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AQI Monitoring and Datalogging System using ESP8266

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Abstract: *Air pollution is an important environmental and public health issue that requires constant monitoring to measure air quality and reduce possible threats. This project is concerned with the design and implementation of an air quality monitor and data logger based on the ESP8266 microcontroller with several gas sensors, such as MQ135, MQ2, and MQ7, and a dust sensor for the detection of various air pollutants. The system is equipped to monitor important air quality parameters like carbon monoxide (CO), carbon dioxide (CO_2), liquefied petroleum gas (LPG), smoke, and particulate matter (PM) in real time. The data collected is wirelessly sent to the ThingSpeak cloud platform, where it is displayed using dynamic graphs and dashboards for easy interpretation. One of the most important characteristics of this system is that it can log air quality data over a period of time and is thus an important aid to environmental research and analysis. ThingSpeak not only offers real-time visualization but also gives access to download historical data in Excel format, making it possible to perform in-depth analysis, trend analysis, and prediction modeling. This makes the system an effective data-logging solution for measuring levels of pollution in urban settings, industrial areas, and indoor spaces. The ESP8266 microcontroller is instrumental in enabling wireless communication, keeping the system cost-effective, portable, and easy to install in different locations. The combination of IoT and cloud computing increases the accessibility of the data, enabling users to remotely access air quality from any internet-enabled device. Due to its low power usage, scalability, and simplicity, this system is an effective alternative to conventional air quality monitoring systems. Through a real-time, cloud-based, and data-driven solution, this project seeks to contribute to environmental sustainability, public health consciousness, and smart city initiatives. The data gathered can be used by researchers, environmentalists, policymakers, and the general public to evaluate pollution patterns, implement regulations, and formulate strategies to enhance air quality.*

Keywords*:* MQ7, MQ2 , ESP8266, IoT

I. INTRODUCTION

Air pollution is an important concern that impacts human health, the environment, and environmental sustainability at large. The existence of toxic gases like carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter (PM) in the air confers a serious threat to health, causing respiratory issues, cardiovascular diseases, and environmental degradation. As urbanization and industrialization are leading to high levels of pollution, the demand is growing for real-time air quality monitoring systems to evaluate and control exposure to pollution. This project deals with designing an air quality monitoring system and data logger based on the ESP8266 microcontroller coupled with MQ135, MQ2, MQ7 gas sensors, and a dust sensor to monitor different air pollutants.It is designed to monitor and measure harmful gases like carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3), LPG, smoke, and particulate matter (PM). They are emitted from different sources like vehicle exhausts, industrial activities, domestic activity, and construction activities. Monitoring of these pollutants has to be ongoing to keep track of air quality trends and control pollution accordingly. The use of multiple sensors guarantees thorough data capture, making this system a viable option for air quality monitoring in various environments.The core of this system is the ESP8266 microcontroller, an inexpensive, Wi-Fi-capable chip that supports wireless data transmission to the ThingSpeak cloud platform. ThingSpeak is an IoT analytics platform that allows real-time data visualization via interactive dashboards. Through Wi-Fi connectivity, the

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system does away with intricate wiring and provides remote monitoring of air quality information from any point on the globe. This aspect makes it particularly suitable for use in smart cities, industrial surveillance, and indoor air quality evaluation.Data logging is among the primary benefits of this system. ThingSpeak enables one to download the historical data in Excel format, which is beneficial for long-term environmental study. Researchers, government agencies, and policymakers can use this logged information to analyze trends in pollution, assess the effect of regulatory controls, and construct predictive models for air quality forecasts. The facility to store and analyze historical data increases the system's functionality beyond that of a real-time monitoring tool.Live visualization of air quality information is important for instant decision-making and generating awareness of pollution levels. The ThingSpeak dashboard offers a user-friendly interface where users can view live sensor readings, identify abrupt changes in air quality, and get alerts when pollution levels surpass safe limits. This facilitates timely actions by individuals, communities, and authorities, including enhancing ventilation, enforcing traffic control measures, or implementing industrial regulations.The suggested system is low in cost, light, and easy to install, which makes it an ideal replacement for costly and heavy air quality monitoring stations. Conventional air quality monitoring systems are usually costly to install and maintain, and hence not very accessible in smaller cities and rural towns. The use of low-cost materials such as ESP8266 and gas sensors in this system offers a low-cost solution that can be easily implemented in environmental monitoring on a large scale.Yet another important benefit of this project is its ability to scale and adapt. The system can be simple to add new sensors for detecting other air pollutants, like nitrogen oxides (NOx) and sulfur dioxide (SO_2). In addition, it can be connected to mobile apps or web platforms for improved end-user interaction and reporting. This flexibility allows the system to be generalizable for many different applications, ranging from indoor air quality monitoring within residences and businesses to large-scale environmental research.
IoT is one of the key drivers in contemporary environmental monitoring systems. Through the integration of air quality sensors with the cloud, this project fits into the vision of smart cities, with the use of digital technology to transform living in urban areas. Real-time sharing of data, inter-stakeholder collaboration, and automatic pollution control are facilitated through IoT-based monitoring of air quality. This supports the worldwide efforts at providing sustainable and improved living conditions.Security and reliability are also important considerations for this system. The ESP8266 supports encrypted data transmission, ensuring that the collected air quality data is securely sent to the cloud without unauthorized access. Additionally, periodic calibration and maintenance of sensors help maintain measurement accuracy and reliability. Proper implementation of these factors ensures that the system delivers consistent and precise air quality data for long-term monitoring and analysis. This project responds to the critical need for real-time, cloud-based air quality measurement and data logging. Through the integration of ESP8266, several gas sensors, and a dust sensor with the ThingSpeak platform, the system gives a low-cost, efficient, and scalable solution for tracking air pollution. With capabilities like real-time visualization, past data logging, and remote access, the system is extremely useful for researchers, environmentalists, policymakers, and general users. By making air quality information more accessible and actionable, this project helps to raise awareness, enhance health outcomes, and encourage cleaner environments for generations to come.

II. LITERATURE REVIEW

Gupta, R., & Sharma, P. (2019) – In their study, the authors developed a GSM-based air quality monitoring system that allows real-time transmission of pollution data via SMS alerts. Their findings suggest that GSM technology is effective for remote monitoring, particularly in areas with limited internet connectivity. However, they noted that GSM incurs higher operational costs due to SMS charges and has slower data transmission compared to modern wireless protocols. Kumar, V., & Jain, A. (2020) – Their research, ″, presents a Bluetooth-based monitoring system designed for short-range air pollution monitoring in indoor environments. The study highlights that Bluetooth Low Energy (BLE) is energy-efficient and cost-effective for personal air quality monitoring. However, the limited transmission range (typically 10–30 meters) restricts its use for large-scale outdoor applications. Lee, S., & Park, H. (2018) – The paper ″ explores the advantages of Zigbee for environmental sensing applications. The authors demonstrate that Zigbee offers low power consumption, secure data transmission, and efficient mesh networking, making it ideal for large-scale deployments. However, they observed that Zigbee requires proper network coordination and is less common than Wi-Fi

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in smart city applications. Gonzalez, R., & Martinez, L. (2021) – Their research, , focuses on Wi-Fi-based monitoring systems that transmit air pollution data to cloud platforms such as ThingSpeak and Blynk. The study emphasizes Wi-Fi's high data transmission speed and seamless integration with IoT platforms, making it a preferred choice for real-time air quality monitoring. The main drawback identified was Wi-Fi's higher power consumption, making it less suitable for battery-operated systems. Ahmed, S., & Patel, N. (2020) – The authors compare GSM, Bluetooth, Zigbee, and Wi-Fi in terms of coverage, cost, power consumption, and scalability. Their study concludes that Wi-Fi is best for real-time cloud-based applications, Zigbee is ideal for low-power mesh networks, Bluetooth is suited for short-range monitoring, and GSM remains relevant for remote areas lacking internet access. Wang, J., & Zhao, M. (2019) – Their paper, , presents a hybrid GSM-IoT system where GSM is used as a backup communication channel in case of Wi-Fi failure. The study demonstrates that GSM enhances system reliability in areas with intermittent internet access, but data transmission delays and higher network costs remain a challenge. Torres, H., & Kim, J. (2021) – The authors compare Zigbee and Wi-Fi in sensor network applications. They conclude that Zigbee is superior for low-power, battery-operated sensors, while Wi-Fi offers better data transmission speed and cloud connectivity. They recommend hybrid systems that combine both technologies for efficient air quality monitoring. Singh, R., & Verma, K. (2018) – Their study, , explores how Bluetooth-based systems can enhance indoor air monitoring. Their system efficiently detects CO_2, VOCs, and particulate matter and sends alerts to nearby smartphones. The authors highlight that Bluetooth's low cost and easy integration make it ideal for personal health monitoring, but its limited range restricts large-scale deployment. Choudhury, B., & Das, T. (2020) – Their work, , focuses on deploying GSM-based systems in rural and industrial settings where internet connectivity is unreliable. The study finds that GSM networks are stable for SMS-based alerts and basic air quality reporting, but the lack of real-time data visualization is a significant drawback compared to Wi-Fi and cloud-based solutions. Zhang, L., & Huang, Y. (2021) – Their research, proposes a multi-protocol system that switches between Wi-Fi, GSM, and Zigbee depending on network availability..

III. METHODOLOGY

Air pollution level monitoring and data logging system is developed with the purpose to monitor and measure air pollution in real time via a mix of MQ135, MQ2, MQ7, and dust sensors. The device is constructed upon the ESP8266 microcontroller, which will read data from these sensors and send it to the ThingSpeak cloud platform for visualization and data storage wirelessly. This work describes the development, implementation, and working strategy of the system.

1. System Architecture

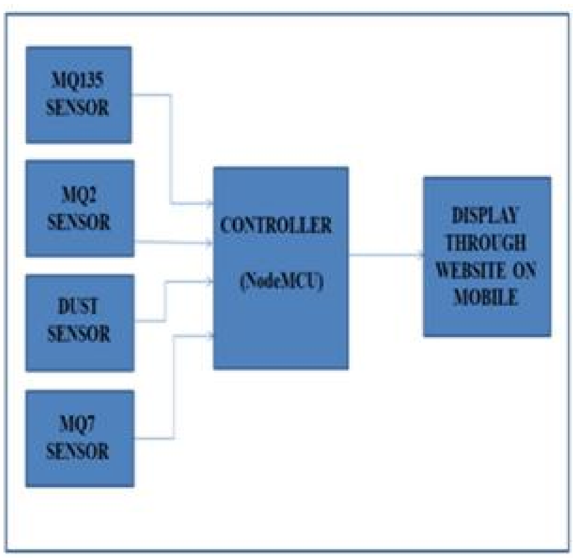

Fig i: Block diagram of air quality monitoring system using esp8266

The system includes four primary elements: sensors, microcontroller (ESP8266), data transmission module, and cloud-based visualization platform. The MQ135, MQ2, and MQ7 sensors identify dangerous gases like CO_2, CO, smoke, LPG, and other contaminants, while the dust sensor quantifies particulate matter concentration in the air. The ESP8266 processes this information and transmits it to ThingSpeak via Wi-Fi, enabling users to track air quality remotely using a dashboard.

2. Sensor Selection and Calibration

Every sensor in the system is selected on the basis of its sensitivity towards certain air pollutants.

MQ135: Detects CO_2, ammonia (NH_3), benzene, and alcohol concentration.

MQ2: Detects LPG, propane, methane, and smoke.

MQ7: Designed specifically for carbon monoxide (CO) detection.

Dust Sensor: Detects the level of fine particulate matter (PM2.5 and PM10) in the air.

Prior to deployment, the sensors are calibrated for correct readings. Calibration is done by exposing the sensors to known gas concentrations and adjusting the sensitivity levels of the sensors accordingly.

3. Microcontroller and Data Processing

The ESP8266 NodeMCU serves as the system's central processing unit. It retrieves real-time sensor data, processes the information, and translates the analog signals into usable values (e.g., ppm for gases and $\mu g/m^3$ for particulate matter). The ESP8266 is coded with Arduino IDE and libraries like MQ135.h and ESP8266WiFi.h to manage sensor communication and Wi-Fi connectivity.

4. Wireless Data Transmission

The ESP8266 is wired into a Wi-Fi network and sends the sensor readings to ThingSpeak at periodic intervals. HTTP GET/POST requests are employed by the microcontroller to send data packets with pollution levels. ThingSpeak API keys and channels are employed for secure data transfer. When a connection fails, the system re-initiates data transmission with a latency period to facilitate uninterrupted monitoring.

5. Cloud-Based Data Visualization

ThingSpeak offers real-time graphs, charts, and dashboards for convenient interpretation of air quality data. The platform can be accessed by any internet-enabled device, and remote monitoring is possible. The system can be set to alert when pollution levels go beyond safe limits, making it possible to take proactive measures.

6. Data Logging and Excel Export

One of the major advantages of this system is its data logging function. ThingSpeak stores sensor history automatically, and users can export this history in Excel format for analysis. This capability enables researchers and policymakers to analyze long-term air quality trends, detect pollution sources, and evaluate the effectiveness of pollution control strategies.

7. Power Management and System Efficiency

The system is optimized to run on low power, hence ideal for continuous monitoring. The ESP8266 goes into deep sleep mode between samples to save power, and the sensors are only powered up when needed. This optimization guarantees extended operation with low power consumption, making the system perfect for battery-powered use.

8. Deployment and Testing

The last step is to implement the system in real-life environments like cities, industrial sites, and indoor environments. The system's performance is measured by comparing its readings with comparative standard air quality measurement equipment. Accuracy, response time, and reliability are tested to confirm that the system can satisfy the necessary environmental monitoring requirements.

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Fig ii: Readings displayed on thingspeak platform

IV. CONCLUSION

The air quality monitoring system and data logger designed with ESP8266, MQ135, MQ2, MQ7, and dust sensors is a cost-effective, real-time, and remotely accessible air pollution level tracking solution. Using ThingSpeak, the system not only allows for visualization of air quality data but also data logging, enabling users to download past records for further analysis. This convergence of cloud computing and IoT makes environmental monitoring more accessible and usable, a useful tool for people, researchers, and decision-makers.One of the strong points of this system is that it can monitor all these pollutants continuously, such as carbon monoxide (CO), carbon dioxide (CO_2), LPG, smoke, and particulate matter (PM2.5 and PM10). Wi-Fi connectivity using ESP8266 ensures that data collected is transmitted to the cloud in real-time, and it does not require manual collection. Automation saves human effort, decreases errors, and enables instant access to air quality information from any internet-connected device.Furthermore, the data logging feature of the system on ThingSpeak offers an additional advantage by enabling users to store and analyze past trends of pollution. The downloadable data in Excel format facilitates researchers and environmental organizations to perform statistical analysis, create reports, and develop policies to fight air pollution. This aspect is especially helpful for long-term monitoring in industrial and urban areas where pollution rates vary based on different activities.Although it has many benefits, the system has some limitations that can be improved in the future. Sensor calibration, environmental conditions influencing sensor accuracy, and reliance on Wi-Fi connectivity are some factors that can affect the reliability of the readings. Machine learning algorithms for data accuracy enhancement, integration of more sensors for a better analysis, and battery-powered variants for use in remote areas are some improvements that can be made in the future.Overall, this IoT-driven air quality monitoring system effectively integrates low-cost hardware, cloud data storage, and real-time visualization to present an effective air pollution monitoring solution. Through enabling users with ongoing air quality information, the system has the ability to help increase awareness, enhance public health, and assist in environmental decision-making. With further improvement, this technology can become an integral part of smart cities and sustainable urban development.

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