

Methodological Insights and Field Feedback for Indoor Air Quality Assessment

Focus on Total Volatile Organic Compounds (TVOC)

C. Falzone · M. Bailor Jalloh · A.C. Romain

SAM Laboratory – Research Unit Spheres, University of Liège (ULiège) | Arlon Campus Environment, Avenue de Longwy 185, 6700 Arlon, Belgium

Context

- Several sources of VOC in indoor air - Building materials: major VOC sources.
 - Their emission profiles underpin Indoor Air Quality (IAQ) assessment strategies.
 - Standard characterisation uses ISO 16000 emission test chambers
 - Compound-specific quantification, material labelling and CE marking under EU Construction Products Regulation (305/2011)
- TVOC: indicator for classifying the IA pollution and the exposure of occupants (In Germany guide value : TVOC must be $< 95 \mu\text{g}/\text{m}^3$)
- Low-cost miniaturised sensor-based systems increasingly used for continuous monitoring
 - Commercialised Devices:
 - Technologies: electrochemical cells, NDIR, PID, MOS, laser
 - Pollutants: CO_2 , TVOC, HCHO , O_3 , NH_3 , H_2S , NO , NO_2 , SO_2 , PM
 - Few of them measure specific VOC except formaldehyde

Methods Overview – VOC Measurement in situ in real environment

**Lab Reference Methods (ISO 16000 series)**
Sampling + lab analysis · Accurate specific VOC quantification
Comparison with guideline values (if they are)
Time-integrated → misses short-term peaks and dynamic exposure events

**Reference chemical analyser**
Continuous monitoring · High temporal resolution
GC-FID, GC-MS, TOF-MS, SIFT-MS
→ too expensive for continuous IAQ assessment

**Sensor-Based Monitoring (TVOC)**
Captures dynamics: temperature, humidity, occupancy, ventilation
BUT usually limited to the measurement of Total VOC

**Odour-Related Indicators**
Perceived air quality assessment
No continuous measurement (few e-nose applications)
Human needed
Odour intensity and hedonic tone more suitable than odour concentration

Complementarity of Approaches

Reference Methods

- ✓ Chemical specificity
- ✓ Regulatory compliance
- ✓ Quantitative accuracy
- ✓ Guideline comparability

On-line chemical analyser

- ✗ Very costly
- ✗ Bulky

Lab method

- ✗ Time-integrated
- ✗ No dynamic event capture

Sensor Monitoring

- ✓ Continuous real-time data
- ✓ Temporal variability captured
- ✓ Emission dynamics (T, RH, occupancy)
- ✓ Cost-effective deployment
- ✓ Deployable at scale
- ✗ Lower quantitative reliability
- ✗ Calibration bias & drift

TVOC Sensor ?

Low-cost sensor



TVOC: indicative measurement, not a true VOC sum !!!

Known limitations:

- Sensor drift over time
- Cross-sensitivity to non-target compounds
- Limited selectivity vs. reference methods



Important consideration: CALIBRATION for TVOC → Quantitative reliability ?

Manufacturer:

- Isobutylene for PID
- Ethanol for MOS sensors



Introduces biases depending on mixture composition

Standard: German approach VDI/VDE 3518

Multigas sensors – Standardized test instructions and test gases for VOC detectors for indoor air quality measurement

- Careful preparation of calibrated VOC mixtures and humidified “normal air”.
- Tests in controlled chambers (T, RH, flow, stabilisation time for each step).
- Long campaigns (days to weeks) covering ranges, T/RH cycles, interferences and ageing.
- High experimental burden: complex setup, strict metrology, difficult to repeat routinely.

This procedure is a cumbersome, time-consuming, and costly process for regulatory agencies

Belgian authorities request :

a simple, reproducible and low-cost procedure for assessing the performance of low cost commercially indoor air quality monitors before their use by the general public



Have to find a compromise : simple quality control procedure

Proposed methodology

- Calibration of a reference selected VOC detector using isobutylene (could be a simple PID),
- Generation of controlled VOC atmospheres (e.g. using certified gas or another controlled VOC source) under stable conditions.
- Simultaneous measurements with ref detector and the IAQ monitor, including MOS sensors and other VOC sensing technologies.
- Monitoring of environmental parameters, particularly temperature and relative humidity
- Comparison of monitors performances.



Sensory & Odour Dimension

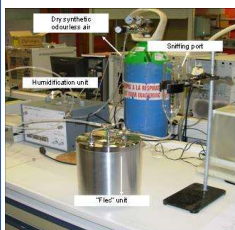
Odour perception is not captured by VOC concentration alone.

Compounds at sub-guideline concentrations — notably aldehydes — can significantly affect perceived air quality due to their very low odour thresholds.

→ Sensory metrics must be systematically integrated into IAQ assessment frameworks alongside chemical quantification.

VOC-odour intensity relationship is a function of chemical composition | It highlights the importance of sensory relevance in IAQ assessment

VOC-odour intensity relationship



(day 3)

Vinyl

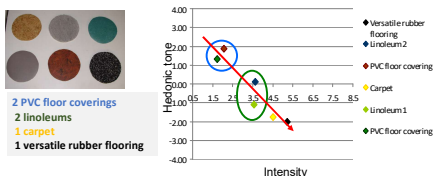
Elevated TVOC concentration: $10\,720 \mu\text{g}/(\text{m}^3)$, lots of alkanes
Low odour intensity: 2 (medium)

Linoleum

Low TVOC concentration $94 \mu\text{g}/(\text{m}^3)$, lots of aldehydes, organic acids and also alkanes
High odour intensity: 4 (average)

Thermal desorption — Thermo, ISQ 7610

- GC-MS quantification of each VOC ; Tenax-TA sorbent cartridges
- French Standard NF X 43-103



E-nose experiments with electronic noses (MOS array) developed by the lab since 2010

Monitor an odour rather than VOCs

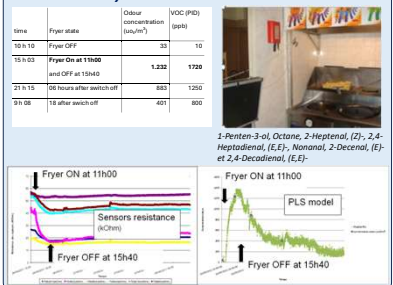
Test of sensor array in real conditions:

- French fries shop ($100\text{--}800 \mu\text{O}_2/\text{m}^3$, max 3000 above the fryer)
- toilet of a company ($100\text{--}600 \mu\text{O}_2/\text{m}^3$)
- garbage room (200 and $500 \mu\text{O}_2/\text{m}^3$)

Results vary depending on the type of odour
✓ Recognition of odour and non odour ambience
✗ Discrimination of the difference in odours
Odour concentration have to be $> 100 \mu\text{O}_2/\text{m}^3$



Illustration : Fryer



Perspectives & Future Work

1. Provide a simple quality control procedure

Simple protocol for supervisory authorities

2. Harmonise sensor evaluation protocols

Common benchmarks for TVOC sensor inter-comparison across laboratories and field deployments

2. Improve calibration strategies

Mixture-aware calibration approaches to reduce bias introduced by compound diversity

3. Integrate sensory metrics

Embed odour perception and perceived intensity into standard IAQ assessment methodologies