IoT-Based Manhole Detection and Monitoring System for Urban Safety

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Abstract— **Urban safety is increasingly becoming a concern due to the failure to detect and manage underground infrastructure hazards such as displaced manhole covers, sewer overflows, and toxic gas accumulations. Traditional inspection methods are labor-intensive and incapable of providing real-time status updates, leading to delayed responses and potential fatalities. This paper proposes an Internet of Things (IoT)-based smart manhole monitoring system that uses a combination of gas sensors, ultrasonic distance sensors, and environmental sensors connected to microcontrollers. The system continuously monitors the condition inside manholes and communicates alerts when thresholds are breached. A centralized dashboard provides visualization and logging of the sensor data, enabling urban municipal bodies to respond proactively. The system is scalable, cost-effective, and adaptable to smart city ecosystems. Extensive testing demonstrates the system's reliability in detecting abnormal conditions such as cover tilting, sludge level rise, gas leaks, and high-pressure buildup indicative of blast threats.**

Keywords— IoT, manhole safety, gas sensors, sludge detection, urban monitoring, Arduino, smart city, environmental sensing.

I. INTRODUCTION

The increasing population in urban cities places significant stress on municipal infrastructure. One critical yet often overlooked component is the manhole system used for sewage and drainage management. Manholes, if left unattended, displaced, or damaged, pose severe risks to pedestrians, vehicles, sanitation workers, and the overall public environment. Reports of accidents due to open manholes or toxic gas emissions have become common, especially during the monsoon or in older parts of cities with aging infrastructure.

Traditional methods for inspecting manholes involve periodic manual checks that are neither time-efficient nor scalable. These methods also endanger workers who are directly exposed to hazardous gases or biological waste. Furthermore, such inspections provide only a snapshot of the condition and lack the ability to offer continuous monitoring.

The proposed system addresses these challenges using an integrated IoT solution. By deploying a network of sensors and microcontrollers, the system can continuously monitor manhole conditions such as gas levels, sludge overflow, environmental temperature, and cover displacement. The collected data is transmitted to a centralized dashboard and mobile interface, ensuring real-time awareness and timely intervention.

II. LITERATURE SURVEY

Several researchers have attempted to automate sewer monitoring using various technologies. In [1], Gupta et al. developed a ZigBee-based alert system for detecting unauthorized manhole access and overflow conditions. However, the system lacked a real-time dashboard and integration with multiple sensors for gas and pressure detection.

A related effort by Zhang et al. [2] implemented an IoT- based waste monitoring system focused primarily on bin level detection rather than sewer systems. The work highlighted the potential of IoT in waste management but did not address multi-factor risks such as gas buildup or cover displacement.

R. Kumar and D. Singh [3] explored the use of a GSM module to send SMS alerts when gas levels cross safe limits. Although effective in isolated use cases, the system lacked integration with other environmental sensors and did not provide a complete safety solution for manhole monitoring.

These limitations highlight the need for a comprehensive system that can integrate various sensors, process data intelligently, and communicate critical events in real-time.

III. OBJECTIVES

The key objectives of this project are as follows:

- Real-Time Monitoring: To provide uninterrupted, live data from manholes using integrated sensor networks.
- Threat Detection: To automatically detect and classify various threats such as gas leakage, manhole cover displacement, sludge overflow, and potential explosion risk due to temperature and humidity conditions.
- Automated Alerts: To send immediate notifications via SMS, email, or dashboard pop-ups to concerned authorities for timely intervention.
- Dashboard Visualization: To create a user-friendly web interface where all real-time data and historical logs can be viewed and analyzed.
- Low-Cost Deployment: To design the system using readily available, low-cost components like Arduino, MQ sensors, and ultrasonic modules.
- Scalability and Maintenance: To allow the system to be expanded across multiple locations with minimal manual intervention.

IV. SYSTEM DESIGN AND ARCHITECTURE

A. Sensor Modules

The hardware system incorporates a range of sensors to detect physical and chemical conditions:

1. Gas Sensors (MQ Series):
    - MQ-2, MQ-7, or MQ-135 sensors detect flammable and toxic gases like methane, carbon monoxide, and hydrogen sulfide.
    - These gases are prevalent in sewage systems and are highly hazardous. Detection beyond threshold levels triggers alerts.
2. Ultrasonic Sensor (HC-SR04):
    - Used for detecting both manhole cover tilt and sludge level.
    - The sensor sends ultrasonic waves and calculates distance based on reflection time. A sudden increase or decrease in distance indicates an anomaly.
3. Temperature and Humidity Sensor (DHT11/DHT22):
    - Tracks changes in internal temperature and humidity which may signal an impending gas build-up or underground chemical reaction.
    - Temperature spikes can indicate biological or chemical activity that could lead to explosions.

B. Microcontroller Unit

An Arduino Uno or ESP32 board serves as the central processing unit. It reads sensor inputs, compares values with pre-set thresholds, and sends data to the communication module.

C. Communication and Transmission

- Wi-Fi/GSM/LoRa: Depending on location and budget, various transmission modules can be used. ESP32 has built-in Wi-Fi; GSM modules (e.g., SIM800L) can be used for SMS; LoRa offers long- range low-power communication for remote areas.

D. Power Supply

A combination of battery and solar power can be used to ensure uninterrupted operation, especially in outdoor or roadside installations.

E. Dashboard

The system includes a custom web-based dashboard developed using tools like Node.js, Firebase, or Thing Speak. It displays:

- Live sensor readings
- Alert logs
- Graphical charts for trend analysis
- Device health status (battery, connectivity)

V. IMPLEMENTATION

The system is designed to continuously monitor various environmental parameters using sensors connected to a microcontroller. For detecting cover tilt, an ultrasonic sensor measures the distance from a fixed point; if this distance changes significantly from the expected value, it suggests the cover has been opened or displaced, and an alert is generated. To identify sludge overflow, the sensor checks the gap between itself and the sludge surface—if it drops below a specific threshold (such as 5 cm), the system warns of a potential overflow or blockage. Toxic gases like Carbon Monoxide (CO) and Hydrogen Sulfide (H_2 S) are monitored using gas sensors. If their concentration goes beyond safe limits—300 ppm for CO or 50 ppm for H_2 S—the system sounds a buzzer and sends notifications via SMS or email. Additionally, a combination of high temperature (above 40°C) and humidity (above 80%) is treated as a blast hazard due to the likelihood of gas pressure buildup, prompting an immediate warning. The microcontroller reads data from the sensors at regular intervals and stores it in real time. Thresholds for alerts are either hardcoded into the software or can be updated through an online dashboard for better control and flexibility.

VI. RESULTS AND DISCUSSION

The prototype was tested in a controlled lab environment. Each hazard condition was simulated to verify the system's responsiveness.

- Gas Detection: A test with LPG near the MQ sensor accurately triggered the gas alert system, confirming the sensor's reliability.
- Ultrasonic Tilt Simulation: A mock-up manhole cover was gradually lifted, and the system detected a significant deviation in distance, activating the cover tilt alert.
- Blast Risk Simulation: A heat source was used to raise temperature and humidity; the system successfully detected risk conditions and alerted authorities.

The data was accurately displayed on the real-time dashboard. The system responded in under 5 seconds for all events. These results validate the feasibility of the system for real-world deployment. Integration with municipal emergency services and Google Maps can further enhance location tracking.

VII. CONCLUSION

This paper presents a comprehensive, sensor-integrated IoT system for real-time manhole monitoring. The system combines multiple sensors and microcontrollers to track gas concentration, sludge levels, cover displacement, and pressure indicators. Through wireless communication and dashboard visualization, it empowers authorities to act proactively and ensure public safety.

The system's modularity, low cost, and scalability make it suitable for large-scale urban deployment. Future enhancements may include AI-based anomaly detection, automated maintenance scheduling, and integration with broader smart city frameworks.

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