Residential Indoor Air Quality Guideline

# OZONE

## Physical and chemical properties

Ozone is a colourless gas. A strong oxidizing agent, it reacts rapidly on surfaces and with other constituents in the air.

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|---|---|
| Molecular formula | $O_3$ |
| Molecular weight | 48 g/mol |
| Melting Point | -192.7 ± 2°C |
| Boiling Point | -111.9 °C |
| Vapour pressure | 0.133 kPa @ 20°C |
| Conversion: ppb → µg/m$^3$ | 2.0 @ 20°C |

## Sources and Concentrations in Indoor Environments

Sources of ozone indoors include ozone generators (i.e., devices sold as home air cleaners that produce ozone intentionally), some other types of air cleaners that release ozone as a by-product, as well as office equipment such as printers and photocopiers. Outdoor ozone is also an important contributor to indoor ozone, depending on the concentrations outdoors and the air exchange rate with indoor environments.

Indoor concentrations of ozone in Canada are usually lower than outdoor concentrations and lower or similar to personal exposure concentrations. The formation, transport, and destruction of ozone indoors are influenced by its indoor sources, outdoor concentrations, outside air infiltration, indoor air circulation rates, and chemical reactions with other gaseous chemicals in indoor air and with surfaces.

Only one study has measured indoor ozone in a Canadian city. An exposure study in Toronto, Ontario assessed indoor, outdoor and personal ozone during summer and winter periods. Summer 12-hour daytime concentrations of ozone indoors were 7.1 ± 12.6 ppb (mean ± standard deviation), and a 95$^{th}$ percentile of 22.6 ppb. Summer 12-hour night time concentrations of ozone indoors were 6.2 ± 9.5 ppb and a 95$^{th}$ percentile of 22.4 ppb. Weekly winter concentrations of ozone indoors were 1.6 ± 4.1 ppb, while the 95$^{th}$ percentile reached 4.0 ppb (Liu et al. 1995) (Health Canada, 2010).

## Health Effects

In human controlled exposure studies, acute exposure (up to 4 hours) of healthy young adults to ozone resulted in lung function decrements, indicated by decreased forced vital capacity (FVC), forced expiratory volume in one second ($FEV_1$), and forced inspiratory volume, reduced tidal volume and increased breathing frequency. Subjective symptoms such as pain upon inhalation were also reported (McDonnell et al. 1983; Seal et al. 1993; McDonnell et al. 1993; Seal et al. 1996; Krishna et al. 1997; Liu et al. 1997). Statistically significant effects were seen at 120 ppb $O_3$, which is considered the Lowest Observed Adverse Effect Level (LOAEL) for this exposure duration (Health Canada, 2010).

The primary effects of prolonged exposure (for durations of 4 to 8 hours) to ozone in human controlled exposure studies were decreases in lung function (FVC and $FEV_1$) and increases in subjective respiratory symptoms (pain upon deep inhalation and total symptoms score).

Three recent studies assessed the effects of exposure to $O_3$ for 6.6 hours in healthy adults while performing intermittent exercise (Adams, 2002; 2003a; 2003b), and one of them (Adams, 2002) included a range of exposure levels (40, 80, 120 ppb $O_3$) enabling the assessment of a dose-response relationship. In this study, no statistically significant effects occurred at the lowest exposure level of 40 ppb $O_3$ when compared to subjects exposed to filtered air; this level is therefore considered the No Observed Adverse Effect Level (NOAEL). Statistically significant effects were seen at 80 and 120 ppb $O_3$, with decreases in pulmonary function and increases in respiratory symptoms being more important at 120 ppb than at 80 ppb $O_3$. The Lowest Observed Adverse Effect Level (LOAEL) is therefore considered to be 80 ppb $O_3$ for this exposure duration (Health Canada, 2010).

Generally, results from toxicological studies seem to be consistent with data obtained in human controlled exposure studies. However, ozone levels investigated in animal studies were usually higher than those found in Canadian residences and therefore are less useful for risk assessment.

Epidemiological studies of the population health impacts of ozone have been a key component to setting outdoor air quality standards and guidelines for more than a decade. In general, they reflect the temporal relationship between outdoor (ambient) ozone concentrations and various health endpoints, integrating the complex air quality processes that drive the formation and destruction of ozone in outdoor air, as well as factors such as individual health and behaviour that modify susceptibility and exposure. Across the range of observed ambient ozone concentrations, these studies have failed to identify a threshold for mortality as an endpoint. However, in developing indoor air quality guidelines that can be used to formulate health protective measures that modify the indoor environment, studies that relate health outcomes to individual exposure at a given point in time are of greatest importance. Therefore, controlled exposure studies of human subjects were selected as the most appropriate basis for deriving indoor reference concentrations.

For each exposure period (acute or prolonged) the studies reviewed were used to establish a reference concentration, which constitutes a value below which adverse health effects are unlikely to be seen. The reference concentration for acute exposure was calculated by taking the experimentally derived LOAEL and dividing by an uncertainty factor of 3 to extrapolate to a NOAEL, and then dividing by a further uncertainty factor of 10 to account for intraspecies variation in susceptibility to ozone. The reference concentration for chronic exposure was calculated by taking the experimentally derived NOAEL and dividing by the uncertainty factor of 10 for intraspecies variation. Reference concentrations of 8 $\mu g/m^3$ (4 ppb) $O_3$ for both acute and prolonged exposure to ozone were derived in this manner based on key controlled exposure studies (Health Canada, 2010).

### Assessment under the *Canadian Environmental Protection Act, 1999*

In 2003, ozone was declared "toxic" under the *Canadian Environmental Protection Act (CEPA), 1999* as the Science Assessment Document (SAD) for Ground-Level Ozone (Environment Canada and Health Canada, 1999) concluded that there is a significant association between ambient (outdoor) ozone and adverse health effects and that significant adverse effects to human health (mortality and morbidity) and vegetation (reduced growth and crop yield) are occurring at ozone levels currently experienced across Canada (Environment Canada and Health Canada, 2003).

## RESIDENTIAL INDOOR AIR QUALITY GUIDELINE FOR OZONE

The key human controlled exposure studies were used to determine a reference concentration, based on the observed NOAELs or LOAELs and incorporating appropriate uncertainty factors. This reference concentration serves as the basis for setting a recommended maximum exposure limit for residential indoor environments, taking into account the feasibility of achieving such a limit.

The original exposure guideline for residential indoor air quality for ozone was for a 1-hour averaged exposure limit (Health Canada, 1987). This update, however, obtained the same reference concentration for acute (2.5 hour) and prolonged (4–8 hour) exposures (Health Canada, 2010). Given the lack of 1-hour exposure data for comparison and since ozone levels are usually higher during daytime, only an 8-hour residential exposure limit for ozone is recommended at this time. This 8-hour averaged exposure period is expected to be more representative of overall exposure to ozone than a 1-hour averaged exposure.

An exposure limit based on the reference concentration for prolonged ozone exposure may not, however, be achievable in many Canadian homes. An indoor ozone exposure study conducted in Toronto, Ontario, for example, reported average summer indoor ozone concentrations that were higher than the reference concentration (4 ppb), with 12-hour daytime concentrations of 7.1 ± 12.6 ppb (mean ± SD) and 12-hour night time concentrations of 6.2 ± 9.5 ppb (mean ± SD) (Liu et al., 1995).

Health Canada therefore recommends a residential maximum exposure limit of 40 µg/m$^3$ (20 ppb) ozone, based on an averaging time of 8-hours. This exposure limit would still be half of the NOAEL derived from a controlled human exposure study (Adams, 2002), while being more realistically achievable in Canadian homes. In the Toronto indoor ozone exposure study, for example, 95% of homes were below 22.6 ppb and 22.4 ppb respectively for daytime and night time 12-hour summer indoor ozone levels (Liu et al., 1995).

**Residential Maximum Exposure Limit for Ozone**

| Exposure period | Concentration | | Critical Effect |
|---|---|---|---|
| | µg/m$^3$ | ppb | |
| 8 hours | 40 | 20 | Decreases in pulmonary function and increases in subjective respiratory symptoms |

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Cat.: H128-1/10-606E
ISBN: 978-1-100-16288-1