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Intelligent Washroom System

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Abstract: *Public washroom hygiene and safety have become increasingly important, necessitating innovative and automated solutions to ensure cleanliness, comfort, and user security. Traditional restroom maintenance methods, which often rely on manual inspections, are typically inefficient and reactive. To address these limitations, the proposed Intelligent Washroom Cleaning System introduces smart monitoring, automated alerts, and integrated security mechanisms for enhanced restroom management. This system utilizes real-time data collection to monitor environmental conditions such as temperature, humidity, and air quality, transmitting this information to a mobile application accessible by facility managers and custodial staff. A key feature includes real-time air quality monitoring; when hygiene levels fall below a defined threshold of 40%, the system autonomously generates an alert to the control room, enabling swift cleaning response without the need for manual intervention. This proactive approach reduces the risk of health issues associated with poor sanitation and ensures a consistent standard of cleanliness. Moreover, the integration of security measures addresses user privacy and safety, making public restrooms more secure and user-friendly. By combining real-time monitoring, remote accessibility, and automated decision-making, the system modernizes restroom management practices, significantly improving operational efficiency, hygiene standards, and overall user experience in public infrastructure.*

Keywords: Intelligent Washroom System, Real-time Monitoring, Automated Hygiene Management, Public Safety, Smart Facility Maintenance

I. INTRODUCTION

In modern urban environments, maintaining hygiene and safety in public restrooms is a growing concern. With increasing foot traffic in public washrooms, ensuring cleanliness and security has become a challenge that requires advanced solutions. Traditional washroom maintenance relies on periodic inspections and manual cleaning, often leading to inefficiencies, unhygienic conditions, and delayed responses to cleanliness issues. The absence of real-time monitoring mechanisms means that issues such as poor air quality, high humidity levels, and lack of sanitation can persist for long periods before corrective action is taken. Additionally, public restrooms often lack adequate security measures, leaving users, especially women, vulnerable to potential safety concerns. As a result, there is a strong need for an intelligent and automated system that can enhance restroom hygiene while also ensuring user safety.

The concept of smart washroom management integrates real-time environmental monitoring with automated responses, offering a proactive approach to maintaining cleanliness and hygiene. By continuously tracking key parameters such as temperature and humidity, this system provides real-time data, allowing facility managers and maintenance personnel to remotely monitor conditions and make informed decisions regarding cleaning schedules. This eliminates the inefficiencies of manual monitoring and ensures that any deviations from standard hygiene levels are promptly addressed. In addition to environmental monitoring, air quality assessment plays a crucial role in determining the level of cleanliness inside the washroom. If the detected air quality indicates excessive dirtiness, falling below a predetermined threshold, the system automatically generates an alert and notifies the control room. This real-time notification mechanism ensures that cleaning personnel are promptly dispatched, reducing response time and improving overall sanitation standards.

Beyond hygiene management, ensuring safety and privacy in public washrooms is equally important. Public restrooms, especially those in high-traffic areas such as shopping malls, transportation hubs, and educational institutions, often

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pose security concerns for users. One of the most critical safety features integrated into this system is an emergency SOS switch, designed to provide instant assistance in distress situations. This feature is particularly beneficial for women, offering a quick and reliable means of seeking help in case of emergencies. By incorporating such an emergency alert mechanism, the system enhances the overall security of washroom users and ensures a safer environment.

Additionally, the system addresses privacy concerns by implementing a gender-based lighting alert. In many cases, restroom maintenance requires staff of the opposite gender to enter the facility for cleaning purposes, potentially leading to discomfort or privacy issues for users inside. To mitigate this, the system includes a mechanism where a specific light is activated when an individual of the opposite gender enters the restroom for cleaning. This visual indicator serves as a notification to restroom users, ensuring that they are aware of maintenance activities while also preventing accidental intrusions. Such a feature enhances user comfort and ensures that restroom facilities remain respectful of privacy considerations.

The integration of automation and real-time monitoring in restroom management represents a significant step toward modernizing public sanitation infrastructure. By replacing traditional manual cleaning schedules with an intelligent, data-driven approach, this system ensures timely intervention, improved hygiene standards, and enhanced safety for users. The ability to remotely monitor and respond to changes in environmental conditions makes restroom management more efficient, reducing operational costs and increasing convenience for facility administrators. Moreover, the added security features contribute to making restrooms safer spaces for users of all demographics.

As urban areas continue to expand and public facilities accommodate increasing numbers of users, intelligent systems such as this play a crucial role in addressing sanitation and security challenges. By leveraging real-time monitoring, automated alert mechanisms, and advanced security features, this system provides a comprehensive solution to maintaining public restroom hygiene and safety. It not only enhances cleanliness but also fosters a more secure and user-friendly restroom experience, making it a valuable innovation for modern infrastructure management.

II. LITERATURE REVIEW

“Health is Hygiene” is one of the most popular quotes and the most meaningful one as well. In the fast-moving world, the advances are growing at a high rate, at the same time the cleanliness in our society is at high risk. The main abstract of the paper is to improve the condition of public toilets and make them accessible to every citizen in a hygienic way. “SwachhBharath”(Clean India) project is one of the most trending schemes in our country. One of the objectives of the scheme is to provide uncontaminated toilets and to design and develop a user-friendly universal toilet which will be sustainable and should be successfully used by the people across all socioeconomic spectrum. This scheme is named as “NAMMA TOILET”. The question now arises, If the toilets are maintained properly and are they clean to use? To monitor cleanliness, autonomously flush and to avoid the bad odor we have proposed this system. We have made use of the proximity sensor, biometric system, gas sensor and a dashboard to monitor and store the data of the cleaner’s activity. With the help of these, we can bring in an effective way to maintain public toilets [1].

In today's world with the everincreasing growth in the population of India, the hygiene of our country is endangered. Our Prime Minister Sir Narendra Modi has introduced "Swach Bharat Abhiyan" Scheme to improve cleanliness in the country. Our project will definitely be a help to improve hygiene condition in India. It will create awareness among people in terms of "Toilet Management". The proposed system "Smart Toilet" is based on IoT, smell sensor, IR sensor, sonic sensor, RFID sensor. The smart toilet will take care of opening and closing of the toilet seat, the IR sensor tracks the dirt present on the toilet seat and raise an alarm, The cleanliness of the toilet will be improved by monitoring the sweeper's activity to maintain the hygiene of the toilet, it also will deal with water conservation [2].

Sanitation is one of the basic necessities required by the human race. Various statistics shows that poor sanitation is a cause for various life threatening diseases. In our work we consider the hygiene of washrooms in public places as they are places from where diseases can be contracted. The cleanliness of washrooms in airports, malls and other public places also decide on business, as customers will be unsatisfied if washrooms are not cleaned regularly. Taking into consideration the various positive benefits of cleaning washrooms consistently in public places we have come out with an automated sensor based system which monitors washrooms for cleanliness by monitoring the air inside the

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washroom. The air inside the washroom can indicate various components of gases present inside the washroom thereby helping to identify whether the washroom is clean. If the values exceed the threshold value then an alert is sent via text to the cleaning team at the public space [3].

Along with the blooming development and rapid change of Internet of Things technology, implementing its related application in everyday life can improve living quality. When people go out, they usually need to use public toilets. The hygiene would affect experience of people using toilets. To enhance user experience using toilets and reduce waiting time, this study proposes to use Internet of Things to monitor the using status of public toilets for the reference of people using these toilets. Combining Ar-duino with ultrasonic sensor and button module, it would report the using status of toilets to cloud management system via wireless communication so that users can refer to the provided information including using status and hygiene state of toilets to decide whether they want to go to these toilets. Moreover, the Raspberry Pi system is used to process the information returned by each public toilet, and to enable cleaning personnel to understand the environmental sanitation of the public toilet in order to decide whether to go to clean it [4].

In this paper realization of the low-power, portable, low-cost multi-sensor system for air and water quality monitoring is described. Developed system is battery-powered with solar panel-based charger unit, and it is intended for use in remote environmental monitoring by collecting information about air temperature (T) and relative humidity (RH), presence of volatile organic compounds (VOC) as well as water temperature and pH level. The hardware of the system is based on the ATmega128 microcontroller which acquires the sensors data [5].

In most Indian villages and slums, public sanitation remains woefully inadequate, with rampant public urination and open defecation due to public toilets being dirty, too few, or poorly maintained. The authorities expend a huge amount of money and manpower to maintain these public toilets. Nevertheless, all these efforts go in vain as there does not exist a centralized system to monitor the cleanliness of the public toilets, track the quality of cleaning by cleaners. In accordance with this, a system that provides centralized monitoring

of all the toilets and provides an interface to the cleaner will be helpful in solving this problem. This paper aims to present an intuitive toilet monitoring system that leverages IoT and Machine Learning. The system incorporates use of various IoT devices, a web server, and a mobile application for the cleaner. The system provides the toilet cleaner and admin with the ability to monitor various cleanliness parameters as well as visualize the future state of the toilet based on past data [6].

Air pollution is an important issue to ruminate about in current environmental situation it has major impact on human health and on nature's own environment balance system. In current scenario various technologies are available which can monitor the quality of air. Objective is to present a system model which can facilitate the assessment of health impacts caused due to indoor air pollutant as well as outdoor and can intimate the human prior about the risk he/she going to have, here we are focusing our work in context to allergic patients as they will be informed by this tool such that they can secure themselves without actually experiencing the risk factors, here a sensing network based microcontroller equipped with gas sensors, optical dust particle sensor, humidity and temperature sensor has been used for air quality monitoring. The design included various units mainly: sensing unit, processing unit, power unit, display unit, communication unit. This work will apply the techniques of electrical engineering with the knowledge of environmental engineering by using sensor networks to measure Air Quality Parameters [7].

In rapidly growing urban slums in India, with little structured urban planning and limited infrastructural facilities, the number of people living without access to basic water and sanitation services is increasing. Tragically in India, a growing slum population and lack of adequate sanitation makes over 50 million men and women to defecate in the open every day. This research paper sought to measure attitudes and behaviour towards toilet construction and its utilization by the poor people in urban areas in India. The survey collected primary data through questionnaire and analysed by cross tabulation, decision tree using chi-Square automatic interaction detector, multiple classification analysis, and logistic regression. Findings guided the design of a mass media communication campaign to impact toilet construction, its increased uptake, universal and consistent use of safe sanitation among poor urban communities, to reduce open defecation in urban areas. Results of the study demonstrate, principally, that while both women, and men, use toilets more during the rainy season, the drop-outs among men in the summer is greater than for women [8].

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A smart city enables the effective utilization of resources and better quality of services to the citizens. To provide services such as air quality management, weather monitoring and automation of homes and buildings in a smart city, the basic parameters are temperature, humidity and CO2. This paper presents a customised design of an Internet of Things (IoT) enabled environment monitoring system to monitor temperature, humidity and CO2. In developed system, data is sent from the transmitter node to the receiver node. The data received at the receiver node is monitored and recorded in an excel sheet in a personal computer (PC) through a Graphical User Interface (GUI), made in LabVIEW. An Android application has also been developed through which data is transferred from LabVIEW to a smartphone, for monitoring data remotely. The results and the performance of the proposed system is discussed [9].

Sanitation is one of the basic necessities required by the human race. Various statistics shows that poor sanitation is a cause for various life threatening diseases. In our work we consider the hygiene of washrooms in public places as they are places from where diseases can be contracted. The cleanliness of washrooms in airports, malls and other public places also decide on business, as customers will be unsatisfied if washrooms are not cleaned regularly. Taking into consideration the various positive benefits of cleaning washrooms consistently in public places we have come out with an automated sensor based system which monitors washrooms for cleanliness by monitoring the air inside the washroom. The air inside the washroom can indicate various components of gases present inside the washroom thereby helping to identify whether the washroom is clean. If the values exceed the threshold value then an alert is sent via text to the cleaning team at the public space [10].

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With the fast-paced world and the progression of the modern technology, the emergence of IoT has been playing a vital role in each and every sector of our daily lives. In the field of home automation and security, it has played a vital and pivot role, it has made our lifestyle easier with the smart features inherited in the automation. The implementation and design of wireless home automation control using Wi-Fi technology handles the devices with integral security and protected system. This Home automation is everything that the modern lifestyle of people demands. This paper gives a detailed hand on IOT and how it can be implemented in security and automation using a micro-controller-based NodeMcu (Esp8266) and an android mobile application [12].

Internet of Things (IoT) devices possess network capabilities and contain at least a part of the application logic, i.e., they have the ability to perform Transmission Control Protocol/Internet Protocol (TCP/IP) communications on their own, and can process some of the sensor data. The IoT thus refers to the network of physical objects embedded with electronics, software, sensors and connectivity to enable objects to exchange data with the manufacturer, operator, and/or other connected devices. At the start of this decade, there were an estimated 12.5 billion IoT devices, almost twice as much as the world's population of 6.8 billion people [1]. The number of IoT devices is expected to grow rapidly in coming years [13].

Along with the blooming development and rapid change of Internet of Things technology, implementing its related application in everyday life can improve living quality. When people go out, they usually need to use public toilets. The hygiene would affect experience of people using toilets. To enhance user experience using toilets and reduce waiting time, this study proposes to use Internet of Things to monitor the using status of public toilets for the reference of people using these toilets. Combining Ar-duino with ultrasonic sensor and button module, it would report the using status of toilets to cloud management system via wireless communication so that users can refer to the provided information including using status and hygiene state of toilets to decide whether they want to go to these toilets. Moreover, the Raspberry Pi system is used to process the information returned by each public toilet, and to enable

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cleaning personnel to understand the environmental sanitation of the public toilet in order to decide whether to go to clean it [14].

In this era, the emerging technologies have no doubt influenced almost every sector around the world. As the part of technology, Internet of Things (IoT) played an important role and became very popular to emphasize the vision of global infrastructures. The utilization of IoT become an opportunity for developing the smart city, where the citizens are given access to the real-time environment for future planning and decision. This paper presents the implementation of an IoT in Smart Toilet for Optimization of Resources. Proposed an architecture shows how the development has been done. Two major things that are taken into consideration which are optimizing the resources in terms of manpower and using the cloud technology for this implementation to have more flexibility. This implementation involves the complete IoT system from sensory level to data management system with Cloud-based Integration [15].

Modern society needs bathrooms. Poor sanitation is caused by worn-out appliances and expensive cleaning. The technique also requires an inexpensive, dependable sensor. This study had three goals. Creating an IoT administration platform is the main goal. Literature evaluations assess the merits and downsides of existing systems. Second, we suggest predictive maintenance to assist predict bathroom equipment breakdowns. Finally, a scheduling algorithm was used to determine how many janitors to hire. We'll measure the model's effectiveness and make future recommendations. Infrared, temperature and humidity sensors create an IoT bathroom. Sensors have been studied to understand how to adapt them to the hygienic and private toilet environment. Sensor accuracy and cost-effectiveness could be enhanced with more development and testing. The Auto-Regressive Integrated Moving Average (ARIMA) model accurately predicts time series lags, making it a good candidate for predictive maintenance. Long Short-Term Memory (LSTM) is good in time series predictions, therefore it's fair to compare the two [16].

To avoid odor in sanitation systems, urine is usually diluted with water (flushed), which leads to high water consumption. The smell may remain in sanitation systems if the systems are not well managed, or if the urine is flushed with insufficient amounts of water. In this study, using the standard threshold odor number (TON) measurement as an indicator the effects of the pH and temperature of the diluting water regarding the amount of water:urine dilution ratio were studied. The effects of temperature and pH of the diluting water on TON when the dilution ratio was constant were investigated. Results show that lowering the pH and temperature of the diluting water can reduce the minimum dilution ratio needed to achieve TON = 0. At constant dilution ratio, reducing pH seemed to be more efficient, sustainable, and economical in comparison to adjusting the temperature of the diluting water. It was found that, based on the specific pH and temperature of the diluting water, there is a minimum dilution ratio required to avoid urine odor. Therefore, in sanitation systems, the amount of flushing should be adjusted based on the characteristics of the flushing water as well as on the amount of urination [17].

The 11 chapters in this publication provide in-depth technical information about the design, construction, operation and maintenance of the major types of on-site sanitation facility, from simple pit latrines to aqua privies and septic tanks, with numerous design examples.The book is divided into three parts entitled: (1) foundations of sanitary practice (four chapters covering the need for on-site sanitation, sanitation and disease transmission, social, and cultural considerations and technical options); (2) detailed design, construction, operation and maintenance (four chapters covering technical factors affecting excreta disposal, operation and maintenance of on-site sanitation, components and construction of latrines, and design examples); and (3) planning and development of on-site sanitation projects (three chapters covering planning, institutional, economic and financial factors, and development) [18]..

III. PROBLEM STATEMENT

Washroom hygiene and maintenance have been ongoing challenges in public and commercial spaces such as malls, railway stations, corporate offices, and educational institutions. Despite numerous advancements in building management and sanitation technologies, the traditional methods of washroom cleaning and monitoring remain outdated and inefficient. The existing systems largely rely on human intervention, periodic inspections, and manual cleaning schedules, which often fail to ensure consistent cleanliness and hygiene. This results in a poor user experience, increased health risks, and operational inefficiencies. The major limitations of the current washroom maintenance system are discussed below.

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1. Lack of Real-Time Hygiene Monitoring

One of the biggest drawbacks of the existing washroom maintenance system is the lack of real-time monitoring. In most cases, washroom cleanliness is assessed based on fixed cleaning schedules rather than actual hygiene conditions. This outdated approach fails to address sudden cleanliness deterioration caused by high foot traffic, plumbing issues, or improper use. When a washroom becomes dirty between scheduled cleanings, users are left to endure unsanitary conditions until the next cleaning round. Additionally, due to the absence of real-time cleanliness tracking, facility managers and cleaning staff remain unaware of the immediate hygiene status of the washroom. Without an automated system to detect dirtiness and odors, washrooms may remain unclean for extended periods, leading to discomfort for users and complaints to management.

2. Ineffective Air Quality Management

Air quality in washrooms is a crucial factor in maintaining a comfortable and hygienic environment. In the existing system, there is no automated mechanism to measure air quality and detect the presence of harmful gases, excessive moisture, or unpleasant odors. Poor air quality in washrooms can lead to discomfort for users and may even pose health risks, especially in enclosed spaces with limited ventilation. Unpleasant odors, often caused by improper ventilation and unclean surfaces, are a major complaint in public washrooms. The current system does not provide a way to track and respond to declining air quality in real time. As a result, washroom users frequently experience poor air conditions, while cleaning staff remain unaware of the need for intervention until someone raises a complaint.

The absence of an automated air quality detection system also means that proactive maintenance is impossible. Cleaning teams often rely on subjective judgment to determine when to refresh the air in washrooms, which is unreliable and inconsistent. An intelligent air quality monitoring system is needed to ensure that washrooms maintain a fresh and hygienic environment at all times.

3. Delayed Cleaning Response and Inefficient Resource Utilization

The current approach to washroom cleaning is highly inefficient, as it relies on predefined schedules rather than actual cleanliness levels. This means that in some cases, cleaning staff visit washrooms that do not require immediate attention, wasting valuable time and resources. Conversely, washrooms that require urgent cleaning may remain unattended for extended periods because they are not included in the current cleaning schedule. In the absence of an automated notification system, cleaning staff have no way of knowing when a washroom requires urgent cleaning. This results in significant delays in addressing hygiene issues, leading to poor sanitation and increased dissatisfaction among users. The lack of real-time alerts also means that management cannot effectively allocate resources based on actual needs, leading to unnecessary labor costs and operational inefficiencies.

4. Safety Concerns for Women in Emergency Situations

Security in public washrooms, especially for women, is a critical issue that is often overlooked in traditional washroom management systems. In many cases, women who find themselves in distress inside a washroom have no direct way to call for help. Whether facing harassment, medical emergencies, or other dangers, the lack of an emergency alert system leaves them vulnerable and without immediate assistance. In isolated areas or late-night hours, public washrooms can become unsafe spaces due to inadequate surveillance and security measures. The absence of an emergency SOS mechanism prevents individuals from quickly alerting security personnel or authorities in case of an emergency. A reliable emergency alert feature is necessary to enhance the safety of washroom users, particularly women, by providing them with a quick and effective way to call for help when needed.

5. Privacy and Unauthorized Entry Issues

Another significant issue with the existing washroom management system is the lack of privacy protection, particularly when maintenance staff enter washrooms for cleaning purposes. In many cases, when male janitors or facility workers need to clean a female washroom, there is no proper alert system in place to notify users inside. This can lead to uncomfortable and potentially distressing situations where users are caught unaware by the presence of a worker inside

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the washroom. Unauthorized entry is also a concern in washrooms where there are no strict access control measures. In some cases, individuals may enter restricted washroom areas, either accidentally or with ill intent, leading to security risks and privacy violations. The absence of a clear indication system increases the chances of such incidents occurring. A proper notification mechanism, such as an indicator light, should be implemented to alert users when cleaning personnel are entering a washroom. This would help ensure privacy and avoid unnecessary distress among users.

6. Over-Reliance on Human Intervention

The current system for washroom maintenance is heavily dependent on human intervention, making it inefficient and prone to errors. In traditional washroom management, cleanliness assessment, maintenance, and security monitoring are all handled manually. This not only increases labor costs but also leads to inconsistent service quality. Since there is no automated system to track washroom conditions in real time, maintenance staff are required to conduct frequent inspections to check for cleanliness and hygiene issues. This process is time-consuming and inefficient, as it does not always lead to timely responses. Additionally, human errors, negligence, and lack of accountability further degrade the effectiveness of the system, making it unreliable. Automated monitoring and notification systems are essential to reduce the dependency on human intervention and ensure a more efficient, reliable, and consistent approach to washroom maintenance.

IV. METHODOLOGY

The hardware implementation starts with designing the circuit and connecting different sensors and modules to the ESP32 microcontroller. The DHT11 sensor is connected to the ESP32 to constantly measure temperature and humidity. The MQ135 gas sensor is used to monitor air quality. A relay module is added to send automatic messages when air quality or other conditions go beyond safe limits. An SPST (Single Pole Single Throw) switch is used as an emergency SOS button, and LEDs are included to show the presence of cleaning staff, which helps maintain user privacy. Power is supplied using a 18650 lithium battery, and a buck converter is used to manage and regulate voltage, ensuring the system works efficiently.

Once the hardware is set up, the ESP RainMaker platform is configured. This allows the ESP32 to send data to the cloud in real-time. The ESP32 is programmed to read sensor values—such as temperature, humidity, and air quality—and send them to the ESP RainMaker cloud. A mobile app is also created so that maintenance staff and administrators can easily view the live data on their phones through a simple dashboard.

Next, the system's automation logic is added. The ESP32 keeps reading values from the DHT11 and MQ135 sensors. If the air quality drops below 40%, the system automatically sends a message to the control room, asking for cleaning. The LED indicators turn on when a cleaner of the opposite gender enters the washroom to alert users for privacy. The SPST switch acts as a panic button—when pressed, it sends an emergency SOS alert to the control room immediately.

After programming the logic, thorough testing and debugging are done. Each part—DHT11, MQ135, relay, LEDs, and the SOS switch—is tested on its own and as part of the full system. The data transmission is also tested to make sure the readings are sent correctly and on time to the cloud and mobile app. Test situations are created to check if the air quality alerts, LED indicators, and SOS features all work correctly in different conditions.

In the final stage, all the parts are neatly placed inside a plastic box to protect them and make the system safe for use in real washrooms. The complete device is tested in real-time to check how well it works, how fast it responds, and how easy it is for people to use.

The Intelligent Washroom System brings together various sensors and components with the ESP32 microcontroller to monitor hygiene and send alerts automatically. It uses a DHT11 sensor for temperature and humidity, and an MQ135 sensor for air quality. The relay controls message alerts, while the SPST switch acts as an emergency button. Gender-indicating LEDs help ensure privacy. The system is powered by 18650 rechargeable batteries and a buck converter for stable voltage.

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After setting up all the circuits, the whole system is packed into a strong plastic case to keep it safe and easy to carry. It is tested for accurate sensor readings, steady performance, and smooth cloud connection through ESP RainMaker, which shows the data live on a mobile dashboard.

The images below illustrate the practical implementation and physical integration of the Intelligent Washroom System:

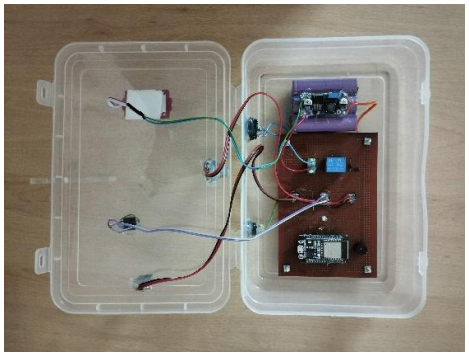

Fig. 1. —(a)Internal Wiring and Component Arrangement.

This internal view displays the organized layout of the system within a plastic enclosure. The ESP32 development board is securely mounted on a custom perforated PCB alongside the relay module and key connecting terminals. At the top-right, two 18650 Li-ion batteries power the system via a buck converter, which provides stable 3.3V/5V output. You can also observe the routing of jumper wires connecting each sensor to its respective ESP32 GPIO pins. This compact design minimizes clutter and ensures that the device remains safe and durable for long-term deployment in a public setting.

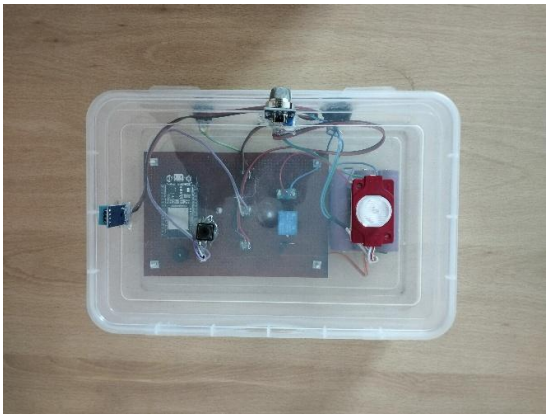

Fig. 1. —(b)Top View with Sensor Mounting

This image shows the top view of the closed hardware setup. Here, various external components are clearly visible and accessible:

•The DHT11 sensor is mounted externally for optimal ambient readings.
•The SOS SPST push button is easily accessible for emergencies.
•The MQ135 gas sensor, housed in a red protective casing, faces outward to detect washroom air quality effectively.
•The ultrasonic module and indicator LEDs are mounted to allow unobstructed signal transmission and visual alerts.

All components are firmly secured to the enclosure using hot glue and drilled slots, ensuring protection against displacement or accidental damage during use.

These two images demonstrate the practical realization of the hardware methodology, transitioning from theoretical design to a working prototype. The integration emphasizes durability, compactness, safety, and functionality—making the Intelligent Washroom System ready for real-world deployment and effective monitoring in public hygiene environments.

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On the software side, the project features a web-based system developed using HTML, CSS, and JavaScript, providing a responsive and user-friendly interface. The software begins with a secure login system, allowing access only to authorized users. Upon login, users are directed to a dashboard that offers a summarized view of all connected washrooms, displaying device names, cleanliness status, air quality readings, and the most recent SOS alerts. Each washroom entry links to a detailed monitoring page, where sensor values such as temperature, humidity, air quality index, and sound levels are visualized through interactive graphs. These graphs are refreshed every 5 seconds, ensuring real-time insights.

The dashboard's core features include a product list showcasing all installed monitoring units, real-time cleanliness indicators, air quality status, and logs of emergency alerts. The system is backed by a MySQL database hosted on WAMP, which manages user credentials and stores all incoming sensor data. Real-time data is fetched and dynamically rendered on the interface, offering administrators a clear and immediate understanding of environmental conditions inside the washrooms.

In conclusion, the Intelligent Washroom System employs a seamless blend of IoT hardware and interactive software to establish an efficient, smart hygiene monitoring solution. It reduces the need for manual inspections, enhances responsiveness to emergencies, ensures gender-sensitive operations, and promotes higher standards of public cleanliness and safety.

V. RESULT

This section showcases the real-time operational interface of the Intelligent Washroom System. The following figures illustrate the user interface of the web-based system, starting from login to data monitoring. These interfaces enable system administrators to track hygiene conditions, emergency alerts, and sensor values efficiently.

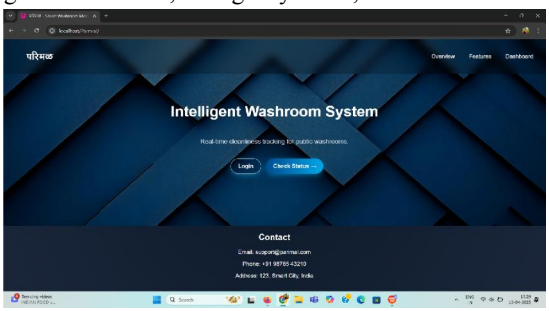

Fig. 2. Home Page

The Home Page serves as the landing interface for users accessing the Intelligent Washroom System. It provides a basic overview of the system's objective, promoting hygiene and automation in public restrooms. Users are guided toward the login panel from this page. The layout is built using HTML and styled with CSS to ensure responsiveness across devices. The design prioritizes simplicity, with direct access links and branding elements such as the system's name and institutional details.

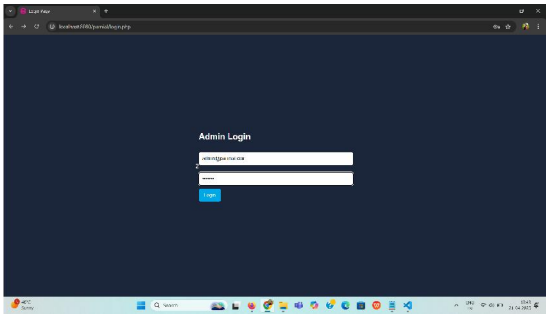

Fig.3. Login Page

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The Login Page provides authentication-based access to the system. This page is protected to allow only authorized personnel, such as administrators or facility managers, to access sensitive washroom data. It includes input fields for username and password, and only validated credentials allow redirection to the admin panel. This level of access control ensures system security, especially in institutional environments where data privacy and control are essential.

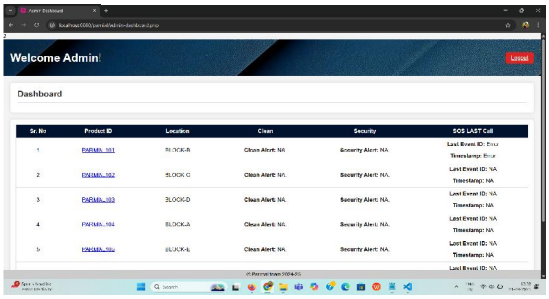

Fig.4. Admin Page

Once a user logs in successfully, they are redirected to the Admin Page. This page serves as the main navigation hub for system administrators. From here, the admin can access:

The washroom monitoring dashboards, System logs, User profile settings, and Device status summaries.

This page maintains consistency in layout and provides navigation options that streamline user access to critical features of the system.

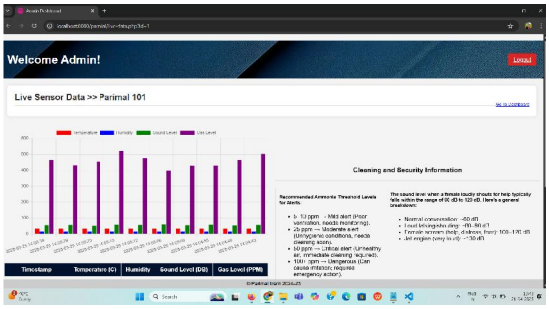

Fig.5. —(a)Admin Dashboard

This image represents the first part of the Admin Dashboard, where real-time environmental conditions are displayed in graphical and tabular format. The dashboard fetches and updates data every 5 seconds using AJAX-based JavaScript and MySQL backend support.

Key features visible in this view include:

- Real-Time Graphs for Temperature and Humidity: These are plotted based on DHT11 sensor readings. The graph helps administrators visualize fluctuations inside the washroom, aiding decisions related to ventilation and humidity control.
- Air Quality Index Table: Displays the cleanliness percentage detected by the MQ135 gas sensor. If the percentage falls below 40%, the system triggers an automatic alert to the control room. This table helps in identifying when cleaning is required and logs previous alerts with timestamps.
- System Status Panels: These indicate whether the washroom is currently clean, requires attention, or has triggered any emergency messages.

This part of the dashboard ensures that hygiene metrics are visible at a glance, enabling quicker decision-making and remote-control operations.

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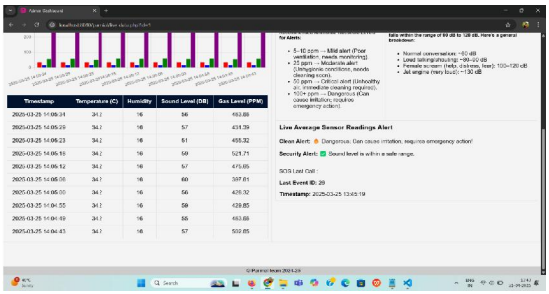

Fig.5. —(b) Admin Dashboard

The second image of the Admin Dashboard focuses on security and emergency functionality, particularly the integration of sound sensors and the SOS switch.

Main elements displayed in this view:

- Sound Detection Alerts: Values from the KY-037 sound sensor are logged. This helps detect suspicious or high-decibel sounds such as distress calls, loud crashes, or potential vandalism. It adds a crucial layer of intelligent safety monitoring, especially beneficial for female users or isolated washroom locations.
- SOS Alert Logs: This panel logs events when the SPST switch is pressed. It includes timestamps and washroom locations, allowing quick identification of emergencies. The dashboard also supports escalation mechanisms by notifying higher authorities if the alert is not resolved within a set timeframe.
- Gender-Based LED Indicator Status: A status panel showing whether the gender-indicating LED has been activated. This informs users if a cleaning staff member of the opposite gender is inside the washroom, improving privacy awareness.

This portion of the dashboard focuses on safety, privacy, and incident management, ensuring the system is not only hygienic but also secure.

VI. FUTURE SCOPE

The Intelligent Washroom System holds significant potential for future development and expansion, making it even more efficient, accessible, and intelligent. One of the primary enhancements is the integration of Artificial Intelligence (AI) to enable predictive cleaning, where the system analyzes usage patterns to automatically schedule cleaning tasks, ensuring proactive maintenance. To further improve accessibility, especially for users with disabilities, voice-activated controls can be incorporated, allowing hands-free interaction with the system. A centralized multi-washroom monitoring dashboard can also be developed to manage multiple facilities within large institutions or commercial buildings from a single interface. Additionally, a user feedback system integrated into the mobile application would allow users to manually report cleanliness issues, ensuring quicker resolution of specific concerns.

The system can also be upgraded to support real-time usage analytics, enabling administrators to assess traffic trends and optimize maintenance schedules accordingly. Multi-language support will make the system accessible to a broader range of users, especially in diverse and multilingual regions. Furthermore, an automated reporting system can generate periodic summaries on hygiene levels and washroom usage statistics, improving overall management efficiency. To enhance sustainability, energy-efficient operations can be prioritized by optimizing sensor activity and minimizing power consumption. The system can also be linked with smart city infrastructure for centralized monitoring in large public areas such as malls, airports, and railway stations. Lastly, the SOS emergency alert system can be expanded to notify nearby security personnel immediately, reducing emergency response time and enhancing user safety.

VII. CONCLUSION

In conclusion, the Intelligent Washroom Cleaning System represents a significant advancement in public hygiene and facility management, offering a proactive, data-driven approach to maintaining cleanliness and safety. However, the system's capabilities can be further enhanced through the integration of advanced automation technologies, improved security protocols, and more efficient data processing mechanisms. These enhancements will enable faster detection of

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hygiene-related issues, quicker response times, and more accurate environmental monitoring. Incorporating AI-driven analytics can also help predict maintenance needs and optimize resource allocation, thereby reducing operational costs and ensuring consistent standards. Additionally, improved user interface design and mobile application integration will provide a more seamless and user-friendly experience for custodial staff and facility managers. Strengthening security measures within the system will ensure the privacy and safety of users, making public washrooms not only cleaner but also more secure. By refining the system's scalability and adaptability, it can be effectively deployed across various public and private facilities, regardless of size or location. Ultimately, enhancing the Intelligent Washroom Cleaning System with cutting-edge technologies and smart design principles will ensure a more efficient, hygienic, and safe restroom environment, contributing to better public health outcomes and a higher standard of living in shared spaces.

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