IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A CASE STUDY OF THE AIR QUALITY MONITORING SYSTEM

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Abstract: Due to factors like industries, urbanization, population growth, and vehicle use, which can have an impact on human health, pollution levels are rising quickly. An Internet of Things (IOT)-based air pollution monitoring system uses a web server to track the quality of the air. When the air quality drops below a certain point—that is, when there are enough dangerous gases like CO2, smoke, alcohol, benzene, NH3, and NOx in the atmosphere—it will sound an alarm. In order to facilitate the easy monitoring of air pollution, the LCD and webpage will display the air quality in PPM. The MQ2 sensor, which can precisely measure the amount of most dangerous gases, is used by the system to monitor the quality of the air.

Index Terms – Air pollution monitoring, Internet of things, MQ2 sensors, AQI.

I. INTRODUCTION

Air pollution is the biggest problem of every nation, whether it is developed or developing. Health problems have been growing at faster rate especially in urban areas of developing countries where industrialization and growing number of vehicles leads to release of lot of gaseous pollutants. Harmful effects of pollution include mild allergic reactions such as irritation of the throat, eyes and nose as well as some serious problems like bronchitis, heart diseases, pneumonia, lung and aggravated asthma. According to a survey, due to air pollution 50,000 to 100,000 premature deaths per year occur in the U.S. alone. Whereas in EU number reaches to 300,000 and over 3,000,000 worldwide. IOT Based Air Pollution Monitoring System monitors the Air quality over a web server using Internet and will trigger an alarm when the air quality goes down beyond a certain threshold level, means when there are sufficient amount of harmful gases present in the air like CO2, smoke, alcohol, benzene, NH3, LPG and NOx. It will show the air quality in PPM on the LCD and as well as on webpage so that it can monitor it very easily. LPG sensor is added in this system which is used mostly in houses. The system will show temperature and humidity. The system can be installed anywhere but mostly in industries and houses where gases are mostly to be found and gives an alert message when the system crosses threshold limit.

II. RELATED WORKS

1. **Marin B. et al. (2017):** This research examines the drawbacks of conventional air pollution monitoring systems, which are often bulky, expensive, and difficult to deploy widely. These challenges result in a sparse distribution of monitoring stations, crucial for accurately tracking air quality, especially in urban environments. The authors highlight that urban air pollution is highly dynamic, influenced by factors like traffic congestion and construction activities. They emphasize the importance of strategically placing monitoring stations in locations with varying pollution levels to ensure the system's effectiveness. This approach suggests a more comprehensive deployment strategy for real-time air quality monitoring.

2. **D. Verma et al. (2019):** Proposes an IoT-based solution to overcome the limitations of traditional monitoring systems. The research focuses on developing a compact, affordable air pollution monitoring system using various sensors, including the MQ2 sensor, to detect harmful gases like CO_2, smoke, benzene, NH_3, NO_x, and LPG. Their system not only provides real-time air quality data but also displays it in PPM on an LCD and a webpage for easy monitoring. Temperature and humidity are also monitored, providing a more comprehensive environmental picture. A key feature of the system is its ability to trigger alarms or send SMS alerts when pollution levels exceed certain thresholds, allowing for real-time, proactive air quality management.

3. **Zhao et al. (2020):** This study investigates the use of IoT for real-time air quality monitoring in smart cities. The authors highlight the growing importance of integrating IoT technologies into urban infrastructures for dynamic pollution tracking. They develop a low-cost air quality monitoring system using a network of environmental sensors, with cloud computing for data processing and analysis. Their system provides real-time feedback on air pollution levels and is designed to be scalable, allowing cities to expand their monitoring networks as needed. Additionally, the system uses a mobile application to deliver air quality data to users, ensuring easy access for citizens and authorities alike.

4. **K. J. Kumar et al. (2021):** This research proposes a smart air pollution monitoring system utilizing IoT and machine learning techniques to predict pollution levels. The system uses sensors for detecting multiple pollutants such as particulate matter (PM2.5 and PM10), CO_2, CO, and NO_x. The system integrates a machine learning model for predicting future air quality based on historical data and weather conditions. Alerts are generated when pollutant levels approach dangerous thresholds, and data is made available on a cloud platform for remote monitoring. The use of machine learning enhances the system's predictive capabilities, offering a more proactive approach to air quality management.

5. **K. B. Shah et al. (2020):** In this work, an IoT-based air quality monitoring system is designed to continuously monitor various pollutants in real time. The system uses a set of sensors, including the MQ7 for CO detection and the MQ135 for detecting gases such as ammonia, benzene, and alcohol. Data from these sensors is transmitted to a cloud platform for analysis and visualization. The system also sends real-time alerts to users when pollutant levels exceed acceptable thresholds. This research emphasizes the importance of combining IoT with cloud computing to provide scalable and accessible air quality monitoring solutions for large populations.

III. TECHNOLOGY STACK

- **Circuit Design & Simulation:**
  - **Proteus**
    Purpose: Electronic circuit design, simulation, and PCB layout design.
    Key Features: Real-time simulation, microcontroller support (Arduino, PIC, AVR, ARM), PCB design, 3D visualization, virtual instruments like oscilloscopes and logic analyzers.
- **PCB Layout Design:**
  - **Circuit Wizard**
    Purpose: PCB layout design from schematic creation to board manufacturing.
    Key Features: Auto-routing, manual routing, design rule checking (DRC), 3D visualization, error-free PCB designs, Gerber file export.

- **Programming:**
  - **Arduino IDE**
    Purpose: Programming microcontrollers (Arduino).
    Key Features: Syntax highlighting, built-in examples, supports multiple Arduino boards (Uno, Mega, Nano),
    libraries for extended functionality, one-click upload, serial monitor for debugging.

- **Mobile Application for IoT:**
  - **Blynk**
    Purpose: Internet of Things (IoT) platform for remote device control and monitoring via smartphones. Key Features: Customizable dashboards, real-time data visualization, support for various microcontrollers (Arduino, ESP32, Raspberry Pi), Blynk Cloud for communication, available on Android and iOS.

- **Sensors:**
  - **MQ-2 Sensor**
    Purpose: Air quality monitoring sensor.
    Key Features: Detection of gas and smoke for environmental monitoring. Data collected displayed on a LCD
    and sent via the internet for user notifications via Blynk.

- **Internet Connectivity:**
  - **Internet Line**
    Purpose: Data transmission for remote monitoring.
    Key Features: Internet connection used to send air quality data to users via Blynk app notifications.

IV. PROPOSED SOLUTION

1. The proposed solution aims to overcome the limitations of traditional air quality monitoring systems by implementing a scalable, cost-effective, and energy-efficient IoT network with real-time data processing and comprehensive monitoring. The system focuses on providing accurate and continuous air quality data across urban and rural areas, enabling immediate responses to pollution threats.

2. **Low-Cost, Energy-Efficient Sensors:** A network of durable, affordable sensors will continuously monitor harmful pollutants such as CO_2, CO, NO_2, SO_2, ozone, and particulate matter (PM2.5/PM10). By utilizing low-power communication technologies like LoRa and Zigbee, the system ensures energy efficiency and long-range data transmission. These protocols are particularly suitable for large-scale deployments with minimal maintenance, reducing both operational costs and the environmental impact.

3. **Cloud-Based Data Processing:** Sensor data will be transmitted to cloud platforms (e.g., AWS IoT, Google Cloud), where it will be stored, processed, and analyzed in real-time. This cloud-based infrastructure allows for efficient data management, real-time processing, and the generation of actionable insights, ensuring that air quality data is always up-to-date and accessible.

4. **Real-Time Monitoring & Visualization**: The system will provide real-time monitoring of air quality through intuitive dashboards, displaying pollutant levels and trends in user-friendly formats. Public access to these dashboards will encourage transparency and empower users to take informed actions. The system will also send alerts when pollutant levels exceed safe thresholds, prompting immediate intervention and raising awareness.

5. **Scalable & Integrated System:** The system is designed to be highly scalable, allowing easy expansion by adding more sensors as needed. It can also be integrated with existing smart city

infrastructures, facilitating coordinated environmental management and offering a holistic view of urban air quality. This integration will enable cities to address pollution more effectively and make data- driven decisions for sustainable urban planning.

6. **Improved Sensor Durability**: Ongoing research will focus on enhancing sensor durability and reliability. Sensors will be engineered to withstand extreme weather conditions, temperature fluctuations, and exposure to high levels of pollutants. By improving sensor longevity, the system ensures consistent performance with minimal maintenance, reducing the overall cost of ownership.

7. **Data-Driven Decision Making:** The collected data will not only help in real-time monitoring but also aid in long-term environmental planning. By analyzing trends in air quality, urban planners and environmental authorities can develop strategies to reduce pollution and improve public health. This proactive approach will lead to better-informed policy decisions that prioritize sustainability.

8. **Public Health Monitoring:** The system will provide detailed insights into the correlation between air quality and public health, offering authorities and citizens valuable information to mitigate risks. Public health campaigns can be launched based on the data collected, targeting areas with the most significant pollution problems.

9. **Cost-Effective Deployment**: Leveraging low-cost sensors and cloud infrastructure ensures that the system can be deployed at a fraction of the cost of traditional air quality monitoring systems. This makes it affordable for both municipalities and private sectors, enabling widespread adoption and large-scale monitoring.

V. CUSTOMER SATISFACTION

The IoT-based air quality monitoring system greatly enhances customer satisfaction by providing real-time, accurate air quality data through an LCD display and web platform. Users can easily monitor harmful gases like CO_2, CO, NO_2, SO_2, ozone, and PM2.5/PM10, which helps them make informed decisions about their environment. The system’s alarm feature activates when air quality falls below safe levels, ensuring users can take immediate action to protect their health and safety, offering peace of mind.

Additionally, the system's integration with mobile apps like Blynk allows users to receive instant notifications on their smartphones, keeping them informed even when they're away from home or the workplace. This convenience and real-time access to air quality data increase user confidence and encourage proactive health management.

The system’s flexibility ensures it meets diverse user needs, from homes to industrial environments. It adapts to various settings, offering value in residential spaces, workplaces, and industrial settings by helping users manage air quality and comply with regulations. With its scalability and ease of installation, the system can grow with the user’s needs, allowing for future expansion and continuous monitoring. This personalized approach to air quality monitoring leads to increased customer satisfaction, as it empowers users to take control of their environment and make informed decisions for their health and well-being.

VI. SUSTAINABILITY

The IoT-based air quality monitoring system promotes sustainability by being cost-effective, energy-efficient, and highly scalable. The system utilizes low-cost, energy-efficient sensors to monitor key pollutants such as CO_2, CO, NO_2, SO_2, ozone, and PM2.5/PM10. This makes the system suitable for deployment in various environments, from urban to rural locations, without significant financial or environmental burdens. The system's use of low-power communication protocols like LoRa and Zigbee ensures long-range, energy-efficient data transmission, contributing to a reduction in its overall carbon footprint.

Cloud-based data processing allows for real-time analysis and visualization of air quality, enabling informed, sustainable decision- making. By integrating this system into both urban and rural areas, municipalities can more effectively monitor pollution levels and reduce their harmful impacts on public health and the environment. The cloud infrastructure also ensures that data is accessible remotely, making it easier for stakeholders to respond to pollution events quickly.

The scalability of the system ensures that it can grow with cities and be integrated into existing smart city infrastructure. This allows for coordinated environmental management, contributing to long-term sustainability efforts. By continually monitoring air quality, the system supports proactive pollution management, helping to reduce harmful emissions and improve public health.
Over time, this contributes to the development of cleaner, healthier urban environments and supports the achievement of sustainability goals at a local and global scale.

VII. FUTURE SCOPE

The future of IoT-based air quality monitoring systems holds significant promise, particularly with the integration of emerging technologies. Advanced sensors will allow for the detection of a broader range of pollutants with greater accuracy, and with the advent of 5G connectivity, data transmission will become faster and more reliable, enabling real-time processing across vast areas. The incorporation of Artificial Intelligence (AI) and Machine Learning (ML) will enhance predictive analytics, allowing governments and organizations to anticipate pollution levels and take preventive actions, such as optimizing traffic flow, controlling industrial emissions, or deploying urban air purifiers. This predictive capability will significantly improve pollution management and environmental risk mitigation.

Additionally, the integration of these systems with smart city infrastructure will automate responses to pollution events. For example, traffic management systems could reroute vehicles to reduce emissions, while building management systems could adjust HVAC settings in real-time to optimize air quality. Personal devices, such as wearable sensors and mobile applications, will also play an important role, providing individuals with real-time updates and health recommendations based on local air quality data. This can help raise awareness and encourage personal behavior changes, further contributing to public health and environmental goals.

Moreover, community-driven IoT networks can expand the scope of air quality monitoring. Low-cost, portable sensors can be deployed widely in dense grids to monitor pollution levels at a more localized scale. These sensors can be powered by renewable energy sources, such as solar power, making the system sustainable, particularly in remote or underdeveloped regions.

Additionally, blockchain technology can be implemented to ensure data integrity, transparency, and trust among all stakeholders, enhancing the credibility and reliability of the collected data.

The potential applications of IoT-based air quality monitoring systems extend beyond environmental management. These systems can also have cross-sector applications in areas such as agriculture, where monitoring pollutants can optimize crop management, or healthcare, where real-time pollution data can inform public health interventions. In transportation, IoT systems can help optimize routes and vehicle emissions, further contributing to the reduction of pollutants.

With the ability to provide actionable insights and support evidence-based policy decisions, IoT-based air quality monitoring systems will be vital in the global effort to combat air pollution, improve public health, and achieve Sustainable Development Goals (SDGs) related to health, environmental sustainability, and urban development.

VIII. CONCLUSION

This research presents the development of an IoT-based air quality monitoring system using the Blynk platform and NodeMCU, which has been successfully demonstrated through experiments. The system offers several important advantages, including real- time monitoring and the ability to send alerts based on gas concentrations and temperature levels. The durability and reliability of the sensors used, combined with the system's expandability, make it suitable for deployment in various environments. NodeMCU plays a critical role by operating the monitoring system and displaying real-time data on an LCD screen via Wi-Fi.

In the future, the system can be enhanced by integrating Artificial Intelligence (AI) for automated decision-making and machine learning to improve the prediction of pollution levels. The system could also evolve by incorporating automated ventilation control systems, which could activate based on detected pollution levels, improving indoor air quality. The ability to expand these

systems, improve their sensor accuracy, and integrate them into broader smart city infrastructures will make them increasingly valuable in addressing the growing challenge of air pollution, leading to healthier and more sustainable environments.

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