Indoor Air Quality and Volatile Organic Compounds

Experts in Environmental Sensing

SENSIRION
THE SENSOR COMPANY

Summary

People spend 90% of their time indoors where concentrations of gaseous pollutants are significantly higher than outdoors. The widespread use of new products and building materials, as well as improved insulation for energy efficiency, has resulted in increased concentrations of volatile organic compounds (VOCs). These VOCs originate mainly from paints and solvents, carpets and furniture, and cleaning agents, and are also emitted by humans. Elevated VOC levels can have a negative impact on well being, comfort, and cognitive abilities. Exposure to high levels of VOCs can be avoided or significantly reduced by regular ventilation, air purification and removal of strong VOC sources. The Total VOC (TVOC) concept has been established as a practical time and cost-effective method of surveying indoor environments for contamination. Sensirion's multi-pixel gas sensor SGP enables measurement of TVOC levels and thus helps to increase the efficiency of ventilation and air purification, and increases awareness of VOC sources and indoor air pollution.

What Are VOCs?

The widespread use of new products and building materials has resulted in increased concentrations of indoor pollutants, in particular volatile organic compounds (VOCs). Nowadays, most people spend more than 20 hours per day indoors where VOC concentrations are more than five times higher than outdoor concentrations[1]. VOCs originate from a number of different possible sources, like building materials, tobacco smoke, people and their activities, and indoor chemical reactions. Exceptionally high VOC levels are typically found in new buildings or after renovation. Further, when using products that contain VOCs, such as air fresheners or cleaning agents, people expose themselves and others to high pollutant levels that can persist long after the activity has finished. VOCs include a wide range of chemical compounds, the most common of which are listed in **Table 1** below.

Typical VOC Sources	Compound Class	Example Compounds
Cleaning agents	Aliphatic hydrocarbons, organochlorides	Tetrachloroethylene
Solvents	Aliphatic and aromatic hydrocarbons	Heptane, decane, toluene, xylene
Cosmetics	Terpenes, ketones	Eucalyptol, limonene
Consumer products	Terpenes, aromatic hydrocarbons	Limonene, α-Pinene, toluene
Carpets and flooring	Esters, aliphatic and aromatic hydrocarbons	Butylacetate, heptane
Paints	Alcohols, aldehydes	Isobutanol
Human occupants		Acetone, methanol, ethanol

Table 1 *Typical indoor VOCs and their sources[2]*

[1] *EPA – the total exposure assessment methology (TEAM) study (1987), Saarela et al., Atmosph. Environ. 37, 5563 (2003)*
[2] *See e.g. Kataoka et al. – Chap. 9 in Mass Spectrometry, Advanced Gas Chromatography - Progress in Agricultural, Biomedical and Industrial Applications (2012)*

Potential Health Effects of High VOC Concentrations

SENSORY IRRITATION

A number of systematic human exposure studies have shown various adverse health effects caused by exposure to elevated VOC levels[3]. Among the effects reported by participants are dryness and irritation of the eye, the nose and the throat, headaches, and dizziness.

COGNITIVE ABILITIES

Poor indoor air quality can lead to decreased cognitive function resulting in significant impacts on productivity, learning, and safety. Recent studies have demonstrated clear negative effects of elevated VOC levels on cognitive abilities such as strategic thinking and decision making[4].

SICK BUILDING SYNDROME

The sick building syndrome[5] includes a variety of health and comfort effects associated with the time spent in buildings with, among other factors, elevated VOC levels. Symptoms of the sick building syndrome include headaches, mucous membrane irritation, asthma-like symptoms, skin irritation and dryness.

Steps to Reduce VOC Levels

VENTILATION

Regular ventilation is an effective way to reduce exposure to VOCs. This can be done either by an automatic demand-controlled ventilation system equipped with suitable sensors, or by natural ventilation through open windows and doors.

SOURCE CONTROL

Most national governmental bodies provide guidelines and recommendations on avoiding and removing VOC sources in indoor environments[6].

AIR PURIFICATION

Air cleaning devices equipped with suitable filters are an effective way to reduce the concentration of VOCs in indoor air, in particular in locations where ventilation with outside air is not appropriate.

[3] *Molhave, Indoor Air 4, 357 (1991), Kjaergaard et al. Atmosph. Environ. 25a, 14 17- 1426 (1991), Otto et al, Neurotoxicol. Teratol., 12, 649 (1990)*
[4] *Allen et al., Environ. Health Perspect. 124, 805 (2016)*
[5] *Godish, T.: Sick Buildings – Definition, Diagnosis and Mitigation, Boca Raton: Lewis Publishers (1995)*
[6] *See e.g., https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality*

The Benefits of Measuring VOCs

An effective reduction of VOC exposure requires the monitoring of VOC levels using suitable sensors. A large number of applications such as ventilation controls, air purifiers, or Internet-of-Things devices benefit from the integration of VOC sensors.

CREATE AWARENESS

Indication of the total VOC levels helps people to better understand their living environment and to identify possible sources of indoor air pollutants; for example, monitoring of air quality with a baby cam.

MAKE DEVICES SMARTER

Enable the operation of autonomous devices; for example, automatic operation of an air purifier.

MAKE DEVICES ENERGY EFFICIENT

Save energy by operating ventilation and air purification devices only when needed; for example, demand-controlled ventilation.

Guidelines for VOCs and the TVOC Concept

The term total VOC (TVOC) refers to the total concentration of VOCs present simultaneously in the air. The TVOC concept is used as a practical time and cost-effective method of surveying indoor environments for contamination. Global consensus has resulted in the emergence of guidelines for TVOC standards of indoor air quality (IAQ) issued by governmental organizations in different countries (e.g. Australia, Finland, Germany, Hong Kong, Japan). Recommended TVOC levels of IAQ that are considered acceptable range from 0.6 to 1 mg/m^3. The German Health Department defines TVOC levels as shown in **Table 2**. The TVOC levels and the corresponding recommendations are based on the results of a large number of controlled exposure studies that established a relationship between increased TVOC levels and adverse health effects.

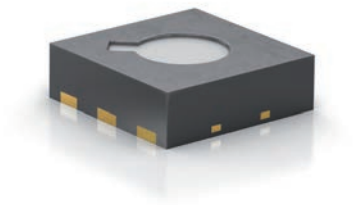
Level	Hygienic Rating	Recommendation	Exposure Limit	TVOC [ppb]
5 Unhealty	Situation not acceptable	Use only if unavoidable / Intense ventilation necessary	hours	2200 – 5500
4 Poor	Major objections	Intensified ventilation / airing necessary Search for sources	< 1 month	660 – 2200
3 Moderate	Some objections	Intensified ventilation / airing recommended Search for sources	< 12 months	220 – 660
2 Good	No relevant objections	Ventilation / airing recommended	no limit	65 – 220
1 Excellent	No objections	Target value	no limit	0 – 65

Table 2 *TVOC guidelines issued by the German Federal Environmental Agency*[7]

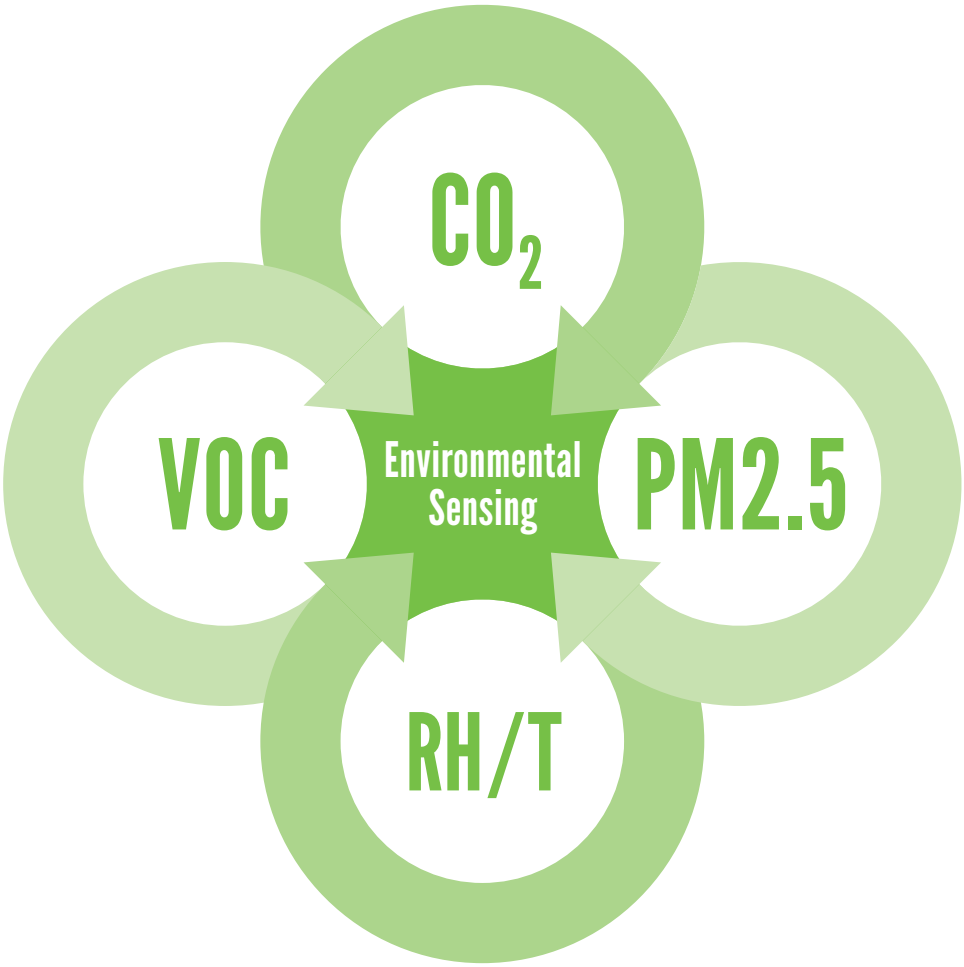
[7] *Bundesgesundheitsbl - Gesundheitsforsch - Gesundheitsschutz 2007, 50:990–1005: Beurteilung von Innenraumluftkontaminationen mittels Referenz- und Richtwerten*

Sensirion's Environmental Sensor Solutions

With the SGP, Sensirion provides a metal-oxide-based VOC sensor for indoor air quality applications. The sensing element features an unmatched robustness against contaminating gases present in real-world applications. This enables a unique long-term stability and low drift. The SGP features a TVOC and CO_2 equivalent signal via an I^2C interface, a small DFN package (2.45 x 2.45 x 0.9 mm^3), and a dust and water protection membrane. These characteristics make the SGP easy to integrate into a large variety of applications such as air purifiers or smart home devices.



Sensirion's sensor solutions provide detailed and reliable data on further key environmental parameters such as humidity, temperature, particulate matter (PM2.5), and CO_2. Sensirion's portfolio of environmental sensors opens up numerous possibilities to create smarter devices that improve our comfort and well being, and increase energy efficiency in various applications.



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