What's that smell!? VOCs and the facilities manager

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The emergence of green buildings and the emphasis on occupant health and wellbeing are two of the main reasons that many in the property and construction industry know what volatile organic compounds (VOCs) are, and why their importance is no longer ignored.

Although many product manufacturers, architects, builders and sustainability managers have considered VOCs for a while, other important building stakeholders, such as tenants and facilities managers, are recognising their importance and their effect on day-to-day operations. Furthermore, as the definition and understanding of sustainability grows and matures from a simple focus on energy efficiency to a more holistic 'triple bottom line' approach, the importance of VOCs and material selection will continue to expand.

The World Health Organization defines VOCs as organic compounds with boiling points between 50 degrees Celsius and 260 degrees Celsius, excluding pesticides. The term encompasses a very large and diverse group of compounds containing carbon, with several thousand synthetic and naturally occurring chemicals that could fall into the category of a VOC. Importantly, over 900 VOCs have been identified in indoor air. Some common VOCs within the built environment, and their sources, can be seen in Table 1 (sourced from Health Canada).

Table 1: Commonly encountered VOCs and their sources

Chemical	Source
Acetone	Paint, coating, finishes, paint remover, thinner, caulking compound
Aliphatic hydrocarbons (e.g. octane, decane, undecane, hexane, isodecane, mixtures)	Paint, adhesive, gasoline, combustion sources, liquid process, photocopier, carpet, linoleum, caulking compound
Aromatic hydrocarbons (e.g. toluene, xylenes, ethylbenzene, benzene)	Combustion sources, paint, adhesive, gasoline, linoleum, wall coating
Chlorinated solvents (e.g. dichlorom ethane or methylene chloride, trichloroethane)	Upholstery and carpet cleaner or protector, paint, paint remover, lacquers, solvents, correction fluid, dry-cleaner clothes
n-Butyl acetate	Acoustic ceiling tile, linoleum, caulking compound
Dichlorobenzene	Carpet, moth crystals, air fresheners
4-Phenylcyclohexene (4-PC)	Carpet, paint
Terpenes (limonene, a-pinene)	Deodorisers, cleaning agents, polishes, fabrics, fabric softener, cigarettes

Volatile organic compounds can be present within a wide range of building materials, including paint, adhesives, flooring materials, ceiling tiles, chairs, workstations and other products. While the content of a material is important, so too is the emission rate of

the product; that is, the amount of VOCs that are emitted from the material over a period of time. As such, content is generally measured according to percentage by weight of volatile organic compound (%w/w), whereas emission rate is calculated by measuring concentrations over a set period of time, as micrograms per square metre per hour (µg/m^2/hr). In a field setting, such as a commercial office building, there are two main methods for determining the level of VOCs within the indoor air. Field equipment, such as that based on photo ionisation, whilst sensitive for specific compounds, is not suitable for IEQ-VOC assessment and cannot identify individual chemicals. The key practical method is to draw a known amount of air through an adsorption tube, which is then analysed by a certified laboratory for total VOC and individual chemicals.

Importantly for the facilities manager and human resources, the World Health Organization recommends that the sum of VOCs within the indoor environment be less than or equal to 500 micrograms per cubic metre (µg/m^3), with no individual chemical contributing more than 250µg/m^3. This should be considered when implementing strategies relating to materials selection of new fit-outs, cleaning, maintenance regimes, and staff occupancy.

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The importance of materials selection

Materials selection refers to the selection of a material (or product) based on a number of performance and cost factors. In its simplest form, it can consist of selecting an end-use appropriate base material (for example, paint, polymer, metal, mineral). In more complex cases, it can extend to selecting an approved product range for a major building project in order to meet requirements that may include:

- sustainability requirements (environmentally sustainable materials)
- indoor air quality (IAQ) or indoor environmental quality (IEQ) standards and voluntary product performance schemes (for example, Green Star, NABERS)
- industry requirements (for example, food, auto, chemical, pharmaceutical)
- life cycle analysis (LCA).

Materials selection is one of the most overlooked, but most important, factors in building and product design because it can have a significant effect on:

- total cost of the product, in situ, for the various stakeholders
- performance of the product, in situ
- indoor environmental quality of the facility
- product stewardship
- repair
- litigation.

Table 2. Typical chemical emissions from fit-out items

Fit-out material	Total VOC emission ($mg/m^2/hr$)
Natural wood	0.2 – 0.5
Coated wood	<0.1
Steel/aluminium	<0.01
Plastic	<0.05 – 0.2
Upholstery fabric	<0.05 – 0.2
Solvent-based glue	5
Water-based glue	<0.05

Having conducted VOC emissions and content testing on building materials and products for over 20 years, Foray Laboratories Pty Ltd, a NATA-accredited subsidiary of CETEC, has established a database of emission results for over 1000 different products. Interestingly, there are some differences that can be seen between the use of local Australian products and products developed overseas. For example, vinyl produced in Australia has been shown to have a typical VOC emission rate of 0.05 to 0.20 $mg/m^2/hr$, in contrast to non-Australian vinyl typically emitting 4 $mg/m^2/hr$, or 20 times that of the Australian variants. Some examples of the VOC emission levels for various building materials are listed in Table 2. Often sealants and adhesives are hidden, and professional help is needed to determine the source of offending VOCs.

Voluntary product performance schemes and regulation

In Germany, Scandinavia and South Korea, there are regulations relating to the acceptability of building products for indoor use. Similar regulations do not exist in Australia; however, voluntary product performance schemes exist in order to drive a market change to sustainable and healthy building products. Some of these voluntary schemes include the following:

- Green Building Council of Australia's Green Star
- Australasian Furnishing Research and Development Institute's Green Tick
- Carpet Institute of Australia's Environmental Certification Scheme
- Ecospecifier's Global Green Tag
- Good Environmental Choice Australia's Ecolabel
- Carpet and Rug Institute's Green Label Plus.

Methods of measuring the VOC emissions or content from materials in accordance with the voluntary schemes listed above will obviously differ due to the differing requirements of the schemes. For example, some emissions tests are required to be carried out in a chamber for the period of 24 hours, while others may require testing for 7, 14, or 28 days. Within schemes, some tests, such as those for adhesives and sealants, will require an analysis of VOC content only, while others will require additional analyses of VOC emissions. They also differ in the range of VOCs that are analysed. For example, the stringent Green Label Plus scheme requires identification and quantification of numerous 'chemicals of concern', such as formaldehyde, acetaldehyde, benzene, caprolactam, 2-ethylhexanoic acid, 1-methyl-2-pyrrolidinone, naphthalene, nonanal, octanal, 4-phenylcyclohexene, styrene, toluene, and vinyl acetate.

Importantly, a wide range of Green Star tools have credits relating to indoor environment quality, which includes VOCs. This credit encourages product suppliers, designers and specifiers to use low-VOC emitting materials. By doing so, the project team can achieve additional Green Star credits (one point each) by using low VOC products for:

- paints
- carpets (or other flooring materials)
- adhesives and sealants.

Innovation and development continues to occur within voluntary schemes. For example, in the emerging Green Star Healthcare tool, there is a requirement for mattresses specified in the project to be low-emitting for VOCs. Furthermore, a research project by Cundall recently looked at how green rating systems in Australia had created positive changes within the industry. Interestingly, the green rating systems have not only reduced the environmental impact of products and materials in buildings, but also the accountability and transparency of their green credentials.

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Case Study 1: When material selection goes wrong: a Melbourne commercial office building

A flooring system was installed in a highly rated commercial office building in Melbourne's central business district. Several months after the installation, a significant odour was present, affecting the ability of the remaining unoccupied tenancies to be occupied, as well as an entire floor deciding to walk out of the office, citing nausea, respiratory irritation, and headaches. Facilities management was given the task of 'fixing' the problem, and CETEC's resulting investigation found that while airborne VOC concentrations within the indoor environment were acceptable (less than the 500$\mu g/m^2/hr$ criteria), the major contributing compound to this total count was toluene, a well-known solvent used in the manufacture of flooring systems, and one that is known to affect occupational asthma, dizziness, headaches, and nausea symptoms.

A further investigation, specifically on the flooring system (as opposed to the airborne results) found that levels exceeded the standard total VOC limit of 500 $\mu g/m^2/hr$ by almost 200 per cent, and the major chemical identified was toluene. The air concentrations were lower than those directly sampled from the carpet and adhesive, due to high air exchange rates from the air conditioning

system, but there was still an offensive odour. Given the disruption to occupation and the risk to occupant health, the facilities manager had no choice but to remove the flooring system, causing financial burden to the building owner, as well as the existing tenants.

Case Study 2: When materials selection goes wrong: a residential flooring system

The owner of a newly built two-storey residence contracted a builder to apply a finish to the timber floorboards throughout the residence. A low-VOC finish was specifically requested, but concern was raised after occupation that this was not applied. This was evidenced by occupant complaints, including dizziness and nausea up to a few months afterwards, which resulted in additional investigations.

Our investigations identified that poor material selection had resulted in airborne VOC concentrations of 2000 µg/m^2/hr on the ground floor, and 4000 µg/m^2/hr on the first floor of the residence. A breakdown of these emissions identified a high concentration of xylenes, as well as di- and tri-substituted benzenes in particular. These concentrations were respectively seven and four times greater than the current occupational guidelines recommended by the WHO. Xylenes are known to contribute to health effects including irritation, discomfort, lack of muscle coordination, dizziness, and headaches. Out of this list, health effects including dizziness and headaches were experienced by the occupants during these months of high exposure.

While this case study identifies VOC emission issues relating to materials selection within a residential property, it can easily be compared and extended to that of an office environment, where the effect on occupant health, wellbeing, and productivity would have had a greater financial impact.

Implications for facilities managers

When occupants become sick or when they decide that they can no longer work in an environment with a 'strange chemical smell' (like the two case studies presented in this article), it can obviously have wide-ranging implications for the operations of the business. These can vary from financial to marketing/branding and even human resources. As the person often responsible for maintaining a high performing and healthy indoor environment, the facilities manager has an important role in establishing the source of poor indoor air quality issues, particularly those resulting from high VOCs in the indoor environment, remediating the issue as soon as is possible, and maintaining the indoor air quality so that the health and wellbeing of occupants is maximised. FP

Please note: This article does not aim or intend to determine a source for elevated results presented within any case studies, nor does it intend to imply the suitability of any one material. The case histories are presented within the theme of this materials selection paper to illustrate practical examples of the impact of materials emissions. The data presented in this paper should be considered to be dynamic, since clients, regulators, manufacturers and administration bodies influence continuous improvement in product performance.

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