

Indoor air quality in Australian buildings

Poor indoor air quality (IAQ) can be a significant health, environment and economic problem, and has become a public health issue and liability for employers and building managers who fail to provide a 'safe' working environment.

The meaning of IAQ is often interpreted differently across disciplines, but this report uses a broad definition for IAQ, which is 'the totality of attributes of indoor air that affect a person's health and well-being'. IAQ measures must therefore determine how well indoor air (a) satisfies thermal and respiratory requirements, (b) prevents unhealthy accumulation of pollutants, and (c) allows for a sense of well-being.

Research has established the occurrence of a range of building-related illnesses, many with identifiable and diverse causes (e.g. asbestos-related diseases, legionnaires' disease, humidifier fever, passive tobacco smoke, respiratory illnesses from unflued fuel combustion appliances). A subset of illnesses – termed the 'sick building syndrome' (SBS) – includes mainly subjective symptoms (mild irritation of eyes, nose and throat, headaches, lethargy). SBS symptoms are believed to arise from multiple causes, which, while not clearly understood, are associated mainly (but not exclusively) with air-conditioned office buildings. Australian studies have been limited, but indicate a similar occurrence to other developed countries for building-related illnesses, SBS-like symptoms and dissatisfaction with office air environments. A large number of pollutants have been investigated in Australian buildings, some in great detail, but for others few observations are available. A

summary of the pollutants, their major sources and the available control measures is presented in Table 1. Many of these pollutants have not been sufficiently researched to determine exposure levels for the Australian population or the most appropriate strategies to reduce exposure.^{1,2}

Major indoor air pollutants (those of indoor origin) typically occur at much higher concentrations than found outdoors, or are completely different pollutants from those outdoors. Unless they are permanent gases such as carbon monoxide and carbon dioxide, pollutants that originate outdoors generally reach indoors at much reduced concentrations due to deposition losses as the outdoor air is mechanically moved or infiltrates through gaps into buildings. Examples here are fine particles and ozone. If these pollutants do not arise indoors, prevention of unacceptable exposures requires limitations on outdoor rather than indoor levels. However, many indoor pollutants reach elevated concentrations compared with outdoor levels, because of their emission from multiple sources and the restrained ventilation conditions indoors (even if ventilation is acceptable to building codes). Thus, the occupants are exposed to much higher concentrations (and longer exposure times because we spend 90% of our time indoors) for such indoor air pollutants.

In Australia, the more significant IAQ pollutants are considered to be:

- environmental tobacco smoke, house dust mites and nitrogen

dioxide (all from observation of high indoor levels)

- respirable particulate matter, microbiologicals and volatile organic compounds including formaldehyde (on the basis of their potential for reaching high indoor levels under specific conditions).

High levels of environmental tobacco smoke have been found in recreational buildings, as conventional mechanical ventilation systems are not capable of removing this pollutant, even when these systems comply with standards' requirements. House dust mite allergen levels are very high in residences from coastal areas and may present a particular health problem for Australia. High nitrogen dioxide concentrations have been found in many residences and schools with unflued gas heaters, and there is an estimated 600 000 of such heaters across Australia (the exception being Victoria where unflued natural gas heaters have effectively been prohibited in residences and schools for decades). While heater rectification programs have commenced for government schools in New South Wales, a vast number of these heaters are used with little control in many States and Territories.

Sectors of the population differ markedly in their sensitivities to pollutants. Infants and children are more vulnerable to respiratory illnesses associated with environmental tobacco smoke, house dust mites and gas combustion products such as nitrogen dioxide. Asthmatics are sensitive to a variety of pollutants that act as inducers and

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Table 1 Pollutants measured in Australian buildings (goals specifically referred to are NHMRC goals; see <http://www.health.gov.au/nhmrc/publications/pdfcover/aircover.htm>)

Pollutant	Indoor concentration range	Major sources	Control
Asbestos fibres	<0.002 f/mL	Friable asbestos products	Risk management, removal
Radon: Conventional dwellings	99.9% < goal of 200 Bq/m ³	Soil under building	Siting of building
Radon: Earth-constructed dwellings	~9% > goal of 200 Bq/m ³	Background radiation of earth walls	Material selection
Environmental tobacco smoke (ETS)	High in recreational buildings	Cigarette smoke	Prohibition of smoking, designated smoking area
Respirable particulate matter	Poorly characterised	ETS, cooking, fuel combustion	Poorly characterised
<i>Legionella</i> spp.	30% of population exposed	Water cooling towers	Maintenance, site selection
House dust mites	10–40 µg/g Der pI allergen in house dust	Allergen build-up in bedding, carpet, furniture	Removal of habitats, humidity control
Microbiological species	100s to 18 000 CFU/m ³	Moist/damp surfaces	Control moisture/mould
Formaldehyde: Conventional buildings	< goal of 100 ppb (1–3 day average)	Reconstituted wood-based products	Source emission control, ventilation
Formaldehyde: Mobile buildings	100–1000 ppb, exceeding goal	Reconstituted wood-based products	Source emission control, ventilation
Volatile organic compounds (VOC): Established buildings	Total VOC < goal of 500 µg/m ³	'Wet' synthetic materials (adhesives, paints), office equipment, printed matter, furniture	Source emission control, ventilation
Volatile organic compounds (VOC): New buildings	Total VOC 2000–20 000 µg/m ³	As above	As above
Pesticides	Limited data, median <5 µg/m ³	Major sources unknown	Floor structure, clean-up, inspection
Nitrogen dioxide	Up to 1000 ppb	Unflued gas heaters and stoves	Source emission control, flued appliances
Carbon monoxide	~10% > goal of 9 ppm	Unflued gas heaters and stoves	Source emission control, flued appliances
Carbon dioxide	Poorly characterised	Exhaled air	Ventilation to standards
Ozone	Poorly characterised	Office equipment, ozone deodorisers	Source emission control, ventilation

triggers. The question of multiple chemical sensitivity and the possible influence of indoor air pollutants is a matter of debate. The protection of sensitive sectors of the population is considered appropriate when selecting IAQ indicators for residential, health and educational building categories. Indicators for other building categories should consider the likely access to them by sensitive sectors of the population.

IAQ is primarily a function of the pollutant sources and their pollutant emission strengths, the ventilation rate, moisture and odour control, and interior materials that act as sinks (a material that adsorbs the pollutant from the air to later release

it when indoor pollutant levels are diminishing). From an environmental and economic standpoint, it is preferable to limit the use of sources of indoor air pollution before they cause IAQ problems. The two major pressures on IAQ are:

- (restrained) building ventilation rates
- (high) emission from pollutant sources.

Data on ventilation rates in Australian buildings are limited, but indicate that ventilation rates have become lower in residential buildings constructed in recent years and may be low in mechanically ventilated buildings constructed to the low ventilation codes of the

1980s. Design, operation and maintenance of mechanical ventilation systems may all contribute to poor IAQ and all need to be addressed for IAQ control. Improved ventilation methods and codes are being introduced in other countries, but their adoption in Australia has been slow. Even with improved ventilation, there remains the need to control emissions from high-polluting source materials. In most developed countries, this is now being achieved through voluntary or mandatory schemes to identify low-emission building materials, furniture and appliances. Development of similar schemes in Australia has been slow.³

Regulatory actions related to IAQ are limited, especially compared with regulation of outdoor air quality and industrial workplace air – a feature also common overseas. While some guidance has been provided by authorities such as the National Health and Medical Research Council (NHMRC) and the National Occupational Health and Safety Commission (NOHSC), there is a need for a more structured approach for evaluation and control of IAQ. A severe limitation is the absence of a single government authority with responsibility for IAQ, though in recent years Environment Australia's Air Toxics program and the enHealth Council have given general guidance on IAQ control.^{2,4} Harmonisation of occupational standards and environmental guidelines is desirable in order to clarify their roles in different indoor environments. Development of improved ventilation codes, voluntary reduction of pollutant emissions from manufactured products, and improved public education should be used to improve IAQ, but have been adopted to only a limited extent in Australia.

The following IAQ indicators (and their critical sources where applicable) were recommended¹ for IAQ assessment and control:

- comfort indicators
 - thermal comfort criteria
 - optimal humidity range 40–60% RH
 - occupant symptom questionnaire⁵
- ventilation indicators
 - concentration of carbon dioxide under steady-state conditions: residences <1000 ppm, commercial buildings <800 ppm
 - operation of mechanical ventilation system to AS1668-1992 air supply requirements
- source indicators
 - asbestos fibres: applicable codes and regulations for hazard assessment of products

- radon: measure for earth-constructed residences or habitable basements
- environmental tobacco smoke: use nicotine or respirable particulate matter (RPM) as indicators for areas with heavy smoking; use combustion-derived particulates⁶ for all smoking levels
- respirable particulate matter: compare to National Environmental Protection Measure (NEPM) for PM_{2.5}
- *Legionella* spp.: use applicable codes and regulations, applied retrospectively
- house dust mite: measure allergens in dust to determine if below 10 percentile level for particular area
- microbiologicals: moist or damp surfaces, with or without visible growths present, are unacceptable; no presence of confirmed pathogens or toxigenic fungi in air or surface samples
- formaldehyde: measure in new buildings or caravans and mobile buildings with other than small usage of reconstituted wood-based products
- volatile organic compounds: a total VOC concentration above 500 µg/m³ indicates significant presence of sources; determine concentrations of carcinogens and irritants if potential sources are present
- pesticides: measure concentrations if visible residues are found or if building has 'leaky' floor, especially for post-construction application of termiticides
- nitrogen dioxide: measure concentrations in all buildings (but particularly residences, schools and hospitals) where unflued gas appliances are used (particularly heaters)
- carbon monoxide: measure concentrations in all buildings with unflued gas heaters (particularly

residences, schools and hospitals) and in enclosed parking sites

- ozone: measure concentrations in rooms with heavy use of electrostatic photocopiers, laser printers and other sources, and at outlets from ozone-based air sterilisers.

In conclusion, IAQ is:

- not a simple factor-based relationship to outdoor air
- related to multiple pollutants, pollutant sources and ventilation strategies within buildings
- capable of affecting occupant health and well-being
- poorly controlled in Australia by industry or government, especially compared with current overseas practice.

References

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