

The Scuba-Diving Air Quality Index (SD-AQI): Definition, Validation, and Application

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Abstract—We propose the Scuba-Diving Air Quality Index (SD-AQI), a compact index tailored for lightweight compressor-site monitoring. SD-AQI fuses readings from inexpensive metal-oxide semiconductor (MOS / MQ) gas sensors and environmental sensors to provide a single operational score that highlights contamination risks relevant to scuba breathing air (e.g., CO, CO₂, hydrocarbons, NO_x, NH₃, H₂). We describe the mathematical formulation, normalization, mitigation for common MOS pitfalls, and illustrative simulations and figures. The implementation captures raw payloads for forensic analysis and supports backfill and calibration.

Index Terms—Air Quality Index, MOS sensors, MQ sensors, scuba diving, SD-AQI, compressed air safety

I. INTRODUCTION

Breathing-air quality in scuba diving cylinders is critical for diver safety. Contaminants such as carbon monoxide (CO), high carbon dioxide (CO₂), hydrocarbons (e.g., CH₄), volatile organic compounds (VOCs), nitrogen oxides (NO_x), ammonia (NH₃), and hydrogen (H₂) present significant health hazards when present at elevated concentrations. Continuous monitoring at compressor sites permits early detection and operational alarms.

Low-cost MOS (MQ) sensors are frequently used for continuous monitoring due to their sensitivity and low cost. However, MOS sensors are semiquantitative and suffer from cross-sensitivity, baseline drift, and environmental confounders. SD-AQI is designed as a pragmatic, robust operational metric that aggregates multiple sensor channels into a single scalar score optimized for early warning.

II. SENSOR SUITE AND DATA MODEL

The SD-AQI system (implemented in the IoT Babar project) collects the following channels (keys shown as stored in the database): LPG (MQ-2), CO (MQ-2, MQ-7, MQ-9), Smoke (MQ-2), CO_MQ7 (MQ-7), CH₄ (MQ-4), CO_MQ9 (MQ-9), CO₂ (MQ-135), NH₃ (MQ-135), NO_x (MQ-135), Alcohol/Benzene (MQ-135), H₂ (MQ-8), Air (MQ-8/MQ-135), and Temperature/Humidity.

Each record $r(t)$ contains sensor values $x_g(t)$ for each gas sensor g and server-side UTC timestamp t . The backend stores a 'raw_payload' JSON text column for every incoming record to support backfilling and forensic processing.

III. SD-AQI FORMULATION

We proceed in three steps: per-gas normalization, weighting, and aggregation.

A. Per-gas normalization

For each sensor channel g we compute a normalized sub-score $s_g \in [0, 1]$ via a clamped linear transform:

$$s_g = \text{clamp} \left(\frac{x_g - b_g}{u_g - b_g}, 0, 1 \right) \quad (1)$$

where b_g is a baseline (clean air) reference and u_g an upper-concern threshold. The clamp function ensures s_g remains in $[0, 1]$. Calibration determines b_g and u_g (manufacturer guidance or local reference measurements).

B. Weighting and aggregation

Assign a weight $w_g \geq 0$ for each gas reflecting toxicity and operational importance. SD-AQI is then a weighted sum scaled to a convenient range:

$$\text{SD-AQI} = C \sum_g w_g s_g \quad (2)$$

where constant C sets the numerical range (e.g., $C = 6$ in the prototype). Example weights (heuristic) used in the IoT Babar implementation:

$$\begin{aligned} w_{CO} &= 0.05, & w_{CO_MQ7} &= 0.1, & w_{CO_MQ9} &= 0.1, \\ w_{CH4} &= 0.1, & w_{H2} &= 0.05, \\ w_{CO2} &= 0.5, & w_{NOx} &= 0.1, & w_{Air} &= 0.05. \end{aligned}$$

When multiple sensors provide redundant information for the same gas (e.g., CO reported by MQ-2, MQ-7, MQ-9), we apply a robust fusion step: compute normalized sub-scores for each sensor and combine them via median or trimmed mean before applying a single gas-level weight. This reduces single-sensor noise influence.

IV. HANDLING SENSOR PITFALLS

MOS sensors exhibit several non-ideal behaviors:

- **Warm-up:** sensors require heating; ignore or down-weight first N minutes after power-on.
- **Baseline drift:** use a rolling baseline estimator (percentile-based or exponential smoothing) to adapt b_g .
- **Humidity and temperature sensitivity:** apply compensation using measured T/H or conditional thresholds.
- **Cross-sensitivity:** use redundancy and statistical methods (PCA/ICA) or down-weight correlated channels.

Fig. 1. Illustrative SD-AQI response as CO increases (synthetic). Convert the SVG to PDF/PNG for LaTeX compilation if needed.

Fig. 2. Simulated time series of gas channels and the resulting SD-AQI (synthetic).

V. ILLUSTRATIVE SIMULATIONS

We provide two illustrative plots: (1) SD-AQI response to increasing CO and (2) a simulated time-series of multiple channels and resulting SD-AQI. The prototype Python snippet (included in the project) demonstrates parameter choices and produces the figures.

Figure ?? shows the SD-AQI as CO increases under linear normalization and the weights above. Figure ?? shows a 30-minute synthetic trace.

VI. THRESHOLDS, INTERPRETATION AND ALARMS

SD-AQI is an operational indicator. Example conservative thresholds (subject to local calibration):

- SD-AQI < 3.0: Normal
- $3.0 \leq \text{SD-AQI} < 6.0$: Advisory — increase inspection frequency
- $6.0 \leq \text{SD-AQI} < 12.0$: Warning — consider stopping fills
- SD-AQI ≥ 12.0 : Critical — stop filling and investigate immediately

Thresholds must be validated against reference analyzers and local safety standards. Because MOS sensors do not measure absolute concentration reliably without calibration, pair SD-AQI alarms with confirmatory measurements.

VII. LIMITATIONS AND FUTURE WORK

This work is exploratory. Limitations include the semiquantitative nature of MOS sensors and the necessity of local calibration. Future directions:

- Formal calibration studies against laboratory-grade gas analyzers to map raw sensor units to concentration and set u_g thresholds.
- Machine-learning-based compensation for cross-sensitivity and environmental confounders.
- Incorporating particulate measurements (PM2.5) in alarm logic and integrating with human factors for actionable alarms.
- Publishing reproducible notebooks and adding automated backfill utilities that extract and re-process `'raw_payload'` to `topopulatenewDBcolumns`.

VIII. CONCLUSION

SD-AQI provides a compact, actionable index for compressor-site monitoring. By combining multiple MOS channels with normalization, robust fusion, and weighting tuned for diving hazards, SD-AQI supports continuous monitoring and operational alarms. The approach is low-cost and enables distributed monitoring, but must be validated with reference instrumentation before use in life-critical decisions.

ACKNOWLEDGMENT

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REFERENCES

- [1] U.S. EPA, "Air Quality Index (AQI) Basics".
- [2] MQ series datasheets (MQ-2, MQ-4, MQ-7, MQ-8, MQ-9, MQ-135).