aranet

VOC detection

Why affordable VOC detection methods are senseless?

Volatile organic compounds (VOCs) are a class of liquid organic chemicals that evaporate easily at room temperature.

Edgars Spārniņš, Normunds Bergs

2022-11-08

What is VOC?

Volatile organic compounds (VOCs) are a class of liquid organic chemicals that evaporate easily at room temperature. The term covers a wide range of chemical compounds that are both man-made and naturally occurring.

Table 1. Vapor-phase organic compounds classes according to WHO [1]

Category description	Acronym	Boiling point range (°C)
Very volatile (gaseous) organic compounds	VVOCs	<0 to 50–100
Volatile organic compounds	VOCs	50–100 to 240–260
Semi-volatile organic compounds	SVOCs	240–260 to 380–400
Organic compounds associated with particulate matter	POMs	>380

There are more than 5000 various VOCs identified. Some VOCs can be malodorous pollutants, sensory irritants, or hazardous air pollutants. Some VOCs are known human carcinogens.

The largest fraction of VOCs in Earth's atmosphere are biogenic, largely emitted by plants: isoprene, terpenes, pinene isomers, methanol, etc. However, it is found [2] that the levels of common organic pollutants are 2 to 5 times higher inside homes than outside, regardless of whether the homes were located in rural or highly industrial areas. Sources are predominantly anthropogenic, including:

- cleansers and disinfectants
- paints and solvents
- glues and adhesives
- moth repellents and air fresheners
- aerosol sprays
- dry-cleaned clothing
- stored fuels and automotive products
- pesticides, etc.

Detection methods

The golden standard in VOC analysis is gas chromatography (GC) coupled with mass spectrometry (MS). GC is a physiochemical separation technique, while MS is an analytical method to analyze compounds by ionization. Each provides complementary information during VOC testing.

There's rarely only one compound in an air sample. Usually, several VOCs are emitted from a facility. A gas chromatograph separates compounds in an air sample so that individual identification of compounds can be made by an analytical detector. A mass spectrometer measures the mass-to-charge ratio of ions. Comparing the data gathered from the mass spectrometer against a list of known compounds based on their mass, VOCs and their concentration can be identified.

GC-MS equipment is very expensive, and the method is time-consuming. Analysis of a single sample can take hours. Therefore, various types of sensors have been developed for VOC detection. which are commonly cheaper, portable, programmable, and easy to use. They cannot identify VOC type but obtain data in real-time.

Electrochemical (EC) sensors

Electrochemical cells are low-cost, low-power, compact sensors. EC sensors must be optimized for the target VOC of interest because each VOC requires a different bias voltage for the best sensitivity. Also, EC cells respond in about 30 seconds, in comparison with one-to-two seconds for photoionization detectors. Their lifetime is limited. Nevertheless, electrochemical sensors are suitable for some applications, where cost is important and performance characteristics are known.

Photoionization Detectors (PID)

Photoionization detectors respond to most VOCs except for small hydrocarbons such as methane, and some halogenated compounds. Each VOC has a characteristic ionization potential and the peak photon energy generated in a detector depends on the PID lamp (xenon, krypton, or argon) used. The choice of the lamp is dictated by the likely VOCs to be measured, lamp lifetime considerations, and the sensitivity and level of selectivity required.

Users of PID instruments should be aware of the variety of responses between different VOCs. They have been calibrated against isobutylene but will respond to a wide range of VOCs at varying degrees of sensitivity. According to US Federal Remediation Technologies Roundtable materials [3], PID sensors exhibit the following additional limitations:

- Not suitable for the detection of semi-volatile compounds.
- May give false positive readings for water vapor.
- High humidity can cause lamp fogging and decreased sensitivity.
- High concentrations of methane can hinder performance.
- Rapid variations in temperature at the detector, strong electrical fields, and naturally occurring compounds, such as terpenes in wooded areas, may affect instrument response.
- The PID must be re-calibrated frequently.
- Detection limits for most PIDs are in the parts per million range. Thus, they are unsuitable for most vapor intrusion indoor air investigations, where screening or action levels are normally in the parts per billion range.

Heated Metal Oxide Sensors (HMOS)

Metal oxide sensors are compact and the least expensive option. But the catalytic element of the instrument has a limited lifespan. They require more power than electrochemical sensors.

Humidity sensitivity and baseline drift are all characteristics of HMOS sensors [4]. HMOS are not as sensitive at low concentrations, compared with PIDs [5]. They must be adjusted regularly (approximately once a month). Gasoline vapors or compounds containing silicone in the test environment could impair the instrument. HMOS sensors also respond to high concentrations of some inorganic gases such as NO, NO2, SO2, H2, and CO. However, HMOS sensors cannot be used to monitor CO because they are not sensitive enough to meet safety requirements.

HMOS may be a more suitable technology than PID in applications requiring the measurement of halogenated VOCs. HMOS are non-selective sensors. Their sensitivity to various gases can differ by order of magnitude [6].

Conclusion

A common drawback of all consumer-grade VOC sensors is their variable sensitivity to different gases. They do not produce quantitative data. Because of the relative nature of the sensor output, the accuracy of the VOC sensor cannot be defined. (By definition, accuracy is the variation from an absolute measurement.) At the current development stage of technology, it is not possible to have a generic, universal VOC sensor. Such a product, if not optimized for specific, predefined conditions, would be senseless as the cost would be prohibitive to the general public.

However, one should remember that the root problem to address is chemical pollution of the indoor air. There are other methods to maintain the quality of ventilation, quantitative CO2 concentration measurement being the most widely recognized, see e.g., [7]. Non-dispersive infrared (NDIR) technology delivers the optimum between price, range, accuracy, stability, and lifespan.

References

1. Encyclopedia of Toxicology, 2nd ed. (2005) Philip Wexler, editor-in-chief. Elsevier.
2. Wallace L.A. (1989) J. American College of Toxicology 8(5), 883.
   doi: 10.3109/10915818909018049.
3. FRTR Field Sampling and Analysis Technologies Reference Guide. Available at:
   https://frtr.gov/site/toc.html (Accessed: November 2, 2022).
4. Müller G. and Sberveglieri G. (2022) Chemosensors, 10, 171.
   doi: 10.3390/chemosensors10050171.
5. Chen Y. et al. (2021), ACS Omega 6(2), 1216.
   doi: 10.1021/acsomega.0c04340.
6. Ponzoni A. et al. (2017) Sensors 17, 714.
   doi: 10.3390/s17040714.
7. Lowther S.D. et al. (2021) Environments 8, 125.
   doi: 10.3390/environments8110125.