Canadian National Ambient Air Quality Objectives: Process and Status

Abstract

National ambient air quality objectives (NAAQOs) (Appendix 1) are the benchmark against which Canada assesses the impact of anthropogenic activities on air quality and ensures that current emission control policies are successfully protecting human health and the environment. Air quality objectives are designed to facilitate air quality management on regional scales. A new framework for ambient air quality objectives has been developed that is more scientifically defensible and accommodates the current understanding of ambient pollutant effects. Specifically, it acknowledges the continuum of receptor effects and the existence of no, or very low, threshold pollutants. This chapter describes the new framework and the process by which NAAQOs are developed.

The process of developing NAAQOs begins with a scientific assessment of dose–response relationships for receptors (human health, vegetation, animals, and aesthetic atmospheric properties), ambient exposures, and receptor risk characterization. Recently, scientific assessments have been completed for carbon monoxide, hydrogen fluoride, particulate matter, and ozone.

To support the development of the air quality objective, risk benefit analyses are performed to provide an indication of the magnitude of current and/or anticipated impacts on human health and/or the environment.

Introduction

The purpose of this chapter is to provide an overview of the new framework and process that has been developed for Canadian national ambient air quality objectives. The federal government sets national ambient air quality objectives (NAAQOs) on the basis of recommendations from the Federal–Provincial Working Group on Air Quality Objectives and Guidelines consisting of representatives from both the health and environment departments. Objectives may be promulgated by Environment Canada and/or Health Canada under the Canadian Environmental Protection Act (CEPA), Part 1, Section 8, and adopted by provincial and territorial jurisdictions for enforcement as standards. The NAAQOs are the benchmark against which Canada can assess the impact of anthropogenic activities on air quality and ensure that current emission control policies are successfully protecting human health, vegetation, materials, and/or aesthetic air quality parameters. The objectives are designed to facilitate air quality management on a regional scale.

The New Framework

The first Canadian NAAQOs were developed in the mid-1970s (Fisheries and Environment 1976) for sulphur dioxide, suspended particulates, carbon monoxide, oxidants (ozone), and nitrogen dioxide. These objectives consisted of three tiers which identified ranges of air quality designed to meet the varied needs for air quality objectives across Canada (SOE 1990).

In 1992, the Canadian Environmental Protection Act/ Federal–Provincial Advisory Committee (CEPA/FPAC) Working Group on Air Quality Objectives and Guidelines (Appendix 2) was established to review existing and develop new air quality objectives. During the review of the most recent human health and environmental effects literature, it became apparent that many air pollutants had no effect thresholds or very low effect thresholds, making it impossible to define more than one effect level. Consequently the three-tiered framework became untenable in light of the observed continuum of receptor effects. The need for a more scientifically sound framework for Canada's NAAQOs was identified.

The new NAAQOs framework for Canada is more scientifically defensible and recognizes the existence of no, or very low, threshold pollutants. The new framework specifies a scientifically determined level above which there are known effects on human health or the environment, and an air quality objective, also science based, which considers the protection of the general population and environment. The two levels areas follows.

- The **reference level** is a level above which there are demonstrated effects on human health and/or the environment. It provides a scientific basis for

establishing goals for air quality management. Reference levels are defined for all receptors for which effects information is available (human health, animals, vegetation, materials, and aesthetic atmospheric parameters). Demonstrated effects are in the area bounded by the no-observed-effect level and the lowest-observed-effect level. Recognizing that the dose–response relationship and/or concentration–response relationship may be continuous, the identification of a "demonstrated effect" may be either statistically or observationally derived.

- National ambient air quality objectives are national goals for outdoor air quality that protect public health, the environment, or aesthetic properties of the environment. They are targets for air quality, measured at relevant receptors (e.g., persons, plants, animals, materials). When an air quality objective is recommended, a rationale document summarizes the relevant scientific information, the risk assessment, and the current and anticipated exposures, and presents the explanation for the selection of the selection of the form and level of the air quality objectives.

The reference level is based on consideration of the scientific factors without regard for other factors. It is recognized that risk assessment judgments are to some extent policy judgments in which disagreements largely reflect policy values (including moral, social, economic, or other nonscientific values). Additional factors can be taken into account in selecting the air quality objective including (1) data on the public health and ecological effects (estimated risks) expressed in terms of measures of incremental impact on various endpoints (e.g., morbidity and/or mortality, transient and persistent effects on the ecosystem), at different exposure levels; (2) an expression of the confidence in the data; (3) data on current and future trends in ambient air pollutant levels; and (4) an exceedance analysis of proposed air quality objectives.

The science assessment activity is the foundation of the new framework and summarizes the most current published science available in a Canadian context. It forms the foundation from which all discussions oriented toward managing air quality proceed. The new framework recognizes that it is not feasible to protect all members of a receptor population from adverse effects of air pollution at all times. Consequently, for the selection of the air quality objective, a subjective decision based on the best information available is required.

Given the need to make subjective scientific decisions based on a broad range of scientific information to define the air quality objective, the following general concepts have been developed to guide the process (WGAQOG 1996):

1. Be consistent with the philosophy of CEPA.

2. Recognize the variable sensitivities of subgroups of the Canadian population and of particular ecosystems and organisms in the environment. Given the large range of these sensitivities, it may not be possible to protect every sensitive individual and ecosystem from all effects.

3. Provide a range of levels reflecting the range of biological responses and sensitivities, allowing for various regulatory options to accommodate regional priorities while endeavouring to maintain consistent national levels of environmental quality.

4. Be reasonable, workable, and usable, reflecting a consultative process that includes government, industry, public advocacy groups, and the Canadian public, and recognizes the importance of scientific, social, and economic considerations.

5. Be based on recognized scientific principles and include risk assessment and risk management. The scientific basis for objectives should be presented in a manner that is readily accessible to, and which can be understood by, the Canadian public.

In addition three other concepts are also considered:

1. To contribute to sustainable development through pollution prevention, an ecosystem approach, maintenance of biodiversity, and the precautionary principle.

2. To consider other sources of exposure on a chemical-specific basis to account for the quality and quantity of total exposure.

3. To follow a development and consultation process that is fully transparent.

Process

The process by which information is reviewed, evaluated, and utilized in developing air quality objective

recommendations is outlined in detail in the *Protocol for the Development of National Ambient Air Quality Objectives* (WGAQOG 1996). Briefly, the process starts with the identification of the need for an objective, followed by the scientific assessment and evaluation of receptor effects information for human health, vegetation, animals, materials, and aesthetic impacts. A reference level is derived for those receptors for which sufficient information exists to identify the concentration/dose–response relationship. The science assessment document, containing the reference level, is reviewed by external scientific peers and distributed for national stakeholder consultation.

A rationale document supporting the recommended air quality objective is prepared summarizing the science assessment document and outlining the various options considered and the incremental risk benefit assessment.

The draft rationale document is distributed for high-level national stakeholder consultation to solicit comments and input to the recommendations. Where necessary, revisions are made and the final recommendations are made to CEPA/FPAC for federal approval. The NAAQO is published in the Canada Gazette, Part 1. It is estimated that the process to review the science and recommend air quality objectives requires three to five years depending on the amount and certainty of the current scientific understanding.

Selection Criteria and Interim Recommendations

Nomination of air contaminants for review are made by the public, industry, and government agencies through various federal–provincial-stakeholder fora. Based on guidelines developed by the United Nations World Health Organization (WHO 1989), the following criteria are used to determine the need for extensive evaluation (WGAQOG 1996):

- capability of the substance to cause adverse effects on human health or the environment, where irreversible effects are of special concern;
- ubiquity and abundance of the substance in the Canadian environment, particularly in the atmosphere;
- environmental transformations to form secondary pollutants or metabolic alterations, when these alterations may lead to the production of chemicals with greater toxic potential;
- persistence in the environment, particularly if the pollutant would resist environmental degradation and accumulate in humans and food chains;
- likelihood of effects, magnitude of the population exposed, and the existence of sensitive subpopulations;
- current or potential relevance to Canada as a national concern for more than one province and/or territory, and priorities of local air quality management jurisdictions;
- appropriateness of managing the substance from a regional/airshed versus site specific approach; and
- appropriateness of managing the substance using air quality objectives, in contrast with other available or established management options.

In the event of significant scientific uncertainty or of limited information relevant to the Canadian context, the science assessment document will be completed and reference levels may be identified. Depending on the state of knowledge, an interim air quality objective or no air quality objective may be recommended. Interim recommendations are intended to encourage the scientific community to address knowledge gaps. They also signify the need to consider a preventive, precautionary approach to the management of the air contaminant.

Science Assessment

The science assessment document provides a review of the following issues: physical and chemical properties of the substance, environmental fate and behaviour, identification and characterization of emission sources, ambient monitoring technologies, and environmental levels. Receptor effects are reviewed for each of the following receptors for which information is available: human health, vegetation, animals, materials, and aesthetic parameters (odour and visual range). The human health assessment reviews available clinical, toxicological, and epidemiological information. Vegetation receptors are subdivided in the review process to evaluate impacts on agricultural species, forest species, horticultural species, and natural ecosystems. Animal receptors are reviewed as livestock, mammalian wildlife, and birds. Material receptors are typically elastomers, textiles, and building materials.

The receptor effects review attempts to characterize (qualitatively and quantitatively) the toxicity of the air

contaminant. The qualitative assessment establishes the adequacy of the scientific data base to derive and support the reference level. At this stage, the consistency of the data base and limitations imposed by irreconcilable contradictions is expressed. During the qualitative assessment, the type of effects (e.g., chronic vs. acute, reversible vs. nonreversible, threshold vs. nonthreshold), the relevance of the effect to other species or receptors, the identification of susceptible or sensitive species and subpopulations, and the relevance to the Canadian context are established.

The quantitative assessment in its simplest form is a numerical expression of the concentration/dose–response relationship. There are two general cases: threshold and nonthreshold. A threshold endpoint is one in which there is measurable level below which there is no discernible effect on the receptor. Above the threshold, there is a dose–response relationship that can be quantified. The threshold is often called the no-observable-adverse-effect level (NOAEL). Where it is not possible to define the NOAEL, there may be an expression of the lowest-observable-adverse-effect level (LOAEL), which indicated the likelihood of threshold's existence. Nonthreshold endpoints are those in which the effect is proportional to the concentration with no definitive loss of the relationship, that is, no concentration at which the effect ceases to be observed.

For receptors for which reference levels are identified, an exposure assessment is performed. This exposure assessment uses available ambient data to establish the exposure of Canadian receptors to the air contaminant. This information is relevant to the risk characterization. The depth and accuracy of the exposure assessment are tailored to the degree of knowledge required to support the risk estimation, and to support the development of focused air quality management strategies.

The risk characterization attempts to define the nature and degree of hazard posed by the air contaminant at known or current exposure levels. An accurate and unbiased discussion of the significance of the data is required, as is information on a variety of endpoints that provide insight into the full spectrum of responses in a number of receptors. Estimates of the proportion of the receptor populations above a specified level of risk, NOAEL, or LOAEL are made which provide an indication of the likelihood of occurrence of the adverse effects associated with exposure to the air contaminant.

Derivation of the Reference Level

In the derivation of the reference level, the science assessment becomes more than a literature review. The information is evaluated to determine the receptors for which there is sufficient information to develop a reference level, and of those receptors, which are relevant to Canada. That is, the receptor should be present in Canada, or extrapolation of the measured endpoint to an effect on a Canadian receptor should be possible. The conditions under which the experiments reported in the literature are performed should occur or be expected to occur in Canada. There should be general consensus among the scientific community regarding the quality of the results and the conclusions regarding the receptor effect upon which the reference level is based.

The weight-of-evidence approach is the preferred approach for deriving the reference level and is used when there are many quality studies upon which to base the concentration/dose–response relationship. For some air contaminants there may be one study that is particularly relevant to Canada, only one study in which environmentally relevant air contaminant concentrations were used, or one study that stands out as being the most comprehensive or applicable in the Canadian context. In such cases, it may be appropriate to use a definitive study approach to the derivation of the reference level. In this case, a single study is selected as best representing the concentration/dose–response relationship and the conditions expected in the Canadian environment. The weight of evidence is provided in summary format to support the definitive study and the identification of the reference level.

In deriving a reference level, the variability in receptor response must be distinguished from the uncertainty in defining the response. Both of these factors are considered explicitly. In determining the reference level the level of uncertainty associated with that level is identified. In a weight-of-evidence approach, the reference level is the best estimation from a number of different tests; thus there will be uncertainty associated with the derived dose and ambient concentration.

The reference level is the level above which there are demonstrated effects on human health and/or the environment. It is scientifically based and defines the boundary between the LOAEL and the NOAEL. It is considered to be the level of exposure just below that

most likely to result in a defined and identifiable but minimal effect. The reference levels have no safety factors applied to them, as they are related directly to the LOAEL, and are the most conservative estimates of the effect level.

Development of Air Quality Objective Options

The air quality objectives are designed to be targets for federal, provincial, or regional air quality management activities. They represent decision making in light of available scientific information on effects, the continuum of receptor effects down to very low concentrations (i.e., the lack of a dose–response threshold), and the level of risk posed by the air pollutant. Selection of a risk-based objective acknowledges that zero risk will not be achieved. Given the diverse nature of factors that may be considered in selecting the objective and the uncertainties associated with the estimates of the toxicological risk, the selection of the objective is inherently subjective and open to debate.

Options are developed based primarily on the scientific considerations of incremental risk, current ambient exposures, and the lowest level at which effects have been identified in a receptor population or significant sensitive subgroup. Selection of the final air quality objective recommendation reflects the guidance to be reasonable and workable in light of developing regional and national air quality management strategies.

Current Status

In the past few years the Federal–Provincial Working Group on Air Quality Objectives and Guidelines has developed a protocol for reviewing the science and deriving the reference levels and has completed science assessment documents for hydrogen fluoride, carbon monoxide, and particulate matter (PM <10 and PM <2.5). Reference levels have been derived for hydrogen fluoride and particulate matter. Work is currently under way to prepare science assessment documents for ozone and total reduced sulphur compounds. Following completion of these reviews, the existing NAAQOs for nitrogen dioxide and sulphur dioxide will be reviewed.

Current harmonization initiatives under the Canadian Council of Ministers of the Environment framework are working toward the development of Canada-wide standards (CCME 1997). These standards encompass qualitative or quantitative standards, guidelines, objectives, and criteria for protecting the environment and human health. The primary focus is on ambient environmental standards for the quality of air, water, soil, biota, other media, and for other components of ecosystems as well as ecosystems themselves. Particulate matter and ozone have been identified as priority substances for the development of Canada-wide standards under the harmonization agreement. Canada-wide standards for particulate matter and ozone will be developed based on the NAAQO science assessments, and air quality objectives will not be identified.

Conclusions

The new framework for air quality objectives in Canada has facilitated the review of existing objectives and the development of new objectives. It has allowed for a credible and peer-reviewed science assessment to form the basis for the NAAQOs, yet provides the flexibility to recognize the broad range of receptor sensitivities and the regional nature Canadian air quality problems. It is a system that is working.

References

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WHO (World Health Organization). 1989. Setting environmental standards: Guidelines for decision making. H.W. de Koning, ed. WHO, Geneva.

Appendix 1

National Ambient Air Quality Objectives

Pollutant		Averaging time			Published	Reviewed
		1 hour	24 hour	Annual		
Carbon monoxide ($mg \cdot m^3$)	D	15	6 (8 h)		1974	1996
	A	35	15 (8 h)		1974	1996
	T		20 (8 h)		1978	1996
Hydrogen fluoride ($\mu g \cdot m^3$)	RL		1.1	0.5 (7 d)	1997	
Nitrogen dioxide ($\mu g \cdot m^3$)	D			60	1975	1989
	A	400	200	100	1975	1989
	T	1000	300		1978	1989
Ozone ($\mu g \cdot m^3$)	D	100	30		1974	1989
	A	160	50	30	1974	1989
	T	300			1978	1989
	RL				*	
PM <10 ($\mu g \cdot m^3$)	RL		25		1998	
PM <2.5 ($\mu g \cdot m^3$)	RL		15		1998	
Sulphur dioxide ($\mu g \cdot m^3$)	D	450	150	30	1974	1989
	A	900	300	60	1974	1989
	T		800		1978	1989
Total reduced sulphur compounds	RL				*	
	AQO				*	
Total suspended particulates ($\mu g \cdot m^3$)	D			60	1974	1989
	A		120	70	1974	1989
	T		400		1978	1989

Notes:

D: Desirable
A: Acceptable
T: Tolerable
RL: Reference level
AQO: Air quality objective

*Reviews in progress.

Appendix 2

CEPA/FPAC Working Group on Air Quality Objectives and Guidelines and Secretariat

(Membership as of December 1998)

Alberta	Randy Angle	Alberta Environmental Protection
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British Columbia	Richard Bennett	Ministry of Environment, Lands and Parks
British Columbia	Ray Copes	Ministry of Health and Ministry Responsible for Seniors
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Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian national ambient air quality objectives: Process and status. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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