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Smart Restroom Environmental Monitoring and Alert System

Dr.Alugonda Rajani

Assistant professor, Dept. of ECE, JNTUK. Rodda Sravani PG Scholar,Dept. of ECE,JNTUK

Abstract:- Maintaining hygiene in public restrooms is essential for ensuring public health and user safety. Traditional cleaning systems rely on fixed schedules, which do not reflect real-time conditions and often lead to inefficient maintenance. This paper presents an Internet of Things (IoT)-based smart restroom hygiene monitoring system that enables real-time assessment using environmental and gas sensors. The proposed system integrates ammonia (NH_3) and carbon monoxide (CO) gas detection, indoor air quality (IAQ) monitoring, and occupancy tracking to provide a comprehensive evaluation of restroom conditions. Sensor data is transmitted using the MQTT protocol to a cloud database and visualized through a dashboard. Alerts are generated when predefined thresholds are exceeded, enabling timely cleaning and safety measures. The inclusion of CO monitoring enhances the system's capability to detect toxic gases, improving overall safety. Experimental results demonstrate improved efficiency, reduced unnecessary cleaning, and enhanced hygiene management.

Keywords: — IoT, Smart Restroom, Ammonia Sensor, Carbon Monoxide, IAQ, ESP32, MQTT

Introduction

Public restroom hygiene plays a vital role in maintaining health standards and ensuring user comfort, particularly in high-traffic environments such as shopping malls, railway stations, airports, and educational institutions. Poor sanitation conditions in restrooms can lead to the spread of infectious diseases, unpleasant odors, and overall user dissatisfaction. Maintaining cleanliness in such environments is a challenging task due to varying usage patterns and environmental factors Traditional restroom maintenance systems primarily rely on fixed cleaning schedules and manual inspections carried out by maintenance staff. While these methods are simple to implement, they often fail to accurately reflect real-time usage conditions and environmental changes. As a result, restrooms may remain unclean during peak hours when usage is high, or they may be unnecessarily cleaned during periods of low usage, leading to inefficient utilization of resources such as water, cleaning agents, and labor. Moreover, manual inspection is time-consuming and prone to human error, making it difficult to maintain consistent hygiene standards.

Another critical issue in restroom environments is the presence of harmful gases such as ammonia (NH_3) and carbon monoxide (CO). Ammonia is commonly generated from urine and waste decomposition, leading to strong odors and potential respiratory irritation. Carbon monoxide, on the other hand, is a colorless and odorless toxic gas that can accumulate in poorly ventilated areas, posing serious health risks including dizziness, headaches, and even life-threatening conditions. In addition, indoor air quality (IAQ) is affected by temperature, humidity, and the excessive use of cleaning chemicals, which can release volatile organic compounds (VOCs) into the air.With the rapid advancement of Internet of Things (IoT) technology, there is a growing opportunity to develop intelligent systems capable of monitoring environmental conditions in real time. IoT enables the integration of sensors, communication protocols, and cloud-based platforms to collect, transmit, and analyze data efficiently. By leveraging these technologies, restroom hygiene can be monitored continuously, and maintenance actions can be performed based on actual conditions rather than fixed schedules.

Furthermore, the system is designed to generate real-time alerts when predefined threshold values are exceeded, enabling timely cleaning and ventilation actions. This data-driven approach not only improves hygiene standards but also reduces unnecessary cleaning efforts and operational costs. By incorporating multi-gas detection and occupancy analysis, the proposed system provides a comprehensive and scalable solution for smart restroom

managementOverall, this work aims to enhance public health, optimize resource utilization, and improve user experience by implementing an intelligent and automated hygiene monitoring system.

LITERATURE SURVEY

In recent years, the application of Internet of Things (IoT) technology in sanitation and hygiene monitoring systems has gained significant attention due to its ability to provide real-time data and improve maintenance efficiency. Several researchers have proposed smart restroom systems that utilize sensors, microcontrollers, and cloud platforms to monitor environmental conditions and optimize cleaning operationsMany existing systems focus on occupancy monitoring using infrared (IR) sensors or passive infrared (PIR) sensors to track user movement and restroom usage. These systems help in estimating the frequency of usage and enable better planning of cleaning schedules. Additionally, automation features such as automatic lighting, water flow control, and flush systems have been introduced to enhance user convenience and reduce resource wastage.

Furthermore, some research works have incorporated environmental sensors to monitor parameters such as temperature, humidity, and air pressure. These factors play a significant role in determining indoor air quality (IAQ) and overall comfort levels. In addition, cloud-based platforms and communication protocols such as Wi-Fi and MQTT have been widely used to enable real-time data transmission, remote monitoring, and visualization through dashboards Despite these advancements, existing systems have several limitations. Most solutions focus on individual parameters such as occupancy tracking or gas detection rather than providing an integrated approach. The lack of multi-parameter monitoring reduces the accuracy and effectiveness of hygiene assessment. Moreover, carbon monoxide (CO), which is a highly toxic and odorless gas, is often neglected in many systems, even though it poses serious health risks in enclosed environments with poor ventilation

Another limitation is the absence of intelligent alert mechanisms and data-driven decision-making. While some systems provide basic notifications, they do not effectively correlate multiple environmental factors to optimize cleaning schedules. As a result, cleaning operations remain either reactive or inefficient To address these challenges, the proposed system integrates ammonia detection, carbon monoxide monitoring, indoor air quality analysis, and occupancy tracking into a single unified platform. By combining multiple sensors with cloud-based monitoring and real-time alert systems, the proposed approach provides a more comprehensive, accurate, and efficient solution for restroom hygiene management. This integrated methodology not only improves cleanliness but also enhances user safety and reduces operational costs.

EXISTING METHOD

Existing restroom hygiene management systems mainly rely on manual inspection and fixed-time cleaning schedules. In most public places, cleaning staff follow a predefined timetable without considering the actual usage or current condition of the restroom. This approach does not reflect real-time situations, especially during peak hours when restrooms are used frequently. As a result, restrooms may become unhygienic before the next scheduled cleaning Some modern systems have introduced basic automation, such as occupancy sensors to detect the number of users and automatic control of lights and water systems. In addition, a few implementations use gas sensors to detect unpleasant odors like ammonia. However, these systems are limited because they focus on only one or two parameters and do not provide a complete picture of restroom hygiene.

Furthermore, most existing systems do not include advanced features such as real-time data monitoring, cloud integration, or instant alert mechanisms. Without proper data analysis, maintenance decisions are not efficient. Therefore, these methods are not sufficient to ensure proper hygiene, safety, and effective resource utilization.

A.LIMITATION OF EXISTING METHODS

1. No Real-Time Monitoring.
2. Fixed Cleaning Schedule
3. Limited Parameters Monitoring
4. Lack of Alert System

B. Proposed Method

The proposed system aims to develop an intelligent and automated restroom hygiene monitoring solution using Internet of Things (IoT) technology. The system is designed to continuously monitor environmental conditions and provide real-time alerts to ensure proper cleanliness and safety. Unlike traditional methods that rely on fixed cleaning schedules, this system adopts a data-driven approach based on actual restroom usage and air quality conditions The system consists of multiple sensors integrated with an ESP32 microcontroller. The sensors include MQ-137 for ammonia detection, MQ-7 for carbon monoxide (CO) detection, BME680 for measuring temperature, humidity, and indoor air quality (IAQ), and an IR sensor for occupancy tracking. These sensors are placed inside the restroom to continuously collect data related to environmental conditions and user activity

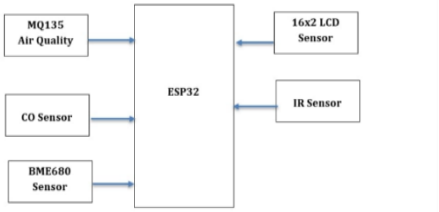


Fig 1 : Block Diagram of Proposed Method

The ESP32 microcontroller acts as the central processing unit of the system. It collects data from all sensors, processes the readings, and prepares them for transmission. The processed data is then sent to a cloud platform using Wi-Fi communication and the MQTT protocol. MQTT is chosen because it is lightweight and suitable for real-time IoT applicationOnce the data is transmitted, it is stored in a cloud database such as thing speak The stored data is visualized using a blynkdashboard, which displays real-time values and graphical representations of parameters such as gas levels, temperature, humidity, and occupancy. This allows maintenance staff or administrators to monitor restroom conditions remotely from any location.The system continuously compares sensor readings with predefined threshold values. For example, if ammonia levels exceed safe limits, it indicates poor hygiene and the need for cleaning. Similarly, if carbon monoxide levels rise, it signals a potentially dangerous situation requiring immediate ventilation. Poor indoor air quality or high occupancy can also trigger alerts When any parameter crosses its threshold, the system automatically sends notifications to maintenance staff through a Telegram alert system. This enables quick response and timely cleaning or corrective actions. As a result, the system ensures that cleaning is performed only when necessary, reducing unnecessary effort and optimizing resource usage Overall, the proposed method provides a smart, efficient, and reliable solution for restroom hygiene management. By integrating multi-gas detection, environmental monitoring, and occupancy tracking with cloud-based analysis and real-time alerts, the system significantly improves cleanliness, user safety, and operational efficiency

Experiment And Results

The experiment was conducted to evaluate the performance of the proposed IoT-based restroom monitoring system with a primary focus on detecting carbon monoxide (CO) levels. Carbon monoxide is a harmful and toxic gas that can pose serious health risks when present in enclosed environments such as restrooms. Therefore, continuous monitoring of CO concentration is essential to ensure user safety and proper ventilation.

Fig 2 : Function node's connection to the database

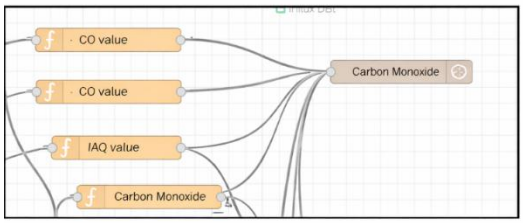
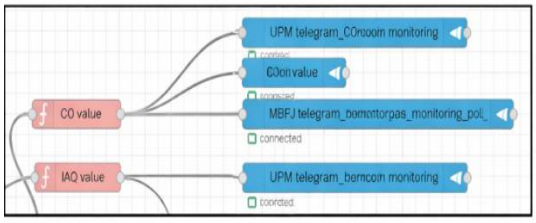


Fig 3 : Function nodes connection to notification.



All sensors were installed inside the restroom environment. The ESP32 collected real-time sensor data and transmitted it to the cloud using Wi-Fi and the MQTT protocol. The collected data was stored in InfluxDB and visualized using a Grafana dashboard. A Telegram bot was integrated to send alerts whenever CO levels exceeded safe limits.

B. Data Collection

The system continuously monitored:

- Carbon Monoxide (CO) concentration
- Temperature and humidity
- Indoor Air Quality (IAQ)
- Occupancy count

Data was collected at regular intervals and stored in the cloud. Special attention was given to CO levels during different time periods, especially during high usage conditionsThe experimental results demonstrated that carbon monoxide (CO) concentration increased significantly during peak restroom usage hours, particularly in enclosed conditions with limited airflow. This rise was primarily attributed to poor ventilation, reduced air exchange, and increased human activity, which collectively contributed to the accumulation of harmful gases within the indoor environment. The observed trend confirms that occupancy and ventilation play a crucial role in determining indoor CO levels.

The MQ-7 gas sensor effectively detected real-time variations in CO concentration and continuously provided stable and reliable readings throughout the monitoring period. The sensor responses closely followed the occupancy-based usage patterns, indicating its suitability for smart indoor environmental monitoring applications. During high-traffic periods, the CO values showed a noticeable upward trend, whereas during low-usage hours the concentration gradually returned to safer levels.

Result

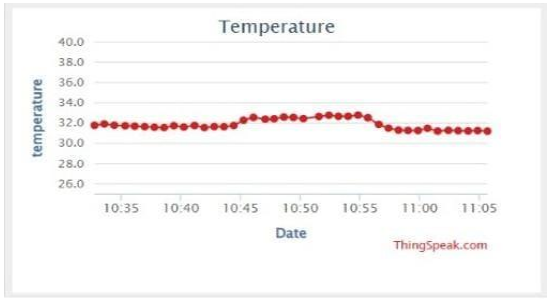


Fig 4: Temperature

Fig 5: Humidity

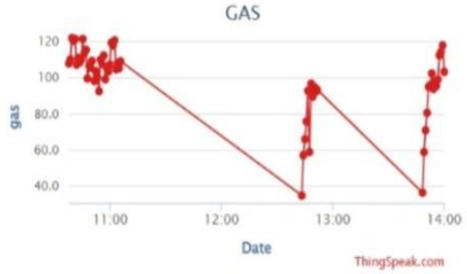


Fig 6: Gas

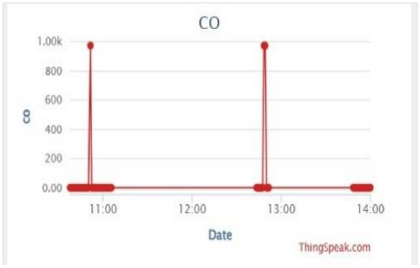


Fig 7: Co

Furthermore, the experimental observations revealed a strong correlation between occupancy level and CO concentration, where higher human presence directly resulted in increased gas accumulation. This increase adversely affected the indoor air quality (IAQ) and highlighted the importance of continuous environmental surveillance in public facilities.

The dashboard-based graphical analysis further validated these observations by clearly illustrating the time-dependent CO trend, threshold crossing events, occupancy-related peaks, and correlation with environmental parameters such as humidity and ventilation conditions. The scatter plots and trend curves confirmed that the proposed system can efficiently identify abnormal CO buildup patterns and support data-driven maintenance decisions.Overall, the results verify that the proposed IoT-based carbon monoxide monitoring and alert system provides an effective solution for real-time indoor safety monitoring, early warning generation, and smart facility management, making it highly suitable for deployment in public restrooms, commercial buildings, and other enclosed spaces.

Future Scope

The proposed IoT-based restroom monitoring system provides an efficient and intelligent solution for maintaining hygiene and safety, with a primary focus on carbon monoxide detection. By integrating the MQ-7 sensor with the ESP32 microcontroller, the system enables continuous real-time monitoring of CO levels, helping to identify harmful conditions inside the restroom environment. The use of cloud platforms for data storage and visualization, along with instant alert notifications, improves maintenance efficiency and ensures quick response to unsafe conditions. This system reduces manual effort and provides a data-driven approach compared to traditional methods In the future, the system can be further enhanced by incorporating artificial intelligence to predict gas level variations and optimize maintenance schedules. Automatic ventilation systems can be integrated to control air quality without human intervention. Additionally, mobile application support, multi-gas detection, and smart cleaning automation can be implemented to make the system more advanced, reliable, and suitable for large-scale smart infrastructure applications

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