

Advancing H₂S monitoring in hydrothermal systems: calibration and laboratory testing of low-cost sensors

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Sulfur plays a key role in geological and atmospheric processes, cycling between deep Earth and surface reservoirs. Hydrogen sulfide (H₂S) is crucial in this cycle, influencing mineralization, atmospheric chemistry, and biogeochemical interactions. However, as a toxic and reactive gas, H₂S contributes to environmental problems like acid rain, air pollution, and respiratory issues. Despite its significance, quantifying H₂S in air remains challenging due to its low concentrations, rapid oxidation, and strong variability. Traditional monitoring techniques are expensive and stationary, limiting data coverage in environments such as volcanic and hydrothermal areas. Affordable, reliable sensors are therefore needed to improve our understanding of H₂S emissions and their role in the sulfur cycle.

This study explores the potential of low-cost H₂S sensors for improving real-time monitoring in air. Two Alphasense B4-H₂S electrochemical sensors, coupled with modified ISB electronics and an Arduino Uno board, were tested under controlled conditions. The sensors, operating in flow-through mode, were calibrated by referring to H₂S measurements carried out using a Thermo 450i H₂S analyzer (1 data per minute) based on Pulsed Fluorescence. The internal pump of this analyzer, with a flow rate of 70 cc/min, ensured a constant flow of gas sampled from a hydrothermal environment through (i) the low-cost sensors and (ii) the reference analyzer. Experiments were conducted in a 45 L polystyrene chamber at different temperatures (8°C, 25°C, 30°C) and relative humidity (20%, 50%, 80%) to assess their influence on sensor performance.

Results demonstrated strong sensor linearity (R² up to 0.99) and minimal inter-unit variability, confirming good repeatability and reliability of the measured data. Compensation models for environmental parameters enabled a calibrated operating range of 0.02–15 ppm, with MAPEs < 10%. Following this initial laboratory phase, the sensors will be tested within the hydrothermal system of Mt. Amiata (central Italy) to validate their performance under real operational conditions.

Low-cost sensors represent a scalable and adaptable solution for H₂S monitoring, enhancing both environmental management and scientific understanding of the sulfur cycle. Their deployment in dense monitoring networks could refine sulfur flux estimates, improve constraints on sulfur-atmosphere