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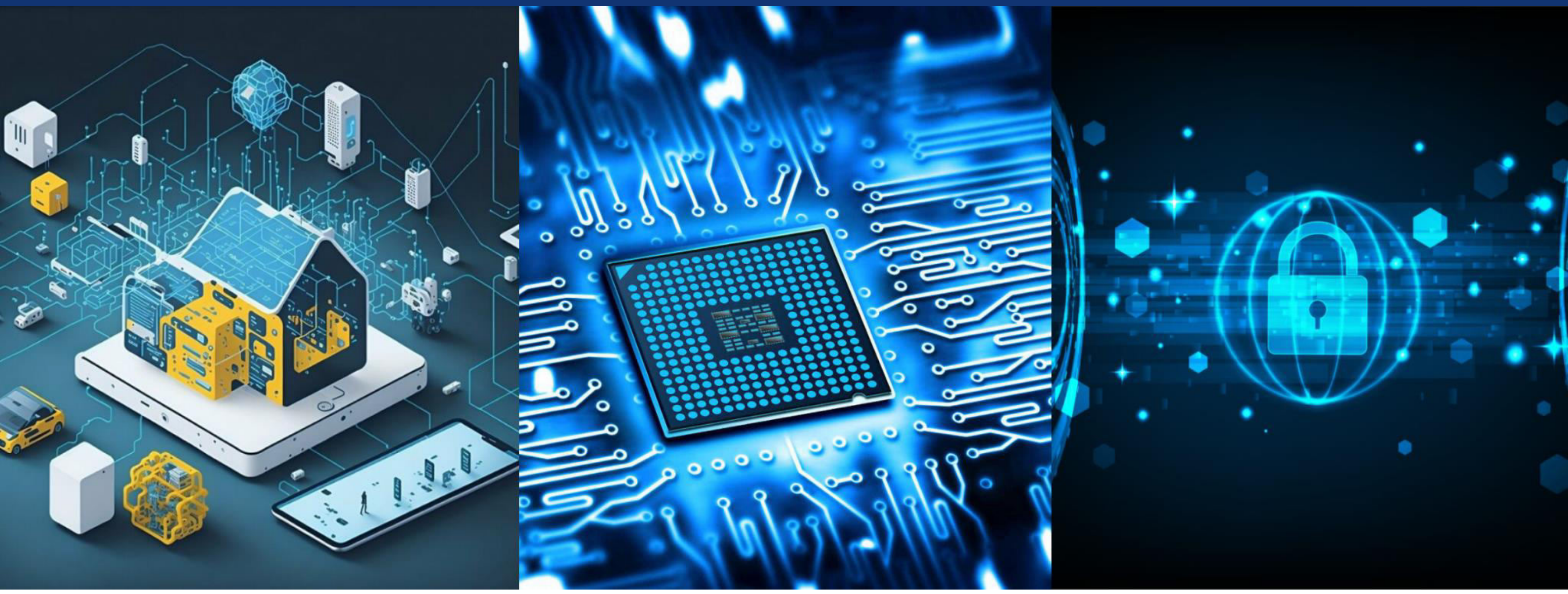

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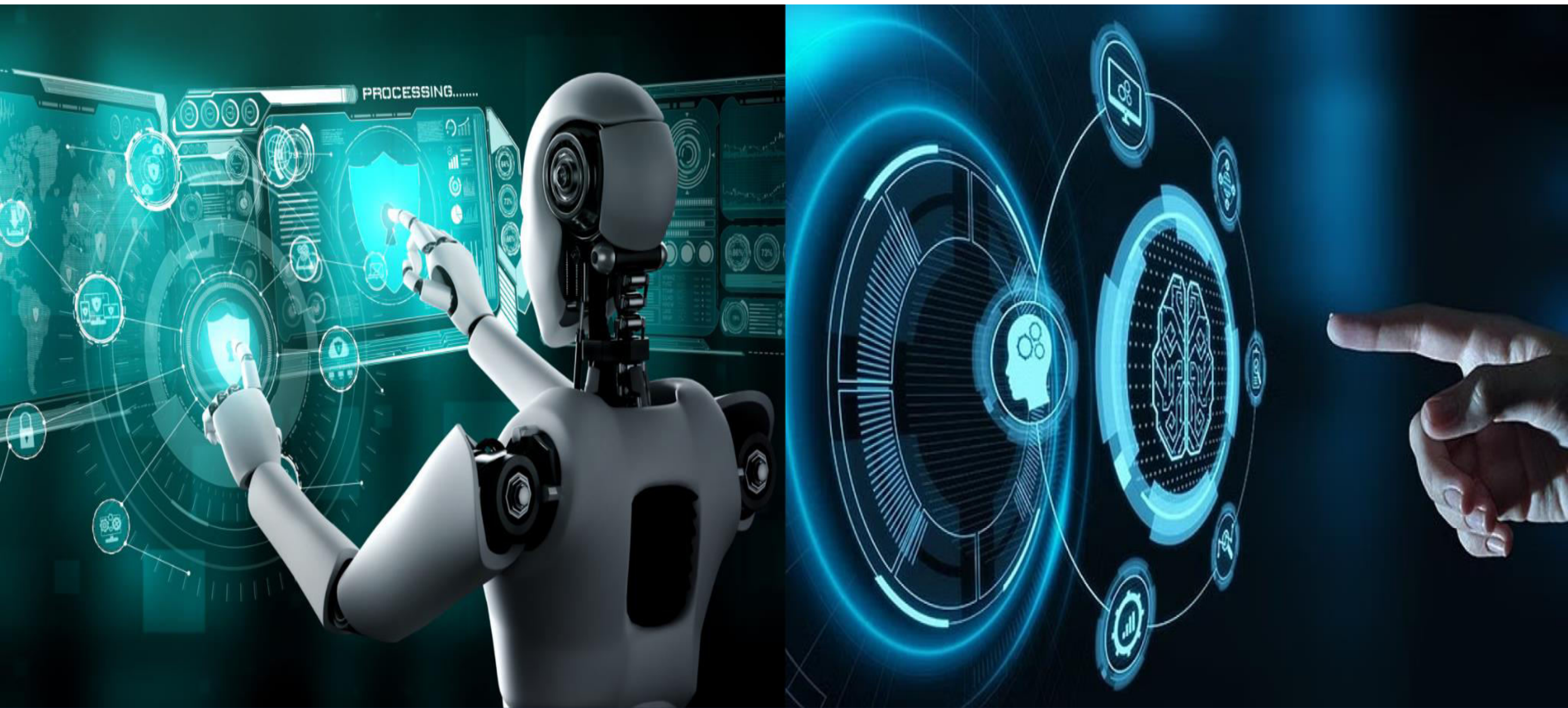


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# IoT-Based Smart Monitoring System for $CO_2$ Emission Control and Worker Safety in Cement Manufacturing

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**ABSTRACT**: Cement manufacturing is a key industry contributing to economic growth, but it is also a significant source of CO2 emissions and environmental pollution. The inhalation of cement dust poses serious health risks to workers, necessitating real-time monitoring and preventive measures. This paper proposes an IoT-based monitoring system that integrates wireless sensors, cloud computing, and automated alerts to track emissions and worker health conditions efficiently. The system utilizes NodeMCU, Arduino, and various sensors to measure critical parameters such as CO2 levels, temperature, and heart rate. The collected data is transmitted to a cloud-based platform for real-time analysis and storage, enabling remote monitoring and automated alerts in case of hazardous conditions. The proposed solution provides a cost-effective and scalable approach to improving environmental sustainability and worker safety in cement factories.

**KEYWORDS**: IoT, CO2 emissions, Cement Manufacturing, Worker Health Monitoring, Wireless Sensors, Cloud Computing.

## I. INTRODUCTION

Cement manufacturing is a crucial industry that significantly contributes to economic development but is also a major source of CO2 emissions and environmental pollution. The inhalation of cement dust poses serious health risks to workers, leading to respiratory diseases, skin irritation, and long-term health complications. Traditional monitoring systems rely on manual inspections and GSM-based alerts, which are inefficient for continuous tracking and real-time decision-making. To address these limitations, an IoT-based monitoring system is proposed, integrating wireless sensors, cloud computing, and automated alert mechanisms to enhance workplace safety and environmental sustainability. Wireless Sensor Networks (WSNs) play a vital role in monitoring industrial environments by detecting air pollutants, temperature variations, and worker health parameters.

The Internet of Things (IoT) further enhances this capability by enabling real-time data transmission and remote access through cloud-based platforms. The proposed system utilizes CO2 sensors, temperature sensors, and health monitoring devices to collect critical data, which is then processed by a microcontroller transmitted to a cloud server via Wi-Fi. This ensures that factory supervisors and health personnel can monitor conditions remotely and receive automated alerts when hazardous thresholds are exceeded.

**Internet of Things (IoT) in Monitoring**

IoT enables real-time tracking of worker health conditions and air quality in cement factories. Smart sensors collect data on temperature, emissions, and worker vitals, which can be accessed remotely via cloud computing.

**Cloud Computing & Wi-Fi**

Cloud technology ensures secure storage and retrieval of monitoring data, allowing quick decision-making. Wi-Finetworks provide seamless data transmission between sensors and monitoring stations.

## II. EXISTING SYSTEM

The traditional methods used in cement manufacturing for monitoring CO2 emissions and worker health conditions rely on manual inspections and GSM-based alert systems. These conventional approaches are inefficient due to delayed responses, limited data storage, and high dependency on human intervention. Cement plants release large amounts of CO2 and other pollutants, posing serious risks to both the environment and workers. However, the lack of continuous monitoring makes it difficult to detect and control excessive emissions in real time. In the existing system, emissions are measured using periodic manual sampling and laboratory testing, which does not provide immediate feedback on

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pollution levels. This delay in data collection and analysis prevents factory supervisors from taking timely corrective actions. Additionally, GSM-based alert systems are used in some factories to notify supervisors of hazardous conditions, but they only send alerts during emergencies and do not support continuous data tracking **or** historical data analysis**.** This makes it difficult to implement long-term emission control strategies.

Worker health monitoring in cement factories is also inadequate, as most systems depend on annual medical check-ups or manual observation. Workers exposed to high levels of cement dust and CO2 emissions are at risk of developing respiratory diseases, lung infections, and cardiovascular issues. Since the existing system lacks real-time health monitoring, it fails to detect early signs of health deterioration, leading to delayed medical intervention. Another major drawback of the current system is the lack of automation in data collection and reporting. Without a centralized data storage system, industries cannot analyze historical trends to improve environmental compliance. Moreover, manual reporting errors can lead to inaccurate emissions records, resulting in regulatory non-compliance and potential fines.

The existing system also lacks remote accessibility, requiring factory supervisors to be physically present to monitor emissions and worker safety. This limits the ability of industries to implement smart monitoring solutions that allow data to be accessed from any location. Additionally, high maintenance costs and limited scalability make traditional systems unsuitable for large-scale cement factories. Due to these challenges, there is a growing need for a real-time, automated, and IoT-based monitoring system that ensures continuous tracking of emissions and worker health conditions. The proposed system aims to overcome these limitations by integrating wireless sensors, cloud computing, and automated alert mechanisms, providing industries with a cost-effective, scalable, and efficient solution for emission control and workplace safety**.**

## III. PROPOSED METHODOLOGY

The proposed methodology focuses on developing an IoT-based real-time monitoring system to track CO2 emissions and worker health conditions in cement manufacturing plants. Traditional monitoring methods, such as manual inspections and GSM-based systems, often result in delayed responses and inefficiencies. To overcome these limitations, the proposed system integrates wireless sensors, microcontrollers, cloud computing, and automated alerts to enable continuous monitoring and proactive intervention.

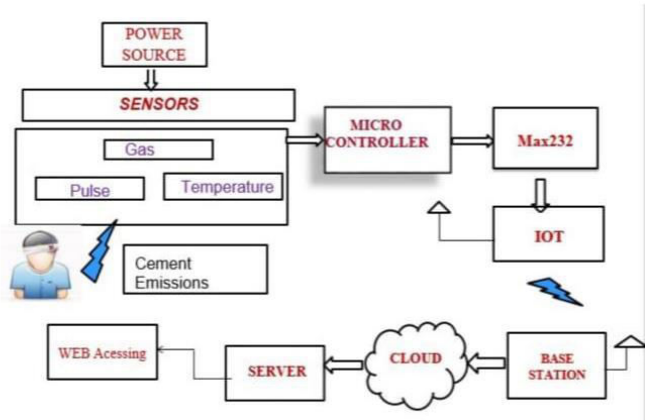


**Fig: 3.1 Block diagram**

The system consists of CO2 sensors, temperature sensors, and health monitoring devices that continuously collect data related to environmental emissions and worker safety. A microcontroller (Arduino/NodeMCU) is responsible for processing the collected sensor data, while the ESP8266 Wi-Fi module facilitates real-time data transmission to a cloud platform such as Firebase or Thingspeak. This cloud integration allows for remote monitoring, data logging, and historical trend analysis, which can help predict potential hazards and ensure compliance with environmental regulations. A mobile and web-based dashboard provides users with live data visualization, enabling factory supervisors to remotely access real-time updates on CO2 emissions and worker health conditions. The system also

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includes an automated alert mechanism, which is activated if CO2 levels exceed a predefined safety threshold or if abnormal worker health conditions are detected. In such cases, instant notifications are sent to factory supervisors, emergency contacts, and health personnel to ensure rapid response and prevent workplace hazards.

The cloud-based storage ensures that emission patterns and worker health trends are available for long-term analysis, allowing industries to adopt data-driven strategies to improve emission control and workplace safety. The system is designed to be cost-effective, scalable, and energy-efficient, making it suitable for large-scale cement manufacturing plants. Additionally, the use of wireless communication technology eliminates the need for manual data collection and reduces human intervention, improving overall efficiency and accuracy. By leveraging IoT technology, real-time data processing, and predictive analytics, the proposed methodology offers an intelligent, automated, and sustainable approach to reducing CO2 emissions and ensuring worker safety in cement industries. This system provides a proactive solution that not only enhances workplace safety but also helps industries comply with environmental regulations and industrial health standards. The integration of smart monitoring and cloud-based analytics ensures that the cement industry moves towards a safer, more efficient, and environmentally friendly manufacturing process.

The proposed system introduces an IoT-based monitoring solution to integrates wireless sensors, microcontrollers (Arduino/ NodeMCU), cloud computing, and automated alert mechanisms to provide real-time data collection, remote access, and predictive analysis.In this system, CO2 sensors, overcome the limitations of existing GSM-based emission tracking and worker health monitoring in cement manufacturing. This system temperature sensors, and health monitoring devices are strategically placed within the cement manufacturing environment to continuously monitor emissions and worker health conditions. These sensors collect real-time data, which is processed by a microcontroller (Arduino/NodeMCU) and transmitted via Wi-Fi (ESP8266) to a cloud-based platform (Firebase/Thingspeak). This ensures secure data storage, historical trend analysis, and remote access via a mobile or web application.

## IV. RESULT AND DISCUSSION

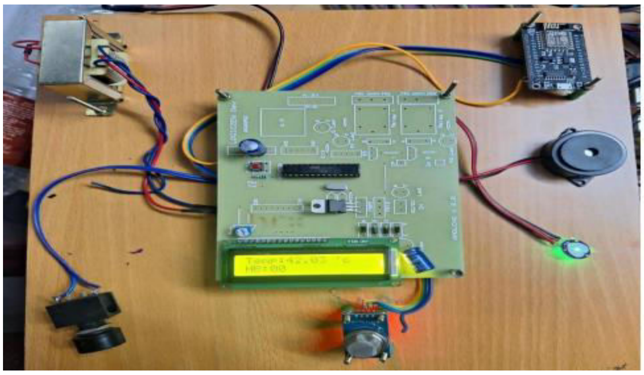

**Fig4.1: Hardware result**

The IoT-based monitoring system was successfully implemented using ATmega328, CO2 sensors, temperature sensors, and health monitoring devices. The microcontroller processed real-time sensor data, while the ESP8266 Wi-Fi module transmitted it to the cloud for remote access. The system displayed live sensor readings on an LCD screen and triggered automated alerts for unsafe conditions. Supervisors received instant notifications via a mobile/web dashboard, ensuring quick response to hazards. The hardware setup proved to be cost-effective, scalable, and efficient for industrial emission control and worker safety.

## V. CONCLUSION

The proposed IoT-based monitoring system efficiently tracks CO2 emissions and worker health in cement manufacturing, ensuring real-time data collection and automated alerts. By integrating wireless sensors, microcontrollers, and cloud computing, the system enables continuous monitoring and proactive risk management. The mobile/web dashboard allows supervisors to access real-time data remotely, improving workplace safety and

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environmental compliance. Future enhancements like AI-based predictive analytics and wearable health sensors can further optimize system efficiency. This solution provides a cost-effective, scalable, and sustainable approach for safer and greener cement manufacturing.

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