technological advances and growing public concern about air pollution have further increased interest in these devices. Their accessibility enables communities and individuals to collect real-time air-quality data, addressing gaps in areas where official monitoring remains limited and enhancing public engagement in environmental assessment [33].

2.1 Sensor technology and operating principles

Low-cost PM sensors primarily rely on optical techniques, where particles passing through a sampling chamber scatter light emitted by a laser or light-emitting diode. A photodiode detects the intensity and pattern of scattered light, enabling the sensor to estimate particle number concentration and approximate size distribution. Internal algorithms then convert these measurements into mass concentrations for $PM_{1.0}$, $PM_{2.5}$, and PM_{10} [3], [6].

Unlike reference-grade instruments, which, often use gravimetric sampling or beta attenuation, optical sensors provide continuous measurements with low power requirements and compact hardware. This enables high-frequency monitoring suitable for identifying short-term variations and localised pollution hotspots [6], [34], [35].

However, the optical method is inherently sensitive to particle composition, refractive index and environmental conditions such as relative humidity or sea-salt aerosol content. These influences alter scattering behaviour and introduce biases in mass estimates [7], [27]. Despite these limitations, the affordability and simplicity of optical sensors support their widespread use in research, community monitoring networks, and citizen-science initiatives [7].

2.2 Performance and limitations

The performance of low-cost PM sensors is determined by sensor design, atmospheric conditions, and the physical properties of airborne particles. Although these sensors provide useful high-resolution data, their measurements generally exhibit lower accuracy and precision compared to reference-grade instruments [30]. Sensor-to-sensor variability is also common, even among identical models, necessitating calibration for meaningful comparison [27]. Field calibration against reference-grade instruments, such as the tapered element oscillating microbalance (TEOM) or beta attenuation monitor (BAM) systems, is widely recommended to correct systematic biases and improve data quality [6].

Sensor accuracy can be enhanced through periodic recalibration, with some studies indicating that a single calibration cycle may sustain improved performance for up to two weeks before drift and ageing effects begin to reduce data quality. Environmental factors further influence sensor stability. Fluctuations in temperature, humidity and wind patterns,

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as well as the presence of coastal aerosols, can introduce additional measurement uncertainty over time [28]. Although correction algorithms and recalibration mitigate several of these influences, such measures cannot fully eliminate all sources of interference.

Low-cost sensors may also exhibit cross-sensitivities, whereby responses are affected by the presence of other pollutants or changing atmospheric conditions [28]. These inherent limitations underscore the importance of careful quality-assurance practices, particularly when deploying sensors in dynamic environments or for long-term monitoring applications.

2.3 Applications and relevance for small islands: The case of the Maltese Archipelago

The compact geography of small islands such as Malta, Gozo, and Comino facilitates the deployment of low-cost air quality sensors. For the Maltese Archipelago, the deployment of these sensors carries substantial benefits given the dense urbanisation, and proximity to diverse emission sources including traffic, industrial activities and maritime transport. Beyond these local contributors, the Maltese Archipelago is also influenced by broader regional pollution patterns within the Mediterranean region, where anthropogenic emissions from transportation, energy production, agriculture, industrial activity and rapid urbanisation contribute to elevated PM concentrations. Across Europe and the wider Mediterranean region, these emissions continue to significantly affect air quality and public health, prompting the establishment of numerous monitoring networks to track pollutants and support regulatory action [36].

Regarding pollution, the combination of local and regional influences leads to pronounced spatial and temporal variability in PM concentrations, which is difficult to capture solely through traditional monitoring networks, given their sparsity. On the Maltese Archipelago, air quality monitoring is accomplished through two principal systems, which are operated by the Environment and Resources Authority (ERA):

i. a passive diffusion tube network comprising approximately 100 sites across the archipelago, and
ii. a continuous air quality monitoring station (AQMS) network, with four stations in Malta (Attard, Msida, Kordin and Żejtun) and one in Gozo (Għarb) [37].

While these networks provide essential regulatory data, diffusion tubes lack real-time capability, and the limited number of stations capable of continuous monitoring, provide a relatively poor spatial coverage.

Low-cost air quality sensors provide a scalable and cost-effective solution for expanding monitoring networks, enabling the collection of high-resolution data in areas where traditional, reference-grade instruments are sparse or unavailable. These sensors make possible the assessment of PM concentrations at urban, suburban, and rural areas, filling data gaps and identifying localised pollution hotspots.

Beyond data collection, low-cost sensors support community-based air quality monitoring, empowering local residents and organisations to participate in environmental assessments. This engagement fosters greater awareness of air pollution and provides critical insights for public health and policy advocacy. The data collected can also support evidence-based policymaking, enabling authorities to track long-term air quality trends and identify pollution sources. By providing real-time measurements at a fraction of the cost of conventional instruments, low-cost sensors offer an affordable alternative for long-term monitoring and facilitate large-scale environmental research, especially concerning exposure risks and the impact of local activities such as tourism and industrial emissions.

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2.4 Challenges and future prospects

A major challenge is the lack of standardisation in sensor design, data reporting and calibration procedures, which complicates data comparison across devices and hinders integration into larger networks. Site-specific adjustments are often necessary, adding complexity for large-scale deployment.

Recent advances offer promising solutions to these challenges. Machine-learning-based calibration has emerged as a potential means of improving the accuracy of low-cost sensors and reducing the effort required for manual adjustment. In this approach, low-cost sensors are co-located with reference-grade monitoring stations, and predictive models are trained to correct measurement errors using environmental data such as weather conditions. While several machine-learning calibration methods have been proposed, the field is still developing, and complete consensus on the most effective approaches, evaluation strategies, and remaining research challenges has not been achieved [28]. The integration of big-data analytics and multi-sensor platforms further enhances the potential for real-time monitoring, predictive modelling, and high-resolution data analysis.

As sensor technology and calibration practices continue to improve, low-cost sensors are expected to play an increasingly important role in real-time air quality monitoring, environmental research, and evidence-based policymaking, particularly in regions with limited conventional monitoring infrastructure.

3 THE LOW-COST AIR QUALITY MONITORING NETWORK INITIATIVE

3.1 Sensor selection: PurpleAir

The PurpleAir sensor is an affordable, high-resolution air quality monitoring device that utilises an optical technique to measure PM concentrations. It provides real-time data on PM_{10}, $PM_{2.5}$, and $PM_{1.0}$, making it suitable for both local and regional air quality monitoring. Its compact design (approximately 85 × 85 × 125 mm [33], [38]), portability, and ease of deployment, make it particularly well-suited for large-scale monitoring projects and community-driven initiatives. This design allows individuals, researchers and organisations to actively contribute to data collection efforts [7], [33].

The sensor supports cloud-based data transmission, ensuring immediate public access to real-time measurements [27]. Previous evaluations have shown strong correlations between PurpleAir data and reference-grade monitors, particularly when appropriate calibration procedures are applied [7], [33]. These capabilities have facilitated the integration of PurpleAir into dense, cost-efficient monitoring networks, such as the one currently being developed across the Maltese Archipelago.

However, several practical considerations must be addressed when deploying low-cost sensors like PurpleAir to ensure optimal data quality. These considerations include continuous access to electrical power, reliable internet connectivity for real-time data uploads, device security, and local weather conditions (especially humidity and extreme weather), all of which can influence data accuracy [8].

The PurpleAir Flex, the updated model, which is currently being deployed, integrates two Plantower PMS-6003 laser-scattering particle sensors for PM measurement and a Bosch BME688 environmental sensor for monitoring temperature, relative humidity, and pressure. Combined with integrated Wi-Fi connectivity, these components offer a comprehensive, user-friendly system for continuous real-time air quality tracking [27], [38]. Live data is

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displayed through a cloud-based platform with a colour-coded air quality index, providing immediate visual feedback on local conditions [33].

3.2 Rationale and implementation of the low-cost air quality monitoring network

The air quality monitoring network being established on the Maltese Archipelago aims to deploy PurpleAir sensors in strategic locations across urban, suburban, and rural areas. The primary goal is to create a high-resolution map of PM concentration, complementing existing monitoring efforts by state agencies and addressing gaps in areas with sparse air quality data. By installing sensors in high-traffic areas, residential zones, and near industrial sites, the network will identify pollution hotspots and track changes in air quality over time. The real-time accessibility of PurpleAir data promotes transparency and engages the public with air quality issues.

The network will consist of approximately 30 PurpleAir stations deployed all over Malta, Gozo, and Comino, marking the first comprehensive low-cost PM monitoring system in the country. With a total land area of 316 square kilometres, this corresponds to an average sensor density of one unit per 10.5 square kilometres, providing unprecedented spatial coverage. The sensors can be easily installed on rooftops, which helps mitigate street canyon effects and provides representative neighbourhood-scale data, rather than focusing solely on hyperlocal microenvironments.

Each sensor installation follows strict criteria to ensure data accuracy and comparability. For instance, the sensors are installed away from obstructions such as trees, fences, or ground dust sources, e.g., unpaved roads, rooftop air in/outlets, electrical generators, etc. [8].

Current stations in Malta are located in Floriana, Valletta, Birkirkara, Sliema, Mellieħa and St Paul's Bay. There is one installation in Xewkija, Gozo and one station on Comino, with an additional unit at Ta' Xbiex (Malta) that is owned and managed by third parties (Fig. 1). Planned future sites currently include, among others, Mġarr and Xagħra, both in Gozo, and Skyparks (Malta International Airport), Paceville (St Julian's) and selected areas in the southern and Cottonera regions in Malta, ensuring balanced spatial coverage across urban, rural, and background environments.

Notably, the Comino station, the first of its kind on the island, provides a low-population reference environment, offering critical baseline data for air quality assessments.

Gozo will host five new sensors, including one at the Giordan Lighthouse, which serves as the network's regional background site. Its elevated hilltop location on the northern coast of Gozo and relative isolation from local emission sources makes it ideal for capturing representative regional atmospheric conditions. Situated along a major shipping lane in the Central Mediterranean, the station monitors ship-emitted pollutants and captures the influence of volcanic emissions from Mount Etna in nearby Sicily [31]. Equipped with reference-grade instruments measuring several gases and aerosols, Giordan Lighthouse provides a unique opportunity to compare and validate data from the PurpleAir sensor that will be installed there.

3.3 Integration with reference air quality and meteorological networks

A reference-grade GRIMM dust monitor will be sequentially deployed across multiple sites for a comparative analysis. Previous co-location studies have demonstrated good agreement between the GRIMM instrument and PurpleAir sensors [8]. This sequential co-location strategy enables the evaluation of each PurpleAir sensor under local atmospheric conditions,

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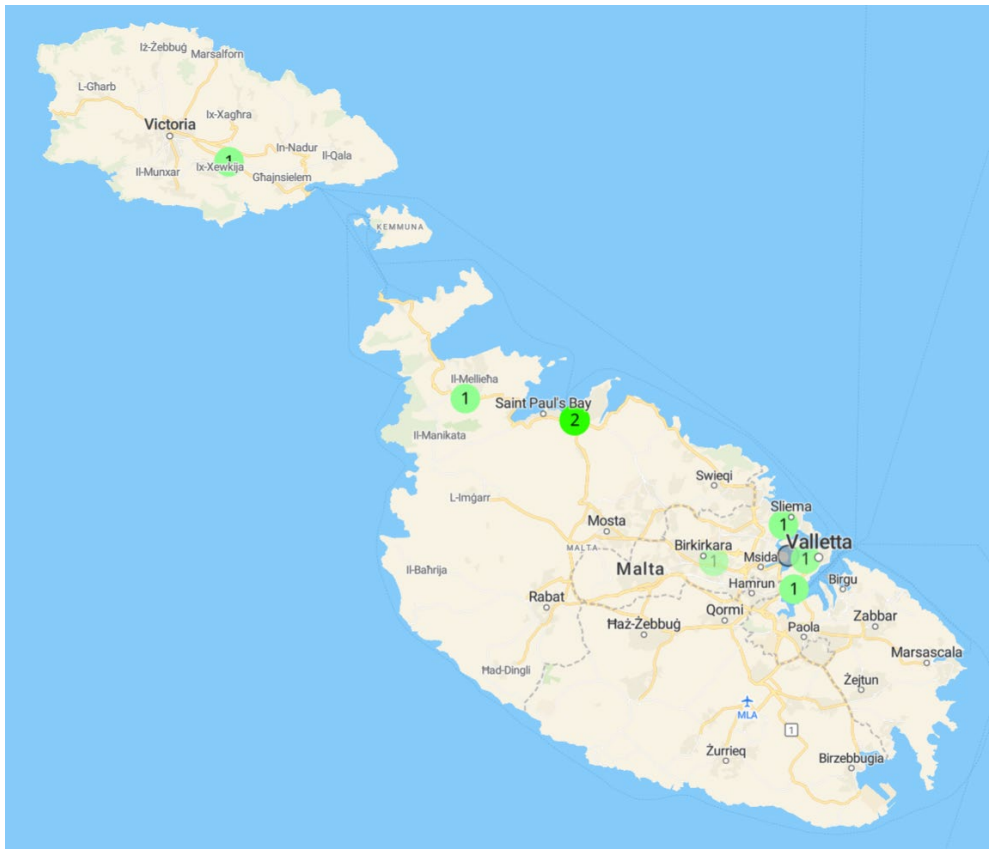


Figure 1: Map of the current PurpleAir sensor locations across the Maltese Archipelago, including Floriana, Valletta, Birkirkara, Sliema, Mellieħa, St Paul's Bay, Ta' Xbiex, all in Malta, Xewkija, in Gozo, and Comino, as displayed on the PurpleAir real-time mapping platform (https://map.purpleair.com). Note that the sensor, which is installed at Ta' Xbiex, is owned and managed by third parties. The sensor that is installed on Comino is not shown since at the time of the screen capture (26 Dec. 2025) it was not operational due to a power failure.

supporting site-specific calibration and ensuring accurate PM concentration measurements all over the Archipelago.

As the network expands, meteorological instruments will be incorporated at several stations to monitor key parameters such as wind speed, wind direction, solar irradiance, and precipitation, enhancing the network's ability to characterise meteorological effects such as rain-induced aerosol washout and local dispersion patterns. Temperature, relative humidity, and barometric pressure are already being measured by the PurpleAir sensors. Meteorological factors significantly influence sensor performance and are essential for accurately interpreting PM concentration data [3], [6], [27], [28], [33].

In Xewkija (Gozo), the PurpleAir sensor, shown in Fig. 2, is installed adjacent to a CIMEL sunphotometer, part of the global AERONET network (https://aeronet.gsfc.nasa.gov). This strategic placement allows for direct comparisons between surface-level PM concentrations

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(measured by PurpleAir) and columnar aerosol optical properties (measured by the CIMEL sunphotometer). This comparison and subsequent adjustments strengthen the network's capability to monitor and validate air quality data in the region. Fig. 2 shows the PurpleAir sensor, the CIMEL sunphotometer, and the Campbell Scientific Present Weather Sensor, along with instruments measuring temperature, humidity, solar irradiance, and various atmospheric trace gas concentrations, which are co-located at the site. Wind speed and wind direction are also measured by a sensor mounted on an adjacent building.



Figure 2: The PurpleAir sensor (circled) installed at Xewkija, Gozo and co-located with a CIMEL sunphotometer, a Campbell Scientific Present Weather Sensor, and instruments measuring temperature, humidity, solar irradiance and various atmospheric trace gas concentrations.

As previously mentioned, the Giordan Lighthouse is equipped with reference-grade instruments to measure concentrations of trace gases and aerosols, as well as ambient temperature, relative humidity, wind speed and wind direction. These measurements support both PurpleAir validation and broader environmental research, particularly in assessing regional atmospheric influences on local air quality. This suite of co-located instruments provide a robust framework for continuous air quality monitoring. Future enhancements will include sensors for sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), and methane (CH_4), offering a more comprehensive view of atmospheric composition and supporting long-term environmental monitoring efforts.

3.4 Data accessibility and current applications

All PurpleAir sensors stream real-time PM concentration data (apart from temperature, relative humidity and barometric pressure) to a publicly accessible online platform, ensuring transparency and enabling residents, researchers, and policymakers to explore air quality patterns across the Maltese Archipelago. By combining the data with co-located reference-grade measurements (refer to Section 3.3), accuracy and reliability of reported concentrations is ensured. This interactive web-based interface allows visualisation of air quality conditions in real-time, empowering communities to make informed decisions regarding outdoor activities, particularly for vulnerable populations such as children, the elderly, and individuals with respiratory and other relevant conditions. Public access to environmental data also raises awareness and encourages civic participation in air quality management.

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Low-cost sensors, while not as accurate as reference-grade instruments, provide a cost-effective means to increase spatial measurement density, detect local pollution hotspots, and improve understanding of temporal and spatial variability in PM concentrations [3], [28]. Dense deployment of PurpleAir sensors complements regulatory monitoring networks by providing better spatial coverage. This high-resolution data can improve estimates of population exposure, support health studies, and minimise exposure misclassification errors due to within-area variability. Open-access data further broadens opportunities for research and environmental analysis.

The inclusion of the Comino station as a low-population reference site is particularly valuable, providing baseline measurements that help distinguish between local pollution sources and regional atmospheric contributions. Despite operational challenges, previous studies have shown that establishing networks of low-cost PM sensors is feasible and can provide valuable data on local air quality [8]. While the network is currently in its experimental deployment stage, it is being designed as a permanent infrastructure to remain operational once fully established, providing a foundation for future research, including artificial intelligence (AI)-based forecasting.

4 FUTURE RESEARCH DIRECTIONS AND NETWORK DEVELOPMENT

The PurpleAir network being implemented on the Maltese Archipelago shall provide a platform for scientific, technological and societal applications in air quality monitoring. Although only a small number of stations are currently operational, the multi-phase expansion of the network, together with the integration of meteorological and reference-grade instruments, is designed to progressively enable advanced analyses as spatial coverage and temporal continuity increase.

As the number of deployed sensors increases, the network will provide the data needed to develop AI-based models for short-term PM forecasting. Machine-learning techniques, including long short-term memory (LSTM) and hybrid physics-informed approaches, may be applied to high-resolution PM and meteorological datasets [39] to investigate pollution episodes associated with traffic activity, village feasts (fireworks), shipping emissions, meteorological stagnation, and regional-scale events such as volcanic eruptions (referring to Mount Etna, Sicily). At the current stage, these applications remain prospective and depend on the continued expansion of the network and accumulation of sufficiently long-time data series.

Future development efforts will focus on expanding both the geographical coverage and the range of monitored parameters. Additional PurpleAir sensors will be deployed across the Maltese Archipelago to improve spatial resolution and better characterise urban–rural gradients, coastal influences, and background conditions. Planned integration with sensors measuring concentration of gaseous pollutants, e.g., SO_2, NO_x, CO_2, CH_4, and meteorological variables, will enable more comprehensive interpretation of air quality as well as support aerosol–meteorology studies and source attribution analyses.

The location of the Maltese Archipelago in the central Mediterranean makes the evolving network particularly valuable for regional and transboundary air pollution studies. As deployment progresses, collaboration with monitoring efforts in neighbouring regions, including Sicily and southern Italy, will facilitate comparative analyses for the understanding of aerosol transport, regional shipping emissions and volcanic influences. Co-located instrumentation, such as the CIMEL sunphotometer at Xewkija, reference-grade instruments at Giordan Lighthouse, and the GRIMM dust monitor, will support aerosol characterisation and validation of PurpleAir concentration measurements.

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As long-term and more spatially representative datasets become available, the network will enable research into vertical and horizontal atmospheric aerosol distribution, regional background variability, long-range transport mechanisms, and satellite-ground data comparison and validation. Real-time, publicly accessible measurements will continue to support public awareness, community engagement, and citizen-led monitoring initiatives, while providing evidence to inform public health guidance and environmental policy.

Despite the potential of the network, several challenges need to be addressed during its continued development. These include maintaining calibration under varying environmental conditions, ensuring reliable electrical power supply and data connectivity, managing sensor drift and data gaps, and integrating heterogeneous datasets for advanced analyses. Addressing these challenges through established quality-control procedures and phased network expansion will be essential to ensure that the network fulfils its long-term scientific, operational, and societal objectives.

5 CONCLUSION

The PurpleAir network being established on the Maltese Archipelago illustrates the applicability of low-cost, high-resolution air quality monitoring in the case of small island environments. By complementing existing reference-grade stations, the network is designed to substantially enhance spatial coverage across Malta, Gozo and Comino, addressing long-standing gaps in air quality monitoring infrastructure. The ongoing deployment of sensors enables the identification of emerging pollution hotspots and supports improved assessment of population exposure, as well as enhanced understanding of urban–rural and coastal air quality gradients.

The network integrates low-cost sensors with co-located reference-grade and meteorological instruments, providing a robust framework for calibration, validation, and interpretation of PM concentration data under local atmospheric conditions. Key sites, including the low-population station of Comino and the regional background site at Giordan Lighthouse, already provide valuable baseline measurements that support multi-scale analyses of local, regional and transboundary air pollution. As additional stations are deployed, the capability of the network to characterise spatial variability and regional transport processes across the central Mediterranean will continue to strengthen.

Beyond its current monitoring capabilities, the expanding network will establish a foundation for future scientific and applied research. The availability of high-resolution, real-time data supports advanced analyses of PM dynamics, facilitates the development of data-driven forecasting approaches, and enables aerosol–meteorology and regional transport studies. Open access to measurements enhances public engagement, supports community-based monitoring, and provides valuable evidence to inform environmental policy and public health strategies.

While challenges related to sensor calibration, environmental sensitivity, operational maintenance, and data management remain, these limitations are manageable through established quality-control protocols and periodic co-location with reference-grade instruments. Overall, the PurpleAir initiative constitutes a scalable, cost-effective, and scientifically robust air quality monitoring infrastructure that, once fully deployed, will significantly improve understanding of air pollution processes and support sustainable environmental management across the Maltese Archipelago.

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