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Restroom Hygiene and Resource Optimizer

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Abstract *- Public sanitation facilities form a critical component of modern urban environments, yet maintaining consistent hygiene and efficient resource usage remains a persistent challenge. Many public restrooms experience issues such as poor air quality, unpleasant odors, excessive water usage, and unnecessary energy consumption due to reliance on manual flushing systems, continuous lighting, and predefined cleaning schedules. These conventional practices often result in delayed maintenance responses and avoidable wastage of resources. Recent progress in Internet of Things (IoT) technologies and embedded systems has enabled the development of intelligent restroom solutions capable of continuous monitoring, automation, and adaptive control. This review paper examines existing smart restroom hygiene and resource optimization systems, focusing on air quality sensing, environmental monitoring, occupancy detection, automated flushing mechanisms, water level supervision, and wireless alert systems. The study highlights the shortcomings of current approaches and emphasizes the necessity for a low- cost, integrated, and autonomous restroom management solution capable of improving hygiene standards while minimizing water and energy consumption.*

Key Words: Smart Restroom, Hygiene Monitoring, IoT, ESP32, Automated Flushing, Water Conservation, Energy Optimization

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I. INTRODUCTION

The rapid expansion of urban populations has significantly increased the demand for reliable, hygienic, and efficient public sanitation facilities. Restrooms located in hospitals, educational institutions, transportation terminals, and commercial complexes experience high footfall, making effective hygiene management difficult. Inadequate sanitation not only causes discomfort for users but also contributes to the spread of infections and health-related risks.

Traditional restroom infrastructure primarily depends on manual flushing systems and continuously operating lighting, which leads to excessive consumption of water and electricity. Additionally, fixed cleaning schedules often fail to align with actual usage patterns or hygiene conditions, resulting in inefficient maintenance practices. To overcome these limitations, IoT-enabled smart restroom systems have gained attention as they allow real-time data collection, automated operation, and intelligent control strategies. Such systems offer a practical approach to improving sanitation quality while optimizing resource utilization.

II. LITERATURE REVIEW

IoT-Based Hygiene Monitoring Systems

Several studies have explored the application of IoT and embedded technologies for restroom hygiene monitoring.

Mahalsekar et al. presented a system that utilizes gas sensors along with temperature and humidity sensors to assess hygienic conditions in public restrooms.The collected data enables real-time observation of odor levels and environmental parameters, supporting maintenance planning based on actual conditions.However, the proposed system primarily focuses on monitoring and does not incorporate automated actions such as flushing control, water management,or energy optimization [1]. **Azman et al.** introduced a smart hygiene monitoring framework that combines multiple sensors with cloud-based data processing to support large-scale deployments. The system offers centralized visualization and real-time alerts for facility managers. However, its heavy dependence on continuous internet connectivity limits local autonomy and may reduce reliability in areas with unstable network access [2].

Zanella et al. discussed the role of IoT architectures in smart city environments, emphasizing sensor-based monitoring, data aggregation, and intelligent service delivery. Their work provides a strong conceptual foundation for smart restroom systems but does not address domain-specific sanitation challenges such as odor control, flushing automation, or water resource optimization [6].

Air Quality and Odor Monitoring

Fowjiya et al. proposed an advanced smart restroom system integrating artificial intelligence with environmental sensors to support predictive maintenance. While AI improves decision- making accuracy, the system demands higher computational power and uninterrupted connectivity, making it less suitable for low-cost or small-scale public restroom installations [3].

Odor generation in restrooms is primarily associated with gases such as ammonia and other volatile organic compounds, making air quality a key indicator of hygiene conditions. Gas sensors like the MQ-135 are widely used for detecting such pollutants in enclosed environments. Elevated humidity further accelerates bacterial growth and odor persistence, intensifying hygiene concerns. Although several studies demonstrate effective detection of poor air quality, many systems lack immediate local responses such as automated ventilation control or on-site alerts [1], [3].

Al-Fuqaha et al. provided a comprehensive survey of IoT enabling technologies, protocols, and architectures. Their work highlights the scalability and flexibility of IoT platforms for environmental monitoring applications, including air quality sensing. However, the study remains generic and does not focus specifically on sanitation or restroom hygiene use cases [4].

Occupancy Detection and Energy Optimization

Occupancy detection using infrared and motion sensors has been widely adopted to optimize energy consumption in public buildings. By automatically controlling lighting and electrical loads based on human presence, these systems significantly reduce unnecessary power usage. Despite their effectiveness, most existing implementations operate independently and are not integrated with hygiene monitoring or water management subsystems [6].

Zanella et al. further emphasized that smart city energy optimization systems often rely on occupancy-based automation. However, when applied to restroom environments, the absence of coordination between occupancy data and hygiene indicators reduces the overall effectiveness of automation strategies [6].

Automated Flushing Systems

Kumar and Gupta developed an automatic flushing mechanism using sensor-based detection to reduce physical contact and improve hygiene. Their system ensures consistent flushing behavior and minimizes user dependency. However, it does not consider water availability or sewage level conditions, which may lead to inefficient operation under constrained resource scenarios [7].

Automated flushing systems improve sanitation standards but often function as isolated units. Without integration with water level monitoring or usage analytics, such systems may contribute to avoidable water wastage or operational faults during low-water conditions [7].

Water Level Monitoring and Resource Management

IoT-based water level monitoring systems using ultrasonic or float sensors play a crucial role in preventing overflow and dry- run situations in storage tanks and pipelines.

Zulkifli et al. emphasized that real-time water monitoring significantly reduces water wastage and supports sustainable infrastructure management. Their review highlights the effectiveness of IoT sensors in detecting abnormal water usage patterns. However, these systems are generally implemented as standalone solutions and are rarely combined with hygiene monitoring, occupancy detection, or automated flushing mechanisms [5].

Public Health Perspective and Sanitation Standards

The **World Health Organization (WHO)** highlights that poor sanitation in public restrooms increases the risk of disease transmission and negatively affects user well-being. The WHO report stresses the importance of continuous hygiene monitoring, timely maintenance, and efficient resource usage to maintain acceptable sanitation standards. However, it does not provide technical implementation guidelines, leaving scope for IoT-based engineering solutions to bridge this gap [8].

III. LITERATURE REVIEW TABLE

Ref No.	Author	Technolog y Used	Contributio n	Limitation
[1]	Mahalse kar et al.	Gas, DHT sensors	Hygiene monitoring	No automation
[2]	Azman et al.	IoT + Cloud	Real-time alerts	Internet dependent
[3]	Fowjiya et al.	AI + Sensors	Predictive maintenance	High cost
[4]	Al-Fuqa ha et al.	IoT framework	IoT foundation	Generic survey
[5]	Zulkifli et al.	IoT water sensors	Water conservation	Standalone system
[6]	Zanella et al.	IoT sensing	Energy optimization	Not hygiene focused
[7]	Kumar et al.	Ultrasonic sensor	Auto flushing	No water monitoring
[8]	WHO	Sanitation standards	Public hygiene	No automation

IV. PROPOSED SYSTEM

Most existing restroom hygiene systems focus mainly on monitoring environmental parameters and generating alerts. For example, Mahalsekar *et al.* and Azman *et al.* proposed IoT- based systems that monitor odor, temperature, and humidity and notify maintenance staff when hygiene levels deteriorate, but they do not include automatic corrective actions such as flushing, ventilation control, or energy optimization [1], [2].

AI-based systems proposed by Fowjiya *et al.* offer predictive maintenance but require high computational resources and continuous internet connectivity, making them costly and unsuitable for small-scale or low-budget installations [3].

In contrast, the proposed project integrates hygiene monitoring, occupancy detection, automated flushing, energy-efficient lighting control, and water level monitoring into a single ESP32- based embedded system. Unlike cloud-dependent systems, it performs real-time local decision-making, allowing immediate actions such as turning ON the exhaust fan, activating buzzer alerts, controlling lighting based on occupancy, and triggering flushing without relying entirely on internet connectivity. Additionally, water and sewage levels are monitored to prevent overflow and dry-run conditions, a feature often missing in standalone flushing systems [5], [7].

The use of battery power with BMS support further improves reliability in areas with unstable power supply. Overall, the proposed system provides a low-cost, automated, and fully integrated solution that enhances hygiene, reduces water and energy wastage, and improves maintenance efficiency compared to existing work [1]–[6], [7], [8]

V. WORKING

The Restroom Hygiene and Resource Optimizer operates on a continuous sensing, processing, and action mechanism.

System Initialization

1. ESP32 microcontroller initializes sensors and communication interfaces.
2. Threshold values for air quality, humidity, and occupancy are loaded.

Air Quality Monitoring

1. MQ-135 sensor detects ammonia and odor-causing gases.
2. If AQI exceeds threshold:

1) alert is activated
2) Notification sent via Blynk
3) Buzzer Status displayed on LCD [1], [2].

Temperature and Humidity Monitoring

1. DHT11 sensor measures temperature and humidity.
2. High humidity indicates bacterial growth risk.
3. Values displayed on LCD [2].

Occupancy Detection and Lighting Control
1. IR sensor detects human presence.
2. Lights turn ON when occupied and OFF when vacant.
3. Energy savings of up to 50–60% achieved [6].

Automatic Flushing
1. Ultrasonic sensor detects user exit.
2. Water pump activates flushing automatically.
3. Contactless and water-efficient operation ensured [7].

Water and Sewage Level Monitoring
1. Float sensors monitor tank levels.
2. LED indicators show water and sewage status.
3. Prevents overflow and dry-run conditions [5].

Notification System
1. ESP32 sends WiFi alerts via Blynk when hygiene thresholds exceed limits.
2. Enables timely maintenance action [3].

VI. VISUALIZATION

The system visualization includes:
1. Block diagram representing sensor–controller–actuator interaction.
2. Flowchart showing decision-making logic.
3. LCD display visualization for AQI, temperature, humidity, and occupancy status.

These visual representations help in understanding system operation.

VII. FLOWCHART

The following flowchart illustrates the workings of the Restroom Hygiene and Resource Optimizer.
The following represents the step-by-step porocess, from data acquisition to visualization, emphasizing the seamless integration of hardware and software.

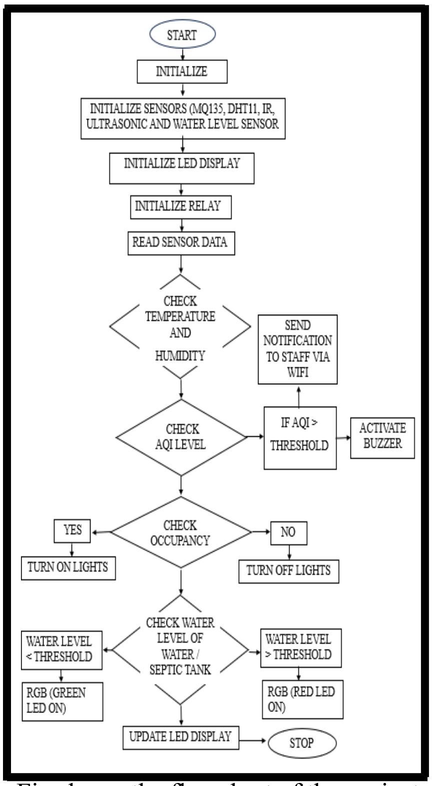

Fig -1: Fig shows the flowchart of the project working.

VIII. RESULT AND DISCUSSION

The reviewed systems demonstrate notable improvements in both hygiene monitoring and resource efficiency. Occupancy- based lighting control significantly reduces electricity consumption, while automated flushing mechanisms enhance hygiene standards and decrease water usage. Real-time alerts enable faster maintenance responses, improving overall user satisfaction. However, the lack of integration among monitoring, automation, and resource management components remains a major limitation in many existing solutions, highlighting the need for comprehensive and unified system designs.

IX. APPLICATIONS

The Restroom Hygiene and Resource Optimizer can be applied in:
1. Hospitals and healthcare facilities
2. Educational institutions
3. Railway stations and airports
4. Shopping malls
5. Corporate offices
6. Smart city sanitation infrastructure

X. FUTURE WORK

Future developments may include:
1. Integration of UV-based disinfection
2. Cloud data analytics for usage prediction
3. Mobile app dashboards
4. Solar-powered operation

XI. CONCLUSION

This paper presented a detailed review of smart restroom hygiene and resource optimization systems developed using IoT and embedded technologies. Existing solutions largely emphasize monitoring and alert generation, with limited automation and system integration. The analysis indicates that a comprehensive approach combining hygiene monitoring, automated flushing, occupancy-based energy control, water level management, and wireless notifications is essential for improving public sanitation facilities. Such integrated systems contribute to sustainability objectives, reduce operational costs, and support the development of smart city infrastructure.

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