SafeWard: An IoT-Based Hospital Environmental and Methane Monitoring System

I. INTRODUCTION

Hospitals are crucial for patient safety, yet many struggle to maintain optimal air quality and control hazardous emissions. Poor indoor air quality contributes to hospital-acquired infections and longer recovery times. In low and middle-income countries, many hospitals fail to meet global safety standards for air and gas management, increasing risks for both patients and staff (World Health Organization, 2020). Aging infrastructure, insufficient ventilation, and outdated monitoring systems make it difficult to detect and respond to environmental hazards promptly. As a result, hospitals are often unprepared to prevent exposure to harmful gases or airborne pathogens, which can compromise patient care and staff safety.

Moreover, *Methane* produced by medical waste and wastewater processes, poses additional health and safety concerns due to its flammable properties and potential respiratory impacts (United Nations Environment Programme, 2024). In Southeast Asia, the challenge is even greater. Hospitals in the region experience higher rates of infection outbreaks and environmental incidents than the global average, frequently tied to inadequate ventilation, aging infrastructure, and insufficient monitoring systems (Asian Development Bank, 2025).

In the Philippines specifically, reliance on manual monitoring methods for hospital environmental conditions such as air quality, temperature, humidity, and gas leaks undermines timely, consistent responses. Around 26.7 percent of the country's hospitals, approximately 550 out of 2,057, have been identified as at high risk of shutdown from climate or environment driven hazards, suggesting a broader systemic vulnerability of healthcare facilities to environmental risk (Cabico, 2023).

Given these challenges, our project, SafeWard: An IoT-Based Hospital Environmental and Methane Monitoring System, provides a proactive solution to improve hospital safety and environmental monitoring. SafeWard uses MQ-5 sensors to detect methane, DHT22 sensors for temperature and humidity, and an ESP32 microcontroller to collect real-time data. All readings

are transmitted to a cloud-based dashboard, where hospital staff can monitor conditions, view historical trends, and receive automated alerts when unsafe thresholds are detected.

II. OBJECTIVES

To develop an IoT-based hospital environmental monitoring system that ensures patient safety by continuously tracking air quality, methane levels, temperature, and humidity, and providing real-time data and alerts through a cloud-based dashboard.

- To design and implement a real-time sensor network using MQ-5 methane sensors, DHT22 temperature and humidity sensors, and an ESP32 microcontroller.
- To develop a cloud-based dashboard that displays live and historical environmental data for hospital staff.
- To integrate automated alerts and notifications when environmental parameters exceed safe thresholds.
- To evaluate the system's effectiveness in detecting hazardous conditions and improving hospital response time.
- To implement an AI analysis module that predicts potential unsafe environmental conditions and provides proactive recommendations for hospital staff.

III. SIGNIFICANCE OF THE STUDY

The SafeWard system is important because it addresses critical safety and health challenges in hospitals. By monitoring air quality, methane gas, temperature, and humidity in real time, the system helps:

- **Protect patients** – By continuously monitoring the hospital environment, SafeWard reduces the risk of hospital-acquired infections and prevents exposure to hazardous gases, ensuring patients recover in a safer, cleaner space.

- **Support hospital staff** – Automated alerts notify staff immediately when conditions become unsafe, allowing them to act quickly, reduce health risks, and focus on patient care instead of manual monitoring.
- **Improve hospital management** – The system stores historical and real-time environmental data, enabling hospital administrators to make informed decisions, identify recurring hazards, and optimize maintenance schedules.
- **Enhance compliance with safety standards** – SafeWard helps hospitals meet international air quality and safety guidelines, ensuring a safer and more resilient environment for both patients and staff.

Overall, this study contributes to creating safer hospital environments, improving patient care, and fostering a proactive approach to environmental safety, rather than relying solely on reactive measures.

IV. FEATURES OF SAFEWARD

1. **Real-Time Environmental Monitoring:**
    - Continuously measures methane gas, temperature, and humidity.
    - Detects unsafe conditions immediately to prevent hazards.
    - Tracks environmental trends over time for analysis and reporting.
2. **IoT Sensor Integration:**
    - MQ-5 sensors for methane detection.
    - DHT22 sensors for temperature and humidity.
    - ESP32 microcontroller for real-time data collection and transmission.
3. **Cloud-Based Dashboard:**
    - Displays live and historical environmental data in an easy-to-read interface.
    - Provides visual alerts for unsafe readings.

- Allows remote access by authorized hospital staff for monitoring and decision-making.

4. **Automated Alerts and Notifications:**

    - Sends immediate alerts when air quality or gas levels exceed safe thresholds.
    - Supports timely response from hospital staff to prevent accidents or exposure.
    - Helps reduce reliance on manual monitoring methods.

5. **Data Analysis Charts:**

    - Analyzes sensor data to detect potential hazards and abnormal trends.
    - Uses AI to predict future unsafe environmental conditions.
    - Provides actionable recommendations to improve hospital safety and environmental management.

V. IMPLEMENTATION PLAN

1. Phase 1: Planning & Requirement Analysis

Objective: Define system goals, scope, and requirements.

- Identify environmental parameters to monitor (methane, temperature, humidity, air quality).
- Establish safe thresholds based on WHO and local guidelines.
- Gather requirements from hospital staff and administrators.
- Select IoT hardware (MQ-5, DHT22, ESP32) and cloud platform.

2. Phase 2: System Design

Objective: Create architecture, data flow, and dashboard layout.

- Design IoT network topology and sensor placement.
- Define data flow: sensor → ESP32 → cloud → dashboard.

- Develop dashboard wireframes and alert notification plan.

Phase 3: Hardware & Software Development

Objective: Build the physical and digital components of SafeWard.

- Install MQ-5 and DHT22 sensors in hospital areas.
- Connect sensors to ESP32 microcontrollers and calibrate them.
- Program ESP32 to read and transmit data to the cloud.
- Set up cloud database and develop dashboard with monitoring, trends, and automated alerts.

Phase 4: Testing & Deployment

Objective: Ensure system reliability and implement it in the hospital.

- Perform unit and integration testing (sensor → ESP32 → cloud → dashboard).
- Simulate hazardous conditions to test alerts and notifications.
- Deploy sensors, ESP32 units, and dashboard in hospital areas.
- Train hospital staff on system usage and response procedures.

Phase 5: Monitoring & Maintenance

Objective: Ensure continuous operation and improvement of the system.

- Regularly check sensor calibration and connectivity.
- Monitor environmental data and system performance.
- Update software/dashboard features as needed.
- Analyze historical data to improve safety protocols and preventive measures.

VI. EXPECTED OUTCOMES

1. **Improved Patient Safety**

   Continuous monitoring of air quality, methane, temperature, and humidity reduces exposure to hazards, lowering the risk of hospital-acquired infections.

2. **Enhanced Staff Efficiency and Response**

   Automated alerts notify staff immediately when conditions exceed safe limits, allowing faster responses and reducing reliance on manual monitoring.

3. **Real-Time and Historical Data Access**

   Hospital staff can view live readings and track trends over time, enabling data-driven decisions for environmental management.

4. **Proactive Hazard Management**

   Early detection of environmental risks prevents accidents, gas leaks, and equipment failures, promoting a safer hospital environment.

5. **Increased Hospital Operational Resilience**

   SafeWard helps maintain safe conditions consistently, reducing the likelihood of shutdowns caused by environmental hazards.

VII. REFERENCES

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