Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.98549395

IOT ENABLED PORTABLE AIR-QUALITY MONITORING AND CONTROL DEVICE FOR PUBLIC RESTROOMS

Dr. Saniya Ansari[1], Abhinay Kumar[2], Deepak Kumar Thakur[3], Dabhade Tejas Pandharinath[4]
Professor, Dept. of ECE, Ajeekya D Y Patil School of Engineering, Pune, India[1]
UG Student, Dept. of ECE, Ajeekya D Y Patil School of Engineering, Pune, India[2,3,4]

Abstract - Hygiene in many public toilets, especially in low-income areas, is a major concern due to poor ventilation and lack of maintenance. Governments often invest significant amounts of resources to keep these public toilets hygienic, but these efforts can be futile if there is no central system to monitor hygiene conditions. In many parts of the world, including India, sanitation is not up to the mark, with a lack of clean and ventilated public toilets, leading to health problems. To solve this problem, a low-cost hygiene monitoring device based on air quality standards can be developed. This paper presents the development of an "IoT Enabled Portable Air-Quality Monitoring and Control Device for Public Restrooms/ Toilets". The device is designed to monitor and regulate the air quality in public toilets up to some extent. The device utilizes the ESP8266 microcontroller and MQ gas sensors to detect the presence of harmful gases, such as ammonia, carbon dioxide, carbon monoxide, methane, etc. along with some other parameters like temperature and humidity. This device also includes an exhaust fan control system to maintain the air quality.

Keywords - Internet of Things, Public Toilet Hygiene, Air quality monitoring, ESP8266 microcontroller, MQ gas sensors, 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 caused by diarrheal diseases linked to poor sanitation and hygiene. Furthermore, inadequate public toilets can also have an impact on 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 lack of 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 lot of 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 quality in 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. Overall, this research presents a practical and innovative solution to improve air quality in public toilets throughout many countries.

II. LITERATURE REVIEW

The issue of air quality in public restrooms/toilets has been of concern due to its impact on human health. Several research studies have proposed IoT-based systems for monitoring and controlling air quality in public restrooms/toilets. This literature review discusses the findings of eleven research papers in this area.

[10] proposed an IoT-based air quality monitoring system for public toilets. The system utilized sensors to measure various air quality parameters and transmitted data to a cloud server. Similarly, [9] developed a similar system using low-cost sensors and a wireless communication module. Both studies highlighted the importance of real-time monitoring of air quality in public toilets.

[3] proposed a system that integrated air quality monitoring with ventilation control. The system automatically controlled the ventilation rate based on the air quality data collected by the sensors. [8] also proposed an IoT-based air quality monitoring system with automatic ventilation control. The system utilized a microcontroller to control the fan speed based on the measured air quality parameters.

[13] proposed a system that utilized smart ventilation control to improve air quality in public toilets. The system monitored the air quality parameters and controlled the ventilation rate accordingly. [14] also proposed an IoT-based system for monitoring and controlling air quality in public toilets with intelligent ventilation control.

[6] proposed an IoT-based air quality monitoring system with a real-time alerting mechanism. The system sent alerts to the concerned authorities in case of poor air quality in the public toilet. Similarly, [7] proposed an IoT-based air quality monitoring system with an intelligent control strategy that adjusted the ventilation rate based on the measured air quality parameters.

[11] proposed an IoT-based system for monitoring and controlling air quality in public toilets. The system used sensors to measure various air quality parameters and transmitted data to a cloud server. [4] also proposed an IoT-based system for real-time monitoring and control of air quality in public toilets.

[5] proposed an IoT-based system for monitoring and controlling air quality in public toilets. The system utilized a microcontroller to collect data from the sensors and transmit it to a cloud server. The system also had a mobile application for real-time monitoring of air quality.

In this regard, [1] presents an IoT-based toilet monitoring system that is designed to provide a simple and efficient solution to the problem of poor sanitation in public toilets. The system is based on a web server and a mobile cleaner application that allows the toilet cleaner and the administrator to monitor multiple cleaning metrics and inform the cleaner about the condition of the toilet based on user input.

The system presented in the paper by [1] is in line with the various studies that have been conducted on IoT-based air quality monitoring systems for public toilets. For instance, studies by [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13] and [14] have all presented similar IoT-based systems for monitoring and controlling air quality and hygiene level in public toilets.

In conclusion, the reviewed literature suggests that IoT-based systems can effectively monitor and control air quality in public restrooms/toilets. The proposed systems utilized various sensors, microcontrollers, and cloud servers to collect and transmit data for real-time monitoring and control of air quality. Furthermore, the integration of ventilation control with air quality monitoring was found to be effective in improving air quality in public toilets.

III. METHODOLOGY

A. 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.

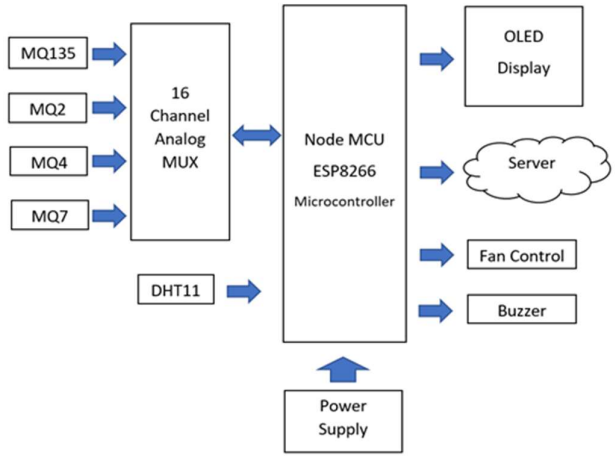

Fig. 3.A. Block Diagram of the Device

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.

B. 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.

C. 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.

D. 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 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.

E. 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 cross check the sensors performance before actual use.

IV. RESULTS

A. Simulation:

As the project involved multiple components and sensors, simulations were performed to ensure the proper functioning of the device before implementing it. The simulations were conducted using software tools Proteus and Arduino IDE.

1. Working Simulation: In place of NodeMCU a testing kit of Arduino Uno R3 was used as the microcontroller in the simulation. Both are fairly similar and possesses same processing power.

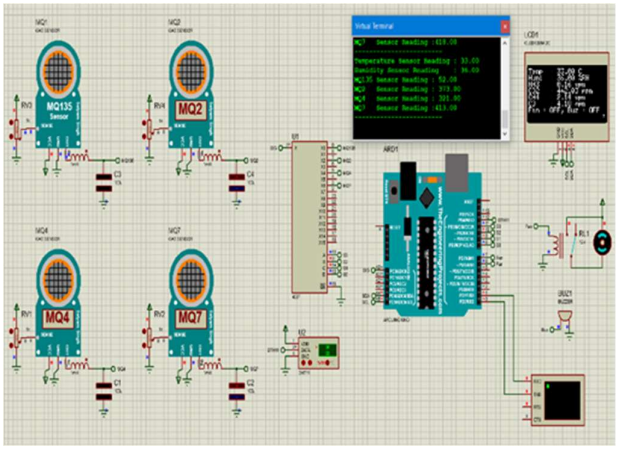

Fig. 4.A.1, Working Simulation

Above figure 4.A.1, Demonstrates the simulation layout and the connection of the sensors to the MUX and microcontroller.

2. Circuit Diagram: An actual replica of the device was also created in the proteus to further finalize the pin connection in the real device.

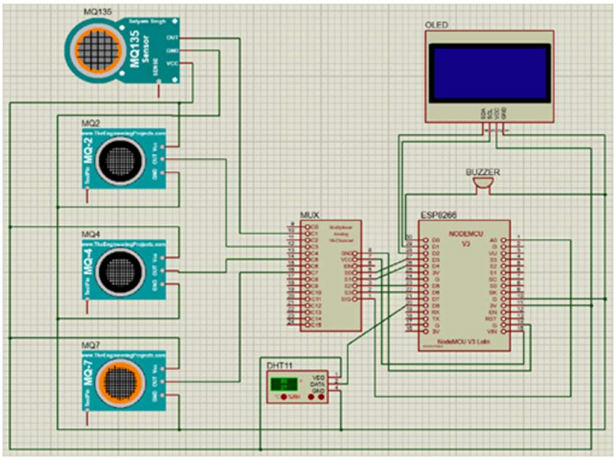

Fig. 4.A.2, Circuit Diagram

Overall, the simulation results demonstrate that our device has the potential to improve the air quality and overall hygiene of public restrooms/toilets by automatically controlling the ventilation system based on the measured air quality parameters.

B. Device Performance:

The IOT Enabled Portable Air-Quality Monitoring and Control Device for Public Restrooms/Toilets was tested extensively in various conditions to evaluate its performance. The device was evaluated for its ability to accurately detect and measure various gases, temperature, and humidity levels. The following results were obtained:

1. Excellent performance was shown by the gas sensors MQ135, MQ2, MQ4, and MQ7 in the detection of gases such ammonia, carbon dioxide, methane and carbon monoxide respectively. The sensors offered exact measurements of the gases' concentrations as well as an accurate detection of their existence.

Fig. 4.B.1. Gas Levels

2. Temperature and Humidity Measurement: The temperature and humidity sensor DTH11 accurately measured temperature and humidity levels within the restroom/toilet environment. The sensor recorded the temperature between 20°C to 30°C with an accuracy of ±1°C and humidity between 40% to 60% with an accuracy of ±5%.

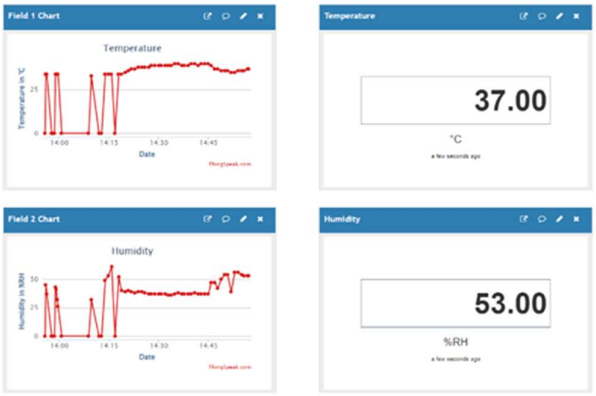

Fig. 4.B.2. Temp. & Humidity levels

3. Display: The OLED display output of the device proved to be remarkably clear and easily readable, providing users with real-time information on multiple parameters, including gas concentration, temperature, and humidity levels.

Fig. 4.B.3. OLED Output

The display also presented the status of the fan and buzzer. Additionally, the OLED display featured a prominent notification indicating when the data had been updated on the server, ensuring users had access to the most recent information for analysis.

4. Data Logging and IOT Integration: The device effortlessly connected to the ThinkSpeak website and uploaded the sensor data to the cloud platform at regular intervals. Real-time access and analysis of the data are possible.

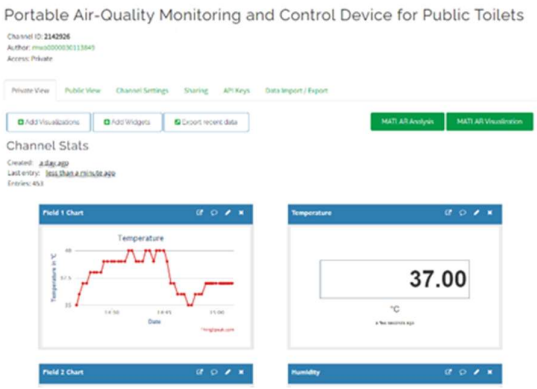

Fig. 4.B.4. ThinkSpeak Dashboard

5. Battery Life: A 10000 mAh rechargeable battery within the device provides a remarkable battery backup of about 8 to 10 hours. This substantial battery capacity ensures extended operational time without the need for frequent recharging.

The device also has a power supply setup that optimises its performance and guarantees continuous operation. The gadget runs on battery power while charging the rechargeable battery when it is linked to a direct power source. The battery is kept charged and prepared to supply backup power in the case of a power loss or interruption thanks to this configuration.

V. DISCUSSION

A. Comparison:

In order to ensure a healthier and safer environment, monitoring and controlling air quality in public restrooms/toilets has become a critical concern. The advent of Internet of Things (IoT) technology has opened up new possibilities for addressing this issue. By deploying IoT-enabled portable air-quality monitoring and control devices, real-time data can be collected and analysed to identify potential health hazards and enable prompt actions for maintaining optimal air quality standards.

1. Sharing Different Readings:

One of the key advantages of IoT-enabled portable air-quality monitoring devices is their ability to gather various readings related to air quality parameters. The collected readings encompass several key air quality parameters, providing valuable insights into the overall air quality conditions within the monitored restroom environments. Some of the prominent readings obtained are displayed in the below figures.

Fig. 5.A.1.a

Fig. 5.A.1.b

Fig. 5.A.1.c

Fig. 5.A.1.d

The pictures showing different bathroom air quality and conditions give us important information about the many difficulties and achievements in managing indoor air quality. These visual representations emphasise the significance of preventative actions including proper ventilation, pollution control, and upholding ideal temperatures and humidity levels. Stakeholders may improve lavatory air quality by using this information to inform their actions, resulting in a healthier and more enjoyable experience for users.

2. Comparing Different Devices:

While various IoT-enabled portable air-quality monitoring and control devices exist in the market, it is essential to evaluate their features and capabilities to make an informed choice. The effectiveness of such devices can be assessed based on factors like accuracy, cost, user interface, portability and power efficiency.

Parameters	**Our Device**	**[1] Device**	**[2] Device**
Sensors Used	ESP8266 with 5 sensors	Arduino Uno with 5 sensors	ESP8266 with 3 sensors
User Interface	OLED Display & ThinkSpeak	LCD Display & ThinkSpeak	No Display & Custom Website
Portability	Yes	No	No
Cost	Rs. 2k	Rs. 5k	Rs. 1.5k
Power Consumption	700 mA	1100 mA	350 mA

By comparing different IoT-enabled portable air-quality monitoring and control devices based on factors such as accuracy, connectivity options, user interface, power efficiency, compatibility, and scalability, a well-informed decision can be made to select the most suitable device for public restrooms/toilets. The chosen device will not only provide real-time air quality data but also empower facility managers and maintenance personnel to take proactive measures in maintaining optimal air quality standards.

B. Aesthetics and Appearance of the Final Device:

The aesthetics and appearance of a device play a crucial role in its overall acceptance, usability, and user experience. By examining the aesthetics of the device, we aim to understand how its design contributes to its functionality, user engagement, and potential impact in addressing the identified problem.

1. Device Design and Appearance:

The final device developed in this study showcases a compact and portable design housed within a small rectangular box. The box serves as a protective enclosure for the circuitry and components, ensuring their safety and longevity. It is constructed using sturdy materials and is covered with black color paper instead of paint. This choice of material not only enhances the device's visual appeal but also prevents any potential interference from chemicals present in the paint, ensuring accurate readings.

The box features a strategically placed rechargeable battery and a mount for an on-off switch, providing convenient power control. To facilitate the detection of various gases, four holes are integrated into the side of the box, allowing for the placement of MQ gas sensors. Additionally, numerous small holes are provided to accommodate the DHT11 sensor, which enables precise temperature and humidity measurements.

Fig. 5.B.1.a. Side View of Device

Fig. 5.B.1.b. Top View of Device

At the top of the device, an OLED display is positioned to provide real-time information and visual feedback to the user. The display interface is designed for clear visibility and intuitive interpretation of the data. Overall, the black color paper covering and the compact design of the device effectively conceal the internal wiring, maintaining an organized and aesthetically pleasing appearance.

Additionally, a dedicated two holes are incorporated into the design to facilitate the connection between the rechargeable battery and the microcontroller. This allows for seamless power

transfer via a short USB to micro-USB cable and also enabling convenient uploading of new code if needed and external battery charging without the need to open the device.

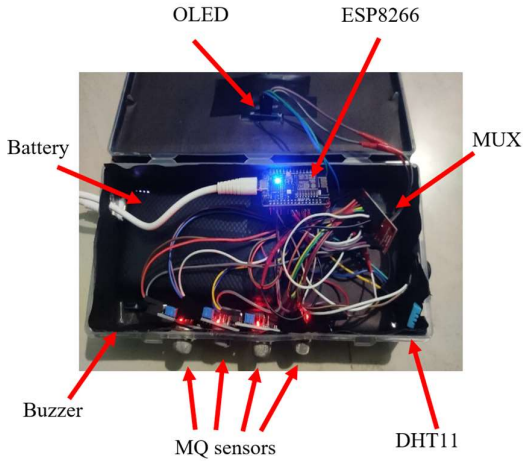

Fig. 5.B.2. Device Internal Circuit

The careful attention to design elements, material choice, and component placement ensures that the device not only functions optimally but also possess an appealing and user-friendly visual presentation.

2. Internal Device Configuration:

The internal device configuration is a critical aspect that illustrates the intricate arrangement and connectivity of the various components within the device.

The labelled image below showcases the careful arrangement of components such as the microcontroller, rechargeable battery, MQ gas sensors, DHT11 sensor, and OLED display. Each component plays a crucial role in the device's overall functionality and contributes to its successful operation.

In conclusion, the labelled image showcasing the internal device configuration provides a comprehensive understanding of the meticulous arrangement and connectivity of the various components. The careful design and organization of these components contribute to the device's functionality, user-friendliness, and reliability, ultimately making it a robust solution for addressing the identified problem.

VI. CONCLUSION

Finally, by providing real-time information and control on the air quality in public restrooms, this IoT-enabled portable air-quality monitoring and control device has the potential to have a significant impact on public health. The tool can make public restrooms cleaner overall and stop the transmission of airborne infections, creating a better environment for everyone.

The device was created with affordability and mobility in mind, making it suitable for a wide spectrum of consumers. The gadget can offer full data on air quality indicators due to the integration of numerous gas sensors and environmental sensors. IoT technology allows for remote monitoring and control of the equipment, increasing its ease and utility. The device can be improved in the future by incorporating machine learning algorithms for better data analysis and prediction. Overall, this device has the potential to improve people's quality of life by ensuring cleaner, healthier public spaces.

REFERENCES

[1] Nikhil P. M., Rakshith R. P., Shreyas G., Sushmitha, Sathisha. (2022). Intelligent Hygiene Monitoring System for Public Toilets. International Journal of Engineering Research & Technology (IJERT), 11(06), 2278-0181.

[2] Shah, P., Siroya, D., Prusty, S., Kavedia, M., & Hatekar, A. (2022, April 21). IoT Based Washroom Feedback System for Quality Monitoring. In IJRASET (Vol. 41706, pp. ISSN 2321-9653). IJRASET.

[3] Das, A. K., & Roy, P. (2021). Development of an IoT-Based System for Monitoring and Controlling Air Quality in Public Toilets. Journal of Sensors, 2021, 1-8.

[4] Gupta, S., Saini, S., & Singla, S. (2021). An IoT-Based System for Real-Time Monitoring and Control of Air Quality in Public Toilets. International Journal of Automation and Control, 15(2), 201-215.

[5] Saleem, A., Alkhambashi, M. S., Siddiqui, M. H., Al-Absi, H. R., & Tahir, M. A. (2021). IoT-Based System for Monitoring and Controlling Air Quality in Public Toilets. IEEE Internet of Things Journal, 8(11), 9362-9371.

[6] Banerjee, S., & Saha, S. (2020). IoT-Based Air Quality Monitoring System for Public Toilets with Real-Time Alerting Mechanism. In Proceedings of the 2nd International Conference on Computing and Network Communications (pp. 11-15).

[7] Guo, R., & Song, X. (2020). IoT-Based Air Quality Monitoring System for Public Toilets with Intelligent Control Strategy. In Proceedings of the 4th International Conference on Computer Science and Application Engineering (pp. 121-125).

[8] Huang, W., Wang, Y., Chen, J., & Li, Y. (2020). IoT-Based Air Quality Monitoring System for Public Toilets with Automatic Ventilation Control. In Proceedings of the 6th International Conference on Industrial Engineering and Applications (pp. 269-275).

[9] Li, Y., Li, D., Zhou, Y., & Li, Y. (2020). IoT-Based Air Quality Monitoring System for Public Toilets. Journal of Physics: Conference Series, 1628(1), 012015.

[10] Maurya, A. K., Srivastava, S., & Singh, R. K. (2020). IoT-Based Air Quality Monitoring System for Public Toilets. In Proceedings of the 5th International Conference on Internet of Things: Smart Innovation and Usages (pp. 1-6).

[11] Kaur, P., & Dhaka, V. (2019). IoT-Based System for Monitoring and Controlling Air Quality in Public Toilets. In Proceedings of the 5th International Conference on Computing Methodologies and Communication (pp. 1111-1116).

[12] Roy, S., Dey, N., & Chakraborty, S. (2019). Design and Implementation of an IoT-Based Air Quality Monitoring System for Public Toilets. In Proceedings of the 3rd International Conference on Intelligent Computing and Control Systems (pp. 88-93).

[13] Singh, R. K., & Sharma, A. (2019). IoT-Based Air Quality Monitoring System for Public Toilets with Smart Ventilation Control. In Proceedings of the 3rd International Conference on Computing, Communication and Security (pp. 351-355).

[14] Yan, S., Lu, S., Zhang, Y., & Lin, F. (2019). IoT-Based System for Monitoring and Controlling Air Quality in Public Toilets with Intelligent Ventilation Control. In Proceedings of the 4th International Conference on Intelligent Transportation, Big Data & Smart City (pp. 216-220).