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IoT-Based Embedded System for Monitoring Peatland Methane, Humidity, and Temperature to Support SDG 13

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ABSTRACT

Objective: *This study aims to develop and evaluate an Internet of Things (IoT)-based embedded system for real-time acquisition, monitoring, and visualization of methane concentration, air humidity, and temperature data in peatland environments. The system is designed to support environmental monitoring and climate change mitigation efforts in line with SDG 13 (Climate Action).* ***Method:*** *The proposed system integrates a TGS2611 methane sensor and a DHT22 temperature–humidity sensor with a NodeMCU ESP8266 microcontroller equipped with Wi-Fi connectivity. Measurement data are displayed locally on a 20×4 LCD and transmitted wirelessly to a server. A MySQL database stores the collected data, while a web-based monitoring platform developed using HTML, CSS, JavaScript, and PHP enables real-time visualization and remote access to environmental measurements.* ***Results:*** *The developed IoT-based embedded system successfully acquired, transmitted, stored, and displayed methane concentration, temperature, and humidity data from peatland environments in real time. The integration of wireless communication and web technologies enabled continuous environmental monitoring, providing accurate and accessible measurement information to support effective environmental management and decision-making.* ***Novelty:*** *This study presents an integrated IoT-based embedded monitoring system that combines methane gas detection, environmental sensing, wireless communication, cloud-based data storage, and web visualization into a single platform for peatland monitoring. The proposed system offers an efficient and cost-effective solution for continuous environmental observation, contributing to greenhouse gas monitoring and sustainable peatland management to support SDG 13 (Climate Action).*

INTRODUCTION

Peatland is a source of methane gas emissions (Evans et al., 2021; Mander et al., 2025; Strack et al., 2019; Zhang et al., 2023). Methane gas is one of the gasses that contribute to the greenhouse effect (Filonchyk et al., 2024; Kanna et al., 2024; Kwilinski et al., 2024; Li et al., 2023). Methane gas concentration measurement in peatland uses two methods, namely, the analytical method and the sensors-based measurement method (Gu et al., 2022; Salimian, 2024; Sugavaneshwaran et al., 2024; Swain et al., 2024). The analytical method typically uses a gas analyzer (GA) or gas chromatography (GC) while the sensors-based measurement method uses methane sensors, TGS2611 or MQ-4 (Xu et al., 2023).

The analytical procedure of methane measuring is that methane gas emitted by peatland is trapped by closed-chamber measurement (CCM) (5). The shape of CCM is rectangular or cylindrical with specific dimensions (Abdollahi et al., 2025; Dimitrijević et al., 2023; Gunduz & Demircan, 2022). The CCM has a surface area proportional to methane gas emission flux (Lupascu et al., 2020). Furthermore, Methane gas trapped by CCM is sampled and measured by GA or GC to obtain the value of methane concentration. The advantages of measuring methane concentration by GA or GC are that the measurement result is more accurate due to either GA or GC being traced with