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Smart Public Restroom/Toilets Monitoring System

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Abstract: *Hygiene concerns in public toilets, particularly in low-income areas, persist due to inadequate ventilation and maintenance. Despite significant government investment in upkeep, ensuring cleanliness remains challenging without a central monitoring system. Across various regions, including India, substandard sanitation infrastructure contributes to health issues. Addressing this, a cost-effective hygiene monitoring device, based on air quality standards, is proposed. This paper outlines the development of an "IoT Enabled Portable Air-Quality Monitoring and Control Device for Public Restrooms/Toilets." The device aims to monitor and regulate air quality within public toilets to a certain extent. Employing the ESP8266 microcontroller and MQ gas sensors, it detects harmful gases like ammonia, carbon dioxide, carbon monoxide, methane, alongside temperature and humidity levels. Furthermore, the device integrates an exhaust fan control system to enhance air quality.*

Keywords: Internet of Things, Public Toilet Hygiene, Air quality monitoring, ESP8266 microcontroller, MQ gassensors, Portable

I. INTRODUCTION

According to a report by WaterAid, more than 50% of the world's population lacks access to safe and clean toilets, with 892 million people practicing open defecation. Inadequate public toilets in low-income areas are a significant contributor to this issue, with many lacking basic facilities such as running water, soap, and toilet paper. This lack of basic hygiene in public toilets can lead to the spread of harmful bacteria and viruses, causing illnesses such as diarrhoea , cholera, and hepatitis A. In fact, the World Health Organization estimates that every year, around 432,000 deaths worldwide are causedby diarrheal diseases linked to poor sanitation and hygiene. Furthermore, inadequate public toilets can also have an impacton mental health, with people avoiding public spaces due to the lack of clean and safe toilets. It is essential to address this issue by investing in proper sanitation facilities and improving the hygiene of existing public toilets to prevent the spread of diseases and ensure the health and wellbeing of all users. Although there are public restrooms in many countries, the lackof proper monitoring and maintenance frequently leads to unsanitary conditions. Without routine maintenance, public restrooms can soon become unclean and endanger the health of those who use them. Furthermore, a lack of accountability and supervision may result in unsafe working conditions for the staff members in charge of cleaning these facilities. To make sure that public restrooms stay sanitary and clean, an efficient system for monitoring and maintaining them must be put in place. It is possible to enhance the general standard of public restrooms and advance public health and safety by introducing regular cleaning schedules, training staff on suitable cleaning techniques, and utilizing cutting-edge technologies like IoT-based monitoring systems.

In this research, we propose, when it comes to keeping public toilets clean and hygienic, monitoring the air quality has a lotof advantages over other methods. Air quality monitoring uses sensors to detect harmful pollutants in real-time, like carbon dioxide, carbon monoxide, methane, etc. This helps us spot potential hygiene issues quickly and take action to address them.Plus, monitoring air quality can help in improve the ventilation system and airflow in public toilets, which is really important for keeping them fresh and clean. Best of all, IoT-based air quality monitoring devices are low-cost, portable, easy to install,and can be managed remotely, which makes them perfect for monitoring public toilets in both cities and rural areas. Thus,the proposed device is expected to contribute towards improving public health by controlling and monitoring the air qualityin public toilets. The device's portability and low cost make it an ideal solution for air quality monitoring and control in public toilets, with potential applications in other indoor environments as well.

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Overall, this research presents a practical and innovative solution to improve air quality in public toilets throughout many countries.

II. PROPOSED BLOCK DIAGRAM

Design of the Device:

The device was designed to be portable and compact, making it suitable for use in public restrooms/toilets. The NodeMCU ESP8266 was used as the microcontroller, which allowed for easy programming and interfacing with the sensors. An OLED display was incorporated to display real-time data readings from the sensors. Gas sensors MQ135, MQ2, MQ4, and MQ7 were used to measure different gases such as ammonia, carbon dioxide, carbon monoxide, and methane, respectively. The temperature and humidity sensor DTH11 was used to measure the ambient temperature and humidity of the restroom/toilet. To extend the analog pin count of the microcontroller, a 16 channel Analog MUX was used. The ventilation control system was also integrated into the device, which could be controlled remotely through the IOT platform along with an email alert to notify the action. The device is powered by 10000 mAh rechargeable battery to ensure portability.

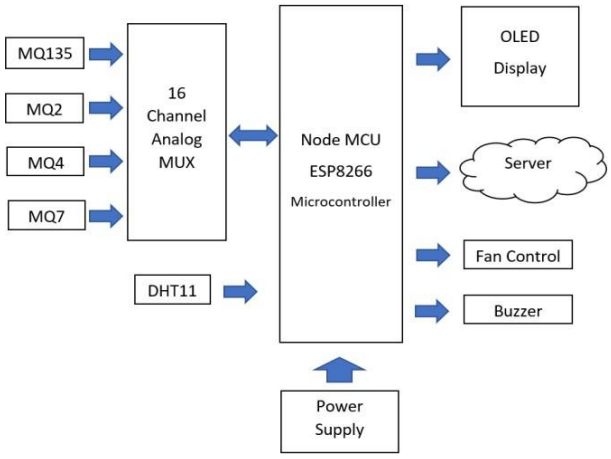

Fig.1. Block Diagram of the device

Data Collection Method:

As part of the data collection process, the sensors continuously detect real-time data on air quality, temperature, and humidity in public restrooms/toilets. The device has gas sensors (MQ135, MQ2, MQ4, and MQ7) to measure various gases released in bathrooms and toilets. The ambient air's temperature and humidity are measured using the temperature and humidity sensor (DTH11). The NodeMCU ESP8266 microcontroller processes the information gathered from these sensors and is set up to send it wirelessly to the ThinkSpeak website and also display it on OLED.

Integrated Ventilation and Alert System:

The integrated ventilation and alert system employed in the restroom ensures the maintenance of optimal air quality, while also incorporating a buzzer and email alert mechanism for timely notifications. This advanced system combines data analysis from gas sensors, temperature and humidity sensors to assess the air quality within the allowed range. The email alert mechanism that promptly notifies designated personnel or facility management. When the air quality reaches an unacceptable level, an email alert is automatically generated and sent to the relevant recipients, providing them with real- time updates regarding the situation.

IOT Implementation:

To enable remote monitoring and control, we are using ThinkSpeak website, an IOT platform, to collect and visualize the data collected by the sensors. The NodeMCU ESP8266 sends the data to the ThinkSpeak website over Wi-Fi using

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the HTTP protocol. We have set up a dashboard on the ThinkSpeak website that displays real-time sensor readings and alerts when air quality is poor

Calibration of Sensors:

A crucial step in ensuring the quality and dependability of sensor readings is calibration. The MQ135, MQ2, MQ4, and MQ7 gas sensors that are employed in this device must be calibrated before use. Exposing the sensor to a known gas concentration during calibration includes changing the sensor output to correspond to the anticipated result.The temperature and humidity sensor (DTH11) are factory calibrated and does not require additional calibration. But it's important to crosscheck the sensors performance before actual use.

III. METHODOLOGY USED

The methodology employed in the development of the smart restroom monitoring system involves several key steps to ensure accurate and efficient monitoring of air quality parameters. Firstly, the selection of appropriate sensors, such as MQ gas sensors for detecting harmful gases, temperature sensors, and humidity sensors, is crucial. These sensors are chosen based on their reliability, accuracy, and compatibility with the IoT framework. Next, the system architecture is designed to integrate the selected sensors with the ESP8266 microcontroller, enabling data collection and processing. The microcontroller serves as the central processing unit, receiving sensor data and executing control commands for the exhaust fan based on predefined thresholds. During the implementation phase, the sensors are calibrated and installed strategically within the restroom environment to capture representative air quality measurements. Calibration ensures the accuracy and consistency of sensor readings, while strategic placement ensures comprehensive coverage of the restroom space. Once installed, the system undergoes rigorous testing and validation to verify its functionality and performance under various operating conditions. Testing involves simulating different scenarios to assess the system's responsiveness and reliability in detecting and responding to changes in air quality. Finally, the system is deployed in real-world public restroom settings, where it undergoes continuous monitoring and optimization based on feedback and performance evaluations. This iterative process allows for further refinement and enhancement of the system's capabilities to ensure effective and reliable restroomhygiene monitoring.

IV. SYSTEM OVERVIEW

The proposed system i.e. "SMART RESTROOM MONITORING" consists of several sensors and controller which are listed below with the overview of their specification –

- NODEMCU ESP8266
- MQ2 Gas Sensor
- MQ4 Gas Sensor
- MQ135 Gas Sensor
- MQ7 Gas Sensor
- DHT11 Sensor
- OLED Display

NODEMCU ESP8266

The NodeMCU is a development board that combines the ESP8266 Wi-Fi module with a microcontroller, typically based on the ESP8266 chipset. It offers a low-cost, easy-to-use platform for IoT (Internet of Things) projects and prototyping. The NodeMCU board provides a convenient way to connect electronic components and sensors to the internet, enabling the creation of various IoT applications. At its core, the NodeMCU features the ESP8266 microcontroller, which integrates a Wi-Fi module, making it capable of connecting to wireless networks and communicating over the internet. This microcontroller is powerful and versatile, with sufficient processing power and memory to handle IoT tasks efficiently. The NodeMCU board also includes various input/output (I/O) pins, allowing users to connect sensors, actuators, and other electronic components easily. These pins enable interaction with the physical world, such as reading sensor data or controlling devices based on input received from the internet. One of the

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key advantages of NodeMCU is its support for the Lua scripting language, which simplifies the development of IoT applications by providing a high-level programming interface. Additionally, NodeMCU is compatible with the Arduino IDE (Integrated Development Environment), allowing users familiar with Arduino programming to transition seamlessly to the ESP8266 platform. Overall, NodeMCU is a versatile and cost-effective solution for building IoT projects, offering the necessary hardware and software capabilities tobring ideas to life in the rapidly growing field of connected devices and smart systems

Fig. 2 Node MCU

MQ2 Gas Sensor-

The MQ2 gas sensor is a widely used component in electronic devices designed for detecting various gases in the atmosphere. It is particularly effective in detecting flammable gases like methane, propane, butane, alcohol, and carbon monoxide, as well as smoke and other harmful gases such as ammonia, benzene, and hydrogen. The sensor operates based on the principle of chemical reaction between the gas molecules and the surface of a semiconductor material inside the sensor. When gas molecules come into contact with the semiconductor surface, they cause a change in its electrical conductivity, which is then measured by the sensor. This change in conductivity is proportional to the concentration of the gas in the environment. The MQ2 sensor consists of a heating element and a sensing element housed in a ceramic body. The heating element is used to raise the temperature of the sensing element, making it more sensitive to gas molecules. When the sensor is powered on, the heating element heats up, and the sensing element starts to detect gas molecules in thesurrounding environment. The output of the MQ2 sensor is an analog voltage signal, which can be read by a microcontroller or other electronic devices. By analyzing the voltage output, the presence and concentration of various gases can be determined. One of the key advantages of the MQ2 sensor is its simplicity and ease of use. It requires minimal external components and can be easily integrated into electronic circuits. However, it's important to note that the MQ2 sensor may have some limitations, such as sensitivity to humidity and temperature variations, and cross-sensitivity to other gases. Therefore, proper calibration and environmental considerations are necessary for accurate gas detection. Overall, the MQ2 gas sensor is a valuable tool for monitoring air quality and ensuring safety in various applications, including industrial, residential, and automotive environments.

Fig.3 MQ2 Gas Sensor

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MQ4 Gas Sensor

The MQ-4 gas sensor is a commonly used component in electronic devices designed to detect gases in the atmosphere. It is particularly effective in detecting gases such as methane, natural gas, liquefied petroleum gas (LPG), and other combustible gases. The MQ-4 sensor operates on the principle of chemiresistive sensing, where the presence of a specific gas causes a change in the sensor's resistance. Inside the sensor, there is a ceramic sensing element coated with a layer of tin dioxide (SnO2), which serves as a sensing material. When the target gas comes into contact with the sensing element, it undergoes a chemical reaction that alters the conductivity of the tin dioxide layer. This change in conductivity is then measured by the sensor and converted into an electrical signal that indicates the presence and concentration of the gas. The MQ-4 sensor requires a heating element to elevate the temperature of the sensing element, increasing its sensitivity to gas molecules. When the sensor is powered on, the heating element heats up, and the sensing element begins to detect gas molecules in thesurrounding environment. One of the advantages of the MQ-4 sensor is its simplicity and ease of use. It can be easily integrated into electronic circuits and requires minimal external components. Additionally, it provides a rapid response to changes in gas concentration, making it suitable for applications where quick detection is critical, such as gas leak alarms. However, like other gas sensors, the MQ-4 sensor may have some limitations, including sensitivity to humidity and temperature variations, as well as cross-sensitivity to other gases. Therefore, proper calibration and environmental considerations are necessary for accurate gas detection. Overall, the MQ-4 gas sensor is a valuable tool for monitoring air quality and ensuring safety in various applications, including industrial, residential, and automotive environments.

Fig.4 MQ4 Sensor

MQ135 Gas Sensor-

The MQ135 gas sensor is a popular component used in electronic devices for detecting a wide range of gases present in the atmosphere. It is particularly effective in detecting gases such as ammonia, nitrogen oxides (NOx), benzene, and various volatile organic compounds (VOCs), as well as carbon dioxide (CO2). Operating on the principle of chemiresistive sensing, the MQ135 sensor utilizes a tin dioxide (SnO2) semiconductor material coated with a sensitive layer. When exposed to gases, this sensitive layer undergoes a chemical reaction, causing a change in the sensor's electrical conductivity. This change in conductivity is then measured by the sensor and converted into an electrical signal proportional to the concentration of the detected gas. The MQ135 sensor typically includes a heating element to maintain a constant temperature, enhancing the sensor's sensitivity and response time. Upon powering the sensor, the heating element elevates the temperature of the sensitive layer, making it more reactive to gas molecules. One of the notable features of the MQ135 sensor is its versatility, as it can detect a wide range of gases with high sensitivity. This makes it suitable for various applications, including air quality monitoring, industrial safety, and indoor environmental monitoring.However, like other gas sensors, the MQ135 sensor may have limitations such as sensitivity to humidity and temperature fluctuations, as well as potential cross-sensitivity to certain gases. Therefore, proper calibration and environmental considerations are necessary to ensure accurate gas detection. Overall, the MQ135 gas sensor is a valuable tool for assessing air quality and detecting potentially harmful gases in different environments. Its reliability,

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sensitivity, and versatility make it a popular choice for a wide range of applications aimed at promoting safety and environmental health.

Fig.5 MQ135 Sensor

MQ7 Gas Sensor-

The MQ-7 gas sensor is a commonly utilized component in electronic devices designed to detect various gases in the atmosphere. It is particularly effective in detecting carbon monoxide (CO), a highly toxic gas produced by incomplete combustion of carbon-containing fuels. Operating on the principle of chemiresistive sensing, the MQ-7 sensor features a semiconductor material coated with a sensitive layer, typically made of tin dioxide (SnO2). When exposed to gases, this sensitive layer undergoes a chemical reaction, leading to a change in the sensor's electrical conductivity. The MQ-7 sensor usually includes a heating element to maintain a consistent operating temperature, which enhances its sensitivity and responsetime. When the sensor is powered on, the heating element elevates the temperature of the sensitive layer, making it more reactive to gas molecules. One of the key advantages of the MQ-7 sensor is its high sensitivity to carbon monoxide, making it well-suited for applications where rapid and accurate detection of this gas is crucial, such as in residential carbon monoxide alarms and industrial safety systems. However, it's essential to note that the MQ-7 sensor may have limitations, including potential cross-sensitivity to other gases and susceptibility to environmental factors such as humidity and temperature fluctuations. Proper calibration and environmental considerations are necessary to ensure reliable gas detection. Overall, the MQ-7 gas sensor is a valuable tool for monitoring carbon monoxide levels in various environments, contributing to the prevention of carbon monoxide poisoning and enhancing safety in both residential and industrial settings. Its reliability, sensitivity, and ease of integration make it a popular choice for gas detection applications requiring high performance and accuracy.

Fig.6 MQ7 Gas Sensor

DHT11 Sensor-

The DHT11 sensor is a widely used component in electronic devices designed for monitoring temperature and humidity levels in the surrounding environment. It provides a low-cost and reliable solution for applications requiring real-time environmental data. The DHT11 sensor operates using digital signal output, making it easy to interface with microcontrollers and other electronic devices. It consists of a capacitive humidity sensor and a thermistor for

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temperature measurement, both integrated into a single module. For temperature sensing, the thermistor changes its resistance with variations in temperature. The DHT11 sensor utilizes this change in resistance to calculate the ambient temperature accurately. Regarding humidity measurement, the DHT11 sensor employs a capacitive humidity sensor. This sensor measures the changes in capacitance caused by moisture absorption in a polymer dielectric. The sensor's electronics then convert this capacitance change into a digital signal, representing the relative humidity. The DHT11 sensor communicates with external devices via a single-wire serial interface, making it easy to integrate into various projects. It utilizes a simpleprotocol for data transmission, where the sensor sends temperature and humidity data in a predefined format to the microcontroller or host device. One of the primary advantages of the DHT11 sensor is its simplicity and ease of use. It requires minimal external components and can provide accurate temperature and humidity readings with reasonable precision. However, it's essential to note that the DHT11 sensor may have limitations in terms of accuracy and response time compared to more advanced sensors. Additionally, it may not be suitable for applications requiring high precision or fast data acquisition rates. Overall, the DHT11 sensor is a cost-effective solution for monitoring temperature and humiditylevels in various environments, making it suitable for applications such as weather stations, environmental monitoring systems, HVAC (heating, ventilation, and air conditioning) control, and home automation projects. Its simplicity, reliability, and affordability make it a popular choice among hobbyists, students, and professionals alike.

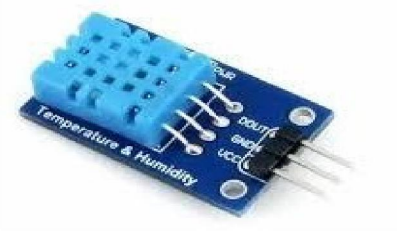

Fig.7 DHT11 Sensor

OLED Display

Fig. 8 OLED Display

An OLED (Organic Light-Emitting Diode) display is a type of display technology that utilizes organic compounds to emitlight when an electric current is applied. Unlike traditional LCD (Liquid Crystal Display) screens, OLED displays do not require a backlight, resulting in deeper blacks, higher contrast ratios, and improved energy efficiency. The structure of an OLED display typically consists of several layers of organic materials sandwiched between two electrodes, one of which istransparent. When a voltage is applied across these electrodes, it causes electrons to move from the cathode to the anode, where they combine with positively charged "holes." This process generates light, with the color and intensity determined by the type and properties of the organic materials used. One of the key advantages of OLED displays is their ability to produce vibrant colors and high contrast images. Since each pixel in an OLED display emits its own light, rather than relying on a backlight like LCDs, OLED screens can achieve true black by simply turning off individual pixels. This results in superior contrast ratios and better image quality, especially in dark environments. Another benefit of OLED displays is their flexibility and thinness. OLED panels can be manufactured on flexible substrates, allowing for curved or even rollabledisplays. Additionally, OLED screens can be made thinner and lighter than traditional LCDs, making them ideal for applications where space and weight are critical considerations.

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OLED displays also offer fast response times and wide viewing angles, making them suitable for use in various devices such as smartphones, tablets, televisions, wearable devices,and automotive displays. However, OLED displays do have some drawbacks, including potential issues with image retention (burn-in) and shorter lifespans compared to LCDs, particularly for blue OLED materials. Manufacturers continueto work on improving OLED technology to address these challenges and expand its applications further. In summary, OLED displays represent a significant advancement in display technology, offering superior image quality, flexibility, and energy efficiency compared to traditional LCD screens. As the technology continues to evolve, OLED displays are expected to become increasingly prevalent in a wide range of consumer electronics and other display applications.

V. CONCLUSION

In conclusion, the introduction of a smart restroom monitoring system offers a transformative solution to address hygiene challenges in public toilets, particularly in underprivileged areas. By integrating advanced sensor technology and IoT capabilities, this system provides a cost-effective and efficient means of overseeing and regulating air quality parameters within restroom environments. Through real-time monitoring of critical factors such as harmful gas levels, temperature, and humidity, the smart restroom monitoring system enables early detection and mitigation of potential hygiene issues. Moreover, the incorporation of an exhaust fan control mechanism facilitates improved ventilation, effectively reducing the accumulation of pollutants and moisture. The system's remote monitoring and control features empower authorities to take swift action in response to emerging hygiene concerns, ensuring that restroom facilities maintain optimal cleanliness and comfort levels for users. The implementation of a smart restroom monitoring system represents a significant step forward in advancing public health and sanitation efforts. By providing enhanced oversight and management capabilities, this innovative solution has the potential to significantly improve the overall hygiene standards and well-being of communities, thereby fostering healthier and more equitable environments for all.

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