RESIDENTIAL INDOOR AIR QUALITY GUIDELINE: NAPHTHALENE

Background

Naphthalene is a two ring hydrocarbon which forms a white crystalline powder. Naphthalene has a distinct and easily detectable odour ("mothball odour"), with mean and lowest air odour thresholds of 0.44 ± 9.95 and 0.01 mg/m^3, respectively (Amoore and Hautala 1983; Devos et al. 1990). Naphthalene is a by-product of combustion of biomass and fossil fuels (Jia and Batterman 2010).

Molecular formula	$C_{10}H_8$
Molecular weight	128.17 g/mol
Vapour pressure	0.082 mm Hg at 25°C
Boiling point	217.9°C
Conversion factor	1 ppm = 5.24 mg/m^3

Sources and Concentrations in Indoor Environments

Naphthalene is present at detectable levels in residential environments and can arise from a wide array of sources, including consumer and building products such as paints, coatings, stains, solvents, adhesives, sealing products, flooring, carpeting, air fresheners, and pest control products (to kill moths and larvae) (Agency for Toxic Substances and Disease Registry 2005; Health Canada 2008).

As a product of incomplete combustion, naphthalene is emitted in cigarette smoke, during cooking, and from kerosene space heaters and wood stoves (Charles, Batterman and Jia 2007; Moir et al. 2008; Jia and Batterman 2010). Naphthalene in exhaust from vehicles and gas-powered equipment and in vapours from stored petroleum products in attached garages may infiltrate into occupied areas of the home (Marr et al. 1999; Schauer et al. 2002). Infiltration of outdoor air may also be a source of naphthalene in indoor air; however, ambient concentrations are generally lower than those found indoors.

Canadians' exposure to naphthalene is attributed predominantly to indoor air, because indoor air levels generally exceed ambient air levels, and because of the greater time spent indoors. Inhalation of indoor air was identified as the greatest source of naphthalene exposure, accounting for more than 95.0% of the total daily intake across all age groups (Government of Canada, 2008).

Median concentrations of naphthalene measured in Canadian residences range from 0.2 to 1.6 $\mu g/m^3$ and average concentrations from 0.3 to 6.3 $\mu g/m^3$ (Fellin and Otson 1994; Sanderson and Farant 2004; Zhu et al. 2005; Héroux et al. 2008; Health Canada 2010a; Health Canada 2010b; Health Canada 2012a; Health Canada 2012b). Peak concentrations can reach values one to two orders of magnitude higher.

Health Effects

Naphthalene has been shown to cause tissue damage and cancer in the nasal passages and lungs of rats and mice exposed to high levels in laboratory studies. It is considered a possible carcinogen for humans, although there is not yet sufficient evidence to prove it causes cancer in humans. Based on its potential cancer risk, and the margin between levels to which Canadians might be exposed and the critical effect level for non-cancer effects, naphthalene has been determined to meet the criteria under section 64(c) of the *Canadian Environmental Protection Act* (CEPA).

In controlled exposure studies, Fischer 344 rats exposed to naphthalene for 6 hours/day, 5 days/week for 105 weeks showed increased nasal lesions at concentrations ranging from 52 to 314 mg/m^3 (National Toxicology Program 2000; Abdo et al. 2001). There are data that indicate a potential progression of effects from tissue damage in the nasal cavities and lungs potentially leading to the development of cancer.

There are data indicating a continuum of effects for acute, subchronic and chronic cytotoxicity and cancer in the rat nasal epithelium; subacute data are lacking for the mouse nose, although similar cytotoxic effects are seen acutely and chronically (National Toxicology Program 2000). There is progression of acute to chronic lesions in the mouse lung; however, the lowest observed adverse effect levels (LOAELs) for pulmonary cytotoxicity in the mouse are higher than the rat nasal no observed adverse effect level/lowest observed adverse effect level (NOAEL/LOAELs) (West et al. 2001; Dodd et al. 2010).

There have also been reports of naphthalene exposure, from breathing it in, swallowing it or contact with skin, causing haemolytic anemia (a breakdown of red blood cells) (Dawson, Thayer and Desforges 1958; Zinkham and Childs 1958; Valaes, Doxiadis and Fessas 1963; Naiman and Kosoy 1964; Shannon and Buchanan 1982;

Ojwang, Ahmed-Jushuf and Abdullah 1985; Ostlere, Amos and Wass 1988; Owa et al. 1993; Santucci and Shah 2000; Trevisan, Di Schio and Pieno 2001; Lim, Poulose and Tan 2009). These reports primarily, but not always, involve people with glucose-6-phosphate dehydrogenase (G6PD) deficiency (a genetic deficiency that causes them to lack a specific enzyme that protects red-blood cells from naphthalene). Since there is no regular screening for this genetic condition, and there are no symptoms prior to exposure, people are unlikely to know that they have this genetic condition.

Prevention of acute and chronic nasal cytotoxicity is considered likely to prevent tumour development on chronic exposure. A short-term indoor air exposure limit was not considered necessary as a short-term reference concentration would be of a similar order of magnitude to the long-term reference concentration. Risk management measures to limit naphthalene exposure are the same for acute or chronic exposure.

Assessment under the Canadian Environmental Protection Act, 1999 *(CEPA 1999)*

Health Canada, in consultation with provincial and territorial health departments, developed a priority list of indoor air contaminants that were national in scope and required government action. Through this process, naphthalene was identified as an indoor air priority pollutant.

In 2008, under the Chemicals Management Plan, a screening assessment of naphthalene was published (Health Canada 2008). On the basis of the carcinogenicity of naphthalene, and the margin between levels to which Canadians might be exposed and the critical effect level for non-cancer effects as well as the potential inadequacy of the margin between the upper–bounding concentration of naphthalene in indoor air and the critical effect level for non-cancer effects, the screening assessment concluded that naphthalene may be entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health. Naphthalene was therefore determined to meet the criteria under section 64(c) of the *Canadian Environmental Protection Act*.

Residential Indoor Air Quality Guideline for Naphthalene

A long-term exposure limit for naphthalene in indoor air was derived based on the LOAEL of 52 mg/m^3 from studies of rats exposed to naphthalene and screened for nasal lesions (National Toxicology Program 2000). This value was then adjusted to account for the difference in the duration of exposure in the study compared to in a residence (i.e. from 6 hours/day x 5 days/week to 24 hours/day x 7 days/week). A total uncertainty factor of 1000 was applied to the LOAEL to account for database deficiencies, interspecies and intra-individual variability (10 x 10 x 10 = 1000).

The recommended long-term maximum exposure limit for naphthalene is presented in the table below, along with the critical health effects on which it was based. Exposure to indoor air concentrations above these limits may result in potential health effects. The minimum recommended sampling time is 24 hours.

Residential Maximum Exposure Limit for Naphthalene

Exposure period	Concentration µg/m^3	Concentration ppb	Critical Effects
Long-term	10	1.9	▪ Nasal lesions in rats

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