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Environmental Monitoring And Pollution Alerts Using Iot

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Abstract: This paper presents the design and development of an Internet of Things based solution for urban environmental monitoring and pollution hotspot detection. The system integrates with a Espressif Systems 32-WROOM microcontroller for sensor data acquisition, while the Espressif Systems 32 Wi-Fi module processes the data and sends it to a central server, where Geographic Information System mapping is used to visualize pollution hotspots in real time. The Long Range Radio Frequency RF module extends the communication range in urban areas with limited cellular coverage. Geographic Information System mapping helps visualize pollution levels across urban areas, facilitating the identification and management of pollution hotspots. To enhance pollution mitigation, the system integrates an Active Carbon Filter, which helps reduce airborne pollutants before data collection. The filter is placed near gas sensors (MQ-135, MQ-7, MQ-8) to compare pre-filtered and post-filtered air quality, providing insights into filtration efficiency. It actively removes harmful gases such as carbon monoxide, Nitrogen Oxides, and Volatile Organic Compounds, supporting sustainable urban management. This system supports data-driven decision-making and timely interventions, contributing to sustainable urban planning and public health initiatives. The system aims to offer valuable insights into pollution trends, aiding in the identification of critical areas for intervention. Additionally, the use of a low-power, low-cost microcontroller makes it suitable for large-scale deployment in urban environments.

***Index Terms* -** Internet of Things (IoT), Long Range radio Frequency (LoRa RF), ESP32 Wi-Fi module, Metal Oxide (MQ), carbon monoxide (CO), Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs), Geographic Information System (GIS).

I. Introduction

Air pollution is a critical global issue, significantly impacting human health, the environment, and economic development. According to the World Health Organization (WHO), ambient air pollution contributes to approximately 7 million premature deaths annually, with major causes being exposure to fine particulate matter (PM2.5) and harmful gases like CO, NO_2, and SO_2 [5], [6]. Rapid urbanization, industrial expansion, and vehicular emissions have intensified pollution levels, particularly in densely populated cities. Traditional environmental monitoring systems, while effective, are often expensive, infrastructure-dependent, and limited in real-time data availability [7], [8]. Consequently, there is an urgent need for cost-effective, scalable, and real-time air quality monitoring solutions to address these challenges.

With advancements in Internet of Things (IoT) technology, sensor-based monitoring systems have emerged as a promising alternative to traditional methods [3], [4]. These IoT-enabled systems leverage low-cost, wireless sensors for real-time environmental data collection, offering improved accessibility and efficiency compared to conventional monitoring networks [2], [9]. In this study, we propose an IoT-based urban environmental monitoring system that integrates a microcontroller, Wi-Fi module, and GIS mapping to track air pollution levels and identify pollution hotspots in urban areas.

The Pollution Monitoring system employs a network of air quality sensors to measure key environmental parameters such as PM2.5, PM10, temperature, humidity, CO_2, and VOC levels. These sensors are interfaced with the microcontroller, which processes the collected data and transmits it via a Wi-Fi module to a cloud-based platform. Utilizing wireless communication protocols, the system ensures real-time data acquisition, storage, and visualization [21], [22].

One of the key advantages of this approach is its ability to offer high-resolution air pollution data, filling the gaps left by conventional monitoring stations that are often sparsely distributed [12], [13]. Additionally, by leveraging LoRaWAN and other long-range communication technologies, the system can support large-scale deployment across smart cities [4], [23].

The significance of this research extends beyond scientific and technological advancements. It offers a practical solution for policymakers, urban planners, and environmental agencies to make informed decisions regarding pollution control measures and urban sustainability planning [1]. For clarity, this paper is organized into six sections.

Problem Statement: Despite the rising pollution in urban environments, existing monitoring solutions are costly, infrastructure-dependent, and lack real-time capabilities.

Objectives: This study aims to develop a low-cost, real-time, GIS-integrated environmental monitoring system using IoT and long-range communication to identify pollution hotspots and support proactive mitigation strategies.

II. Air Quality Index (AQI) Monitoring

Air pollution and environmental monitoring have been extensively studied using various IoT-based technologies. The World Health Organization (WHO) has provided detailed reports on global air pollution exposure and its health impacts [1,2]. The Health Effects Institute [3] and the World Bank [4] have also contributed to strategies for improving air quality monitoring.

Air Quality Monitoring:

Gas sensors such as MQ-135, MQ-7, and MQ-8 have been widely used for detecting air pollutants. MQ-135 is an air quality sensor capable of detecting gases like NH_3, NOx, alcohol, benzene, and CO_2. It operates based on resistance variation in the presence of pollutants. The sensor's resistance

Rs is related to gas concentration C by:

$$R_S = R_0 \times \left(\frac{C}{C_0}\right)^{-m} \quad (1)$$

where R0 is the sensor resistance in clean air, C0is the reference concentration, and mmm is an empirical constant. MQ-7 is specialized in carbon monoxide (CO) detection. It requires heating cycles for better accuracy, alternating between 1.5V and 5V. Its formula follows:

$$\text{PPM} = A \times \left(\frac{R_S}{R_0}\right)^{B} \quad (2)$$

Where A and B are constants derived from calibration. MQ-8 is used for hydrogen gas detection, following a similar resistance-based principle as MQ-7 and MQ-135.Several studies have explored the calibration and optimization of these sensors. Ali et al. [4] integrated LoRaWAN and machine learning to enhance sensor accuracy.

Noise Pollution Monitoring:

Noise pollution is another critical environmental concern. Noise sensors detect sound pressure levels (SPL), commonly measured in decibels (dB). The relationship between SPL and sensor voltage Vout is typically given by:

$$\text{SPL (dB)} = 20 \log_{10}\left(\frac{V_{out}}{V_{ref}}\right) \quad (3)$$

where Vref is a reference voltage. Noise monitoring has been integrated into IoT-based pollution tracking systems, as seen in studies such as Abraham et al.[22].

Temperature & Humidity Monitoring:

The DHT22 sensor is widely used for temperature and humidity monitoring, crucial in environmental studies. It provides digital output with the following formulas:

Humidity (%RH):

$$RH = \frac{(S_{humidity} \times 100)}{2^{16} - 1}$$

Temperature (°C):

$$T = \frac{S_{temp}}{10} \quad (4)$$

where Shumidity and Stemp are raw sensor readings. DHT22 integration has been studied for real-time environmental monitoring, including applications in GIS-based air quality mapping [9,18].

Integration with IoT & GIS:

IoT-based smart city applications have advanced real-time monitoring. Studies like Dhingra et al. [19] introduced mobile air pollution monitoring using IoT, while Nowshin and Hasan [23] developed microcontroller-based monitoring systems for sensor-based air quality tracking. While several studies propose IoT-based environmental monitoring systems, many lack integration with GIS visualization or fail to evaluate pre- and post-filter air quality. This study addresses these gaps by implementing a real-time, GIS-enabled system with Active Carbon Filtration for comparative air quality analysis.

III. Proposed System

The proposed system is an IoT-based urban environmental monitoring and pollution hotspot detection framework that integrates a microcontroller for sensor data acquisition and an ESP32 module for data transmission. It utilizes LoRa for long-range communication and GIS mapping for real-time visualization of pollution levels. LoRa (Long Range) is a low-power wide-area network (LPWAN) protocol designed for wireless communication over long distances with minimal power consumption. It operates in unlicensed frequency bands and is ideal for IoT applications due to its ability to support multiple sensor nodes in harsh environments with limited connectivity. An Active Carbon Filter enhances air quality analysis by comparing pre-filtered and post-filtered data. This system aligns with research on air pollution monitoring [1], [3], [5] IoT-based solutions [14], [19] and GIS integration [21], [22]. It enables data-driven decision-making for urban planning and public health, supporting sustainable city management [7], [18], [23].

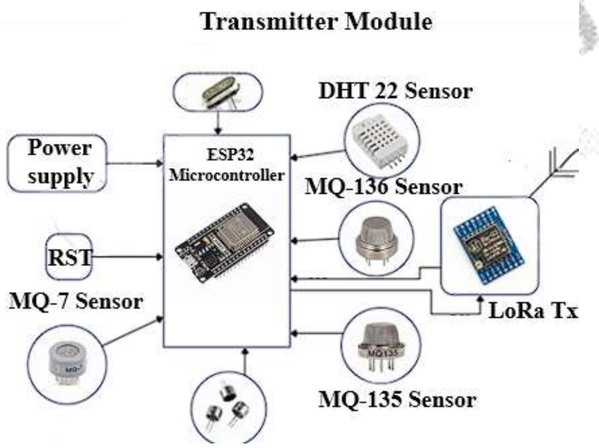

Figure 1: Transmitter Module Block Diagram showing ESP32-WROOM and connected sensors.

A. **Transmitter and Receiver Module**

The transmitter module comprises a ESP32-WROOM microcontroller, which collects data from multiple environmental sensors, including MQ-135, MQ-7, MQ-8 (for gas detection), a noise sensor, and a DHT22 (for temperature and humidity monitoring). The LoRa RA-02 RF module enables long-range wireless communication, transmitting sensor data to the receiver module. An Active Carbon Filter is integrated near the gas sensors to compare pre-filtered and post-filtered air quality. enhancing pollution mitigation efforts.

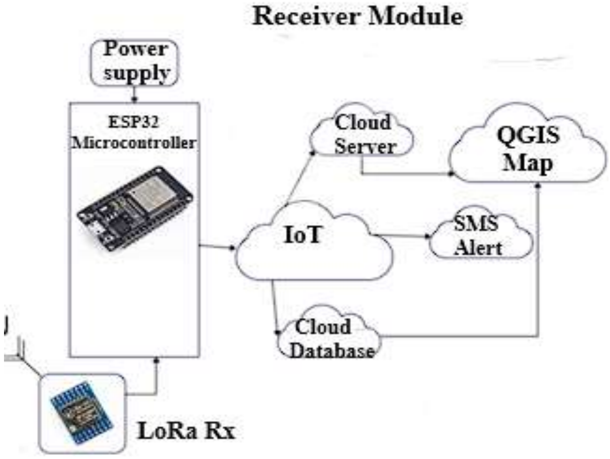

Figure 2: Receiver Module Block Diagram

The receiver module features an ESP32 Wi-Fi microcontroller for data processing and cloud integration. It also includes a LoRa RA-02 RF module to receive transmitted data from the sensor nodes. The ESP32 forwards the collected data to a MySQL database hosted on XAMPP. The system leverages GIS mapping to visualize pollution levels, enabling authorities to monitor pollution hotspots effectively.

B.**Pollution Control System**

Pollution Control System integrates an Active Carbon Filter to enhance pollution control by reducing airborne contaminants before sensor data collection. The filter is strategically placed near MQ-135, MQ-7, and MQ-8 gas sensors to compare pre-filtered and post-filtered air quality, providing insights into filtration efficiency. It effectively removes harmful gases such as CO, NOx, and VOCs, improving the accuracy of pollution measurements. This approach not only supports real-time environmental monitoring but also contributes to sustainable urban management by mitigating air pollution at the source, thereby improving overall air quality and public health.

IV. Hardware Components

Microcontroller and Communication Modules

The system uses the ESP32-WROOM microcontroller for sensor data acquisition and processing, while the enables Wi-Fi connectivity for real-time data transmission. Additionally, the LoRa SX1278 module extends communication range in urban environments with limited cellular coverage, ensuring reliable data transfer to the central server.

Figure 3: ESP32 Microcontroller

Sensors

The system integrates multiple sensors for environmental monitoring. The MQ-135 detects pollutants like NH3, NOx, benzene, and CO2, while the MQ-7 measures carbon monoxide (CO) levels, and the MQ-8 monitors hydrogen (H2) concentration. The DHT22 sensor records temperature and humidity variations, and a noise sensor captures ambient sound levels to assess noise pollution. These sensors provide comprehensive environmental data for analysis and visualization.

Figure 4: MQ-135, 7 and 8 Sensors

Active Carbon Filter

To enhance pollution mitigation, an Active Carbon Filter is incorporated to reduce airborne pollutants before data collection. It is placed near the gas sensors (MQ-135, MQ-7, and MQ-8) to compare pre-filtered and post-filtered air quality, offering insights into filtration efficiency. This filter actively removes harmful gases like CO, NOx, and VOCs, improving data accuracy and supporting sustainable urban air quality management.

Software Components

Embedded Programming and Firmware Development

The ESP32 microcontroller is used for both sensor data acquisition and communication through Wi-Fi and LoRa modules. For ESP32, Arduino IDE with the ESP32 core is used to handle Wi-Fi connectivity and LoRa communication.

Database Management and Web Integration

Sensor data is transmitted to a MySQL database hosted on XAMPP, ensuring secure storage and real-time accessibility. A PHP-based web server retrieves and processes this data for web-based monitoring.

GIS Mapping and Data Visualization

To display real-time pollution data, the system integrates QGIS for GIS-based visualization. HTML, CSS, and JavaScript are used to develop a web-based GIS dashboard, which helps in pollution hotspot detection. Python scripts process and analyze the sensor data, enabling real-time alerts and insights for urban air quality management.

V. Results and Discussion

The proposed IoT-based environmental monitoring system was successfully implemented and tested. The system consists of a transmitter module for real-time sensor data acquisition and a receiver module for data processing and visualization. The results are discussed based on the different components of the system, including hardware functionality, database storage, GIS mapping, and alert mechanisms. The transmitter module, consisting of a ESP32 microcontroller, LoRa RA-02 RF module, and environmental sensors (MQ-135, MQ-7, MQ-8, noise sensor, and DHT22), successfully collected and transmitted data. The sensor data was accurately processed and sent via LoRa communication, ensuring long-range transmission even in urban environments with limited cellular coverage. The ESP32 Wi-Fi microcontroller received the transmitted sensor data via the LoRa RA-02 RF module.

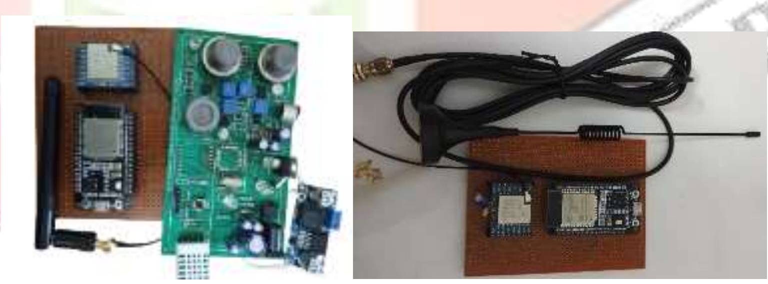

Figure 5: Transmitter Module and Receiver Module

The data was then forwarded to the MySQL database hosted on XAMPP for storage and further analysis. The system ensured real-time reception and accurate data logging.

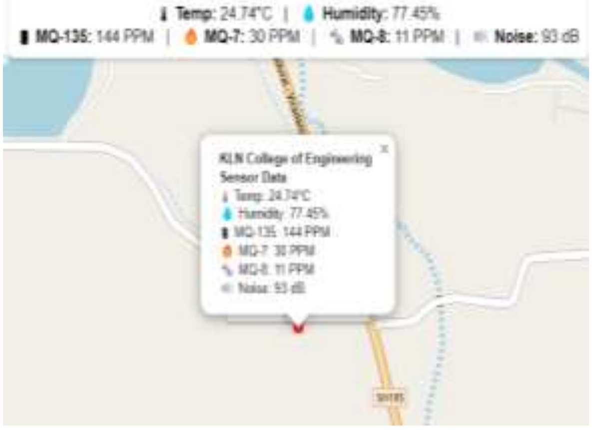

Figure 6: GIS Mapping

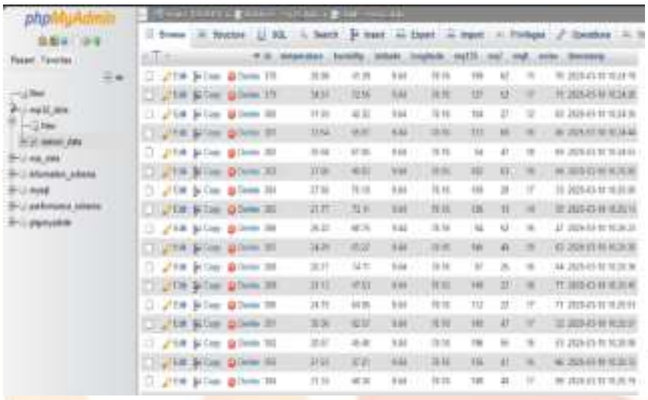

Figure 7: Database in XAMPP Software

The real-time environmental data was visualized using GIS mapping, allowing pollution hotspots to be identified across urban areas. The GIS-based visualization provided insights into pollution trends, supporting urban planning and public health management. The system effectively mapped pollution intensity, helping authorities take timely interventions.All sensor data was stored in a MySQL database for future analysis and historical tracking. The database structure allowed efficient retrieval and processing of air quality data. The XAMPP server successfully managed sensor logs, enabling smooth integration with GIS visualization and alert mechanisms.

Sensor	Range	Threshold Level	Pollution condition
MQ-135(Co2, NO2)	10-1000 (PPM)	200PPM	Good
MQ-7(Co)	20-2000 (PPM)	70 PPM	Bad
MQ-8(H2)	100-10000 (PPM)	10 PPM	Good
Noise Level(db)	0-140 (db)	90 PPM	Good
Temperature	0°C-40°C	32°C	Bad
Humidity	0–100%RH	80%RH	Bad

Tabel 1: Sensor Specifications

The data analysis for the environmental monitoring sensors is being conducted using ThingSpeak, an IoT analytics platform. Sensor data from MQ-135, MQ-7, MQ-8, DHT22, and the noise sensor is transmitted to ThingSpeak in real-time via ESP32 WROOM . The platform processes and visualizes the data through dynamic charts, graphs, and heatmaps to monitor pollution levels effectively. MATLAB analytics in ThingSpeak is used to perform statistical analysis, detect anomalies, and generate predictive insights based on historical data trends. Alerts are configured to notify users via email or Telegram when pollution levels exceed predefined thresholds.

Figure 8: Data Analysis For Sensor

Figure 9: SMS Alert System

Compared to prior systems such as those by Abraham et al. [3] and Nowshin and Hasan [4], the proposed system offers real-time GIS visualization and incorporates a dual-stage air quality assessment using Active Carbon Filters, enhancing both detection accuracy and pollution mitigation.

VI. Conclusion

This research proposes a comprehensive IoT-based urban environmental monitoring and pollution hotspot detection system that integrates low-cost hardware components and advanced communication protocols to address the limitations of traditional monitoring methods. By utilizing a ESP32 microcontroller for sensor interfacing, an ESP32 Wi-Fi module for cloud connectivity, and LoRa RF modules for long-range data transmission, the system ensures real-time, scalable, and reliable environmental data collection. The integration of Geographic Information System (GIS) mapping enables spatial visualization of pollution intensity, allowing authorities to pinpoint and respond to pollution hotspots effectively.

A notable innovation is the inclusion of an Active Carbon Filter to measure pre- and post-filtration air quality, providing a practical approach to evaluating pollutant reduction in real-time. Additionally, the use of Telegram alerts and cloud-based databases enhances timely intervention and public awareness.

The system's low-power, low-cost, and modular design makes it suitable for large-scale deployment in smart cities, promoting data-driven urban planning and proactive public health management. Future enhancements will aim to broaden the sensing capabilities, implement predictive analytics using machine learning, and improve system autonomy for long-term field deployment.

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References

1. Arboleda, Bermudez, Maria; Shamim, Atif; "Self-Powered and Cost-Effective Wireless Sensor Node for Air Quality Monitoring With an Optically Transparent Smart Antenna System," IEEE SENSORS JOURNAL, VOL. 24, NO. 18, 15 SEPTEMBER 2024.doi: 10.1109/JSEN.2024.3435885.
2. Munsadwala, Yashvin; Joshi, Pankti; Patel, Pranav; Rana, Keyur . (2019). "Smart Innovation and Usages (IoT-SIU) - Identification and Visualization of Hazardous Gases Using IoT," doi:10.1109/IoT-SIU.2019.8777481.
3. Abraham, Shiny; Beard, Joshua; Manijacob, Renjith. (2017). [IEEE 2017 IEEE Global Humanitarian Technology Conference (GHTC) - San Jose, CA, USA (2017.10.19-2017.10.22)] 2017 IEEE Global Humanitarian Technology Conference (GHTC) – "Remote environmental monitoring using Internet of Things (IoT)," doi:10.1109/GHTC.2017.8239335.
4. Nowshin, Nadia; Shajedul Hasan, Md; (2021). "Microcontroller Based Environmental Pollution Monitoring System though IoT Implementation. 2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)," doi:10.1109/icrest51555.2021.9331
5. World Health Organization. (2016). Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease. https://apps.who.int/iris/handle/10665/250141.
6. World Health Organization. (2021). Ambient Air Pollution Attributable Deaths, World Health Organization. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/ambient-airpollution-attributable-deaths.
7. Health Effects Institute. (2019). State of Global Air 2019. Special Report. Accessed: Dec. 10, 2022. https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf.
8. Y. A. Awe, J. Nygard, S. Larssen, H. Lee, H. B. Dulal, and R. Kanakia. (2015). Clean Air and Healthy Lungs : Enhancing the World Bank's Approach To Air Quality Management. Open Knowl. Repository. Accessed: Dec. 5, 2022. https://openknowledge.worldbank.org/handle/10986/18025
9. W. Avis and S. Bartington, "Monitoring air quality in low-income and lower middle-income countries," Inst. Develop. Stud., K4D Helpdesk Rep., Brighton, U.K., 2020.https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/15694.
10. R. W. Pinder et al., "Opportunities and challenges for filling the air quality data gap in low- and middle-income countries," Atmos. Environ., vol. 215, Sep. 2019, Art. no. 116794, doi: 10.1016/j.atmosenv.2019.06.032.
11. World Health Org. WHO Ambient Air Quality Database 2022 Update. Status Report. Accessed: Sep. 20, 2022. https://cdn.who.int/media/docs/default-source/air-pollutiondocuments/air-quality-and-health/who-air-quality-database-2022— v7.pdf
12. A. Kumar and S. Chaudhuri, "Improving urban air quality monitoring in Delhi, India: Reflections on low-cost air quality sensors (LCAQS) and participatory engagement," Environ. Urbanization ASIA, vol. 13, no. 2, pp. 265–283, Sep. 2022, doi: 10.1177/09754253221122752
13. J. S. Apte et al., "High-resolution air pollution mapping with Google street view cars: Exploiting big data," Environ. Sci. Technol., vol. 51, no. 12, pp. 6999–7008, Jun. 2017, doi: 10.1021/acs.est.7b00891.
14. A. Soltani and E. Sharifi, "Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide," Frontiers Architectural Res., vol. 6, no. 4, pp. 529–538, Dec. 2017,doi: 10.1016/j.foar.2017.08.001.
15. R. E. Britter and S. R. Hanna, "Flow anddispersion in urban areas," Annu. Rev. Fluid Mech., vol. 35, no. 1, pp. 469–496, Jan. 2003, doi: 10.1146/annurev.fluid.35.101101.161147.
16. AQMD. Air Quality Sensor Performance Evaluation Center (AQSPEC)– Gas-Phase Sensor Evaluations. Accessed: Jan. 2024. [Online]. Available: https://www.aqmd.gov/aq-spec/evaluations/criteriapollutants/summary-gas

17. S. Ali, T. Glass, B. Parr, J. Potgieter, and F. Alam, “Low cost sensor with IoT LoRaWAN connectivity and machine learning-based calibration for air pollution monitoring,” IEEE Trans. Instrum. Meas., vol. 70, pp. 1–11, 2021, doi: 10.1109/TIM.2020.3034109.
18. P. Das, S. Ghosh, S. Chatterjee, and S. De, “A low cost outdoor air pollution monitoring device with power controlled built-in PM sensor,” IEEE Sensors J., vol. 22, no. 13, pp. 13682–13695, Jul. 2022, doi: 10.1109/JSEN.2022.3175821.
19. T. Becnel et al., “A distributed low-cost pollution monitoring platform,” IEEE Internet Things J., vol. 6, no. 6, pp. 10738–10748, Dec. 2019, doi: 10.1109/JIOT.2019.2941374.
20. R. Purbakawaca et al., “Ambient air monitoring system with adaptive performance stability,” IEEE Access, vol. 10, pp. 120086–120105, 2022, doi: 10.1109/ACCESS.2022.3222329.
21. M. Bacco, F. Delmastro, E. Ferro, and A. Gotta, “Environmental monitoring for smart cities,” IEEE Sensors J., vol. 17, no. 23, pp. 7767–7774, Dec. 2017, doi: 10.1109/JSEN.2017.2722819.
22. S. Dhingra, R. B. Madda, A. H. Gandomi, R. Patan, and M. Daneshmand, “Internet of Things mobile–air pollution monitoring system (IoT-Mobair),” IEEE Internet Things J., vol. 6, no. 3, pp. 5577–5584, Jun. 2019, doi: 10.1109/JIOT.2019.2903821.
23. A. Cavaliere et al., “Development of low-cost air quality stations for next generation monitoring networks: Calibration and validation of PM2.5 and PM10 Sensors,” Sensors, vol. 18, no. 9, p. 2843, 3390, doi: 10.3390/s18092843.
24. P. Kumar et al., “The rise of low-cost sensing for managing air pollution in cities,” Environ. Int., vol. 75, pp. 199–205, Dec. 2015, doi: 10.1016/j.envint.2014.11.019.
25. C. Borrego et al., “Challenges for a new air quality directive: The role of monitoring and modelling techniques,” Urban Climate, vol. 14,pp. 328–341, Dec. 2015, doi: 10.1016/j.uclim.2014.06.007.