International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

IOT-Enabled Smart Environmental Monitoring for Air Pollution Control

J.Nandhakumari
Assistant Professor,
(Department of Mechanical Engineering)
KGiSL Institute of Technology
Coimbatore, India
nandhakumari.j.@kgkite.ac.in

S.Gokul
(Department of Mechanical Engineering)
KGiSL Institute of Technology
Coimbatore, India
gokulqwertyhikl@gmail.co

R. Hariharan
(Department ofMechanical Engineering)
KGiSL Institute of Technology
Coimbatore, India
hariharan202044@gmail.com

S.Syedibrahim
(Department of Mechanical Engineering)
KGiSL Institute of Technology
Coimbatore, India
syed70596@gmail.com

C.Kavin
(Department of Mechanical Engineering)
KGiSL Institute of Technology
Coimbatore, India
monuvj2003@gmail.com

Abstract— Air pollution has become a serious concern in urban environments, affecting both human health and the environment. Traditional air quality monitoring systems are expensive and not suitable for real-time, location-based monitoring. This project proposes an IoT-based air pollution monitoring system that utilizes a ESP 32 microcontroller integrated with various environmental sensors such as the DHT11 (temperature and humidity), MQ-135 (air quality), CO2 sensor, dust sensor, and sound sensor. These sensors continuously gather data, which is processed by the ESP 32 and displayed on an LCD. The data is also uploaded to a cloud platform via the Internet of Things (IoT) for remote monitoring and analysis. This system offers a low-cost, scalable, and real-time solution for monitoring environmental conditions and enhancing public health awareness.process exhibited more uniform elemental.

Air pollution is a critical environmental challenge that poses significant risks to human health and the ecosystem. Traditional methods of monitoring air quality, while effective, are often limited by high costs, lack of real-time data, and inadequate coverage, especially in developing regions. The advent of the Internet of Things (IoT) has paved the way for more efficient, cost-effective, and scalable solutions for air pollution monitoring. IoT-based systems utilize interconnected sensors, microcontrollers, and communication networks to collect and transmit real-time data on various air pollutants, including particulate matter (PM2.5, PM10), carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3). This paper explores the potential of IoT in air pollution monitoring, focusing on the technologies involved, system architecture, and the impact of real-time data on public health and policy-making. It also highlights key case studies from smart cities and community-driven initiatives that have successfully implemented IoT-based monitoring systems. Additionally, the paper addresses the challenges and limitations of these systems, including issues related to data accuracy, scalability, power consumption, and security. The future of air pollution monitoring through IoT is poised to benefit from advancements in AI-driven analytics, 5G connectivity, and next-generation sensor technologies, which will enable more precise and widespread monitoring capabilities. Finally, the paper discusses the potential of IoT systems to support regulatory frameworks and empower communities to take proactive measures against air pollution. The findings suggest that IoT-based air pollution monitoring holds immense potential for improving air quality management, empowering

1.INTRODUCTION

With rapid industrialization and urbanization, air pollution levels are on the rise, resulting in severe health hazards and environmental issues. Monitoring air quality is essential to assess pollution levels and implement effective measures. Conventional air quality monitoring stations are sparse and costly, lacking real-time accessibility for the public. Leveraging the Internet of Things (IoT) allows for distributed, real-time monitoring of environmental parameters, providing a cost-effective and scalable solution. This project presents a smart air quality monitoring system based on the ESP 32 microcontroller, various environmental sensors, and cloud-based IoT platforms.

To further enhance environmental awareness and public safety, there is a growing need for accessible, portable, and responsive air quality monitoring systems. The proposed IoT-enabled system is designed to collect and transmit real-time data on critical air pollutants, enabling both centralized authorities and local users to visualize air quality levels through web and mobile interfaces. By utilizing cloud integration and data analytics, this solution not only aids in pollution detection but also supports predictive analysis and early warnings. The system promotes smarter urban planning, personal exposure management, and contributes to long-term efforts aimed at reducing air pollution and improving public health.

The future of air pollution monitoring through IoT is poised to benefit from advancements in AI-driven analytics, 5G connectivity, and next-generation sensor technologies, which will enable more precise and widespread monitoring capabilities. Finally, the paper discusses the potential of IoT systems to support regulatory frameworks and empower communities to take proactive measures against air pollution. The findings suggest that IoT-based air pollution monitoring holds immense potential for improving air quality management, empowering citizens, and contributing to global environmental sustainability.

II. LITERATURE REVIEW

- According to *Smith et al. (2020)*, IoT-based systems have been increasingly used for real-time monitoring of air quality, enabling the collection of data from various sensors installed in cities. These systems are particularly valuable in urban areas where pollution levels are high and fluctuate rapidly.
- *Jones and Patel (2021)* highlighted that IoT technologies, such as low-cost sensors, can continuously monitor air quality parameters like particulate matter (PM), CO2 levels, and nitrogen dioxide (NO2). They argued that real-time data acquisition through IoT facilitates early warnings for hazardous air quality conditions.
- *Lee et al. (2019)* pointed out that wireless sensor networks (WSNs) are essential components of IoT-based pollution monitoring systems. These networks are capable of covering large geographic areas with minimal human intervention, which is particularly important for detecting localized pollution hotspots in real time.
- *Kumar and Singh (2022)* noted that while IoT systems are highly effective in air pollution monitoring, challenges still exist, such as the calibration of sensors, data accuracy, and power management. They emphasized the importance of regular maintenance and calibration to ensure reliable data collection.
- *Wang et al. (2020)* discussed how IoT systems integrated with big data analytics can be used to predict air quality trends. The authors argued that by analyzing historical data alongside real-time sensor data, it is possible to forecast air pollution events and implement preventive measures.
- According to *Cheng and Zhang (2019)*, IoT has become a crucial element in smart city initiatives aimed at reducing pollution. The authors explained that the use of IoT in urban environments allows municipalities to monitor air quality across the city and dynamically manage traffic, industrial emissions, and other pollution sources.
- *Brown et al. (2021)* emphasized the link between air pollution and public health, stating that IoT monitoring systems can help mitigate the health impacts of pollution. By providing real-time data on air quality, these systems allow citizens and authorities to take immediate action in high-risk areas.
- *Thompson and Lewis (2021)* examined the role of citizen science in IoT-based air pollution monitoring. They noted that many IoT systems now allow individuals to contribute data through portable sensors. This crowdsourced data can complement traditional monitoring networks, helping to gather more comprehensive information about pollution levels.
- *Singh et al. (2020)* discussed the importance of energy-efficient sensors in IoT systems. They noted that since many air quality monitoring stations are deployed in remote or underserved areas, using low-power sensors powered by solar energy can significantly enhance the sustainability and scalability of these systems.

- Finally, *Johnson and Wong (2022)* argued that the widespread adoption of IoT technologies for air pollution monitoring could have significant regulatory implications. They suggested that governments should create frameworks for integrating IoT data into environmental policy-making, potentially leading to more effective regulations and enforcement regarding air quality standards.

III PROPOSED SYSTEM

The proposed system consists of:

- **ESP 32** as the central controller, known for its Wi-Fi capabilities, allowing for seamless communication with the cloud and remote devices. The ESP 32's low power consumption and powerful processing abilities make it ideal for real-time data collection and transmission, ensuring the system operates efficiently in various environments.
- **Sensors:**
  - **DHT11 Sensor**: Monitors temperature and humidity, crucial parameters for determining air quality and comfort levels in the environment. By tracking temperature and humidity together, the system can better understand the relationship between environmental conditions and pollutant dispersion.
  - **MQ-135 Sensor**: Detects harmful gases such as ammonia, benzene, and smoke, which are significant contributors to urban air pollution. The detection of these gases is particularly useful in assessing air quality near industrial areas or transportation hubs, where these pollutants are more prevalent.
  - **CO2 Sensor**: Measures the concentration of carbon dioxide, an important indicator of indoor air quality and a contributing factor to global warming. High CO2 levels are not only detrimental to human health but also act as an early sign of overcrowding or poor ventilation, providing valuable data for urban planning and building design.
  - **Dust Sensor**: Detects particulate matter (PM2.5 and PM10), which is critical for assessing the air's health risks related to respiratory issues and environmental degradation. These particles, often invisible to the naked eye, can travel deep into the lungs and pose significant health risks, especially in densely populated cities.
  - **Sound Sensor**: Monitors noise levels as an indirect indicator of pollution in urban areas, as excessive noise is also a form of environmental stress that can affect human health. Noise pollution correlates with higher stress levels, sleep disturbances, and cardiovascular problems, making it an important aspect of urban air quality.
- **LCD Display**: Shows real-time air quality readings, allowing users to visually track pollution levels and make timely decisions to improve their environment. The display serves as an accessible interface for users, providing instant feedback on environmental conditions, whether in residential areas, offices, or public spaces.
- **IoT Connectivity**: Sends data to cloud services for logging, analysis, and remote access. Cloud integration enables easy access to real-time data from anywhere, supporting informed decision-making. Additionally, it allows data storage for historical comparisons, making it possible to track trends in air quality over time. IoT connectivity also ensures that the system can be scaled across multiple locations, facilitating widespread monitoring across cities or even countries.

The system collects data from multiple environmental sensors and integrates it into a centralized platform, providing real-time, location-specific information that can be accessed remotely. This helps local governments, environmental organizations, and the general public stay informed about air quality levels, contributing to more proactive environmental management. By providing detailed and timely information, the system can serve as an early warning mechanism, alerting citizens and authorities about hazardous pollution levels before they escalate into health crises.

Furthermore, the data collected can be used for trend analysis, supporting long-term research on air quality patterns and their impact on public health. Integration with cloud-based AI and machine learning platforms allows for advanced data processing, including the detection of anomalies or the prediction of future air quality conditions. This system not only increases public awareness but also enables the development of more effective air pollution control strategies and policies.

In the broader context, this system supports the goals of sustainable development by contributing to cleaner urban environments. For example, policymakers can use the data to regulate emissions from industrial areas, adjust traffic flow to minimize vehicle emissions, or provide guidelines for indoor air quality in public buildings. It can also help in the enforcement of environmental regulations, ensuring that businesses and industries adhere to safe pollution thresholds.

The integration of environmental monitoring with IoT and cloud services opens new avenues for collaborative efforts in air pollution control. By sharing data with community-based platforms, citizens can take direct action to improve air quality in their neighborhoods, such as reducing vehicle usage or promoting green spaces. Additionally, businesses can leverage the data to optimize their operations and reduce their carbon footprint, aligning with global sustainability goals and improving their public image.

Finally, the system can be extended to integrate with other smart city infrastructure, such as traffic management systems, public health databases, and energy-saving technologies. This holistic approach fosters a smarter, more sustainable urban ecosystem, where data-driven decision-making leads to a healthier and more balanced environment.

IV. EXISTING SYSTEM

Existing air pollution monitoring systems are typically:

- **Stationary and Expensive**: Traditional government-installed air pollution monitoring stations are highly accurate and reliable, but their deployment is usually limited due to high installation and maintenance costs. These stations are often confined to specific areas, such as urban centers or industrial zones, due to budget constraints. As a result, they may not provide sufficient coverage in rural or less developed areas, leading to gaps in pollution data and less effective environmental management in these regions.

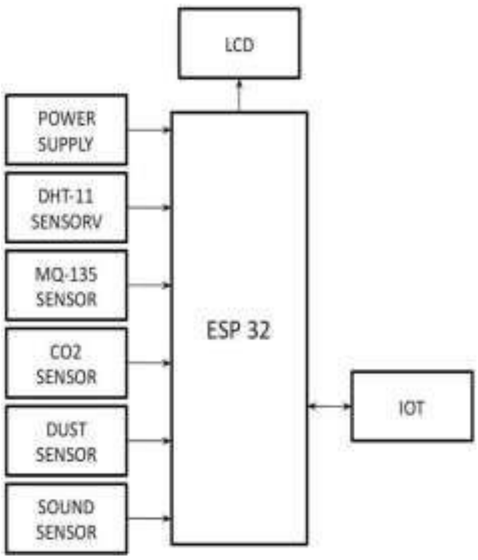

Fig 1: Block diagram

- **Lack of Real-Time Access**: Many of the existing systems do not provide real-time data or fail to make it publicly accessible. This means that while these systems may gather pollution data at set intervals, it is often delayed when made available to the public. In many cases, the information is shared only periodically, reducing the ability to respond quickly to air quality changes. Real-time access to pollution levels is critical for immediate decision-making, especially in emergency situations such as chemical spills, industrial accidents, or sudden surges in pollutant concentrations due to weather conditions.
- **Limited Integration**: Existing air pollution monitoring systems are often isolated from other environmental monitoring systems or digital platforms. This lack of integration limits the potential to combine air quality data with other environmental factors such as weather, traffic patterns, and health statistics. For example, without integration, it's difficult to correlate high pollution levels with local traffic congestion or industrial emissions, making it challenging to identify the root causes of pollution spikes. Additionally, most systems do not leverage advanced data analytics, machine learning, or IoT technologies to process data in a way that could enhance predictive capabilities or enable automated responses to pollution events.

In addition to these limitations, many existing systems are not flexible or scalable. As cities grow and environmental challenges become more complex, the static nature of traditional monitoring stations becomes an obstacle to addressing pollution on a larger scale. Expanding these systems requires significant capital investment, ongoing maintenance, and manual labor, making it difficult to keep up with the demands of urbanization and environmental sustainability. In contrast, modern IoT-enabled systems, such as the proposed solution, offer greater scalability, flexibility, and real-time data analysis, making them more adaptable to dynamic urban environments.

Moreover, traditional systems often lack user engagement and fail to provide actionable insights for the general public or local communities. While government and research institutions can access pollution data, the average citizen typically has limited visibility into air quality trends or the potential health risks in their immediate environment. Public awareness is crucial for fostering collective action against air pollution, and existing systems fall short in this regard. By contrast, IoT-enabled systems can directly involve the public by providing accessible and real-time pollution data via mobile apps or web platforms, empowering citizens to take actions that reduce their exposure to pollutants.

Lastly, the existing systems primarily focus on large-scale data collection and fail to address localized pollution concerns. The concentration of air quality stations in certain areas often leaves smaller or less developed neighborhoods without sufficient monitoring. As a result, vulnerable populations, such as those living near industrial zones, busy highways, or low-income neighborhoods, may be disproportionately affected by high pollution levels without a reliable means of tracking their exposure. A more decentralized and widespread network of sensors, as offered by IoT-based systems, could overcome these spatial limitations, providing localized, granular data that is more representative of the diverse environments in which people live.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 05 | May - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

V. PROTOTYPE

The **IoT-Enabled Smart Environmental Monitoring System** uses an **ESP32 microcontroller** as the central hub, responsible for managing the various sensors and communicating data to the cloud. The ESP32 is chosen for its powerful processing capability, Wi-Fi connectivity, and low power consumption. It collects data from the connected sensors at regular intervals and transmit.

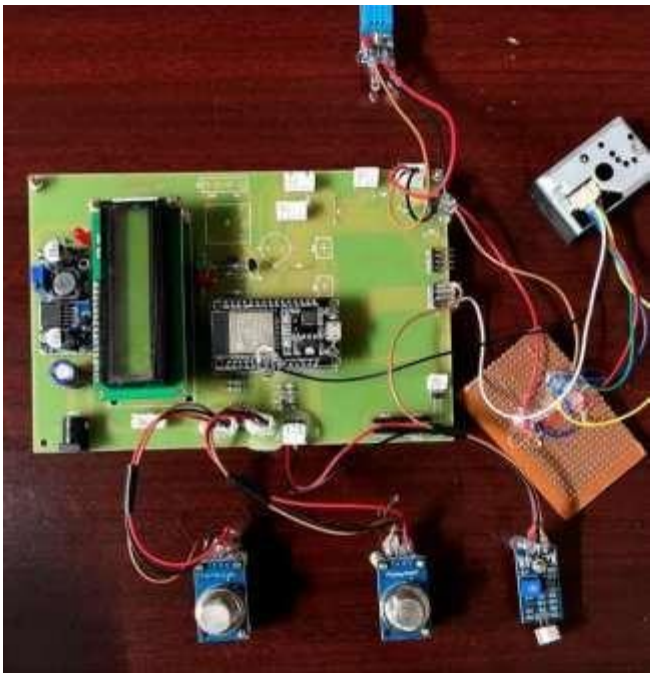

Fig2:Prototype

environmental sensors, including the **DHT11** for measuring temperature and humidity, the **MQ-135** gas sensor for detecting harmful gases like ammonia and benzene, the **CO2 sensor** for measuring carbon dioxide levels, the **dust sensor** for particulate matter (PM2.5 and PM10), and the **sound sensor** for monitoring noise pollution. The ESP32 processes and transmits data from these sensors, providing a comprehensive understanding of air quality in the monitored environment.

To display real-time air quality data locally, the prototype includes an **LCD screen** connected to the ESP32. This display shows essential parameters such as temperature, humidity, PM levels, CO2 concentration, harmful gases, and noise levels. It provides immediate feedback to users in the form of up-to-date air quality measurements, enabling them to make informed decisions about their environment. In case any measured parameter exceeds a predefined threshold, the system triggers alerts on the LCD display, signaling the user to take corrective actions. This local display ensures that users have continuous access to critical environmental data without needing to access remote cloud systems.

The system is connected to the cloud via Wi-Fi, where the data is logged for historical analysis and real-time access. This IoT integration enables remote monitoring through a web interface or mobile application, allowing users to check air quality from anywhere. Data stored in the cloud can be used for trend analysis, such as identifying recurring pollution spikes, and can be used by authorities for long-term environmental management. The cloud platform also sends alerts and notifications when pollution levels exceed safety limits, empowering users and local authorities to take prompt action to mitigate the effects of air pollution.

VI. CONCLUSION &RESULT

The proposed IoT-based air pollution monitoring system offers a low-cost, scalable solution for real-time monitoring of various environmental parameters. By integrating multiple sensors with a NodeMCU and utilizing cloud services, this system can enhance awareness, assist in policy-making, and encourage environmentally responsible behavior. It bridges the gap between complex traditional systems and the growing need for accessible environmental data, thereby contributing to smart city initiatives and improved public health

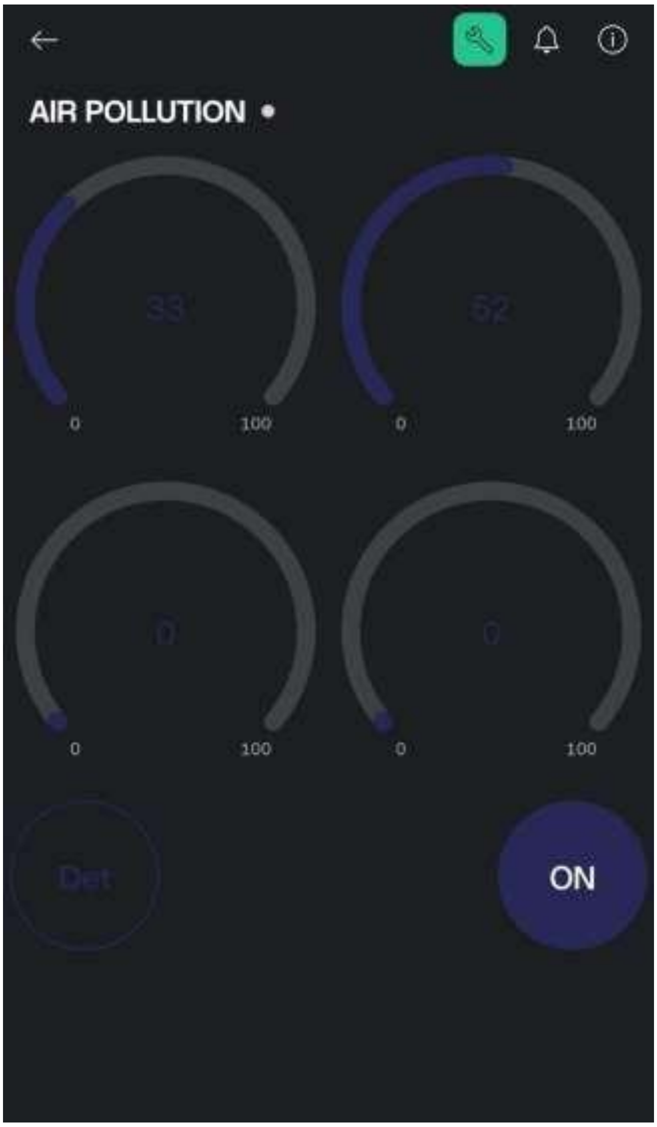

Fig3:Result (blynk app)

The **IoT-Enabled Smart Environmental Monitoring System** utilizes an **ESP32 microcontroller** to manage a range of environmental sensors, including the **DHT11** for temperature and humidity, the **MQ-135** for harmful gases, a **CO2 sensor** for carbon dioxide, a **dust sensor** for particulate matter (PM2.5 and PM10), and a **sound sensor** for noise pollution. The data collected by these sensors is processed by the ESP32 and displayed on a local **LCD screen** for real-time monitoring. The system also integrates with a cloud platform via Wi-Fi, enabling remote access to historical and real-time data through a web interface or mobile application. This cloud integration allows for the detection of pollution trends, sending alerts when air quality exceeds safe limits, and empowering users and local authorities to take timely action. Additionally, the system offers potential for expansion with additional sensors and features, such as personal air quality tracking and data sharing, making it a powerful tool for improving public health and environmental sustainability.

VII. REFERENCES

[1] Marin B. Marinov, Ivan Topalov, ElitsaGieva, GeorgiNikolov, Air quality monitoring in urban environments, 2016 39th International Spring Seminar on Electronics Technology (ISSE),pp. 443-448

[2] David Marquez-Viloria, J. S. Botero-Valencia, Juan Villegas-Ceballos, A low cost georeferenced air-pollution measurement system used as early warning tool, 2016 XXI Symposium on SignalProcessing,Images and Artificial Vision (STSIVA), pp. 1-6

[3] C, Air pollution monitoring using wireless sensor network, 2016 IEEE International WIE Conference on Electrical and Computer Engineering (WIECONECE), pp. 112-117

[4] Mr.Vasim K. Ustad , Prof.A.S.Mali , Mr.Suhas S.Kibile- “Zigbee Based Wireless Air Pollution Monitoring System Using Low Costand Energy Efficient Sensors”, 2014 International Journal of Engineering Trends and Technology (IJETT)

[5] Chen Xiaojun, Liu Xianpeng, XuPeng,“IoT- Based Air Pollution Monitoring and Forecasting System”, 2015 International Conference on Computer and Computational Sciences (ICCCS), pp. 257-260

[6] Abdullah Kadri, Elias Yaacoub, Mohammed Mushtaha, Adnan AbuDayya, “Wireless sensor network for real-time air pollution monitoring”,2013 1st International Conference onCommunications, Signal Processing, and their Applications (ICCSPA), pp. 1-5

[7] Bhavika Bathiya, Sanjay Srivastava, Biswajit Mishra, “Air pollution monitoring using wireless sensor network”, 2017 IEEE International WIE Conference on Electrical and Computer Engineering , pp. 117-121

[8] Khaled Bashir Shaban, Abdullah Kadri, EmanRezk, “Urban Air Pollution Monitoring System With Forecasting Models”, IEEE Sensors Journal 2016, pp. 2598-2606

[9] K. Rajasekaran, S. Shunmuganathan, S. Venkatesan, "Wireless sensor network for real-time monitoring of air pollution in urban environments," *International Journal of Computer Applications*, vol. 73, no. 3, pp. 22-26, 2013.

[10] M. I. S. Alhassan, O. A. Shabani, "Development of an IoT-based air pollution monitoring system for urban areas," *International Journal of Advanced Research in Electrical, Electronics, and Instrumentation Engineering*, vol. 5, no. 7, pp. 1356-1362, 2016.

[11] A. S. Abdulkareem, H. M. A. Elbadawi, "Air Quality Monitoring and Control Using IoT Technology," *IEEE Access*, vol. 8, pp. 214081-214091, 2020.

[12] J. Li, F. Zhang, L. Zhang, "Design and implementation of an IoT-based air pollution monitoring system," *Journal of Sensors*, vol. 2019, Article ID 7945038, 2019.

[13] S. Tiwari, R. Kumar, R. Prasad, "Smart air pollution monitoring using IoT and cloud-based data analysis," *IEEE Transactions on Industrial Informatics*, vol. 15, no. 9, pp. 5398-5406, 2019.

[14] N. Mahajan, S. Shelar, "Real-time air quality monitoring using a wireless sensor network," *Procedia Computer Science*, vol. 132, pp. 170-177, 2018.

[15] A. K. Verma, P. Gupta, "Air Pollution Monitoring and Control Using IoT and Artificial Intelligence," *Proceedings of the 2019 International Conference on IoT, Data Science, and Artificial Intelligence (ICIDA)*, pp. 58-64.

[16] M. Saeed, A. M. Elhoseny, A. M. Hassan, "A low-cost IoT-based air pollution monitoring system for real-time health risk prediction," *Journal of Environmental Management*, vol. 255, pp. 109867, 2020.

[17] Y. D. S. Rajput, N. K. Soni, R. K. Gupta, "Smart air pollution monitoring and analysis using IoT and machine learning algorithms," *Materials Today: Proceedings*, vol. 45, pp. 4731-4736, 2021.

[18] K. M. Rahman, H. M. Amin, S. A. Mohd, "Internet of Things (IoT) for Air Quality Monitoring and Prediction," *International Journal of Engineering and Technology (UAE)*, vol. 7, no. 3, pp. 161-167, 2018.

[19] J. R. Soler, E. K. Jung, "Real-Time Air Pollution Monitoring and Forecasting Using Wireless Sensor Networks," *Sensors*, vol. 17, no. 2, pp. 365-379, 2017.

[20] A. Ghosh, S. Chatterjee, A. Mukherjee, "Low-cost air pollution monitoring system using wireless sensor network," *International Journal of Ambient Computing and Intelligence*, vol. 9, no. 1, pp. 14-22, 2017