JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 07, ISSUE 08, 2020

An IoT-Based Smart Device for Sewage Gas Monitoring and Alert System

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DOI: 10.48047/jcr.07.08.612

Abstract:

In order to ensure public health and environmental sustainability, sewage systems are essential. However, the buildup of toxic gases in these systems poses significant threats to human health and environmental problems. The design and implementation of a smart Internet of Things device for sewage gas monitoring and alert system are presented in this research study. To identify and alert about the presence of dangerous gases in real-time, the suggested system combines gas sensors, data processing algorithms, connection characteristics, and an alert mechanism. The gadget includes programmable alert settings, remote monitoring capabilities, and the possibility of interaction with current wastewater management systems. The device's usability, data processing methods, communication protocols, and hardware and software components are all covered in the study. The outcomes show how well the suggested system performs in terms of timely notifications and permitting proactive measures to reduce the dangers related to exposure to sewage gas.

Keywords: IoT, sewage gas monitoring, alert system, gas sensors, data processing, connectivity, remote monitoring, wastewater management.

I. Introduction:

In order to effectively remove and treat wastewater, sewage systems are essential infrastructures. They play a critical role in preserving environmental sustainability and public health. However, these systems can also include dangerous gases that pose serious threats to the environment and human health. In the sewerage system, organic matter breaks down, producing sewage gases such carbon dioxide (CO2), methane (CH4), and hydrogen sulphide (H2S). The buildup of these gases can cause a variety of health concerns, including respiratory troubles, headaches, and in severe cases, mortality, if they are not monitored. These gases' release into the environment also adds to air pollution and greenhouse gas emissions [1]. Manual inspections or periodic samples have been the mainstays of conventional sewage gas monitoring methods, but these methods are time-consuming, expensive, and frequently inefficient at providing real-time information about gas levels and associated dangers. The development of smart monitoring systems that can continually and correctly identify the presence of hazardous gases in sewage systems is now possible because to the development of the Internet of Things (IoT) technology [2]. These systems would send out prompt notifications to help reduce risks and enable proactive management. The design and implementation of an IoT-based smart device for sewage gas monitoring and alert system are presented in this research study. In order to provide real-time monitoring of sewage gas levels and timely warnings when gas concentrations surpass predefined criteria, the suggested system makes use of the capabilities of IoT, gas sensors, data processing algorithms, networking features, and an alert mechanism. The tool intends to boost environmental sustainability, safeguard the health of both workers and the general public, and increase sewage management safety and efficiency.

The goals of this research are twofold: first, to create a sewage gas monitoring system that is trustworthy and accurate and can measure hazardous gas concentrations in real-time; and second, to put in place a reliable alert system that quickly notifies stakeholders when gas concentrations reach potentially dangerous levels. By attaining these goals, the suggested approach will make it easier to take preventative steps to reduce the hazards of exposure to sewage gas, which will enhance safety and safeguard the environment [3]. There are various advantages to implementing the suggested IoT-based smart device for sewage gas monitoring and alert system successfully. In the beginning, it permits real-time monitoring, giving prompt knowledge of any hazardous gas buildup in sewage systems. The possible health risks to workers and the general public are reduced because to this rapid detection, which enables swift response and mitigation actions. The gadget also enables trend analysis and the detection of trends or trouble regions within the sewage system by providing historical data on gas levels [4]. Decisions for system optimisation and preventive maintenance can be guided by this information. Thirdly, by eliminating the need for manual inspections and enabling real-time data access from anywhere, the remote monitoring capabilities increase operational efficiency. Finally, the ability for interaction with current wastewater management systems enables thorough data integration and analysis, leading to a comprehensive strategy for sewage system management. In order to improve the security, effectiveness, and sustainability of sewage management, this research study concludes by presenting an Internet of Things (IoT)-based smart device for sewage gas monitoring and alarm system. To identify and alert about the presence of dangerous gases in real time, the suggested system combines gas sensors, data processing algorithms, connectivity characteristics, and an alert mechanism. The device offers proactive efforts to reduce the hazards associated with sewage gas exposure by continually monitoring gas levels and sending out prompt alerts. The findings of this study show that the suggested method is reliable and effective in preserving public health, preserving the environment, and enhancing the overall management of sewage systems.

II. Literature Review:

The goal of the literature review is to offer a thorough overview of the ongoing studies and technological advancements concerning smart IoT devices for sewage gas monitoring and alert systems. It examines the improvements in data processing algorithms, networking techniques, and alerting systems that have been applied in related applications. This review highlights the gaps, difficulties, and possible areas for advancement in the design and use of smart IoT devices for sewage gas monitoring by assessing the present status of the field [5]. As they provide the detection and measurement of hazardous gases, gas sensors are essential parts of sewage gas monitoring systems. Similar applications have used electrochemical sensors, metal oxide semiconductor sensors, and infrared sensors, among other gas sensing methods. Electrochemical sensors are well suited for detecting gases like hydrogen sulphide (H2S) because they have high sensitivity, selectivity, and response times. Methane (CH4) and volatile organic compounds (VOCs) can both be detected using metal oxide semiconductor sensors in an affordable manner. For particular gases like carbon dioxide (CO2), infrared sensors provide precise and trustworthy measurements [6]. These highly-researched gas detecting technologies can be included into intelligent Internet of Things devices for sewage gas monitoring. Effective data processing techniques are needed to extract relevant information from the raw data gathered by gas sensors. These methods include data filtering, estimate of gas concentrations, and calibration. By adjusting for sensor drift and ambient factors, calibration is important to assure the precision and dependability of gas sensors. Techniques for data filtering, like noise reduction and outlier detection, enhance the quality of the data that has been gathered. Gas concentration estimate techniques transform sensor signals into useful gas concentration levels using mathematical models [7]. The accuracy of gas concentration prediction has also been improved by using machine learning algorithms like neural networks and support vector machines. The goal of this research is to create robust and flexible algorithms that will improve the functionality of sewage gas monitoring systems.

Remote monitoring and control are made possible by the incorporation of IoT technology in sewage gas monitoring systems. Wi-Fi, Ethernet, and cellular networks are just a few of the communication options that have been used. Wi-Fi is appropriate for local monitoring applications because it offers dependable connectivity within a constrained area [8]. Ethernet is perfect for industrial applications because it provides dependable and fast communications. Wider coverage offered by cellular networks makes remote monitoring in expansive sewage systems possible. The connectivity option to choose is determined by the particular specifications of the sewage gas monitoring system, including the geographic distribution of monitoring points and the accessibility of network infrastructure. In order to reduce potential dangers related to gas exposure, timely alarms are essential in sewage gas monitoring systems [9]. Visual cues, aural alarms, and email or mobile device notifications are some examples of alert methods. On-site staff receives prompt local notifications from visual indications like LEDs. A loud siren draws attention and warns people to leave the area. Notifications sent via email or mobile devices allow for remote alerting and speedy responses from the right parties. The goal of this research is to create effective alarm systems that are dependable, adaptable, and simple to include into the overall monitoring system [10]. The development of smart IoT devices for sewage gas monitoring has advanced significantly, but there are still a number of obstacles to overcome and room for improvement. The selection and calibration of gas sensors to enable accurate and reliable measurements in challenging and unpredictable environmental conditions within sewage systems is one of the biggest challenges. Additionally, there are technical and interoperability issues that need to be resolved when integrating the monitoring system with current wastewater management systems. Additionally, IoT device power management is essential to maintain continuous functioning and reduce maintenance needs. To improve the functionality and intelligence of the monitoring system, future research should concentrate on creating energy-efficient solutions, utilising alternate power sources, and investigating advanced data processing techniques like edge computing and predictive analytics. Furthermore, the use of sophisticated machine learning and artificial intelligence algorithms can provide anomaly identification and predictive modelling, allowing for proactive system maintenance. The addition of further environmental parameters to the monitoring system is a further field for future study. In addition to gas concentrations, variables like temperature, humidity, and pressure can offer helpful background knowledge that improves comprehension of the behaviour of the sewage system and prospective gas emissions [11]. In order to monitor sewage gas, smart IoT devices' scalability and adaptability must be taken into account. For widespread adoption, it is essential to be able to deploy and maintain a network of devices across various sewage system scales and configurations. Research should concentrate on creating adaptable, modular systems that can be quickly scaled up or down to meet the demands of various contexts. Additionally, IoT-based monitoring systems must take data security and privacy into account. To safeguard sensitive information and stop unauthorised access or modification, secure data transport, storage, and access control measures are crucial. The rapid deployment of smart IoT devices for sewage gas monitoring is largely due to their cost-effectiveness [12]. Innovative and affordable solutions, such as the use of inexpensive sensors, reduction of power consumption, and exploitation of open-source hardware and software platforms, should be the subject of research.

In the topic of smart IoT devices for sewage gas monitoring and alarm systems, the literature review emphasises developments in gas sensor technologies, data processing algorithms, connectivity options, and alert mechanisms. The significance of precise and trustworthy gas sensors, effective data processing algorithms, reliable connectivity, and prompt alert mechanisms is emphasised [13]. To improve the functionality and usability of these monitoring systems, a number of issues, including sensor calibration, integration with current systems, power management, and data security, must be resolved. Utilising cutting-edge technologies like machine learning, predictive analytics, and edge computing, future research should concentrate on producing scalable, flexible, and cost-effective solutions [14][15]. Smart IoT devices for sewage gas monitoring can significantly enhance public health, environmental sustainability, and the overall management of sewage systems by tackling these issues and looking into new potential.

III. Methodology

Finding and choosing the best gas sensors that can accurately and sensitively detect the desired gases, such as H2S, CH4, and CO2, is known as sensor selection. The selected sensors must be dependable, economical, and suited to the challenging environmental conditions found in sewage systems.

ISSN- 2394-5125 VOL 07, ISSUE 08, 2020

Creating a hardware platform that incorporates the chosen gas sensors, a microcontroller or single-board computer, a power source, and the required interfaces for connectivity is known as hardware design. Given the deployment needs of sewage systems, the hardware should be made to be lightweight, robust, and power-efficient.

Data acquisition is the process of connecting the microcontroller or single-board computer to the gas sensors in order to get data on gas levels. Analogue or digital signals may be used to represent the data that is acquired; these signals are then processed and transformed into useful data.

Development of software algorithms for the processing and analysis of the data gathered from the gas sensors. Calibration of the sensors, data filtering, and interpretation of gas levels based on established thresholds or gas concentration models may all be necessary in this situation. The algorithms should deliver in-the-moment measurements of the gas concentration that are precise and trustworthy.

Establishing a Wi-Fi, Ethernet, or cellular network connection to the internet in order to provide remote monitoring and control. With this connectivity, the device can transfer data to a local server or a cloud-based platform for additional processing and archiving. Additionally, it makes the monitoring system accessible to stakeholders from any location, supporting remote management and decision-making.

Implementing an alert system that instantly informs users or accountable staff when petrol levels exceed predetermined thresholds. Different notification techniques, including SMS, email, push notifications, and aural alarms, may be used by the alert system. To deliver rapid local notifications, the device can additionally include visual indications like LEDs.

User Interface: Creating an intuitive user interface that enables users to customise device settings, keep an eye on gas levels in real-time, see historical data, and adjust alert settings. This interface can be a mobile application, a web-based dashboard, or a hybrid of the two, assuring usability and accessibility for various sewage management stakeholders.

Consideration should be given to the device's scalability and integration with current building management or wastewater management systems, as appropriate. The sewage infrastructure's various parts can communicate and work together seamlessly because to this integration. The device should also be made to be scaleable, enabling simple installation in sewage systems of various shapes and sizes.

Power management: Depending on the deployment circumstances, optimising power usage to increase device battery life or using alternative power sources like solar panels or power over Ethernet (PoE). The monitoring system will run continuously without many disruptions thanks to effective power management.

Planning for routine maintenance, calibration, and firmware updates can help to ensure the long-term accuracy and dependability of the device. In order to preserve measurement accuracy, routine maintenance comprises periodic inspections for any hardware or software problems as well as sensor calibration.

IV. Proposed System

A. IoT Device Package:

Gas Sensors: This component represents the gas sensors used in the device. Gas sensors are responsible for detecting and measuring the levels of hazardous gases in the sewage system.

Microcontroller: The microcontroller acts as the central processing unit of the device. It receives data from the gas sensors, performs data processing, and controls the overall operation of the device.

Connectivity: This component represents the connectivity options used by the device, such as Wi-Fi, Ethernet, or cellular network. It enables communication between the device and external systems, such as the cloud platform.

Data Processing: The data processing component processes and analyzes the data collected from the gas sensors. It may involve calibration, data filtering, and conversion of raw sensor readings into meaningful gas concentration measurements.

Alert System: The alert system component is responsible for generating timely notifications or alerts when gas levels exceed predefined thresholds. It can use various methods, such as visual indicators, audible alarms, or notifications sent to mobile devices or email.

B. User Interface Package:

Web Dashboard: The web dashboard component represents the user interface accessible through a web browser. It allows users to monitor gas levels, configure device settings, and view historical data. The web dashboard provides a convenient way to access and manage the monitoring system.

Mobile Application: The mobile application component represents a dedicated mobile application that allows users to interact with the device and access the monitoring system. It provides similar functionalities as the web dashboard but in a mobile-friendly format.

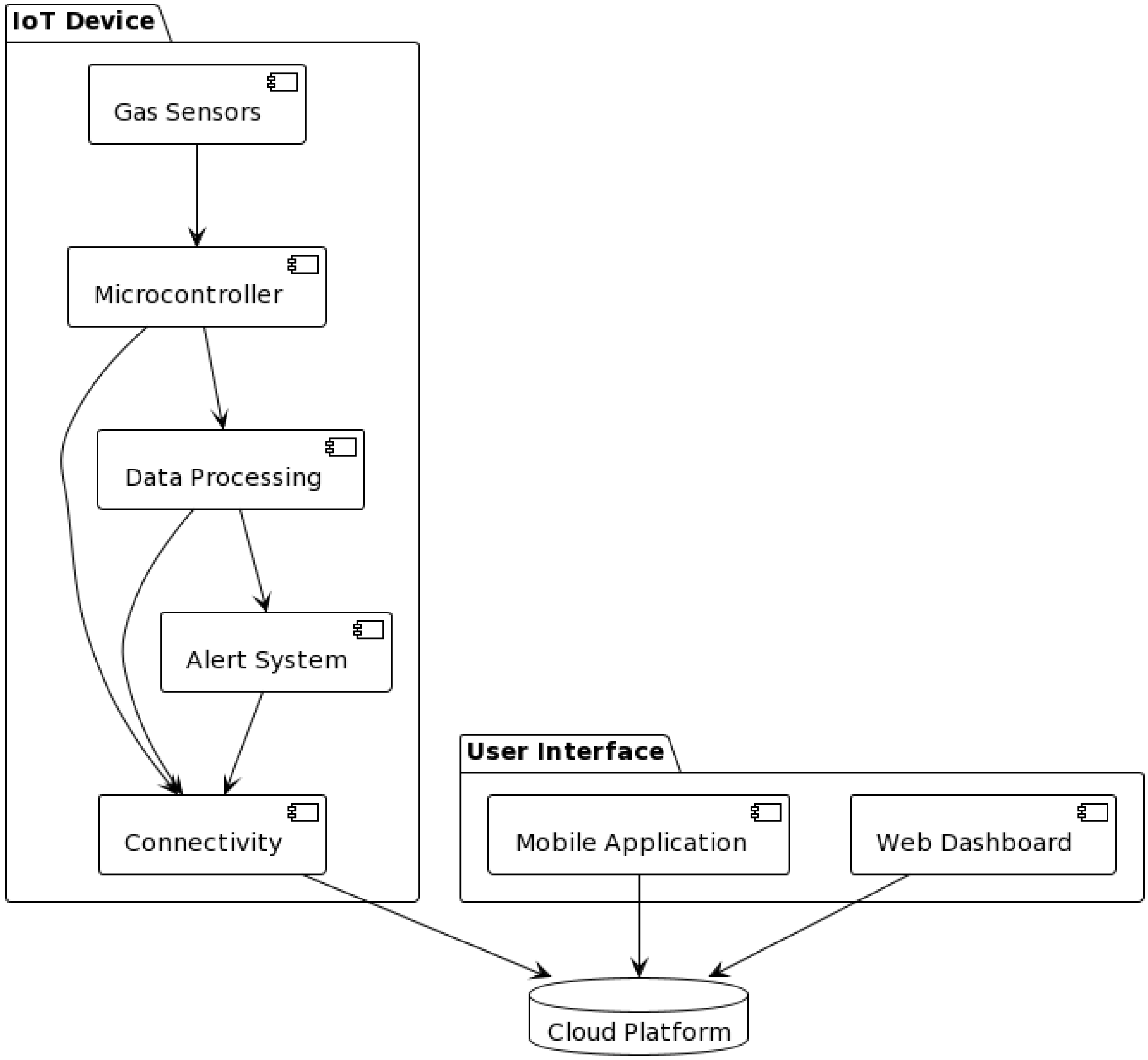

Figure 1. Proposed System

C. Cloud Platform:

The cloud platform component represents a centralized cloud-based platform where data from the device is stored, analyzed, and accessed. It serves as a central repository for data management and allows for remote monitoring and control of the device.

The relationships between the components are represented by the connecting lines:

- The gas sensors are connected to the microcontroller, indicating that the microcontroller receives data from the gas sensors.

- The microcontroller is connected to the connectivity component, representing the device's ability to establish a connection to the external systems, such as the cloud platform or user interfaces.
- The microcontroller is connected to the data processing component, indicating that the collected sensor data is processed and analyzed within the microcontroller.
- The data processing component is connected to the connectivity component, indicating that processed data can be transmitted to external systems, such as the cloud platform.
- The data processing component is connected to the alert system, representing the interaction between data analysis and the generation of alerts.
- The connectivity component is connected to the cloud platform, indicating that the device can communicate with the cloud-based platform for data storage and remote access.
- The web dashboard and mobile application components are connected to the cloud platform, indicating that they can retrieve data from the cloud platform and provide a user interface for accessing and managing the monitoring system.

V. Challenges

There can be a number of difficulties while implementing an IoT-based smart device for sewage gas monitoring and alert system. Here are some typical difficulties with such systems:

- Gas sensors used for sewage gas monitoring need to be precisely calibrated in order to achieve accurate and precise measurements. It can be difficult to calibrate sensors in the harsh and unpredictable sewage system environment. The sensors should also be immune to fouling and disruption from other elements frequently present in sewage, such as sediments or chemicals.
- Adaptation to Current Systems: It can be technically challenging to integrate the monitoring system with pre-existing wastewater management or building management systems. Connecting the IoT device to these systems may present compatibility problems, data exchange methods, and interoperability difficulties. For effective and thorough sewage management, it's essential to provide seamless integration and data synchronisation.
- IoT devices operating in sewage areas may have trouble getting enough power since there aren't many outlets nearby or because remote monitoring is required. To increase the battery life of the device and lessen the need for frequent maintenance visits for battery replacement or recharging, power consumption optimisation becomes crucial. Sustainable solutions can be found by investigating alternate power sources like solar energy or power over Ethernet (PoE).
- Data Security and Privacy: It is essential to guard the gathered data against unauthorised access, alteration, or breaches. Data transmission and storage should be encrypted to safeguard data privacy as IoT devices are prone to security flaws. To reduce potential threats and preserve the system's integrity, reliable access control measures and frequent security updates are required.

- Scalability and Adaptability: The smart device must be scalable and adaptable in order to be deployed across various sewage system layouts and sizes. The monitoring system must to be able to handle a variety of monitoring points and sewage system configurations. For a system to be widely adopted, it must be designed as a flexible, modular system that can be readily scaled up or down in response to unique needs.
- Environmental elements The durability and dependability of the IoT device may be hampered by the harsh and corrosive environment of sewage systems. The apparatus ought to be made to endure changes in humidity, temperature, and exposure to substances frequently found in sewage. For the gadget to function over an extended period of time, durability and environmental protection are essential.
- Cost-effectiveness: It should be affordable to create and implement an IoT-based monitoring system for sewage gas monitoring. Sensor and communication module costs, infrastructure costs, and maintenance costs should be compared to the project's budget and expected returns. The system can be made more affordable by looking into cost-effective methods, such as utilising inexpensive sensors or open-source hardware and software platforms.

VI. Conclusion

Developing and implementing an IoT-based smart device for sewage gas monitoring and alerting systems has the potential to dramatically enhance sewage system management and reduce the hazards related to hazardous gas emissions. These monitoring systems provide real-time monitoring, data analysis, and timely notifications to pertinent stakeholders by using developments in gas sensor technology, data processing algorithms, networking solutions, and alert mechanisms. To enable the successful deployment and operation of such systems, a number of issues must be resolved. These difficulties include environmental considerations, cost-effectiveness, data security and privacy, scalability and flexibility, integration with current systems, sensor calibration and reliability, and power management. Researchers and developers can improve the monitoring systems' accuracy, effectiveness, and dependability by concentrating on these issues. The focus of future research should be on the creation of reliable calibration methods for gas sensors, seamless integration with current wastewater management systems, power consumption optimisation for extended operation, and the adoption of effective security measures to safeguard data. Additionally, systems that can be easily installed in a variety of sewage system designs should be designed to be scalable and adaptable. Exploring low-cost options, such utilising open-source hardware and software platforms, can help these monitoring systems become more widely used. The IoT-based smart gadget for sewage gas monitoring and alarm system has a lot of promise to enhance environmental sustainability, public health, and sewage system management in general. These systems can help with safer and more effective sewage management, resulting in cleaner ecosystems and healthier communities, by addressing the issues and looking into new prospects.

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