

RESEARCH ARTICLE

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IOT BASED SMART INDUSTRIAL CARBON EMISSION MONITORING AND ALERT SYSTEM

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ABSTARCT

Industrial carbon emissions are a major contributor to environmental pollution and climate change. Continuous monitoring of these emissions is essential to ensure compliance with environmental regulations and to promote sustainable industrial operations. This project presents an Internet of Things (IoT)-based Smart Industrial Carbon Emission Monitoring and Alert System designed to monitor carbon-related gases in real time and provide instant alerts when emission levels exceed predefined limits.

The proposed system utilizes gas sensors, such as CO₂ and CO sensors, connected to a microcontroller (ESP8266/ESP32 or Arduino) for data acquisition. The collected data is transmitted to a cloud platform through IoT technology, enabling remote monitoring and analysis. A web dashboard or mobile application displays real-time emission levels, historical trends, and system status. When the concentration of harmful gases exceeds the safe threshold, the system automatically generates alerts through notifications, emails, or alarms to notify plant operators and environmental authorities.

The implementation of this system helps industries reduce environmental impact, improve workplace safety, and comply with emission standards. By providing accurate, continuous, and remote monitoring capabilities, the proposed solution offers a cost-effective and efficient approach to managing industrial carbon emissions. The system contributes to sustainable industrial development by enabling proactive emission control and supporting environmental protection initiatives.

Keywords: IoT, Carbon Emission, Gas Sensors, Industrial Monitoring, Alert System

INTRODUCTION

Industrialization has significantly contributed to economic growth and technological advancement, but it has also led to increased environmental pollution through the release of harmful gases and carbon emissions. Carbon dioxide (CO₂), carbon monoxide (CO), and other greenhouse gases emitted from industrial processes are major contributors to global warming, climate change, and health-related issues. Therefore, continuous monitoring and control of industrial emissions have become essential for maintaining environmental sustainability and ensuring compliance with government regulations.

Traditional emission monitoring methods often involve manual inspections and periodic measurements, which may not provide real-time information about emission levels. As a result, sudden increases in harmful gas concentrations can go undetected, leading to environmental hazards and safety risks. The rapid development of the Internet of Things (IoT) has enabled smart and automated monitoring systems that can collect, process, and transmit data in real time.

Whenever the emission level exceeds a predefined threshold, the system generates immediate alerts through alarms, notifications, or messages, allowing timely corrective actions.

This system provides a cost-effective, reliable, and efficient solution for industrial emission monitoring. It helps industries reduce environmental impact, improve workplace safety, comply with environmental standards, and support sustainable development goals. By integrating IoT technology with real-time monitoring and alert mechanisms, the proposed system offers a modern approach to environmental management in industrial sectors.[1][2]

LITERATURE SURVEY

The monitoring and control of industrial carbon emissions have become important research areas due to increasing environmental concerns and stringent government regulations. Several researchers have proposed IoT-based systems for real-time monitoring of air quality and industrial emissions.

1. IoT-Based Air Pollution Monitoring Systems

Many studies have focused on the development of IoT-enabled air pollution monitoring systems using gas sensors and wireless communication technologies. These systems collect data on harmful gases such as carbon dioxide (CO₂), carbon monoxide (CO), and methane (CH₄) and transmit the information to cloud platforms for real-time analysis. The research shows that IoT technology provides a cost-effective and scalable solution for environmental monitoring.

2. Wireless Sensor Networks for Industrial Emission Monitoring

Researchers have utilized Wireless Sensor Networks to monitor industrial emissions continuously. Multiple sensor nodes are deployed across industrial areas to collect emission data and send it to a central monitoring station. These systems improve monitoring accuracy and help detect pollution sources quickly. However, traditional WSN systems often lack cloud integration and remote accessibility.

3. Cloud-Based Environmental Monitoring Systems

Cloud computing has been integrated with IoT devices to store and process large amounts of environmental data. Studies indicate that cloud-based monitoring systems enable remote access, data visualization, historical trend analysis, and predictive maintenance. Such systems provide industries with valuable insights for emission control and regulatory compliance.

4. Smart Alert and Notification Systems

Several research works have introduced automated alert mechanisms for environmental monitoring applications. These systems generate alerts through SMS, email, mobile notifications, or alarms whenever pollutant levels exceed predefined thresholds. Real-time alerts help industries take immediate corrective actions, reducing environmental risks and ensuring worker safety.

5. Industrial IoT (IoT) for Sustainable Manufacturing

Recent advancements in Industrial Internet of Things (IoT) technology have enabled intelligent monitoring and automation in manufacturing environments. Researchers have demonstrated that IoT-based emission monitoring systems can improve operational efficiency, reduce carbon footprints, and support sustainable industrial practices through continuous data collection and analysis.[3][4]

METHODOLOGY

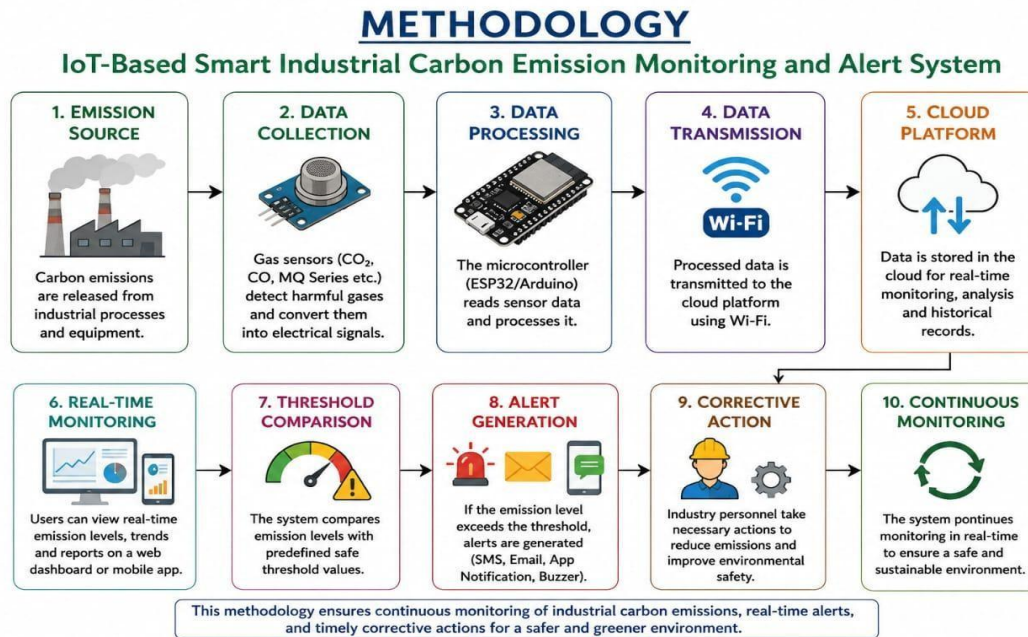


Fig 1: Methodology

The fig 1 The proposed IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System is designed to continuously monitor carbon emissions from industrial environments and provide real-time alerts when emission levels exceed safe limits. The system integrates gas sensors, a microcontroller, cloud services, and alert mechanisms to ensure effective monitoring and environmental protection.

System Components

Gas Sensors (CO₂/CO Sensors) – Measure the concentration of carbon-related gases in the atmosphere.

Microcontroller (ESP32/ESP8266/Arduino) – Collects sensor data and processes it.

Wi-Fi Module – Enables communication between the monitoring device and cloud server.

Cloud Platform – Stores and analyzes emission data.

Dashboard/Mobile Application – Displays real-time and historical emission information.

Alert System – Generates alarms, SMS, emails, or notifications when emission levels exceed the threshold.[5][6]

WORKING METHODOLOGY

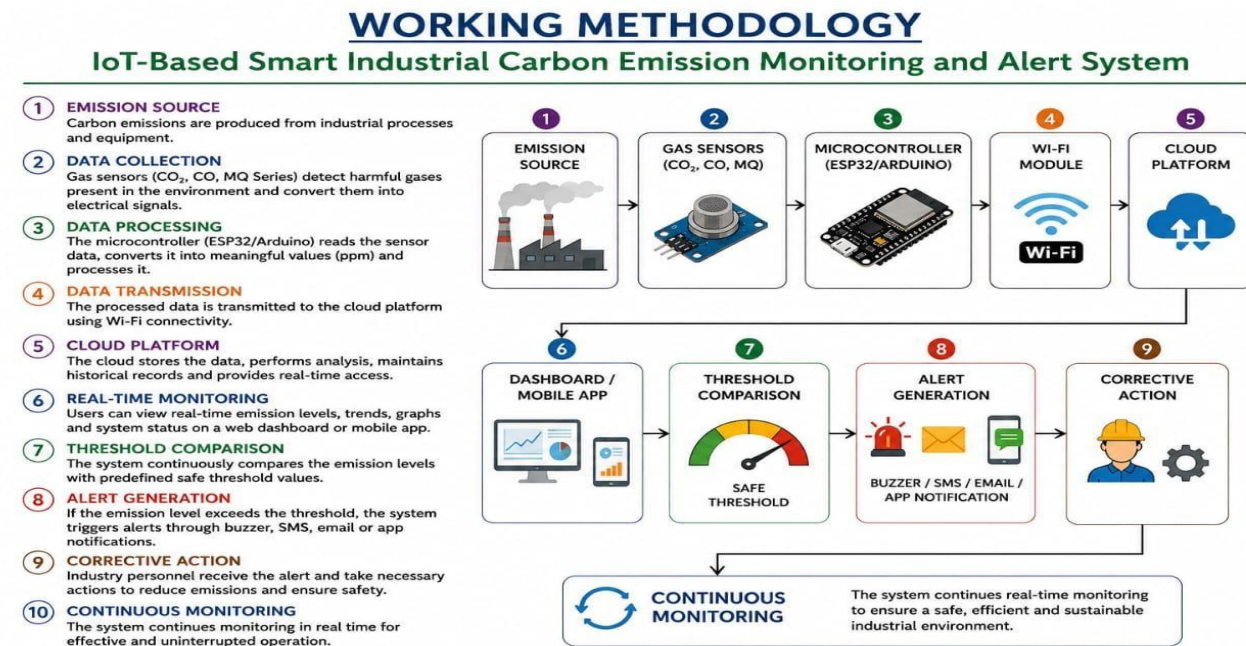


Fig 2: Working Methodology

The fig 2 illustrates the working methodology of the proposed IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System continuously monitors carbon emissions generated from industrial processes. Gas sensors installed in the industrial environment detect the concentration of harmful gases such as carbon dioxide (CO₂) and carbon monoxide (CO). These sensors convert the detected gas levels into electrical signals, which are then collected by a microcontroller such as ESP32 or Arduino.

The microcontroller processes the sensor data and transmits it to a cloud platform through a wireless communication network. The cloud platform stores the received information and performs data analysis to monitor emission patterns and environmental conditions in real time. The processed data can be accessed remotely through a web dashboard or mobile application, allowing users to monitor emission levels from any location.

The system continuously compares the measured gas concentrations with predefined safety limits. Whenever the emission level exceeds the permissible threshold, an alert is generated automatically through a buzzer, SMS, email, or mobile notification. These alerts enable industry personnel to take immediate corrective actions to reduce emissions and prevent environmental hazards.

The continuous monitoring capability of the system ensures timely detection of abnormal emission levels, improves industrial safety, supports environmental regulations, and helps industries minimize their carbon footprint. By integrating IoT technology with cloud computing and real-time alert mechanisms, the system provides an efficient and reliable solution for industrial carbon emission management. [7][8]

GLOBAL OBSERVATION

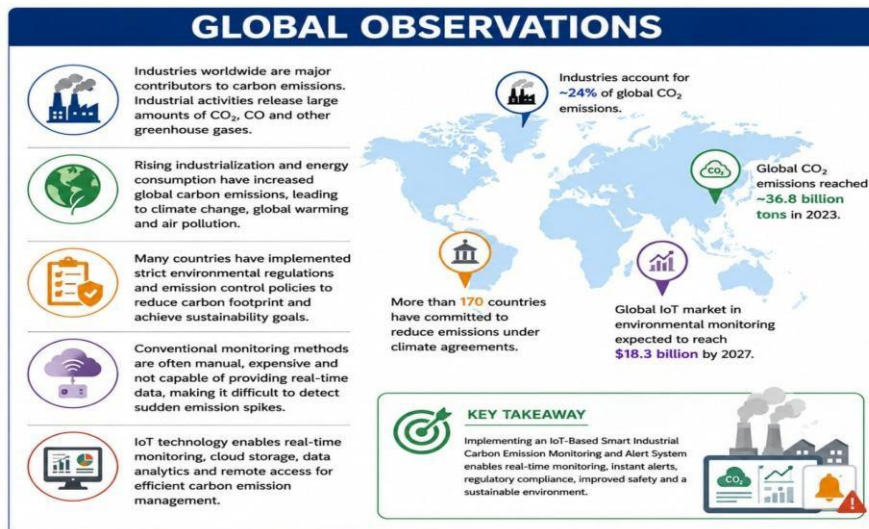


Fig 3: Global Observation

The fig 3 illustrates the growing global the increasing level of industrial carbon emissions has become a major global environmental concern. Industries across the world release significant amounts of carbon dioxide (CO₂) and other greenhouse gases during manufacturing and production processes. These emissions contribute to global warming, climate change, air pollution, and adverse health effects. According to environmental studies, industrial activities account for a substantial share of global greenhouse gas emissions, making emission monitoring and control a critical requirement.

Many developed and developing countries have introduced strict environmental regulations to limit industrial emissions and promote sustainable industrial growth. However, conventional monitoring systems are often expensive, labor-intensive, and unable to provide continuous real-time data. This creates a need for smart and automated monitoring solutions that can accurately track emission levels and provide immediate alerts when harmful gas concentrations exceed safe limits.

The emergence of Internet of Things (IoT) technology has revolutionized environmental monitoring by enabling real-time data collection, cloud-based analysis, and remote accessibility. IoT-based monitoring systems help industries improve operational efficiency, reduce environmental impact, and comply with environmental standards. As industries worldwide move toward smart manufacturing and sustainable development, the adoption of IoT-enabled carbon emission monitoring systems continues to grow.[9][10]

BLOCK DIAGRAM

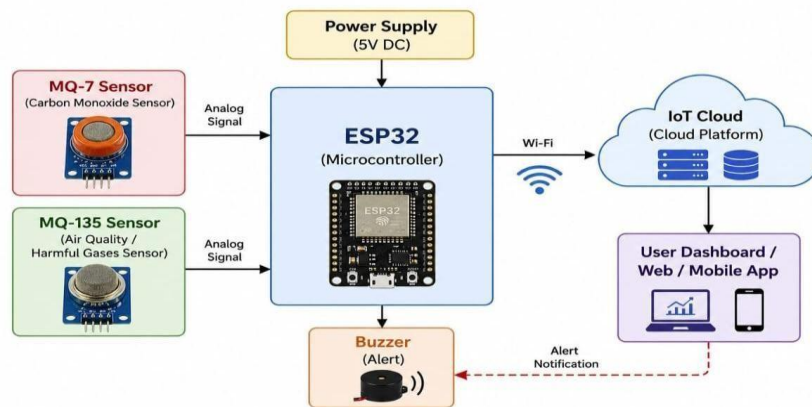


Fig 4: Block Diagram

The fig. 4 Block Diagram of IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System

The proposed system is designed to continuously monitor carbon emissions produced by industrial activities and provide real-time alerts whenever harmful gas concentrations exceed safe limits. The system consists of several interconnected modules that work together to ensure efficient emission monitoring and environmental protection.

1. Industrial Emissions

Industrial processes such as manufacturing, power generation, and chemical production release carbon dioxide (CO₂), carbon monoxide (CO), and other harmful gases into the atmosphere. These emissions are the primary source of environmental pollution and are continuously monitored by the proposed system.

2. Gas Sensors

Gas sensors such as MQ135, MQ7, or CO₂ sensors are installed in industrial areas to detect the concentration of harmful gases. The sensors continuously measure gas levels in the surrounding environment and convert them into electrical signals. These signals represent the amount of carbon emissions present in the atmosphere.

3. ESP32 / Arduino Microcontroller

The microcontroller acts as the central processing unit of the system. It receives data from the gas sensors, processes the readings, and converts them into meaningful values such as parts per million (ppm). The microcontroller also compares the measured values with predefined threshold limits to determine whether the emission levels are safe or hazardous.

4. Wi-Fi Module

The Wi-Fi communication module enables wireless transmission of data from the microcontroller to the cloud platform. In ESP32-based systems, Wi-Fi functionality is built into the controller. This module ensures seamless communication between the monitoring device and remote servers.

5. Cloud Platform

The cloud platform stores the received emission data and performs further analysis. It maintains historical records, generates reports, and provides real-time access to monitoring information. Cloud storage allows users to access emission data from any location using internet-enabled devices.

6. Dashboard / Mobile Application

The dashboard or mobile application provides a user-friendly interface for monitoring industrial emissions. It displays real-time gas concentration values, graphical trends, historical records, and system status. Industry operators

7. Alert System

The alert system is activated whenever the measured emission levels exceed predefined safety limits. Alerts can be

INDIAN STATISTICS

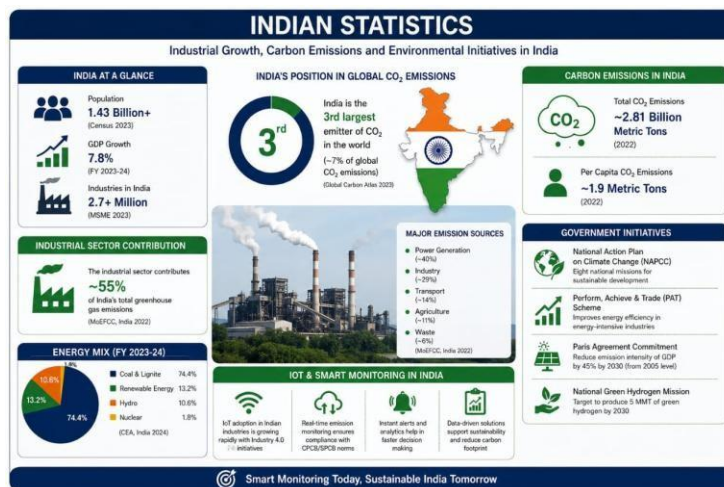


Fig 5: Indian Statics

The fig 5 represents the current scenario of Indian Statistics. India is one of the fastest-growing economies in the world, with rapid industrialization contributing significantly to energy consumption and carbon emissions. The industrial sector, including manufacturing, cement, steel, chemicals, and power generation, is a major source of greenhouse gas emissions. Monitoring and controlling these emissions have become essential to achieve sustainable development and environmental protection.

According to recent environmental reports, India is among the world's largest carbon dioxide (CO₂) emitters due to its large population, expanding industries, and dependence on fossil fuels. The industrial sector contributes a substantial share of the country's total greenhouse gas emissions. To address this challenge, the Government of India has introduced various initiatives such as the National Action Plan on Climate Change (NAPCC), Perform, Achieve and Trade (PAT) Scheme, and commitments under the Paris Climate Agreement to reduce emission intensity and promote cleaner technologies.

The adoption of Industry 4.0 technologies, including the Internet of Things (IoT), is increasing across Indian industries. IoT-based monitoring systems enable real-time tracking of industrial emissions, helping industries comply with environmental regulations issued by the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs). These smart systems provide accurate data collection, remote monitoring, and instant alerts, making emission management more efficient and cost-effective.

The figure shows the growing focus on sustainability and smart manufacturing, IoT-based carbon emission monitoring solutions are becoming increasingly important in India. Such systems support pollution control efforts, improve industrial safety, and contribute to India's long-term goal of achieving a cleaner and greener environment.

HARDWARE IMPLEMENTATION

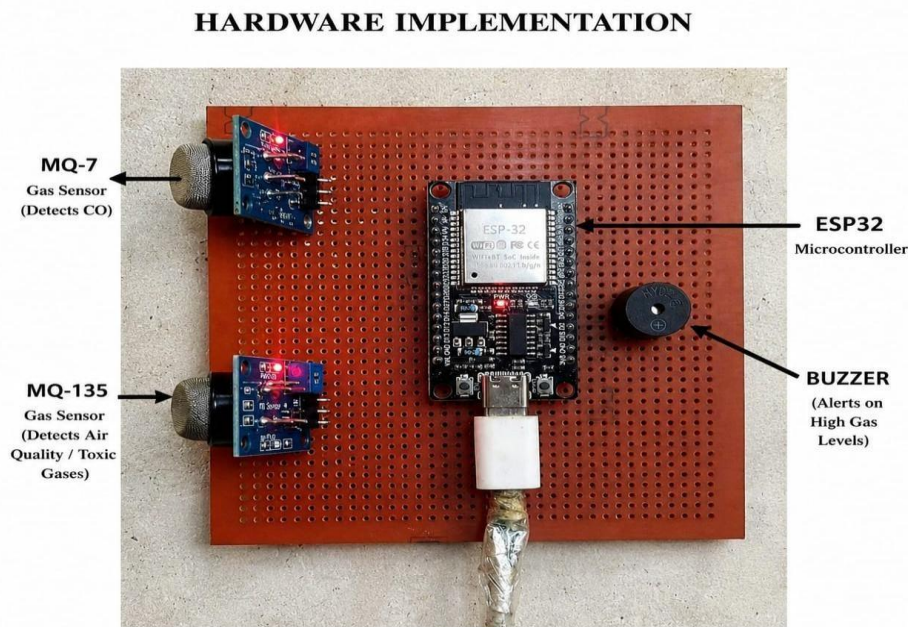


Fig: Hardware Implementation

Fig 6: Hardware Implementation

The fig 6 of the IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System consists of gas sensors, a microcontroller, communication modules, and alert devices. The system is designed to continuously monitor carbon emissions in industrial environments and transmit the collected data to a cloud platform for analysis and monitoring.

HARDWARE OUTPUT

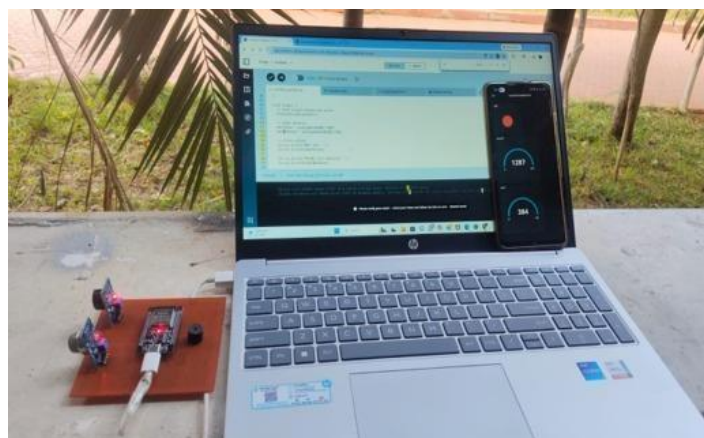


Fig 7: Hardware Output

The fig 7 illustrates the final output of the IoT-based Smart Industrial Carbon Emission Monitoring and Alert System. This system helps industries continuously monitor pollution levels, improve safety, and reduce harmful carbon emissions effectively.

OVERALL RESULT AND DISCUSSION

S.NO	PARAMETER	OBSERVATION	RESULT OBTAINED	DISCUSSION
1	Carbon Emission Monitoring	MQ135/CO ₂ sensor continuously monitors gas concentration	Accurate emission values obtained Enables real-time detection of harmful gases	Enables rea
2	Gas Sensor Performance	Sensor responds to changes in gas concentration	Reliable and stable readings achieved Effective for industrial air quality monitoring	Effective for detecting abnormal temperature conditions
3	ESP32 Data Processing	ESP32 processed sensor data efficiently	Fast response and abnormality detection achieved	Improved overall system performance and reliability
4	Wi-Fi Communication	Sensor data transmitted to cloud platform	Successful real-time data transfer achieved	Supports remote monitoring capabilities
5	Cloud Data Storage	Emission data stored and analyzed in cloud	Historical records maintained successfully	Facilitates trend analysis and reporting
6	Alert System	Alerts generated when threshold exceeds limit	Immediate notifications sent successfully	Reduces response time during hazardous conditions
7	Mobile/Web Dashboard	Users access data remotely through dashboard	Real-time monitoring achieved	Improves accessibility and decision-making
8	Environmental Safety	Continuous monitoring prevents excessive emission	Enhanced industrial safety achieved	Supports pollution control and worker protection

9	Overall System Performance	Integrated hardware and software operated successfully	Reliable carbon emission monitoring achieved	Suitable for industrial IoT applications and environmental compliance
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Table 1: Comparison table of observation and result

The table 1 shows the overall results and discussion of the proposed IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System successfully monitoring industrial carbon emission in real time. The gas sensors accurately detected harmful gases while the ESP 32 processed and transmitted data to the cloud platform efficiently. The alert mechanism responded immediately whenever emission level exceeded predefined threshold. The dashboard provided remote access

CONCLUSION

The IoT-Based Smart Industrial Carbon Emission Monitoring and Alert System provides an effective solution for monitoring and controlling industrial carbon emissions in real time. The system utilizes gas sensors, ESP32/Arduino microcontrollers, cloud computing, and wireless communication technologies to continuously measure carbon dioxide (CO₂) and other harmful gas concentrations. The collected data is processed and transmitted to a cloud platform, enabling remote monitoring through web and mobile applications.

The implementation results demonstrate that the system can accurately detect abnormal emission levels and generate immediate alerts whenever predefined safety thresholds are exceeded. This helps industries take timely corrective actions, reduce environmental pollution, and improve workplace safety. The cloud-based monitoring feature further enhances accessibility by allowing users to monitor emission levels from any location.

The proposed system is cost-effective, reliable, and suitable for industrial environments. It supports environmental sustainability by helping industries comply with pollution control regulations and reduce their carbon footprint. Future enhancements may include Artificial Intelligence (AI)-based prediction models, machine learning techniques for emission forecasting, and integration with automated pollution control mechanisms. Overall, the system contributes significantly to smart industrial monitoring and environmental protection.

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