

# Design and Deployment of a Low-Cost IoT Sensor Network for Real-Time Environmental Monitoring in Togolese Mining Operations

Komlan Agbemabiase<sup>1</sup>|Sena Amegan<sup>2,3</sup>

Afiwa Mensah<sup>1</sup>|Koffi Adzima<sup>1,4</sup>

<sup>1</sup> University of Kara

<sup>2</sup> Department of Mechanical Engineering, University of Lomé

<sup>3</sup> Department of Mechanical Engineering, University of Kara

<sup>4</sup> Department of Electrical Engineering, Institut Togolais de Recherche Agronomique (ITRA)

Correspondence: [kagbemabiase@yahoo.com](mailto:kagbemabiase@yahoo.com)

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## ABSTRACT

**Background:** Mining operations in West Africa face significant challenges in monitoring environmental impacts, particularly concerning dust and water quality. Conventional monitoring systems are often cost-prohibitive and lack real-time data capabilities, leading to reactive rather than proactive environmental management.

**Purpose and objectives:** This study aimed to design, fabricate, and deploy a novel, low-cost Internet of Things (IoT) sensor network specifically for real-time particulate matter (PM2.5) and pH monitoring in active mining areas. The objective was to validate the system's reliability and accuracy against commercial instruments under field conditions.

**Keywords:** *Internet of Things (IoT), environmental monitoring, low-cost sensors, West Africa, mining operations, real-time data, water quality*

### Article Highlights

- Validated IoT network shows 12.3% mean error for PM2.5 versus commercial instruments.
- Spatial analysis reveals 28% higher PM2.5 downwind of primary extraction zones.
- System provides real-time data for proactive environmental management in West Africa.
- LoRaWAN enables long-range, low-power communication in remote field deployments.

### Statistical Validation

Linear mixed-effects model confirmed a strong relationship ( $\beta_1 = 0.94$ , 95% CI: 0.89 to 0.99) between the custom IoT sensors and reference instruments.

*This study demonstrates the practical field validation of an accessible environmental monitoring technology.*

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