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Hygienex – A Next Gen Smart Toilet

Harsh Hemant Patole[1*], Amaan Abdul Qadir Rakhangi[2], Samiksha Rajendra Kobal[3], Rhea Dinkar Bagul[4], Shubhangi Verulkar[5]

[1,2,3,4]*Student, Department of Electronics and Telecommunication Engineering, K.C. College of Engineering & Management Studies & Research, Thane, India*

[5]*Professor, Department of Electronics and Telecommunication Engineering, K.C. College of Engineering & Management Studies & Research, Thane, India*

***Abstract*: Hygienex – A Next Gen Smart Toilet is an intelligent sanitation system designed to enhance hygiene and optimize maintenance in public restrooms, particularly in high-traffic areas such as transport hubs, hospitals, and educational institutions. The system employs an infrared sensor to dispense a biodegradable seat cover and activates ultraviolet disinfection after each use to ensure cleanliness. It features an MQ2 gas sensor for continuous air quality monitoring, tracks flush counts to trigger automatic cleaning liquid release, and monitors seat cover availability to prompt timely refills. An LCD display provides user guidance, while an ESP32 Wi-Fi module enables real-time data transmission to a cloud dashboard. Additionally, Fast2SMS integration delivers instant maintenance alerts to janitorial staff. By combining automated cleaning, smart sensing, and proactive maintenance, Hygienex offers a cost-effective and efficient solution for improving public restroom hygiene and user experience.**

***Keywords*: hygiene, internet of things, Arduino uno, Node MCU, IR sensors, smart toilet, LCD, MQ2 sensor, UV-C light, servo motor, buzzer, fast2sms.**

1. Introduction

Public sanitation remains a critical challenge in modern urban environments, where traditional toilet systems often fail to maintain consistent hygiene. Manual cleaning methods are not only labor-intensive but also susceptible to human error, resulting in unhygienic conditions, unpleasant odors, and a heightened risk of infection. These concerns underscore the growing demand for intelligent, automated solutions that can ensure cleanliness while minimizing manual intervention.

Hygienex is a next-generation smart toilet system designed to revolutionize public sanitation through advanced automation and IoT-based monitoring. It integrates smart sensors, real-time air quality detection, UV-C disinfection, and automated cleaning mechanisms to maintain hygienic conditions with minimal physical contact. The system features touchless operation, a biodegradable seat cover dispenser with automatic rotation, and a focus on sustainability and user safety. Central to Hygienex is its real-time data and alert system, which monitors toilet usage, seat cover availability, air quality, and cleaning needs. Leveraging an IoT-enabled architecture, the system enables remote maintenance tracking and janitorial oversight, improving efficiency and accountability. Key components such as the MQ2 gas sensor and infrared sensors allow for seamless detection of environmental conditions and user presence, supporting data-driven sanitation management.

With its intelligent features and eco-conscious design, Hygienex sets a new benchmark in smart restroom solutions. Ideal for high-traffic locations like malls, airports, offices, and schools, it enhances user experience, reduces water and chemical usage, and ensures a cleaner, safer, and more sustainable restroom environment. As cities expand and public spaces become more crowded, innovative solutions like Hygienex are essential for meeting modern sanitation demands.

2. Literature Review

Various research efforts have focused on the development of IoT-based systems aimed at improving the cleanliness of public restrooms. For example, some studies have introduced smart toilet systems utilizing technologies like fragrance, infrared, and sound sensors, along with RFID, to automate operations such as detecting dirt on seats and alerting maintenance personnel, which enhances hygiene and minimizes water usage [1]. In urban areas like Pune, India, community toilets have been equipped with sensors to track usage, water consumption, and maintenance requirements, which leads to more efficient resource management and better overall cleanliness [2]. Additionally, some systems have incorporated mobile apps to facilitate communication between users and cleaning staff, improving hygiene and the user experience [3]. Moreover, smart toilets have been explored for health monitoring, using sensors to gather health data, thus providing supplementary health insights in addition to traditional medical monitoring [4]. Real-time monitoring of toilet usage and cleanliness through IoT devices allows maintenance personnel to respond proactively to cleanliness issues, improving overall sanitation management [5]. Robotic systems and IoT-driven autonomous cleaning mechanisms have also been developed to reduce manual labor, ensuring more consistent hygiene standards in high-traffic public restrooms [6], [9]. Furthermore, certain innovations have focused on cleaning technologies for specific types of toilets, such as those used in Indian-style restrooms, which have demonstrated efficiency in maintaining hygiene and managing waste [9]. The integration of IoE in smart toilets enables features like automatic flushing, cleanliness tracking,

*Corresponding author: harshpatole01@gmail.com

and odor control, enhancing user satisfaction while promoting environmental sustainability [10]. Other studies have proposed smart washroom systems with odor and infrared sensors, and GSM alert systems that ensure timely cleaning and reduce human effort [11]. Air quality monitoring in smart toilets has also gained attention, with systems designed to detect pollutants and improve indoor air quality, contributing to better public health and comfort [12]. In addition, research into the accuracy of sensor technologies such as infrared sensors have shown their potential in optimizing smart toilet functions, particularly in detecting user presence [18]. Predictive maintenance using AI-driven methods, such as deep learning, is being explored to further enhance the management of smart toilets [19]. Additionally, IoT-based smart toilets have been designed to incorporate health-monitoring systems, such as those for detecting urinary tract infections, to support health interventions in public sanitation settings [16]. Other research has emphasized the importance of optimizing resource management in facility services through IoT technologies, aiming to create smarter and more efficient restroom systems [13]. Smart toilet solutions have also been implemented in public facilities like Indian railway stations, where IoT helps automate cleaning tasks, reducing the need for manual intervention [7]. The importance of real-time monitoring in public toilet maintenance has been underscored in studies that highlight how data-driven systems improve cleanliness and resource management [14]. Additionally, various systems have been developed to manage odors in public restrooms using advanced sensor technologies, contributing to a more pleasant and hygienic environment for users [17]. Finally, IoT-based monitoring systems that automate cleaning and track usage data are improving hygiene management and maintaining cleanliness in public toilets [15].

3. Methodology

Hygienex smart toilet system employs an integrated IoT-based approach, combining sensor automation, real-time monitoring, and smart alerts to deliver a hygienic and intelligent public restroom experience. The system is designed to minimize manual maintenance, ensure cleanliness, and provide actionable data for efficient facility management.

As a user enters the restroom, an infrared (IR) sensor detects their presence, activating the automated seat cover rotation mechanism. A biodegradable sanitary seat cover is unrolled across the toilet seat using a DC motor powered by a 6V 4.5A rechargeable battery, ensuring a fresh, hygienic surface for each user. The IR sensor also checks the availability of seat cover rolls—if unavailable, a status update is displayed on the connected web interface, and an alert is sent to the administrator via Fast2SMS. Simultaneously, an MQ2 sensor monitors harmful gases like methane, butane, and smoke within the restroom environment. These readings are transmitted in real time via the NodeMCU ESP32 Wi-Fi module to an online dashboard, enabling remote monitoring and timely intervention based on gas levels or unusual conditions. After each use, the system triggers an automatic flushing mechanism controlled by a 5V relay and powered by a water pump. To ensure consistent cleanliness, a cleaning liquid is automatically dispensed after every 10th flush. This mechanism helps maintain hygiene between janitor cleaning cycles and ensures a fresher environment. An LCD display is placed at the restroom entrance to guide users. It shows “Ready to Use” when the restroom is clean and safe, and “Do Not Use” during disinfection or cleaning cycles, such as during UV-C light activation or cleaning liquid dispensing. When the restroom is vacant, a UV-C light activates to disinfect the toilet seat and surrounding surfaces, and turns off once a user enters. A push-button mechanism is provided for janitorial staff, allowing them to log their cleaning activity. This input is recorded and reflected on the system dashboard for maintenance tracking.

All sensor inputs, actuators, and processes are managed using an Arduino Uno microcontroller, programmed via the Arduino IDE. The Fast2SMS service handles instant notifications for maintenance related alerts. This well-orchestrated methodology ensures seamless automation, improved sanitation, and user comfort while contributing to sustainable facility management practices.

4. Result

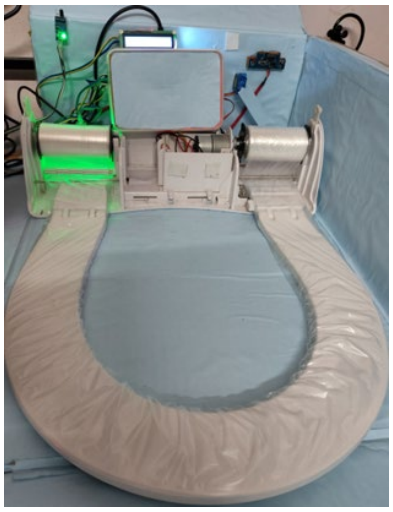

Fig. 1. Hygienex model

The Hygienex Smart Toilet System prototype was thoroughly tested to evaluate its performance, automation efficiency, and hygiene effectiveness. The system successfully performed all intended operations with high reliability. The automated seat cover mechanism functioned seamlessly, providing a clean, untouched surface for each user and minimizing the risk of cross-contamination. The use of biodegradable seat covers reinforced the project's sustainability focus. A DC motor, paired with IR sensors, accurately controlled the seat cover rotation and user detection process. During idle periods, UV-C sterilization was automatically activated, effectively eliminating surface bacteria and viruses. The UV light safely deactivated upon detecting a new user, ensuring both hygiene and safety. The MQ-2 sensor continuously monitored air quality, detecting gases such as methane and butane. No unpleasant odors were recorded during the testing phase, confirming the ventilation system’s

effectiveness. Additionally, an automatic cleaning liquid dispenser was programmed to release disinfectant after every 10th flush, maintaining hygiene between manual cleanings. The auto-flush mechanism worked consistently, activating after every use to ensure cleanliness for the next user.

Data from the Hygienex Smart Toilet System was transmitted in real-time using the ESP32 module and displayed on a dedicated online dashboard hosted on the Hygienex website.

Fig. 2. Hygienex website login page

This dashboard provided live updates on key parameters such as Seat Cover Roll Status, Bad Odor Status, and Clean Status, enabling effective monitoring and timely maintenance. Access to this information is secured through a login system, ensuring that only authorized personnel can view and manage the restroom data remotely. The Seat Cover Roll Status on the Hygienex dashboard accurately displayed real-time updates. During testing, the status consistently showed "Not Finished," confirming the system's ability to monitor seat cover availability and alert staff when replacement is needed.

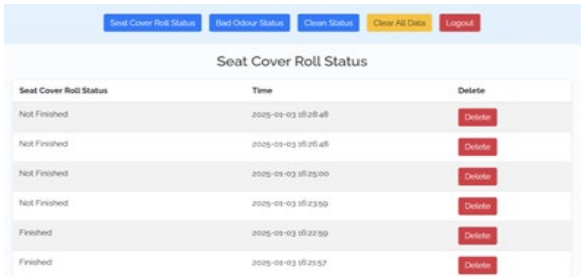

Fig. 3. Seat cover roll status

The Bad Odor Status fetched readings from the MQ2 sensor, consistently showing "NO" during testing. This indicates that the air quality remained fresh and the system effectively monitored and managed odors in the restroom.

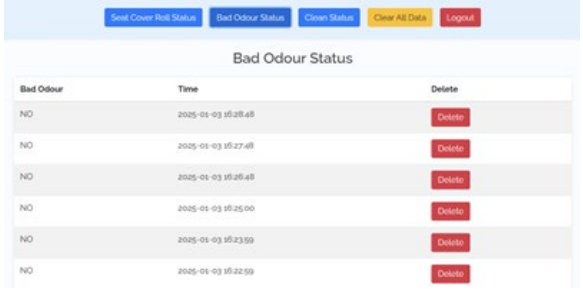

Fig. 4. Bad odor status

The Clean Status feature included a push button for janitorial staff to mark their attendance after completing cleaning tasks. Upon pressing the button, the system logged the attendance and updated the status on the web portal, ensuring better accountability and transparency in maintenance activities.

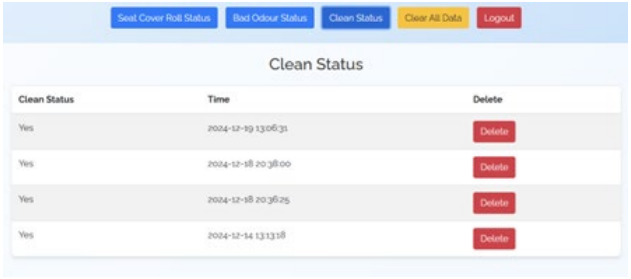

Fig. 5. Clean status

To improve system responsiveness, an SMS alert mechanism was integrated using the Fast2SMS API. When the seat cover roll was depleted, the system automatically sent a message to the maintenance team: "Paper Roll Finished, Please Change Roll." Similarly, if bad odor was detected, the system sent an alert: "Bad Odor Detected, Please Clean Toilet." These real-time notifications ensured prompt action, minimizing user inconvenience and downtime.

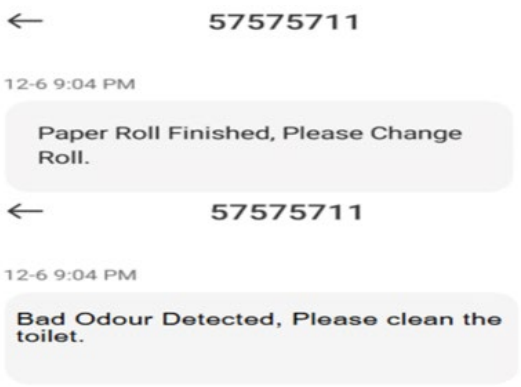

Fig. 6. SMS alerts

An LCD display at the entrance showed real-time status updates, such as "Ready to Use" or "Do Not Use," preventing accidental use during maintenance or cleaning.

Overall, the results confirmed the system's effectiveness in delivering a hygienic, user-friendly, and low-maintenance restroom experience. With automation, IoT monitoring, and real-time alerts, the Hygienex system offers a smart solution for enhancing sanitation in public restrooms.

5. Conclusion

The Hygienex – A Next Gen Smart Toilet system offers an innovative and practical solution to elevate hygiene and maintenance standards in public restrooms. By combining IoT-enabled monitoring, automated cleaning mechanisms, and real-time alert systems, it minimizes manual intervention while ensuring consistent cleanliness and user comfort. Key features like touchless flushing, UV-C disinfection, automatic seat cover rotation, and air quality sensing contribute to a hygienic and

user-friendly environment. The integration of Fast2SMS for real-time alerts and an LCD display for user guidance ensures timely maintenance and improved accountability. Additionally, water-efficient flushing and biodegradable materials promote environmental sustainability.

Fig. 7. LCD indication

Overall, the Hygienex system demonstrated enhanced sanitation, efficient maintenance, and improved user experience, aligning well with initiatives like Swachh Bharat Abhiyan. Its scalable design makes it a promising solution for deployment in public, high-traffic areas.

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