Indoor Air Quality (IAQ)

Technical Overview of Volatile Organic Compounds

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Overview

Organic chemical compounds[1] are everywhere in both indoor and outdoor environments because they have become essential ingredients in many products and materials.

- Outdoors, VOCs are volatized or released into the air mostly during manufacture or use of everyday products and materials.
- Indoors, VOCs are mostly released into the air from the use of products and materials containing VOCs.

VOCs are of concern as both indoor air pollutants and as outdoor air pollutants. However, the emphasis of that concern outdoors is different from indoors. The main concern indoors is the potential for VOCs to adversely impact the health of people that are exposed. While VOCs can also be a health concern outdoors, EPA regulates VOCs outdoors mainly because of their ability to create photochemical smog under certain conditions.

Although the same term "VOC" is used for both indoor and outdoor air quality, the term is defined differently to reflect its predominant concern in each context. This has created a misunderstanding in the marketplace and in the environmental community. In addition, the measured quantity and composition of VOCs in the air can vary significantly depending on the measurement methods used, which has generated additional confusion.

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General Definition and Classifications

Volatile organic compounds (VOC) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates and ammonium carbonate, which participates in atmospheric photochemical reactions, except those designated by EPA as having negligible photochemical reactivity[2].

Volatile organic compounds, or VOCs are organic chemical compounds whose composition makes it possible for them to evaporate under normal indoor atmospheric conditions of temperature and pressure[3]. This is the general definition of VOCs that is used in the scientific literature, and is consistent with the definition used for indoor air quality. Since the volatility[4] of a compound is generally higher the lower its boiling point temperature, the

volatility of organic compounds are sometimes defined and classified by their boiling points.

For example, the European Union uses the boiling point, rather than its volatility in its definition of VOCs.

A VOC is any organic compound having an initial boiling point less than or equal to 250° C measured at a standard atmospheric pressure of 101.3 kPa.[5, 6, 7]

VOCs are sometimes categorized by the ease they will be emitted. For example, the World Health Organization (WHO) categorizes indoor organic pollutants as:

- Very volatile organic compounds (VVOCs)
- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)

The higher the volatility (lower the boiling point), the more likely the compound will be emitted from a product or surface into the air. Very volatile organic compounds are so volatile that they are difficult to measure and are found almost entirely as gases in the air rather than in materials or on surfaces. The least volatile compounds found in air constitute a far smaller fraction of the total present indoors while the majority will be in solids or liquids that contain them or on surfaces including dust, furnishings and building materials.

Classification of Inorganic Organic Pollutants (adapted from WHO[8])

Description	Abbreviation	Boiling Point Range (°C)	Example Compounds
Very volatile (gaseous) organic compounds	VVOC	<0 to 50-100	Propane, butane, methyl chloride

Volatile organic compounds	VOC	50-100 to 240-260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal
Semi volatile organic compounds	SVOC	240-260 to 380-400	Pesticides (DDT, chlordane, plasticizers (phthalates), fire retardants (PCBs, PBB))

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EPA Regulatory Definition of VOCs that Impact Photochemical Oxidation in Outdoor Air

Background

In the United States, emissions of VOCs to the outdoors are regulated by EPA mostly to prevent the formation of ozone, a constituent of photochemical smog. Many VOCs form ground-level ozone by “reacting” with sources of oxygen molecules such as nitrogen oxides (NOx), and carbon monoxide (CO) in the atmosphere in the presence of sunlight. However, only some VOCs are considered “reactive” enough to be of concern. VOCs that are non-reactive or of negligible reactivity to form ozone under these conditions are exempted from the definition of VOCs used by EPA in its regulation. Since first establishing the list of exempt compounds in 1977, the EPA has added several to the list, and frequently has several petitions for additional compounds undergoing review. In addition, some states have their own definitions and lists of exempted compounds. Thus, for regulatory purposes, the specific definition of VOCs outdoors can change by what is excluded from that definition.

Misunderstanding and Confusion about VOCs

EPA formerly defined the regulated organic compounds in outdoor air as "Reactive Organic Gases" (ROG). This terminology clarified its meaning as being limited to reactive chemicals. However, EPA later changed that terminology to "VOC". Unfortunately, the use of the term "VOC" rather than ROG has created a misunderstanding when applied to indoor air quality. Many individuals and organizations, including manufacturers of building materials and products, and third party certification organizations have come to think of VOCs as "only those regulated by EPA for outdoor air", and apply the same definition for indoor air purposes.

To the extent that some exempted compounds impact the health of exposed individuals indoors, the definition of VOCs regulated for outdoor air has the potential to create serious misconceptions for indoor air quality, therefore, such VOCs should not be excluded from consideration for indoor air. For example, methylene chloride (paint stripper), and perchloroethylene (dry cleaning fluid), are exempted compounds for outdoor regulation, but they could pose serious health risks to exposed individuals if present indoors. The first is listed by the International Agency for Research on Cancer (IARC) as a potential human carcinogen and the second is listed as a probable human carcinogen. Indoor VOCs react with the indoor ozone[9] even at concentrations below public health standards. The chemical reactions produce sub-micron sized particles and harmful by-products that may be associated with adverse health effects in some sensitive populations.

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Classifications of VOCs

When discussing indoor environments, all organic chemical compounds that can volatize under normal indoor atmospheric conditions of temperature and pressure are VOCs. While the demarcation line between the Very Volatile Organic Compound (VVOC), Volatile Organic Compound (VOC) and Semivolatile Organic Compound (SVOC) classifications (see table above) is somewhat arbitrary, it does show the wide range of volatility among organic compounds.**The three classifications are all important to indoor air, and are all considered to fall within the broad definition of indoor volatile organic compounds.** Other than volatility (or boiling point) no other criteria are used to define VOCs indoors.

Measurement for VOC in Indoor Air

Knowledge about the VOCs that are present at low concentrations normally found in indoor air. in any given situation is highly dependent on how they are measured. All available measurement methods are selective in what they can measure and quantify accurately, and none are capable of measuring all VOCs that are present. For example, benzene and toluene are measured by a different method than formaldehyde and other similar compounds. The range of measurement methods and analytical instruments is large and will determine the sensitivity of the measurements as well as their selectivity or biases. This is why any statement about VOCs that are present in a given environment needs to be accompanied by a description of how the VOCs were measured so that the results can be interpreted correctly by a professional. In the absence of such a description, the statement would have limited practical meaning.

Labeling of Products

It is important for consumers to understand that information on labels or other product literature with broad claims about environmental impact using terms such as “green” or “environmentally friendly” may or may not include some of the VOCs emitted from the product, and therefore may not otherwise consider their adverse health effects.

There are, however, national and international programs that certify and label products and materials based on their indoor air quality impacts such as various human health and comfort effects including odor, irritation, chronic toxicity, or carcinogenicity. Such programs are likely to include consideration of at least some of the VOCs of concern for indoor air. However, the norms and requirements currently used within the product labeling and certification industry for indoor products are not standardized. The government or third-party organization has not yet established the ground rules to craft consistent, protective standard test methods to rate and compare products and materials. This lack of standardization makes it difficult for the consumer to fully understand what the labels and certifications mean in most cases.

Some VOC labels or certification programs are based on the VOCs emitted from the product into the indoor environment and possible related health impacts. However, some are based on the content of VOCs that are

regulated to control the formation of photochemical smog outdoors. Therefore VOC labels and certification programs may not properly assess all of the VOCs emitted from the product, including some chemical compounds that may be relevant for indoor air quality. This is especially true of most wet products, such as paints or adhesives that may be labeled as “low-VOC” or “zero VOC”.

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Conclusion

Reducing the concentration of VOCs indoors and outdoors is an important health and environmental goal. However, it is important to understand that there are VOCs of concern indoors and outdoors that do not impact photochemical oxidation and therefore are not regulated by EPA (42 U.S.C. §7401 et seq. (1970)). It is important to make and understand this distinction when advocating or using strategies to improve indoor air quality. For indoor air quality, ALL organic chemical compounds whose compositions give them the potential to evaporate under normal atmospheric conditions are considered VOCs and should be considered in any assessment of indoor air quality impacts.

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References

1. An organic compound is any of a large class of chemical compounds whose molecules contain carbon. For historical reasons, a few types of compounds such as carbonates, simple oxides of carbon and cyanides, as well as the allotropes of carbon, are considered inorganic. The division between "organic" and "inorganic" carbon compounds is useful, but may be considered somewhat arbitrary.
2. Code of Federal Regulations, 40: Chapter 1, Subchapter C, Part 51, Subpart F, 51100. EXIT accessed 8 February 2009, and EPA's Terms of Environment Glossary, Abbreviations, and Acronyms.
3. Normal indoor atmospheric conditions of temperature and pressure used here refers to the range of conditions usually found in buildings occupied by people. Thus, depending on the type of building and its

geographic location, the temperatures could be from the mid-30s (in Fahrenheit degrees) to the 90° F range and the pressure could be from sea level to the elevation of mountains where buildings might be located. This is not to be confused with "Standard Temperature and Pressure," often used in analysis and presentation of scientific studies, but defined variously by different authorities. The most used, although not universally adopted, definitions are those of the International Union of Pure and Applied Chemistry (IUPAC) and the National Institute of Standards and Technology (NIST). IUPAC's standard is a temperature of 0° C (273, 15 K, 32° F) and an absolute pressure of 100 kPa (14.504 psi), NIST's definition is a temperature of 20° C (293, 15 K, 68° F) and an absolute pressure of 101.325 kPa (14.696 psi).

4. Volatility is indicated by a substance's vapor pressure. It is a tendency of a substance to vaporize or the speed at which it vaporizes. Substances with higher vapor pressure will vaporize more readily at a given temperature than substances with lower vapor pressure.
5. "Directive 2004/42/CE of the European Parliament and the Council" EUR-Lex. European Union Publications Office. Retrieved on 2007-09-27.
6. 101.3 kPa = 1 atmosphere, the normal pressure at sea level.
7. 250° C = 482° F
8. World Health Organization, 1989. "Indoor air quality: organic pollutants." Report on a WHO Meeting, Berlin, 23-27 August 1987. EURO Reports and Studies 111. Copenhagen, World Health Organization Regional Office for Europe.
9. Indoor ozone concentrations may be affected by the amount of ozone emitted indoors by office equipment such as photocopies and laser printers, as well as by outdoor ozone introduced indoors either by the infiltration or by the air.

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