Australian Building Codes Board Indoor Air Quality Handbook – Review and Update

https://consultation.abcb.gov.au/engagement/indoor-air-quality-handbook-review-and-update/

Consultation Response by A/Prof Robyn Schofield, School of Geography, Earth and Atmospheric Sciences, University of Melbourne.

Indoor gas cooking and heating installations

Need for mandated rangehoods and flues to exhaust air to outside as well as mandated IAQ monitoring for public buildings

There should be a requirement if combusting for cooking or heating within a building that the air is exhausted externally – to remove PM, NOx and CH_4. Lebel et al., 2022[1] show that even without having the gas ovens operating significant levels of methane leakage inside buildings occurs (3/4 of domestic methane emissions are from gas oven installations is from leaking while not operating) – this constitutes a large health and climate risk in buildings. When operating under usual cooking circumstances, emissions of 21.7 [range: 20.5 - 22.9] ng NO_x J^{-1} is being produced and the 1 hour US standard of 100 ppb (Australia's 1 hour NEPM NO_2 standard is 80 ppb) is surpassed in minutes - when there is no exhausting of air to outside.

Current kitchen building codes allow gas cooktops to be installed without consideration or requirement to exhaust the air containing fumes/gases to outside. i.e. rangehood products such as https://www.bunnings.com.au/bellini-60cm-white-slimline-rangehood_p0195633 just recirculate the cooking fumes and gases, such as NOx, back into the room.

Installation of gas ovens and gas cooktops should only be possible with mandated outside exhausting rangehood installation, and an education program on the dangers of cooking with gas in unventilated kitchens should be undertaken.

Installation of gas heaters and cooking (i.e. whenever gas in piped through a building) within public buildings requires that VOCs, $PM_{2.5}$, CO and NO_2 are monitored for IAQ purposes.

Mercury

Mercury is not currently a criteria outdoor air pollutant, but its production and use is now controlled under the Minamata convention on Mercury (ratified by Australia in 2021).

Reporting under the Minamata convention for Australia will now follow reporting requirements expected of all Parties (who ratified after the 2013 adoption) – i.e. conducting

[1] **Lebel, E. D.**, Finnegan, C. J., Ouyang, Z., and Jackson, R. B. (2022). Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*. DOI: 10.1021/acs.est.1c04707

full life-cycle analyses of mercury use. Coal power stations in Japan are noted to emit 1.3t of Hg per year to the air, and 0.75 t of Hg within coal fly ash is used in cement production[2]. Australia coal electricity generators emitted 1.8t of Hg in 2020/2021 to the air (NPI[3]), without quantities (or quality) of coal fly ash used in Australia building construction being reported, it is conceivable that a similar quantities areis being used here in Australia i.e. 0.75t of Hg is ending up in cement in the building sector. Exposed cement in buildings (i.e. carparks) could potentially represent a large mercury (and other heavy metals) source to the air and water ways. A review study of fly ash leeching by Kurda et al.[4], notes that "avoiding the use of Fly Ash concrete for drinking water tank and architectural concrete applications." A Fly Ash white paper notes: "California's Collaborative for High-Performance Schools (CHPS) has put limits on the mercury content for fly ash in concrete under their green building rating system, and the recently released LEED™ for Healthcare also has a credit that limits mercury levels in supplemental cementitious materials" – this should be considered here in Australia also[5]. There are no regulation protections in Victoria or Western Australia on the toxic composition of fly ash, NSW has protective legislation which AGL noted some of its products exceeded which caused their withdrawal of fly ash products from the market[6].

US EPA calculated mercury exposure for a room constructed with fly-ash concrete[7] to be 100 ngm^{-3} (for reference background outside air mercury levels[8] are ~1 ngm^{-3}). US EPA (in 2001) concluded this is considered 'safe' because it is lower than the US EPA reference standard (also established in 2001[9] and not revised since the Minamata convention 2013) of 300 ngm^{-3}. These values are certainly well below the Australian workplace 8-hour standard[10] for exposure to mercury of 0.003 parts per million (0.025 mg/m^3 or 25,000 ngm^{-3} which is extra-ordinarily high). Indoor air levels generally range from 2 -10 ngm^{-3} in a recent, well conducted study in Basel[11].

WHO 2021[12] provides an updated guideline of a tolerable concentration of 0.2 µg/m³ (200 ng/m³) for long-term inhalation exposure to elemental mercury vapour. This represents 200 times outdoor mercury concentrations in Australia, and would be indicative of serious indoor ventilation / emission issues representing an intolerable indoor health risk. IAQ standards should adopt 200 ng/m³ as a reference standard for Hg(0) in air.

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[2] https://www.mercuryconvention.org/sites/default/files/documents/submission_from_government/Japan_Article14.pdf (accessed 8 September 2022)

[3] National Pollution Inventory: mercury emission to air from electricity generators http://www.npi.gov.au/npidata/action/load/emission-by-source-result/criteria/destination/ALL/industry-source/261/substance/55/source-type/INDUSTRY/subthreshold-data/Yes/substance-name/Mercury%2B%2526%2Bcompounds/year/2021

[4] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5968176/

[5] https://assets.ctfassets.net/t0qcl9kymnlu/1Tx57nRsWYYMEC824CkOaI/38239c5e0fb2044af10bc2b1fac38cf8/FlyAsh_WhitePaper.pdf`

[6] https://www.envirojustice.org.au/wp-content/uploads/2019/06/EJA_CoalAshReport.final_.pdf

[7] https://www.epa.gov/sites/default/files/2014-12/documents/ccr_bu_eval.pdf

[8] Schofield, R, et al. 2021. Atmospheric mercury in the LatrobeValley, Australia: Case study June 2013. Elem Sci Anth,9: 1. DOI:https:// doi.org/10.1525/elementa.2021.00072

[9] Carpi, A.; Chen, Y. Gaseous elemental mercury as an indoor air pollutant. *Environ. Sci. Technol.* **2001**, *35*, 4170– 4173, DOI: 10.1021/es010749p

[10] https://www.dcceew.gov.au/environment/protection/npi/substances/fact-sheets/mercury-compounds

[11] Wohlgemuth, L., et al., *Environ. Sci. Technol. Lett.* 2020, 7, 4, 234–239

[12] https://www.who.int/publications/i/item/9789240023567

Asbestos

Indoor air within buildings without specific asbestos sources have concentrations generally below 1000 Fibres/m^3; with rural / clean urban having just 10-30 Fibres/m^3 (counted via electron microscopy)[13]. For comparison the current Australian workplace TWA for Asbestos[14] is 0.1 f/ml or 10,000 Fibres/m^3.

"Asbestos is a proven human carcinogen (IARC Group 1). No safe level can be proposed for asbestos because a threshold is not known to exist. Exposure therefore should be kept as low as possible." [12]

Any elevations of Asbestos within buildings above outside air levels is therefore intolerable. 200 Fibres/m^3 is considered a high urban exposure level. Construction workers can experience 1000-10000 Fibres/m^3 (but will have appropriate PPE made available to them).

Indoor air quality within buildings should be investigated and mitigated when inside air Asbestos levels exceed 200 Fibres/m^3 – particularly in sensitive settings such as childcare, schools, and healthcare.

[13] https://www.euro.who.int/__data/assets/pdf_file/0015/123072/AQG2ndEd_6_2_asbestos.PDF
[14] https://www.safeworkaustralia.gov.au/system/files/documents/1912/workplace-exposure-standards-airborne-contaminants.pdf

Suggested Health based Guideline Indoor Air Quality Standards for Public Buildings

Public Buildings such as Schools, Universities, Sports facilities are Class 9b buildings under the Australian Building code[15]

[15] The Building code of Australia has the following classes of buildings:
Class 1 – Houses or dwellings of a domestic or residential nature
Class 2 - Apartment buildings
Class 3 - A residential building, other than a Class 1 or 2 building, which is a common place of long term or transient living for a number of unrelated persons.
Class 4 - Part of a building that is a dwelling or residence within a non-residential building (Class 5 to 9), such as a caretaker's residence in a hospital.
Class 5 - Office buildings for professional and/or commercial purposes
Class 6 - Shops, restaurants and cafés
Class 7 - Buildings including carparks, warehouses or storage buildings
Class 8 - Factories—buildings used for production, assembling, altering, repairing, finishing, packing, or cleaning of goods or produce.
Class 9 - Public buildings - with three sub-classifications:

- **class 9a** - healthcare buildings such as hospitals and day surgery clinics
- **class 9b** - buildings where people assemble for social, political, theatrical, religious or civic purposes, e.g. churches, schools, universities, sports facilities, night clubs
- **class 9c**—aged care facilities.

Class 10 - Non-habitable buildings or structures. This class includes three sub classifications:

- **class 10a**—non-habitable buildings including sheds, carports, and private garages.
- **class 10b**— structures such as fence, mast, antenna, retaining wall, swimming pool
- **class 10c**—private bushfire shelter associated with, but not attached to, a class 1a building.

Pollutant	**Existing Current Recommendations**	**WHO[16,17]**	**Recommended Indoor Air Threshold Guidelines for Public buildings[18]**	**Australian Occupational exposure limit (2019)[19]** TWA – Time Weighted Average STEL – Short Term Exposure Limit
Carbon Dioxide CO_2	ASHRAE 62.1 – 1000ppm AS 1668.2 for mechanical ventilation control – 600-800 ppm NCC IAQ design standard – 850ppm Review of All IAQ Standards[20]: <750-1000ppm = Good; >1500 ppm = Poor		• 1500 ppm 15 minute maximum (99th percentile limit) • 800 ppm (1 hour average)	TWA - 5000 ppm (8 hours) STEL – 30000 ppm (15 minutes)
Carbon Monoxide CO [1 ppm = 1.145 mg/m^3]	NEPM – 9 ppm NCC (Class 9b): • 90 ppm (15 minute average) • 50 ppm (30 minute average) • 25 ppm (1 hour average) • 10 ppm (8 hour average)	100 mg/m^3 (87.3 ppm) 15 minute average 35 mg/m^3 (30.5 ppm) 1 hour average 10 mg/m^3 (8.7 ppm) 8 hour average 4 mg/m^3 (3.5 ppm) 24 hour (99th percentile limit)	• 90 ppm (15 minute average) • 50 ppm (30 minute average) • 25 ppm (1 hour average) • 9 ppm (8 hour average)	TWA - 30 ppm (8 hours)

[16] World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO

[17] https://www.euro.who.int/__data/assets/pdf_file/0009/128169/e94535.pdf

[18] Where conversion required: the general equation is $\mu g/m^3$ = (ppb)*(12.187)*(M) / (273.15 + °C); using 25°C and 1013.25hPa.

[19] https://www.safeworkaustralia.gov.au/doc/workplace-exposure-standards-airborne-contaminants-2019

[20] Lowther,S.D.; Dimitroulopoulou, S.; Foxall, K.; Shrubsole, C.; Cheek, E.; Gadeberg, B.; Sepai, O. Low Level Carbon Dioxide Indoors—A Pollution Indicator or a Pollutant? A Health-Based Perspective. *Environments* **2021**, *8*, 125. https://doi.org/10.3390/ environments8110125

Nitrogen Dioxide NO_2 [1 ppb = 1.88 µg/m^3]	NEPM: • 80 ppb Averaged over 1 hour • 15 ppb Averaged over 1 year NCC: • 40 µg/m^3 (0.0197 ppm) Averaged over 1 year; and • 200 µg/m^3 (0.0987 ppm) Averaged over 1 hour	200 µg/m^3 (106.3 ppb) 1 hour averaging time 25 µg/m^3 (13.3 ppb) 24 hour (99th percentile limit) 10 µg/m^3 (5.3 ppb) Averaged over 1 year	• 80 ppb 1 hour maximum (99th percentile limit) • 13 ppb 24 hour / daily maximum (99th percentile limit) • 5 ppb Averaged over 1 year	TWA - 5.6 mg/m^3 (3 ppm) (8 hours) STEL - 9.4 mg/m^3 (5 ppm) (15 minutes)
Ozone O_3 [1 ppb = 2.00 µg/m^3]	NEPM - Outdoor: • 0.065 ppm Averaged over 8 hours NCC - 100 µg/m^3 (50.0 ppb) 8 hour daily maximum limit Indoor levels known to be 10-50% of outdoor due to deposition onto surfaces[21]	100 µg/m^3 (50.0 ppb) 8 hour daily maximum (99th percentile limit) 60 µg/m^3 (30.0 ppb) 6 month average of 8 hour daily maximum (99th percentile limit)	• 50 ppb - 8 hour daily maximum (99th percentile limit)	TWA - 0.2 mg/m^3 (0.1 ppm) Peak limit (8 hours)
Sulfur Dioxide SO_2 [1 ppb = 2.62 µg/m^3]	NEPM: • 100 ppb Averaged over 1 hours • 20 ppb Averaged over 1 day NCC – None listed	500 µg/m^3 (190 ppb) 10 minute averaging time 40 µg/m^3 (15 ppb) 24 hour (99th percentile limit)	• 190 ppb 10 minute averaging time • 100 ppb 1 hour averaging time • 15 ppb 24 hour (99th percentile limit)	TWA - 5.2 mg/m^3 (2 ppm) (8 hours) STEL - 13 mg/m^3 (5 ppm) (15 minutes)
Lead Pb	NEPM: • 0.50 µg/m^3 1 year average	0.50 µg/m^3 1 year average	• 50 µg/m^3 (8 hours) • 0.15 µg/m^3 3 month average	TWA - 50 µg/m^3 (8 hours)

[21] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1626413/

	• US EPA[22]: 0.15 µg/m^3 (3 month average) • NCC - 100 µg/m^3 (50.0 ppb) 8 hour daily maximum limit			
Particulate Matter less than 10 µm PM_{10}	NEPM: • 25 µg/m^3 averaged over 1 year • 50 µg/ m^3 averaged over 1 day NCC: • 20 µg/m^3 averaged over 1 year • 50 µg/ m^3 24 hour (99th percentile) limit	• 15 µg/m^3 averaged over 1 year • 45 µg/m^3 24 hour (99th percentile) limit	• 15 µg/m^3 averaged over 1 year • 45 µg/m^3 24 hour (99th percentile) limit	No current recommendations
Particulate Matter less than 2.5 µm $PM_{2.5}$	NEPM: • 8 µg/m^3 averaged over 1 year • 25 µg/ m^3 averaged over 1 day NCC: • 10 µg/m^3 averaged over 1 year • 25 µg/ m^3 24 hour (99th percentile) limit	• 5 µg/m^3 averaged over 1 year • 15 µg/m^3 24 hour (99th percentile) limit	• 5 µg/m^3 averaged over 1 year • 15 µg/m^3 24 hour (99th percentile) limit	No current recommendations
Elemental Mercury Hg(0)	No current recommendation	200 ng/m^3	• 200 ng/m^3 (1 hour averaging time)	25,000 ngm^{-3} TWA (8 hours)

[22] https://www.govinfo.gov/content/pkg/FR-2008-11-12/pdf/E8-25654.pdf

Nickel	No current recommendation	25 ng/m³ (annual average)	• 25 ng/m^3 (1 year averaging time)	25,000 ngm^{-3} TWA (8 hours)
Cadmium	No current recommendation	5 ng/m³ (annual average)	• 5 ng/m^3 (1 year averaging time)	25,000 ngm^{-3} TWA (8 hours)
Arsenic	No current recommendation	6.6 ng/m³ (annual average)	• 6.6 ng/m^3 (1 year averaging time)	25,000 ngm^{-3} TWA (8 hours)
Total Volatile Organic Compounds TVOC	NEPM – Xylene, Toulene, PAH and Benzene all have independent investigation limits[23]: Benzene – 3 ppb (annual average) Toulene – 1 ppm 24h average Xylene – 250 ppb 24h average BaP – 0.3 ng/m³ (annual average) NCC – TVOC 500 µg/m^3 (250.0 ppm) 8 hour daily maximum limit	Benzene[24] – No safe limit - threshold 1.7 µg/m³ Benzo(a)pyrene BaP[24] – threshold 0.012 ng/m³	• TVOC: 500 µg/m^3 (250.0 ppm) 8 hour daily maximum limit • Toulene – 1 ppm 24 hour average • Xylene – 80 ppb 8 hour average • Benzene – 1.7 µg/m^3 • Benzo(a)pyrene BaP – 0.12 ng/m^3	Benzene - TWA 3.2 mg/m^3 (8 hours) Xylene - TWA 80 ppm (8 hours)
Formaldehyde HCHO	NEPM (investigation level)[2] – 40 ppb 24h average	0.1 mg/m^3 (80.1 ppb[26]) Averaged over 30 minutes	• 80 ppb 30 minute average • 40 ppb 24 hour average	TWA - 1 ppm (8 hours) STEL - 2 ppm (15 minutes)

[23] https://www.legislation.gov.au/Details/F2011C00855
[24] No safe limit threshold values for 1/1,000,000 risk of excess lifetime cancer risk
[26] https://www.ncbi.nlm.nih.gov/books/NBK138711/

	NCC - 0.1 mg/m^3 (80.1 ppb[25]) Averaged over 30 minutes			
Asbestos and < 1% crystalline silica	No current recommendation	No safe limit. 200 Fibres/m^3 is a high urban exposure.[13]	• 200 Fibres/m^3	0.1 f/ml or 10,000 Fibres/m^3
Radon	Arpansa[27, 28]: • 200 Bqm^{-3} for households • 1000 Bqm^{-3} for workplaces EU[29]: • 300 Bqm^{-3} workplaces and dwellings IAEA[30]: • 300 Bqm^{-3} for homes • 1000 Bqm^{-3} for workplaces	100 Bq m^{-3}, but not more than 300 Bq m^{-3} for areas with high soil emissions. [31]	• 100 Bqm^{-3}	No current recommendation
Trichloroethylene	No current recommendation	No safe limit[24] - 2.3 µg/m^3	• 2.3 µg/m^3 (1 year averaging time)	54 mg/m^3 TWA (8 hours) 216 mg/m^3 STEL (15 minutes)
Tetrachloroethylene	No current recommendation	No safe limit[24] – 0.25 mg/m^3	• 0.25 mg/m^{-3}	340 mg/m^3 TWA (8 hours) 1020 mg/m^3 STEL (15 minutes)

[25] https://www.ncbi.nlm.nih.gov/books/NBK138711/
[27] https://journals.sagepub.com/doi/10.1016/j.icrp.2011.08.011
[28] https://www.arpansa.gov.au/research-and-expertise/australian-radon-action-plan
[29] https://eur-lex.europa.eu/eli/dir/2013/59/oj
[30] International Atomic Energy Agency https://www.iaea.org/sites/default/files/20/11/rasa-radon.pdf https://www-pub.iaea.org/MTCD/publications/PDF/Pub1651Web-62473672.pdf https://www.iaea.org/file/document/2018/module2radonpptx
[31] https://www.who.int/news-room/fact-sheets/detail/radon-and-health

Bioaerosols	• Pollen • Fungi • Bacteria		In cooling tower water Legionella count must be <1000 cfu/mL and the heterotropic colony count <5,000,000 cfu/mL[32]	

[32] https://www.health.nsw.gov.au/environment/legionellacontrol/Pages/legionella-taskforce.aspx