Design and Development of an Intelligent IoT- Based Hazardous Gas Surveillance and Early Warning System Architecture for Occupational Safety in Confined Sewage Infrastructure

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Abstract— **It remains difficult to protect workers in sewage pipes because dangerous gases including methane, ammonia and carbon monoxide together with other lethal substances accumulate persistently. The gases become fatal hazards which create dangerous health conditions unless technicians identify them right away. An intelligent Internet of Things-based hazardous gas surveillance and early warning system will be designed and developed for providing real-time hazardous gas level monitoring and control through the project implementation. A system employs Internet of Things-based sensors for constant gas concentration detection along with cloud connection services for data storage and alerting mechanisms together with integrated sensor data analysis for threshold evaluation. A smartphone application enables the device to rapidly send alerts about unsafe gas conditions surpassing specified safety benchmarks to distant users. The elimination of manual inspections while enabling continuous environmental monitoring becomes possible through this technology because it reduces human mistakes. Its scalability allows the system to support multiple urban infrastructure needs because it combines with larger smart city sanitation frameworks through integrated implementations. This architectural design makes the system affordable and easy to sustain for continuous surveillance. Experimental tests conducted in real sewage environments have demonstrated the system's reliability and its reactivity as well as its practicality. Real-time hazard detection alongside early warning functions from this system generates improved working environments for sanitation workers thus increasing overall occupational safety.**

Keywords— Hazardous Gas Detection, Internet of Things, Real-Time Monitoring, Occupational Safety, Confined Space Surveillance

I.INTRODUCTION

Public health depends on sanitation workers because they work in developing sewage systems which present critical dangers to their safety. These environments present substantial occupational safety risks because harmful gases such as carbon monoxide, ammonia, hydrogen sulfide, methane accumulate throughout the area [1]. Small exposures to these scentless gases result in fatal health effects since they cannot be easily detected. The combination of hand inspections and portable gas detectors fails to achieve continuous hazard detection and immediate response for dangerous conditions [2]. Current technology demands a dependable intelligent system which will help stop safety threats as it conducts environmental monitoring in real time [3].

The recent development of the Internet of Things creates the essential technological basis to build a system able to monitor hazardous gasses in real-time and trigger prompt alerts [4]. Researchers will establish an Internet of Things-based intelligent hazardous gas monitoring system that specifically serves limited sewage infrastructure through specific architecture development. The system removes the requirement for manual inspections because it enables persistent hazardous gas evaluation and provides immediate responses during dangerous conditions [5]. Its software-based architecture makes it a suitable choice for larger smart city sanitation frameworks due to its low cost and flexible structure and scalability Tests done on sewage

samples inside laboratories demonstrate both system consistency and maximum operational efficiency [6].

The safety conditions in hazardous confined spaces improve substantially through the intelligent hazardous gas monitoring and early warning system thus making workplace safety solidarity for sanitation workers more effective [7]. Smart technology integration within urban infrastructure increases possibilities to enhance worker safety in restricted sewage infrastructure. Traditional approaches fail at monitoring gas concentration alterations as well as warning delivery in a timely manner [8-9]. The proposed system serves the purpose of a hazardous gas surveillance system through real-time detection combined with autonomous data analysis accompanied by mobile alert functions. The system monitors dangerous gases by applying calibrated sensors that detect toxic substances such as carbon monoxide, ammonia and methane [10]. The system delivers the information to both an edge processor and cloud platform. This configuration enables both local as well as remote measurements of gas concentration levels [11]. Mobile applications through cloud-connected notification enable both supervisors and sanitation workers to receive immediate alerts for prompt action [12].

II. STRUTURAL CONFIGURATION OF THE PROPOSED SYSTEM

An Internet of Things-based gas detection device functions as part of the system design to track dangerous chemical concentrations found in sewage environments. Different gasses are released through the environmental source which consists of the sewage system. Multiple sensors including MQ-135 for dangerous gases and ammonia detection as well as MQ-4 for detecting methane and MQ-7 for carbon monoxide measurement serve this purpose. Real-time detection of dangerous sewer atmosphere gases depends on sensors that maintain optimal positions for precise gas level measurement. Dangerous gases methane, carbon monoxide and ammonia occur at the sewage system interface due to decomposition of organic molecules as well as chemical reactions. The detection system starts operating at this first stage. The MQ-series sensors detect these gases through their respective devices: methane uses MQ-4 and carbon monoxide uses MQ-7 and ammonia uses MQ-135. Proportional to gas concentration in parts per million the sensors create analog voltage outputs. The determination of sensors depends on cost, availability along with the gas types specific to sewage conditions that they detect.

The analog input ports of the ESP32 microcontroller function as receivers of sensor output from the gas sensors. The ESP32 controls analog signal reading based on its integrated ADC functionality. The ESP32 collects sensor information through its running program. As predetermined safety thresholds exceed

normal occupational exposure norms the microcontroller generates both local and remote alerts. The ESP32 operates a exhaust circuit that creates an alarm for local alerting purposes. Sewage professionals operating at the site need this instant feedback to enable quick ventilation or evacuation of the area. ESP32 uses its embedded Wi-Fi feature to transmit data to both Blynk IoT cloud platform and local exhaust circuit simultaneously. A warning notification containing description and concentration data about the gas arrives through the Blynk mobile application which has already received system pairing and application configuration. A warning displays at specific times on phones belonging to supervisors and employees while presenting current monitoring conditions and preserving past incident records for inspection purposes.
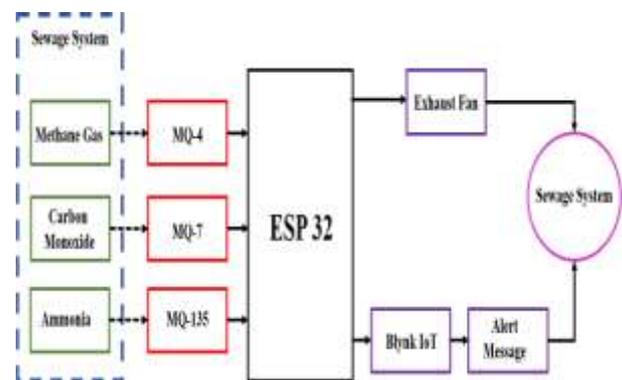

Fig. 1. Block Diagram of the Proposed System.

Companies can execute firmware updates and system calibration through the Blynk IoT platform and perform remote monitoring functions with this platform. The design features of this system allow it to expand through adding new sensors and to link with other IoT networks depending on specific site needs. The block diagram of the proposed system in shown in the Figure 1. The device functions with either a battery pack or a small DC supply board to perform operations at remote locations that do not receive electric service. Device efficiency combines quick response times with real-time analysis and precise warning systems thus making it suitable for crucial sewage monitoring applications.

III. SEQUENTIAL OPERATION OF THE PROPOSED SYSTEM

The system detects three different gases at the same time. The three different sensors each detect three separate gases and the reading of the sensors are given as input to the ESP module. A threshold value for each of the gas is programmed in the ESP module. As there will always be certain amount of toxic gas in sewage system. When the amount gas crosses the threshold, it becomes harmful.

The process of the entire system is shown in the Figure 2. Even when a single sensor crosses the threshold

limit an exhaust fan will be activated that indicates the presence of high-level harmful gas in sewer at the location. A data from the ESP module is send to Blynk for identification of which gas that has higher concentration.
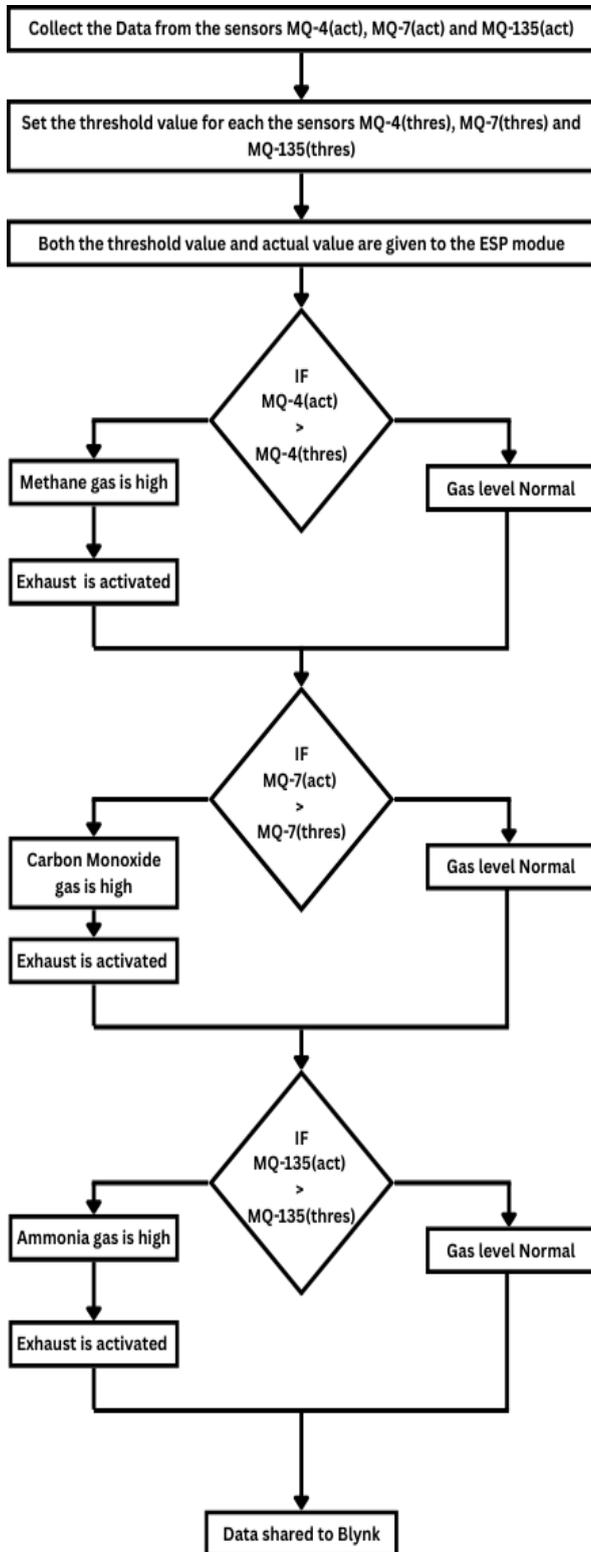

Fig. 2. Process and Data flow of the Entire System.

The actual current measured value of the gases is indicated as

- MQ-4(act)
- MQ-7(act)
- MQ-135(act)

The MQ-4 measures the amount of methane gas concentration in the sewer system. The MQ-7 measures the amount of carbon monoxide gas concentration in the sewer system. The MQ-135 measures the amount of ammonia concentration in the sewer system.

The threshold value that has been set on ESP for the gases are,

- MQ-4(thres)
- MQ-7(thres)
- MQ-135(thres)

The threshold value indicates that lowest amount concentration a gas required to be harmful.

IV. TECHNICAL BLUEPRINT OF THE PROPOSED SYSTEM

The system architecture of the proposed solar-powered air quality monitoring and alert mechanism is a thoughtfully designed integration of hardware and software components that collectively serve the purpose of detecting, reporting, and responding to hazardous indoor gas concentrations in real time while operating independently of the electrical grid. At the core of this architecture lies the ESP32 microcontroller, a highly capable and energy-efficient device chosen for its dual-core processor, integrated Wi-Fi and Bluetooth modules, and extensive GPIO support. Real-time, embedded monitoring systems are a perfect fit for these traits. The MQ-4 and MQ-135 gases sensors most away together in the announcement of different hazardous gases while the ESP32, H2 and MQ135.

In the meanwhile, MQ-4 senor is sensitive to the combustible gases such as methane, propane, hydrogen, etc., while MQ-135 sensor is with sensitivity to hazardous gases under air exposure, such ammonia, benzene, carbon monoxide, smoke. These sensors provide analog voltage signals which are representative of the concentration of the gas under test in the ambient surroundings. The ESP32 constantly reads these signals with its internal analog-to-digital converters (ADCs), analyses the data, and compares it with predefined threshold levels for unsafe gas level detection. When the gas concentrations exceed permissible limits, the ESP32 triggers an instantaneous alert response by turning on a 12V exhaust fan to delude the locked area. This addition of live counteraction features, ultimately makes the system an active preventive rather than a passive monitoring tool that's able to reduce risk and enhance air circulation by alerting those in close proximity of

hazardous conditions. For fully autonomous operation and removing dependence on grid electricity, the system runs on renewable solar power installation. A 12V solar panel serves as the main source of energy, transforming the sunlight into electricity at daylight.
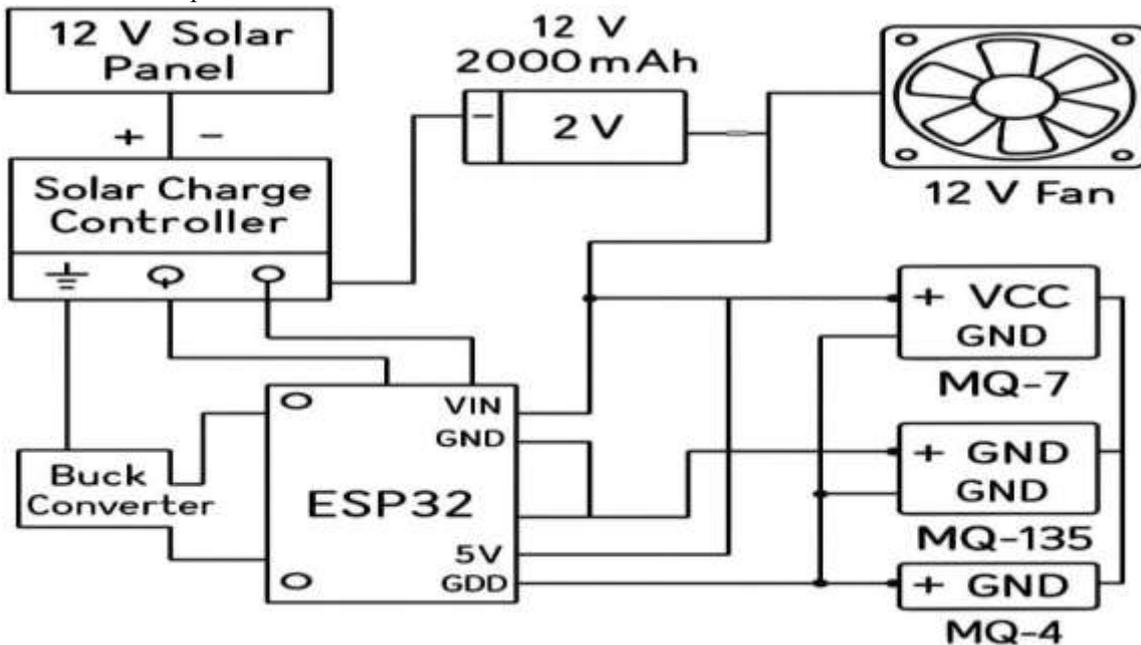

Fig. 3. Architecture diagram of the proposed system.

The energy then passes through a solar charge controller which maintains the voltage and current to provide an optimal charging voltage to 2000mAh lithium-ion battery. Another duty of the charge controller is to prevent the battery from over-charging and deep-discharging, which can reduce battery life expectancy and create hazardous operational conditions. The energy is supplied from the battery, to the exhaust fan, directly, while the voltage down is provided by a buck converter output which is compatible with the ESP32, gas sensors and the exhaust. This high-low voltage compatibility makes it possible both high-voltage and low-voltage components to coexist in a circuit allowing the combination of new power supply components no safety or efficiency compromises.

The control of the exhaust fan is done through a relay or transistor circuit, through which the ESP32 can effectively and safely turn on and off high current devices with a microcontroller using low voltage.

V. SIMULATION RESULT S OF THE PROPOSED SYSTEM

As for the software, it is the firmware running on the ESP32 reads analog data from the sensors, is closed. The code also consists of delay functions, averaging functions for smoothing noisy sensor data and debouncing logic for ignoring very short, inconsequential spikes in gas concentration. A key determinant of the system architecture is the requirement for robust operation in off-grid and low-resource settings. As the whole unit consumes comparatively little power, and power regulation is included in the unit circuitry, it is able to operate to operate routinely for long periods of time free of manipulation by humans. This makes it ideal for use in rural health clinics, disaster relief shelters, remote classrooms and low-income homes, where indoor air quality is generally overlooked and where it is crucial to well-being. In addition, the modular architecture of the system enables other sensors or wireless modules to be included in future versions. For example, by combining a temperature/humidity sensor, the control of ventilation with adjusted air flow with climate could be considered, and by adding a GSM.MIN_EX3 or Wi-Fi module.

The architecture is thus future-proof and suitable for Internet of Things based systems. Moreover, every part of the system was chosen according to cost, availability and energy efficiency to improve both affordability and replicability of the solution. The MQ-4 and MQ-135 sensors are easy to come by and are highly sensitive to various toxic gases, whereas the Its dual-core processing helps for responsive and power consumption systems. Buck converter ensures high efficiency, low power losses during the voltage conversion, and solar charge controller for high safety and long battery life, protecting battery from overcharge or over discharge. Good PCB layout and heat sinking is required for performance, particularly around the buck converter and relay circuitry that handle currents. Great attention must be paid to electrical isolation and noise reduction from a deployment standpoint, the system's simplicity allows even users with minimal technical knowledge to install and maintain it, which is a significant advantage in rural or under-resourced areas. Indicators such as LEDs can be added to show system status—such as charging, fan operation, or sensor activity—making the unit more user-friendly. Overall, the system architecture balances technical sophistication with practical usability, energy independence, and low production costs. It not only provides a robust solution to indoor air pollution. It has

not just been an effective fix for indoor air pollution. Aids global sustainability goals as it is completely dependent on renewable solar power, and provides the means for preventative health measures in exposed communities.
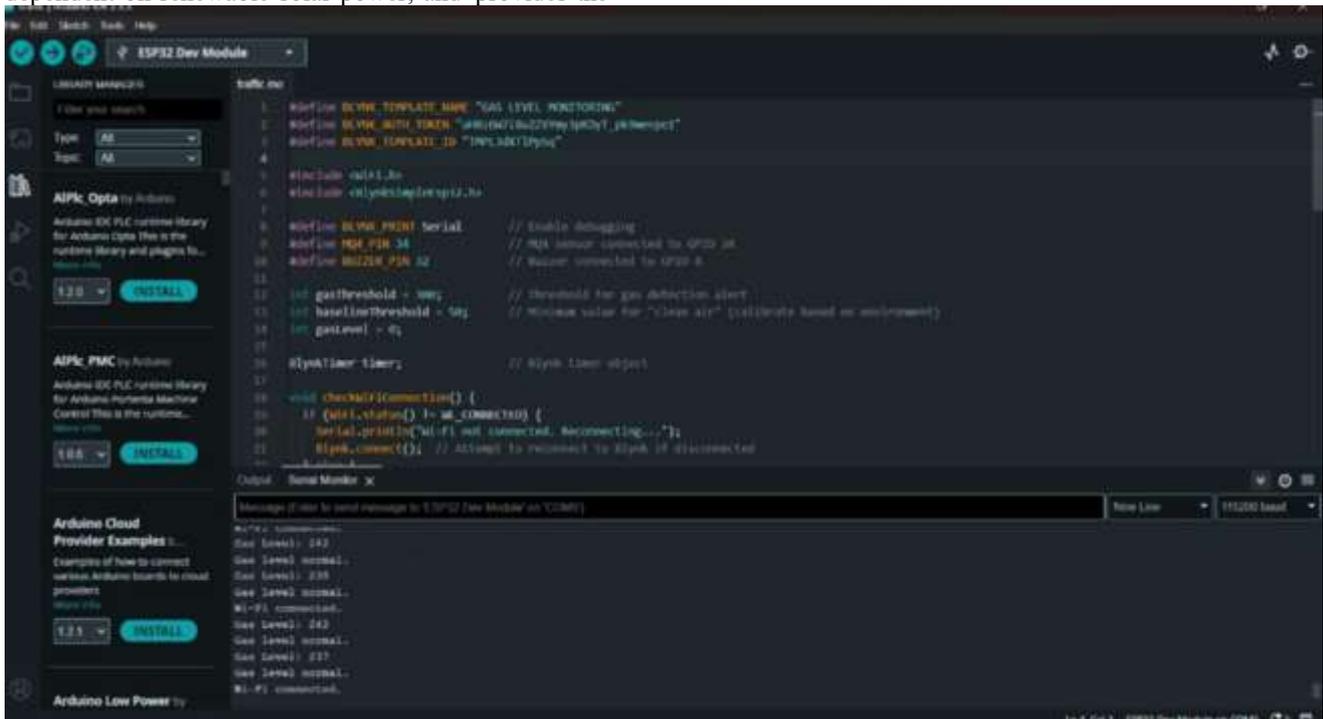

Fig. 4. Simulation result of the proposed system in Arduino IDE software

Future improvements could incorporate logging data through SD card modules, linking up with mobile apps for Realtime alerts, and even utilising machine learning algorithms to forecast pollution and automate the scheduling of ventilation. While some of these future potentials are currently unrealistic, the present architecture has shown that building a reliable, autonomous air quality control system that leverages microcontrollers, gas sensors, and solar technology to deliver tangible social impact.

TABLE I. POWER CONSUMPTION CALCULATION OF THE PROPOSED SYSTEM.

Component	Voltage (V)	Current (A)	Power (W)
ESP 32	5	0.25	1.25
MQ-135	5	0.15	0.75
MQ-7	5	0.1	0.5
MQ-4	5	0.15	0.75
12V Fan	12	0.4	4.8
Solar panel	6	0.18	1.1

VI. RESEARCH EXTENTIONS

The proposed system creates a firm ground for subsequent developments in intelligent gas monitoring of hazardous environments. Future work endeavours can combine AI and machine learning techniques and allow the system to predict gas build-up trends before critical levels are reached. The accuracy can be improved if dynamic threshold adjustment is used in combination with environmental condition and historical data. Also, Geographical information system (GIS) and GPS integration can be used to monitor real time movement of field personnel thereby; there will be location-based alerts and coordination of emergency response. The system can then also be expanded to handle multi-node at large sewer networks while allowing centralized monitoring through the cloud dashboards. Other enhancements such as voice alerts and battery health monitoring increase's reliability further and thus may render the system suitable for deployment in large-scale smart city sanitation infrastructure.

VII. CONCLUSION

The design and deployment of an intelligent, software-driven IoT architecture for real-time toxic gas detection and remote alerting in confined sewage environments is done. The system continuously monitors hazardous gas levels, processes sensor data, and triggers instant alerts through cloud-based platforms to ensure worker safety. Its software-centric approach provides scalability, ease of deployment, and adaptability to various urban sanitation systems. By minimizing the need for manual inspection, the system enhances operational efficiency and reduces health risks for sanitation workers. Future improvements may include AI-driven predictive alerts, dynamic threshold calibration, and integration with GIS-based worker tracking. Overall, the proposed solution offers a reliable, cost-effective, and impactful approach to improving

occupational safety in high-risk underground infrastructures.

REFERENCE

[1]. J. Rajasubha, R. Ramya, A. H. Juliet, J. V, S. R. Devi and K. S, "An Industrial IoT Driven Approach for Sewage Gas Identification and Reporting System using Intelligent Sensors with Logical Controller," 2024 1st International Conference on Innovative Sustainable Technologies for Energy, Mechatronics, and Smart Systems (ISTEMS), Dehradun, India, 2024, pp. 1-6, doi: 10.1109/ISTEMS60181.2024.10560086.

[2]. S. G, H. J, V. K and S. S, "Advanced Toxic Gas Monitoring and Health Protection System for Sewage Tanks," 2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), Chennai, India, 2024, pp. 1-6, doi: 10.1109/ICPECTS62210.2024.10780258.

[3]. M. A. Archana, K. Anisha, C. Parthasarathy, R. Malathi, K. Umapathy and S. Omkumar, "Intelligent Sewage Monitoring System using IoT," 2025 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2025, pp. 570-574, doi: 10.1109/ICEARS64219.2025.10940595.

[4]. A. Kumar, R. Gupta, A. Kumar, A. Aditya and A. Rai, "Simulation and Development of Sewage Cleaning & Monitoring Robot using IoT," 2023 International Conference on Computational Intelligence and Sustainable Engineering Solutions (CISES), Greater Noida, India, 2023, pp. 536-541, doi: 10.1109/CISES58720.2023.10183525.

[5]. E. Terence, L. Manoharan, V. Vasanthkumar, V. S. Reddy, A. Arikesh and U. Charan, "Innovative Sewage Treatment of Villa Residences: A Circular Economy Perspective," 2024 5th International Conference on Data Intelligence and Cognitive Informatics (ICDICI), Tirunelveli, India, 2024, pp. 572-577, doi: 10.1109/ICDICI62993.2024.10810870.

[6]. L. Yuanyuan, W. Jiekang, L. Xinmiao, T. Wenhao, L. Junlei and L. Xun, "An Optimized Management Model for User Demand Response," 2024 6th International Conference on Power and Energy Technology (ICPET), Beijing, China, 2024, pp. 902-907, doi: 10.1109/ICPET62369.2024.10940846.

[7]. F. S. Barkindo, A. Salihu, B. Kulmedov and O. N. Mogbo, "Sustainable Performance of Wastewater Treatment Plant : A case study of Wupa sewage treatment plant," 2023 2nd International Conference on Multidisciplinary Engineering and Applied Science (ICMEAS), Abuja, Nigeria, 2023, pp. 1-6, doi: 10.1109/ICMEAS58693.2023.10379236.

[8]. R. Dronavalli, K. Seelam, P. Maganti, J. Gowineni and S. D. Challamalla, "IoT-based Automatic Manhole Observant for Sewage Worker's Safety," 2022 International Conference on Automation, Computing and Renewable Systems (ICACRS), Pudukkottai, India, 2022, pp. 310-316, doi: 10.1109/ICACRS55517.2022.10029252.

[9]. R. S. Ganesh, M. Mahaboob, J. AN, L. C, P. S and K. K. Kumar, "Smart System for Hazardous Gases Detection and Alert System using Internet of Things," 2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2021, pp. 511-515, doi: 10.1109/ICECA52323.2021.9676149.

[10]. L. WENG et al., "Study on Removal of Wastewater Treatment Plant Odorous Gases by Biofilter and Pulse Plasma Discharge Technology," 2024 IEEE 7th International Electrical and Energy Conference (CIEEC), Harbin, China, 2024, pp. 283-287, doi: 10.1109/CIEEC60922.2024.10583304.

[11]. B. Rajalakshmi, S. Saranya, S. Surya and A. Saliha Bathool., "Electronic Nose System for protecting workers in sewage system," 2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS), Coimbatore, India, 2022, pp. 1689-1692, doi: 10.1109/ICAIS53314.2022.9743047.

[12]. A. Kumar, S. K. Gupta and M. Rai, "Real-Time Commuincation based IoT enabled Smart Sewage Workers Safety Monitoring System," 2021 5th International Conference on Information Systems and Computer Networks (ISCON), Mathura, India, 2021, pp. 1-4, doi: 10.1109/ISCON52037.2021.9702405.