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Environmental Air Pollution and Water Quality Systems in Educational Institutions

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Abstract

An intelligent environmental monitoring system receives real-time conditions through continuous interpretation of several environmental parameters to provide dependable results alongside ongoing updates. The data communication through IoT connectivity creates a smooth transmission to central platforms which enables remote observation along with preventive decision-making to boost health and environmental sustainability. The system operates over extended periods by using automated analytics that track environmental changes with data-driven evaluation methods. It provides an accessible platform that helps users track essential parameters effectively, supporting public security and healthcare initiatives. The system enables environmental management alongside public health due to its feature set, which includes early alerts, quick responses, and strategic decision-making abilities. It requires the integration of machine learning and improved data analytics to advance its prediction functions.

Keywords: Real-Time Monitoring, IoT Connectivity, Environmental Sustainability, Data Analytics, Pollution Detection.

1. Introduction

Air and water contamination are two of the most important environmental issues in the world, and their effects are especially critical in high-density, confined spaces such as schools. These contaminants have very serious impacts on the health and mental performance of students, teachers, and staff. For example, poor air quality is associated with higher rates of

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asthma and lower academic achievement, while contaminated water sources have been shown to cause gastrointestinal illness and long-term developmental problems. And yet most schools and colleges still use outdated manual sampling methods that slow detection and response. With the era of smart cities and digital infrastructure underway, there is an increasing drive to incorporate real-time monitoring in public and institutional environments. Schools present a special case due to their high usage, around-the-clock operation, and the importance of protecting young populations. An environmental monitoring system in real time has the ability not only to notify authorities of dangerous conditions but also to serve as an educational tool, informing students about environmental science and technology in a hands-on manner.

This work presents a low-cost, scalable, and comprehensive IoT-based monitoring platform for air and water quality across educational campuses. The system combines several gas sensors and a turbidity sensor to monitor environmental parameters in real-time. With the ESP32 microcontroller's integrated Wi-Fi, the system provides real-time data over a web-based dashboard that is accessible to administrators and facility managers. An alert is raised when pollutant levels exceed defined safety levels, allowing for timely intervention. The increase in environmental pollution is of a serious concern for public health and ecosystem balance, with air and water pollution leading to respiratory diseases and waterborne diseases. Conventional monitoring systems have a delayed response, constraining preventive measures. This project proposes a smart environmental monitoring system that continuously monitors air and water quality through automated sensors and IoT connectivity. [1] Real-time transmission of data alerts authorities when pollution levels surpass safe limits, such as monitoring smoking in prohibited areas. Web and mobile interfaces for remote monitoring through internet-enabled devices allow authorities and citizens to take timely action. The uniqueness of our solution is in combining air and water quality monitoring into one compact system along with remote access and real-time alerting. The integration of this solution into schools is our vision to enhance environmental conditions, diminish health hazards, and encourage sustainability awareness among young minds. The subsequent sections provide details of existing related work, system architecture, methodology, evaluation strategy, experimental results, and future directions for enhancement.

2. Hardware Components

The Environmental Air Pollution and Water Quality Checking System in Educational Institutions makes use of several hardware components for accurate and efficient monitoring. The ESP32 microcontroller is the core processor that receives sensor readings and sends them to an IoT platform. [5] Monitoring of air quality is done using MQ135, MQ6, MQ2, and MQ3 gas sensors that identify pollutants like carbon monoxide, methane, and other toxic gases, including smoke emissions. [7] For water quality measurement, a turbidity sensor detects water clarity in real-time to measure levels of contamination. A controlled power supply provides stable operation for electronic components. [2].

2.1 ESP32 Microcontroller

The ESP32 microcontroller serves as its processing unit, allowing real-time acquisition and processing of sensor data. Turbidity sensors measure water quality, while gas sensors detect air pollution, such as CO_2, smoke, CO, alcohol, hexane, LPG, etc. The system executes environmental evaluation algorithms to provide constant updates to the IoT-based surveillance platform. With Wi-Fi, the ESP32 enables quick transmission of data to web servers with real-time observation through web dashboards. The integration of cloud storage allows for prolonged data analysis and improves long-term environmental monitoring. The low energy consumption, fast processing speed, and wireless operation of the ESP32 make it perfect for power-efficient and dynamic environmental monitoring. [11]

2.2 Networking and Communication Components

This system needs real-time connectivity to ensure continuous monitoring activities and data transfer. The system uses various networking components that facilitate seamless data transfer between sensors, the ESP32 microcontroller and the IoT-based monitoring platform. The system relies on a stable internet connection, as it allows users to view water and air quality monitoring results remotely. [3]

ESP32 comes with an inbuilt Wi-Fi module which enables the real time data to be sent to a cloud-based server and environmental parameters are always updated. Since air and water quality data are displayed by the system on a web dashboard, users can see this information in real time. It is capable of detecting any abnormalities in real time and responding quickly when necessary. [14]

3. Software Components

The ESP32 microcontroller is programmed by the Arduino IDE, which allows for the collection of sensor data and transmission via the server. [8] A front-end application using PHP provides structured environmental data to the user. Historical data is stored in a flat-file organization for trend observation and long-term monitoring. HTML and CSS create the web dashboard for easy data visualization.

3.1 CSS (Cascading Style Sheets)

This interface depends on CSS for styling layout, colour palette, font style, and displaying data to guarantee user friendliness. CSS design formatting aligns real-time environmental information, making it easy to read and present well. [9]. Users have easy access to viewing environmental status from anywhere. This organized and enhanced interface increases usability, rendering pollution data more accessible and comprehensible.

3.2 HTML (Hypertext Markup Language)

It is intended to provide a well-organized and easy-to-use experience. It facilitates the presentation of real-time environmental information in a well-structured format, so that users can easily track air and water quality. [3] The system is segmented into various sections to ensure clear categorization of pollution levels, alerts, and past trends.

3.3 PHP (Hypertext Preprocessor)

This system employs PHP as its server-side scripting language for processing backend operations and managing real-time environmental data. Rather than employing a conventional database, the system uses a flat file database for storing and recovering sensor readings seamlessly. [4] PHP makes data handling efficient, allowing air and water quality data to be easily available via the web dashboard. The server-side scripts of PHP enhance system reliability and provide users with live access to environmental information without the overhead of a relational database.

3.4 Flat File

This system uses a flat file database to store and retrieve environmental data in an efficient manner. The sensor values are stored in a pure, simple, unstructured text, rather than a relational schema, allowing the system to quickly access pollution information without the hassle of SQL based database complexities. [7] With this method, users can easily log air and water quality measurements with real time visibility into sensor data. Due to its lightweight and simple nature, a flat file database is a good option for real time IoT based monitoring systems with negligible overhead processing and easy handling of data.

4. Operation

Through its Environmental Air Pollution Detection System using IoT users can monitor their surroundings in real-time using sensitive measurement sensors. The system operates with stability through the combination of the ESP32 microcontroller and the RPS (Regulated Power Supply) board.

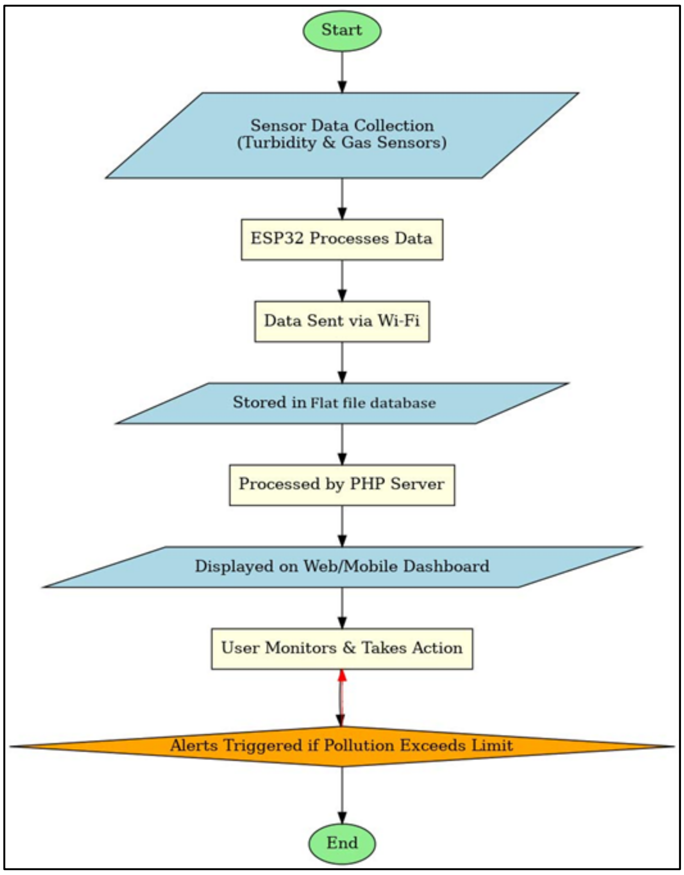

Figure 1. Flowchart of Proposed System

The Environmental Air Pollution Detection System uses MQ2, MQ3, MQ6, MQ135, and turbidity sensors to identify toxic gases such as CO_2, ammonia, benzene, water pollution caused by suspended particles. [13] The integrated Wi-Fi functionality of ESP32 devices sends environmental data from the ESP32 unit directly to cloud-based processing servers which transform the information into web dashboard visual displays. Through this system user can access remote monitoring of pollution levels and gas detection alerts in a user-friendly presentation. [3] The pollution monitoring system starts with sensor-based data collection and then uses an ESP32 microcontroller for processing, as seen in Figure 1. The information is processed by a PHP server, saved in a flat-file database, and sent over Wi-Fi. Lastly, the data is displayed on a dashboard that can be accessed by mobile or online devices, allowing users to monitor the situation and receive notifications if pollution levels exceed allowable limits.

5. Results and Discussion

Table 1. Comparison between Traditional Method vs. Proposed IoT-Based System

Feature	**Traditional Method**	**Proposed IoT-Based System**
Detection Approach	Manual sampling and laboratory testing	Real-time monitoring using IoT sensors
Response Time	Delayed (results available after lab analysis)	Instantaneous (real-time updates and alerts)
Technology Used	Gas chromatography, spectroscopy, manual sensors	IoT-based sensors (MQ2, MQ3, MQ6, MQ135, TDS)
Data Transmission	Manual record-keeping, offline storage	Automatic data upload via Wi-Fi
Data Storage	Paper-based records or local databases	Cloud-based storage with web visualization
User Accessibility	Restricted to experts with lab equipment	Accessible via web and mobile applications
Power Source	Manual operation, often stationary	RPS-powered with autonomous monitoring
Scalability	Limited to specific monitoring stations	Highly scalable for multiple locations

Alert System	No real-time alerting, only post-analysis reports	Instant alerts when pollution exceeds limits
Cost Efficiency	Expensive due to equipment, lab tests & maintenance	Low-cost, energy-efficient IoT solution
Accuracy & Predictability	Subject to human error and delay	Accurate real-time data collection but with predictive analysis

The table 1 shows the overall comparison of the traditional and proposed IoT-based systems.

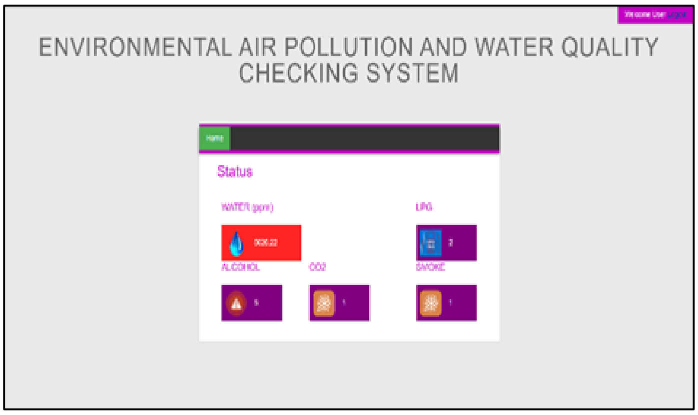

Figure 2. Water Quality Checking

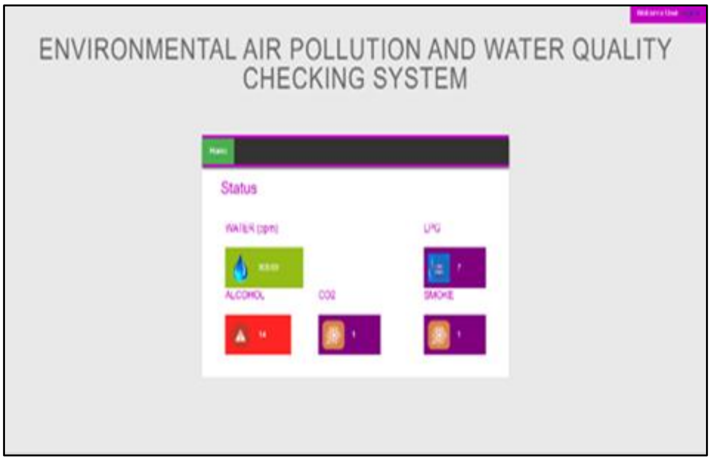

Figure 3. Alcohol Level Checking

The system interface offers real-time feedback on water quality metrics, allowing for an instant assessment of pollution levels, as seen in Figure 2. The alcohol level checking module, which tracks and reports the presence of alcohol in the environment to improve safety and regulatory compliance, is similarly depicted in Figure 3.

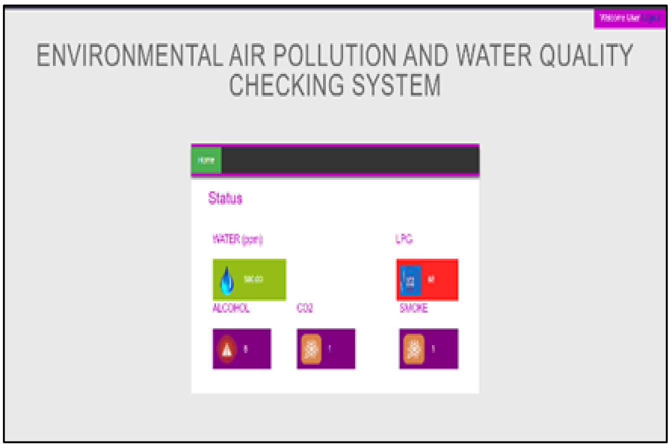

Figure 4. LPG Level Checking

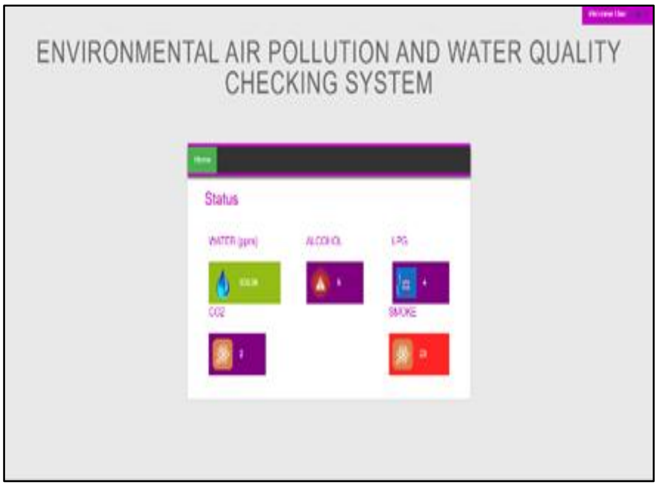

Figure 5. Smoke Checking

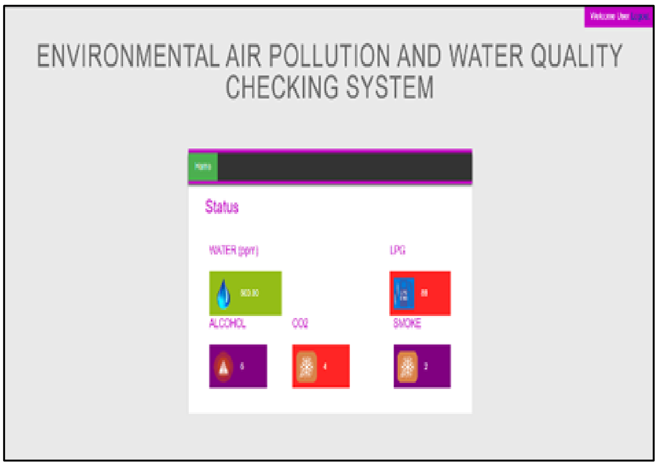

Figure 6. CO2 Checking

The system effectively monitors LPG gas levels, as shown in Figure 4, and sends out immediate alerts when concentrations surpass the safe threshold. The smoke monitoring interface, which detects airborne particles for early pollution or fire detection, is seen in Figure 5. Similarly, CO_2 level monitoring is shown in Figure 6, which aids in real-time environmental safety and air quality assessments.

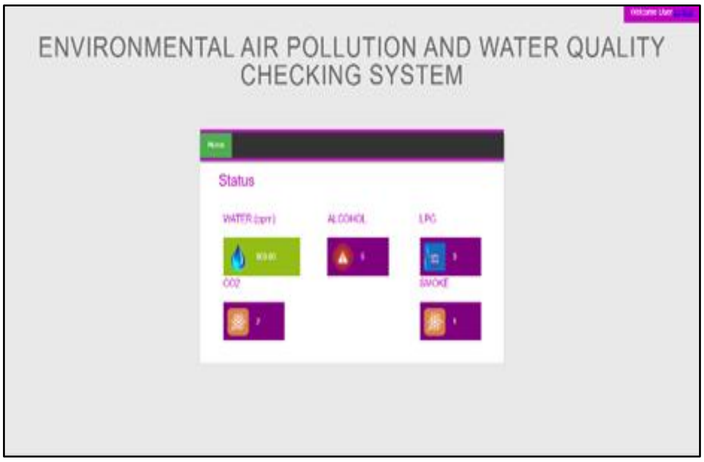

Figure 7. Normal Level of the Gases and Water

The environmental monitoring system confirms a safe and pollution-free environment by displaying all metrics within permissible limits, as illustrated in Figure 7. This includes normal levels of CO_2, alcohol, LPG, smoke, and water quality.

The developed system draws concepts from existing research that enhances real-time environmental pollutant monitoring alongside alert detection. The system displays instant gas concentration data by changing the indicator color from the standard hue to red when threshold values are exceeded through its visualization capability. The system provides quick response abilities through its sensor web interface that enables distant monitoring. The ESP32 microcontroller delivers real time information, and gas and turbidity sensors from the system detect pollutants with precision for alcohol, CO_2, LPG and smoke. A user-friendly dynamic dashboard (HTML, CSS, PHP) offers real-time insights for easy decision-making. [12] The system adopts a modular architecture that allows the addition of new sensors without manual testing requirements for system expansion. The system performs early pollution detection with the added advantage of health risk reduction while maintaining sustainability. The flat file database operates well for commercial, industrial, and educational applications because it achieves fast and efficient retrieval of sensor data. [8].

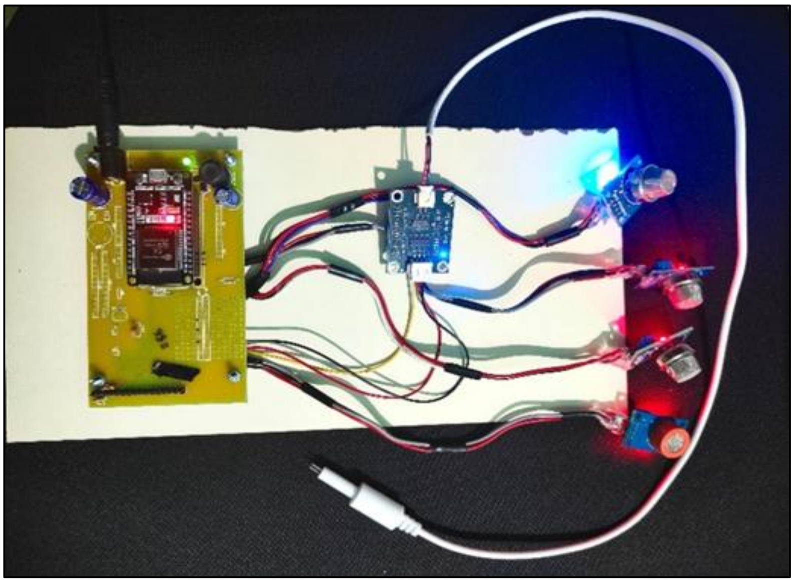

Figure 8. Hardware Implementation of Proposed System

The hardware solution, which incorporates gas sensors, a water quality sensor, and a microcontroller module for real-time monitoring, is detailed in Figure 8.

6. Conclusion

The Environmental Air Pollution and Water Quality Checking System in Educational Institutions employs IoT connectivity, autonomous sensors, and cloud-based data management for real-time environmental monitoring. The ESP32 microcontroller gathers and processes data from gas and turbidity sensors to facilitate precise evaluation of water and air quality. The system provides users and authorities with a web-based interface to obtain real-time pollution data, including a smoking detection feature to enhance air quality control. Automation eliminates manual testing and provides instant alerts when pollution levels exceed safety limits, ensuring proactive environmental protection. The framework unifies HTML, CSS, PHP, and JavaScript to reach safety threshold, ensuring active environmental protection. The system combines HTML, CSS, PHP to build a dynamic and responsive user interface and employs a flat file database for data storage and retrieval in an efficient manner. With frontend, backend, and IoT integration, the system provides an effective and scalable solution for monitoring the environment. By employing real-time access to data and automated decision-making, the technology maximizes pollution control, encourages sustainability, and ensures environmental safety in educational campuses.

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