Measurement of Chemical Emissions from Building Products

SUBBALAKSHMI YERRAMILLI,
CETEC Pty. Ltd.,
Lakshmi.Yerramilli@cetec-foray.com.au

ROBERT SCHILLER,
CETEC Pty. Ltd.,
Robert.Schiller@cetec-foray.com.au

RENEÉ DOWNIE,
CETEC Pty. Ltd.,
Renee.Downie@cetec-foary.com.au

VYT GARNYS,
CETEC Pty. Ltd.,
Vyt.Garnys@cetec-foray.com.au

People generally spend as much as 90 percent of their time indoors and therefore, the condition of indoor air has a vital impact in human health. Today, buildings are designed to be airtight to save energy, resulting in less fresh air intake and a general build up of pollutants in the indoor environment. The overall quality of indoor air is influenced by thermal acceptability and air contaminants.

Many researchers have investigated the volatile organic compounds (VOCs) within new and established buildings. With established buildings the total volatile organic compound (TVOC) concentrations though low are higher than found in outdoor air. However, much higher VOC concentrations can be detected in new or renovated buildings, persisting above "baseline" levels for several weeks. Indeed up to 96% of VOCs found in large office buildings following construction had resulted from materials used to construct and furnish the building.

The World Health Organisation defines VOCs as organic compounds with boiling points between 50°C and 260°C, excluding pesticides. The term encompasses a very large and diverse group of carbon-containing compounds. There are probably several thousand chemicals, synthetic and natural, that can be called VOCs. Of these, over 900 have been identified in indoor air. Some of the most commonly encountered ones and their sources are listed in Table 1.

Formaldehyde, another VOC, can also be found inside buildings as it can be used to manufacture building materials, fabrics, cleaning fluids and numerous other household products; e.g. composite wood (MDF, plywood) such as panelling and furniture, foam insulation, textiles and adhesives.

The health effects of exposure to VOCs including formaldehyde in the non-industrial indoor environment range from sensory irritation at low/medium levels of exposure to toxic effects at high exposure levels. The latter may include neurotoxic, organotoxic and carcinogenic effects. In general, the responding tissues are mucous membranes of the eyes, nose and throat, skin on the face, neck and hands, and the upper and lower airways. The health, well-being and productivity of occupants can be affected by the presence of VOCs/formaldehyde in a building and lead to the issue of Building Related Illness.

In Germany and South Korea regulations exist for the acceptability of building products for indoor use. However, there are no regulations in Australia. Instead organisations formed to drive the adoption of "green building" practice; e.g. Green Building Council of Australia, have provided guidelines for the emissions of VOCs and formaldehyde from building materials. Industry Associations have followed (e.g. Carpet Institute of Australia) with the development of environmental certification schemes that include the consideration of material emission limits. Architects are now universally requiring certified sustainable products.

Chemical	Source
Acetone	Paint, coatings, finishers, paint remover, thinner, caulking
Aliphatic hydrocarbons (octane, decane, undecane hexane, isodecane, mixtures, etc.)	Paint, adhesive, gasoline, combustion sources, liquid process photocopier, carpet, linoleum, caulking compound
Aromatic hydrocarbons (toluene, xylenes, ethylbenzene, benzene)	Combustion sources, paint, adhesive, gasoline, linoleum, wall coating
Chlorinated solvents (dichloromethane or methylene chloride, trichloroethane)	Upholstery and carpet cleaner or protector, paint, paint remover, lacquers, solvents, correction fluid, dry-cleaned 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)	Deodorizers, cleaning agents, polishes, fabrics, fabric softener, cigarettes

Table 1 *Commonly Encountered VOCs and Their Sources*[1]

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1 Fisk et al (2003), University of California
2 Seppänen et al (2006), Helsinki University of Technology

The emerging trend is that building material suppliers are required to provide documentation of their product's conformance to material emissions limits in order for the product to be used in a building.

CETEC is a consulting company which provides a broad range of scientific services[2] and specializes in evaluating the chemical emissions from materials, especially building products and their impact upon the indoor environment. In the present paper we describe the methodology used to test the chemical emissions from various products used in the construction, finishing and furnishing of buildings. Generic data is presented to compare and assess against recognised compliance criteria.

Methodology

Chemical emissions from building materials are collected using the technique of small scale environmental chambers for testing chemical emissions from indoor materials/products[3]. A schematic diagram is shown in Figure 1. CETEC is able to test samples derived from item of the individual components used in a larger assembled item.

An electropolished stainless steel chamber is used to contain a test specimen. The product/material loading is maintained at 0.5-1.0 m^2/m^3. Purified air generation is circulated through the chamber (23 $^oC \pm 0.5^oC$, 50%±5%RH) to capture the chemical emissions from the test specimen, which are then trapped onto specialised absorbent media. The chemical emissions are collected for a specified period e.g. for 1 day, 7-day, 14 days or 28 days.

VOCs and formaldehyde emissions are typically collected, but the facility is not limited to these compounds. VOCs are measured by gas chromatography mass spectrometry whereas formaldehyde can also be determined by high performance liquid chromatography. The output of the test is the determination of the material emission rate – milligrams of VOC per square metre per hour.

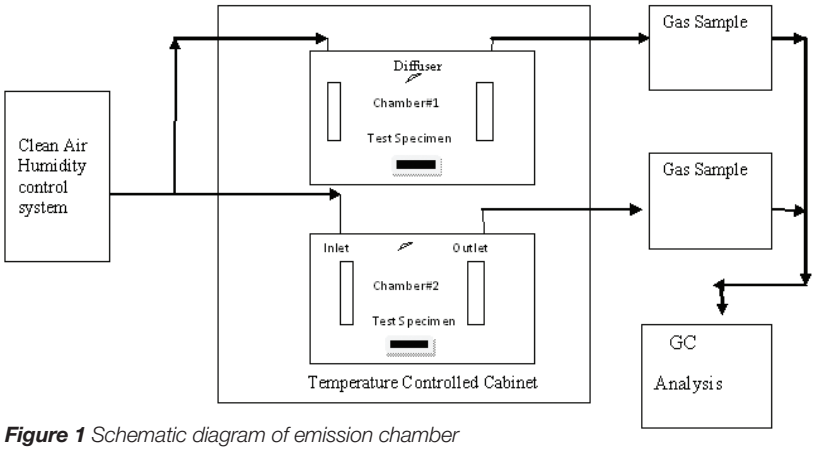

Figure 1 *Schematic diagram of emission chamber*

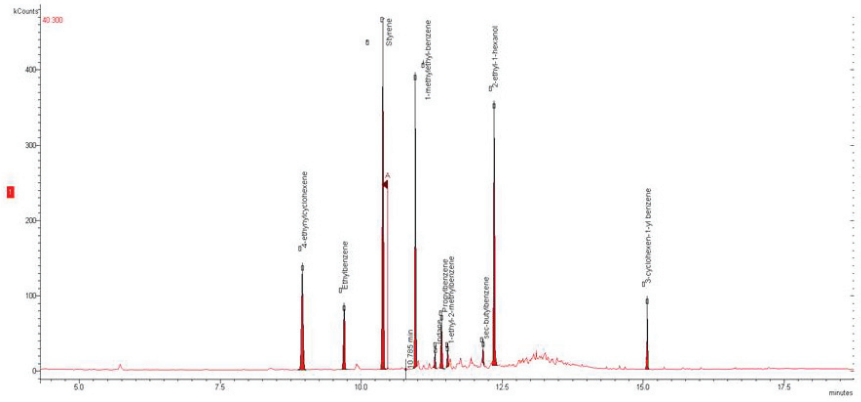

Figure 2 Total ion chromatogram showing TVOC emissions collected from a carpet. Note styrene is a major component. In addition, 2-ethyl- 1-hexanol and other aromatic and aliphatic hydrocarbons were also detected.

Analysis Results

In the last few years CETEC has been actively assessing a wide range of materials used in buildings. This has enabled manufacturers/suppliers to obtain emission data for their product to demonstrate compliance with relevant criteria. As that same time CETEC has established a VOC emission "fingerprint" bank of various building materials that is used in CETEC's indoor air quality investigations.

Figure 2 shows a representation of total ion chromatogram of TVOC emissions collected from a carpet product. Those VOCs that would be expected to be released from this type of material, can be identified e.g. styrene from the backing material.

Table 2 shows some typical values for building products currently used in Australian buildings. In most cases the guideline requirement is to have less than 0.5 milligrams per square metre per hour at 24 hours or seven days depending on the product. This guideline requirement has been established through organisations such as Green Building Council of Australia via the "Green Star" building rating scheme. Such guideline requirements have evolved into defacto regulations or architectural requirements for the acceptability of a product for use in a building.

Most Australian manufactured building materials meet the acceptance criteria. Over the last few years TVOCs and formaldehyde levels have been reduced to satisfactory levels. As well the interpretation of the product "fingerprint" shows the material emissions to contain compounds at their no observed adverse effect level. There could be scope to reduce acceptance criteria for some classes of products and thereby further control the potential indoor air concentrations generated.

Building materials originating from non-Australian sources can show levels of chemical emissions above the acceptance criteria. As well there is the potential for compounds with known toxic effects to be present. Non-Australian manufacturers would appear not to be as diligent in seeking to minimise the indoor air quality impact of their product.

Feedback is provided to manufacturers/ suppliers of building product about the

Application	Material	Typical Chemical Emission mg/m^2/hour	Criteria Acceptance mg/m^2/hour
Flooring	Carpet (Australian)	0.1 – 0.3 TVOC	<0.5 24 hours
		0.04 – 0.01 4-PC	<0.05 24 hours
	Carpet (non-Australian)	0.2 – 0.7 TVOC	<0.5 24 hours
		0.04 – 0.01 4-PC	<0.05 24 hours
	Vinyl (Australian)	0.05 – 0.2	<0.5 24 hours
	Vinyl (non-Australian)	4	<0.5 24 hours
	Rubber	0.5 - 2	<0.5 24 hours
	Cork	0.1 – 0.4	<0.5 24 hours
Fit-Out			
	Plasterboard	<0.05 – 0.2 TVOC	<0.5 7 days
		<0.02 Formaldehyde	
	Cement Sheet	0.02 – 0.1 TVOC	<0.5 7 days
		0.01 – 0.04 Formaldehyde	
	MDF	0.1 – 0.3 TVOC	<0.5 7 days
	Plywood	0.1 – 0.3 TVOC	<0.5 7 days
	Particleboard	0.1 – 0.3 TVOC	<0.5 7 days
	High Pressure Laminate	<0.05 TVOC	<0.5 7 days
	Bamboo	<0.05 TVOC	<0.5 7 days
		0.1 Formaldehyde	
	Ceiling Tile	0.1 – 0.4 TVOC	<0.5 7 days
		<0.01 – 0.05 Formaldehyde	
	Fibreglass Insulation	0.05 – 0.2 TVOC	<0.5 24 hours
		<0.03 Formaldehyde	
	Polyester Insulation	<0.05 TVOC	<0.5 24 hours
		<0.01 Formaldehyde	
	Rubber Insulation	0.1 – 0.5	<0.5 24 hours
Furniture Items			
	Natural Wood	0.2 – 0.5 TVOC	<0.5 7 days
	Foam	0.1 – 0.6 TVOC	<0.5 7 days
	Steel/Aluminium	<0.01 TVOC	<0.5 7 days
	Oil-Based Glue	5 TVOC	<0.5 7 days
	Water-Based Glue	<0.05 TVOC	<0.5 7 days
	Plastic (PP, PE, ABS, PVC)	<0.05 – 0.2 TVOC	<0.5 7 days
	Stone/Marble	<0.01 TVOC	<0.5 7 days
	Fabric	0.05 – 0.2 TVOC	<0.5 7 days

Table 2 Typical chemical emission from building product/ material.

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(continued)

← indoor health impact of their product as it relates to TVOCs, VOC species and Formaldehyde.

The data collected from testing building products has been used to conduct risk assessments of particular structures (e.g. modular buildings) in regards to indoor air quality. CETEC has provided an indication if the structure as designed will present a low risk to occupants or if material substitutions should be undertaken to reduce the occupant exposure risk.

Conclusions

A variety of building products have been tested for chemical emissions utilizing a recognised standard method. Recommended guideline limits for the emission of VOCs and Formaldehyde has been established by non-Government organisations. Most tested product had chemical emissions that satisfactory met these guideline limits. The results have allowed end user to sell, market, and design or research ecologically sustainable building products.

Acknowledgement

We acknowledge here the technical assistance provided by Zheng Fei Chen from Melbourne University to carry out emission tests at CETEC in his part time capacity.

References

1. **www.hc-sc.gc.ca**
2. **www.cetec-foray.com.au**
3. ASTM D 5116: Standard guide for small-scale environmental chamber determinations of organic emissions from indoor materials/products.