Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement

GUIDANCE DOCUMENT ON ACHIEVEMENT DETERMINATION FOR CANADIAN AMBIENT AIR QUALITY STANDARDS FOR NITROGEN DIOXIDE

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BACKGROUND ON THE AIR QUALITY MANAGEMENT SYSTEM

Air quality is important for all Canadians and it affects many aspects of our lives and our society, including human health, the natural environment, buildings and infrastructure, crop production, and the economy. In Canada, air quality management is a responsibility shared between federal, provincial, and territorial governments. Under the Canadian Council of Ministers of the Environment (CCME), federal, provincial and territorial governments are working collaboratively to improve air quality by implementing the Air Quality Management System (AQMS)[1]. Key elements of AQMS include:

1. Air zones – geographical areas that are used to manage local air quality within the provinces and territories in which they are located.
2. Airsheds – broad geographic areas that encompass a number of air zones and may cross provincial, territorial, and international boundaries. They provide a framework for inter-jurisdictional collaboration to address transboundary air quality issues.
3. Canadian Ambient Air Quality Standards (CAAQS) – health and environmental-based air quality objectives to further protect human health and the environment and to provide the drivers for air quality improvement across the country.
4. Air Zone Management Framework – a framework to manage air quality in air zones.
5. Base-level industrial emissions requirements (BLIERs) – emission requirements that are intended to apply to major industrial sectors or equipment types to ensure that significant industrial sources achieve a good base-level of performance.
6. Mobile Sources – work that builds on the existing range of federal, provincial and territorial initiatives aimed at reducing emissions from mobile sources.

In addition to being endorsed by CCME, the CAAQS have also been established as ambient air quality objectives by the federal government under the *Canadian Environmental Protection Act, 1999*.

This document provides information on the CAAQS and management levels for nitrogen dioxide (NO_2) and information on the procedures, methodologies and criteria for determining whether the CAAQS for NO_2 are achieved or exceeded at monitoring stations and within air zones.

[1] Although Québec supports the general objectives of the AQMS, the province will not implement the System since the System calls for federal industrial emission requirements that duplicate Québec regulations. However, Québec is collaborating with jurisdictions on developing other elements of the system, notably air zones and airsheds.

1.0 INTRODUCTION

Under the Air Quality Management System (AQMS), provinces and territories have been delineated into one or more air zones by the respective jurisdiction. Air zones provide a defined area within which stakeholders, other interested parties and governments work together to improve local air quality and maintain air pollutant concentrations below the Canadian Ambient Air Quality Standards (CAAQS).

As part of AQMS, provinces and territories have agreed to regularly publish air zone reports for each of their air zones in a timely fashion. These reports are key to the integrity of the AQMS and will include information on the achievement status of the CAAQS and their management levels. Achievement status means whether ambient concentrations of air pollutants are less than or equal to the corresponding standard (*CAAQS is achieved)* or greater than the standard (*CAAQS is exceeded*). To ensure that reporting on CAAQS achievement status is comparable among provinces and territories, guidance is needed on the monitoring, procedures and methodologies to use. This document outlines this guidance for nitrogen dioxide (NO_2). Its main purpose is to:

- present the CAAQS and management levels for NO_2
- provide guidance on the NO_2 monitors and monitoring stations to use for reporting on the achievement status of the NO_2 CAAQS
- provide the procedures for calculating the concentrations to use for direct comparison to the NO_2 standards (called metric values)
- provide the procedures for determining whether an NO_2 CAAQS is achieved or exceeded at monitoring stations and in air zones.

More information on AQMS and guidance on its implementation is available on ccme.ca.

2.0 CANADIAN AMBIENT AIR QUALITY STANDARDS FOR NITROGEN DIOXIDE

CAAQS are health and environmental-based air quality objectives to further protect human health and the environment and to provide the drivers for air quality improvement across Canada. All CAAQS consist of three inter-related elements:

1. an averaging time
2. a concentration “standard” (or “numerical value”) associated with the averaging time
3. the statistical form for the standard.

CCME has established CAAQS for NO_2 for 2020 and 2025, listed in Table 2-1. The federal government established these CAAQS as ambient air quality objectives on December 9, 2017 pursuant to sections 54 and 55 of the *Canadian Environmental Protection Act, 1999*[2]. The 2020 CAAQS came into effect on December 10, 2017 and will remain in effect until December 31, 2024. The 2025 CAAQS will become effective on January 1, 2025. The years 2020 and 2025 represent the years by which the associated standard should be achieved. The intended use of all CAAQS is discussed in the CCME Guidance Document on Air Zone Management (CCME 2019a).

Table 2-1: The CAAQS for nitrogen dioxide

Averaging time[3]	**Standard** (numerical value)		**Statistical form of the standard**
	2020	**2025**	
1-hour	60 ppb*	42 ppb	The 3-year average of the annual 98th percentile of the NO_2 daily-maximum 1-hour average concentrations.
1-year (annual)	17.0 ppb	12.0 ppb	The arithmetic average over a single calendar year of all NO_2 1-hour average concentrations in the year.

* ppb-parts per billion by volume

As can be seen in Table 2-1, CAAQS for NO_2 have been established for 1-hour and 1-year (or annual) averaging times. This takes into consideration that effects on health and the environment can occur over both short (1-hour) and long-term (1-year) exposure times and concentrations.

For ease of discussion, an NO_2 1-hour average concentration is denoted by "NO_2 1-hour" and the daily maximum of the NO_2 1-hour as the "NO_2 Dmax 1-hour".

The averaging times in Table 2-1 refer to the averaging period over which the corresponding standard applies. The statistical form describes the calculation method for the specific concentration that must be used for comparison to the standard to determine whether the concentrations measured at a monitoring station exceed the standard. The 1-hour NO_2 standard of 60 ppb (for 2020) applies to NO_2 1-hour. The statistical form of the standard means that the concentration to use to determine whether 60 ppb was exceeded at a monitoring station is the 3-year average of the annual 98th percentile of the NO_2 Dmax 1-hour measured at the station. In a year with complete data (see section 5.3), the 98th percentile is the value of the eighth highest NO_2 Dmax 1-hour. The annual NO_2 standard applies to the average of all NO_2 1-hour measured at a station over a single calendar year.

[2] Canada Gazette Part 1, Volume 151, December 9, 2017. http://www.gazette.gc.ca/rp-pr/p1/2017/2017-12-09/pdf/g1-15149.pdf.

[3] This is referred to as "averaging period" in some jurisdictions.

To simplify terminology, the concentrations measured at a monitoring station calculated in the statistical form of a standard are referred to as “CAAQS metric values” or simply “metric values”[4]. An NO_2 CAAQS is achieved at a monitoring station if the corresponding metric value is less than or equal to the standard; otherwise the standard is exceeded. An NO_2 CAAQS is achieved in an air zone if the highest metric value in the air zone is less than or equal to the standard; otherwise the standard is exceeded. In other words, an NO_2 CAAQS is achieved in an air zone if the metric values at *all* NO_2 CAAQS reporting stations in the air zone are less than or equal to the standard.

For clarity, for the 1-hour standard a 3-year average is to be computed backward in time. As such, the first formal achievement determination of the 1-hour standard for 2020 will be based on metric values for the 3-year period from 2018 to 2020. For the 2025 standard it will be based on metric values for the period 2023 to 2025. For the annual standard, the first formal achievement determination will be based on the NO_2 1-hour measured in 2020 for the 2020 standard and measured in 2025 for the 2025 standard.

Text Box 1 provides a simplified example for the calculation of the 1-hour NO_2 CAAQS metric values in an air zone with two monitoring stations. Since the 3-year period for this example is 2018-20, the 2020 standard of 60 ppb applies. For this example, the NO_2 1-hour standard is achieved at Station A (since the metric value of 44 ppb is less than the standard of 60 ppb) and exceeded at Station B. Since the highest metric value in the air zone exceeds the standard, the air zone does not achieve the 1-hour standard.

To ensure that reporting on CAAQS achievement is comparable across provinces and territories, there are specific procedures to use for obtaining the 98th percentiles, the metric values and for number rounding. These are addressed in section 5.

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[4] It should be noted that the annual maximum 1-hour average concentration and a single annual 98th percentile of the daily-maximum 1-hour average concentrations cannot be used to determine whether the 1-hour standard is achieved or exceeded because neither of these correspond to the statistical form of the standard.

Text Box 1: Example for calculating the NO_2 1-hour CAAQS metric value

	Annual 98th percentile of the NO_2 Dmax 1-hour		
	2018	**2019**	**2020**
Station A	39.4 ppb	55.6 ppb	38.0 ppb
Station B	92.7 ppb	85.6 ppb	70.5 ppb

	3-year average of the annual 98th percentile	1-hour NO_2 CAAQS metric value for 2018-2020
Station A	(39.4+55.6+38.0)÷3 = 133÷3 = 44.333 ppb	44 ppb
Station B	(92.7+85.6+70.5)÷3 = 248.8÷3 = 82.933 ppb	83 ppb

2.1 Basis for the Statistical Form of the Standards

CAAQS are established to further protect the health of Canadians and their environment. They are used to guide the air quality management actions to implement as part of the Air Zone Management Framework (AZMF section 3). If ambient concentrations of air pollutants exceed their corresponding standard, the AZMF calls for the implementation of the most rigorous actions.

Exceedances of a standard, and generally variations in ambient concentrations from one year to the next, are influenced not only by changes in the quantity of emissions of air pollutants but also by variations in the prevailing meteorological conditions (see for example, Turner 1961)[5]. This implies that exceedances of a standard can at times be influenced by the occurrence of meteorological conditions that are conducive to elevated ambient concentrations of air pollutants even though emissions do not increase substantially. As such, an air zone can shift in and out of achievement of a standard because of variations in meteorological conditions rather than because of sustained changes in emissions. To reduce this risk, the statistical form of a standard is established considering not only the need to capture the associated health and environmental effects, but also the need that it not be overly influenced by variations in meteorological conditions.

For the NO_2 1-hour CAAQS, studies indicate that the risk of adverse health impacts appears linear throughout the range of concentrations experienced in Canada, with no clear signs

[5] For example, the average NO_2 concentrations measured at a monitor may be higher in a year where the wind transports the plume from a nearby source more frequently towards the monitor and lower in a year where the plume is more frequently transported away from the monitor.

of a threshold for such effects. While studies using various short-term averages of NO_2 (from 1 to 24 hour) demonstrate effects of similar public-health consequence, the majority of studies utilize 1-hour averages and thus the greatest understanding of effects is associated with this 1-hour timeframe. As the effects have been shown to increase almost linearly with concentration throughout the range examined, the greatest risks are associated with the annual highest 1-hour average concentration.

However, data analyses indicate that the annual highest varies more from year to year than the annual 98th percentile, likely because the annual highest is more sensitive to meteorological conditions[6]. In a year with complete data the 98th percentile is the eight (8th) highest NO_2 Dmax 1-hour and, as such, it is representative of the higher NO_2 concentrations. Therefore, given that the 98th percentile varies less, and given that it is also representative of the higher NO_2 concentrations, a 98th percentile form was adopted for the 1-hour CAAQS. In addition, a 98th percentile form also aligns with the NO_2 standard of the United States, which is a desirable feature since it allows direct comparison of NO_2 air quality between the two countries. The final form as a 3-year average of the 98th percentile was selected as a mean to further reduce the variability between years.

For the annual NO_2 CAAQS, all NO_2 1-hour measured in a year (up to 8760 or 8784 in a leap year) are considered. Data analyses indicate that annual averages based on all NO_2 1-hour are typically not overtly influenced by meteorological conditions. As such, a single year average of all 1-hour NO_2 measured in the year was deemed appropriate for the annual CAAQS.

3.0 NITROGEN DIOXIDE MANAGEMENT LEVELS

AQMS includes an AZMF, which provides guidance to jurisdictions on the level of monitoring, reporting and management actions to implement in air zones depending on the prevailing concentrations of air pollutants. The framework includes four air quality management categories, or levels, denoted by the colours green, yellow, orange, and red. Each of these management levels is associated with a corresponding range of concentrations of air pollutants that have been established concurrently and under the same process as the corresponding CAAQS. The current NO_2 management levels are presented in Table 3-1.

The concentrations in Table 3-1 have the same statistical form as the corresponding CAAQS. Accordingly, the NO_2 CAAQS metric values discussed in section 2 are also used

[6] Substantial changes in emissions between years may also cause variability in the annual highest. However, meteorological conditions likely have a more variable influence. For example, meteorological conditions may cause the plume from a nearby source to directly impinge a monitor in one year (causing elevated 1-hour concentrations), and never directly impinge the monitor in another year (resulting in lower concentrations).

for comparison to the management levels to determine the management level into which the air zone falls. The procedures that provinces and territories use to assign management levels to each of their air zones are discussed in CCME 2019a.

Table 3-1: Management levels for nitrogen dioxide

Management level	NO_2 1-hour		NO_2 annual	
	2020	2025	2020	2025
Red	> 60 ppb	> 42 ppb	> 17.0 ppb	> 12.0 ppb
Orange	32 to 60 ppb	32 to 42 ppb	7.1 to 17.0 ppb	7.1 to 12.0 ppb
Yellow	21 to 31 ppb		2.1 to 7.0 ppb	
Green	≤ 20 ppb		≤ 2.0 ppb	

4.0 MONITORS AND REPORTING STATIONS

This section provides guidance on the NO_2 monitors to use for reporting on the achievement status of the NO_2 CAAQS. It also provides guidance on the location of monitoring stations for reporting on the achievement status (CAAQS reporting stations).

4.1 Requirements for Monitors

The monitors for reporting on the achievement status of the NO_2 CAAQS should:

1. measure NO_2 concentrations on an hourly basis
2. be designated as either *Federal Reference Method* (FRM) or *Federal* E*quivalent Method* (FEM) by the United States Environmental Protection Agency (U.S. EPA 2016)
3. be subject to data validation procedures that meet (or exceed) the Ambient Air Monitoring and Quality Assurance and Quality Control Guidelines: NAPS Program (CCME 2019c).

The NAPS Program is a collaborative air quality monitoring network jointly operated and maintained by the provinces and territories and Environment and Climate Change Canada. Metro Vancouver and Ville de Montréal also contribute to the NAPS Program.

4.2 CAAQS Reporting Stations

Provinces and territories are responsible for designating the NO_2 CAAQS reporting stations. Ideally, all CAAQS reporting stations should be planned to be operational for the long-term.

Results of analyses of ambient NO_2 concentrations measured in urban and rural areas of Canada indicate that concentrations are higher at monitoring stations located in urban centers. The analyses indicate that concentrations are highest in urban centers with population of 500,000 or more and lowest in communities with population less than 30,000. Some of the overall highest concentrations were recorded near major urban roads located in communities with population of 500,000 and more, where traffic emissions are an important sources of nitrogen oxides (NO_X, consisting mostly of nitric oxide and NO_2)[7].

Some high NO_2 concentrations were also measured at stations close to major point sources of NO_X. However, since many of these stations were also located near major roadways, traffic emissions may also have influenced these concentrations. Generally, the relative contributions from roadway traffic, other transportation sources (e.g. rail), and various industrial sources will vary from station to station depending on the spatial distribution of sources near the station.

In studies from Health Canada, it is discussed that NO_2 concentrations at all station types (e.g. residential and traffic) exhibited a common pattern by season, with wintertime maxima and summertime minima. The summertime minima is consistent with increased mixing heights[8] and photochemical oxidation of NO_2 and decreased emissions from residential heating compared with winter (Health Canada 2016).

Since NO_2 concentrations are higher in urban centers, from a population health perspective urban centers of Canada should have one or more NO_2 CAAQS reporting stations preferably located in an area that represents the community-wide exposure. Within urban centers, monitors should be located close to major roadways where people live or work as it is estimated that approximately one third of Canadians (approximately 10 million people) live or work within 500 meters of highways or 100 meters from major urban roads (Brauer

[7] Close to 90% of the NO_X released from combustion sources is nitric oxide (NO). Once in the air, NO rapidly converts to NO_2 by reacting with other substances present in the air.

[8] The mixing height can be considered as being the height above ground up to which pollutants can disperse. The higher the mixing height, the lower the concentrations of air pollutants can be.

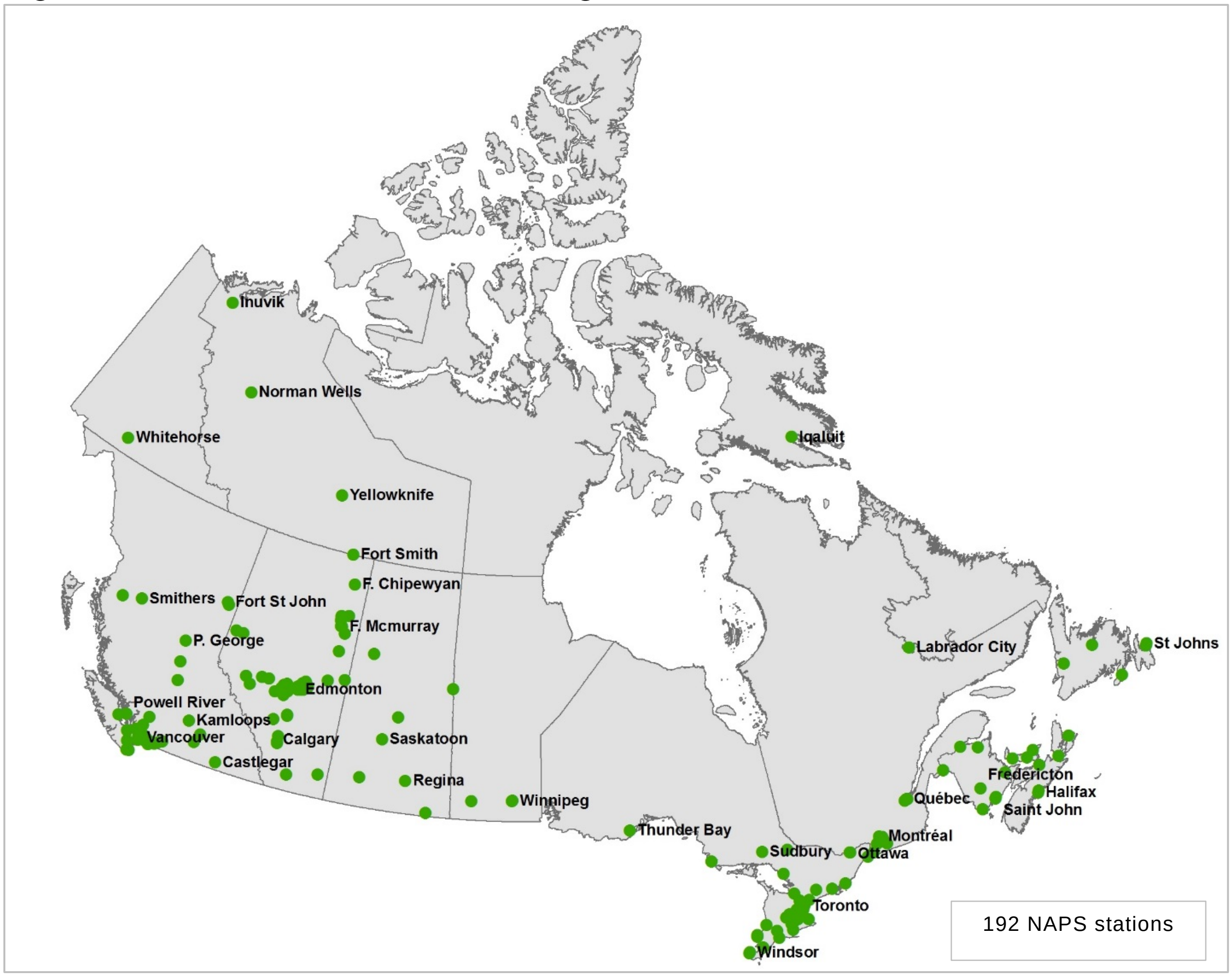
et al. 2013). Monitoring stations could also be located in communities having large sources of NO_2.

From an environmental perspective, stations could also be located in air pollution-sensitive ecosystems as priorities and resources allow. Sensitive ecosystems encompass national and provincial parks, protected areas, areas of cultural or heritage value and areas that are or may be susceptible to adverse effects from direct exposure to NO_2, acid deposition or eutrophication.

Provincial and territorial jurisdictions may determine that ambient monitoring for NO_2 is not required in an air zone, but ideally, each air zone should have at least one NO_2 CAAQS-reporting station, preferably located in the community with the largest population. In 2018, NO_2 was monitored on an hourly basis at 192 NAPS stations (Figure 4-1), most of which are located in populated centers and some of which are close to major urban roads. As a start, the NAPS NO_2 stations should be used as NO_2 CAAQS-reporting stations[9].

[9] The NO_2 monitors at NAPS stations are all designated as either FRM or FEM by the EPA and they all meet the Ambient Air Monitoring and Quality Assurance and Quality Control Guidelines: NAPS Program (CCME 2019c).

Figure 4-1: The NAPS NO_2 monitoring stations for 2018



To augment spatial coverage, provinces and territories could also use additional stations that they deem appropriate, as long as the NO_2 monitors satisfy the requirements discussed in section 4.1. These additional stations can include, for example:

1. provincial and territorial non-NAPS stations
2. stations owned by air zone organizations[10]
3. stations owned by third parties.

Provinces and territories are encouraged to use any additional stations wherever a major source of NO_2 is near a populated area or a sensitive ecosystem. Stations located at or near the property (fence) line of an industrial facility should not be used for NO_2 CAAQS reporting unless the station is near a populated area or a sensitive ecosystem. Under NAPS, a fence-line monitoring station is defined as: a station that is located within or on the

[10] These are not-for profit organizations with a multi-stakeholder membership and are established by some provinces and territories to address air quality within the air zone. Some organizations operate their own monitoring stations.

property line of a facility or a station that is very near to a facility and in areas not used or accessed by the public or with no nearby population of appreciable size. The determination of what is considered "near" can be evaluated on a case-by-case basis by the reporting jurisdiction. For example, what is considered near for emissions released at ground level may be different than for emissions released from a tall stack.

5.0 CALCULATION OF THE NITROGEN DIOXIDE METRIC VALUES

This section provides guidance on the procedures for calculating the NO_2 CAAQS metric values, the data completeness criteria and the number of decimal places that measured concentrations and calculated values have to be reported. Appendix A provides an example for the calculation of the 1-hour metric values. As mentioned in section 2, an NO_2 1-hour average concentration is denoted by "NO_2 1-hour" and the daily maximum of the NO_2 1-hour as the "NO_2 Dmax 1-hour".

NO_2 CAAQS metric values can be calculated for any NO_2 monitoring station. However, for reporting on NO_2 CAAQS achievement status and management level only stations designated by provinces and territories as NO_2 CAAQS reporting stations should be used.

5.1 Calculation of 1-hour Metric Values

The 1-hour NO_2 CAAQS metric value at a monitoring station is the average of three annual 98th percentile values over three consecutive years and is calculated as per equation 5.1.

$$\textbf{1-hour metric value}_{Y1\text{-}Y3} = (\mathbf{98P_{Y1} + 98P_{Y2} + 98P_{Y3}) \div 3} \quad \text{(equation 5.1)}$$

In this equation, $98P_{Y1}$, $98P_{Y2}$ and 98_{Y3} represent the annual 98th percentiles of the NO_2 Dmax 1-hour for the consecutive calendar years Y1, Y2 and Y3 respectively.

An annual 98th percentile is to be obtained based on the following three main steps:

Step 1: Select the NO_2 Dmax 1-hour for each day.

Step 2: Select the eight highest NO_2 Dmax 1-hour in the year and rank them in decreasing order of magnitude, repeating common values as often as they occur, as in the example in the Table 5-1.

Table 5-1: Example of eighth highest NO_2 Dmax 1-hour in decreasing order

NO_2 Dmax 1-hour (ppb)	Rank	Date measured
89.9	Highest	15-01-2018
76.4	Second highest	18-12-2018
76.4	Third highest	11-01-2018
63.2	Fourth highest	18-04-2018
57.1	Fifth highest	11-05-2018
45.9	Sixth highest	13-03-2018
44.3	Seventh highest	29-12-2018
40.1	Eighth highest	23-01-2018

Step 3: Use Table 5-2 to obtain the value of the annual 98^{th} percentile depending on the number of NO_2 Dmax 1-hour available in the year.

Table 5-2: The 98^{th} percentile as a function of available data

Number of NO_2 Dmax 1-hour available in a year (N_{DM})	98^{th} percentile value
1 to 50	The highest NO_2 Dmax 1-hour
51 to 100	Second highest
101 to 150	Third highest
151 to 200	Fourth highest
201 to 250	Fifth highest
251 to 300	Sixth highest
301 to 350	Seventh highest
351 to 366	Eighth highest

Table 5-2 is from the percentile ranking approach and it is discussed in detail in Appendix B. Under this approach, the value of the annual 98^{th} percentile of the NO_2 Dmax 1-hour is one of the eight highest NO_2 Dmax 1-hour measured in the year depending on the number (N_{DM}) of available NO_2 Dmax 1-hour. For example, for N_{DM} = 355 the 98^{th} percentile value is the eighth highest NO_2 Dmax 1-hour; for the example in Table 5-1, this would be 40.1 ppb.

There are different methods for obtaining a 98^{th} percentile and each may give different results. Off-the-shelf software and in-house written computer programs can be used only if they always provide the same results as the percentile ranking approach.

5.2 Calculation of Annual Metric Values

The annual metric value at a monitoring station is the average of all NO_2 1-hour measured in a single calendar year and is calculated as per equation 5.2.

$$\textbf{Annual metric value} = (C_1 + C_2 + \cdots + C_{N1h}) \div N_{1h} \quad \text{(equation 5.2)}$$

In this equation, C_i is the NO_2 1-hour for the "i^{th}" hour in the year. "N_{1h}" is the number of NO_2 1-hour available in the year and it ranges from 1 up to 8760 (8784 in leap years). Note that for the annual metric value the selection of the daily maximum 1-hour is not required.

5.3 Data Completeness Criteria and Exceptions

Generally, only data that meet completeness requirements should be used in the calculation of the NO_2 metric values, and only metric values based on complete data should be used for CAAQS reporting. Table 5-3 specifies the data completeness criteria under which concentrations and metric values may be considered to be based on complete data.

There are exceptions to the data completeness criteria; these are indicated in column 3 of Table 5-3. These exceptions ensure that potential exceedances of a standard are captured. If a parameter in column 1 does not meet its completeness criteria in column 2 but meets the exception criteria in column 3, it will then still be used for CAAQS reporting. For example, at a given monitoring station criterion 1 for the annual 98^{th} percentile (75% data completeness) was not satisfied and the 98^{th} percentile of the available NO_2 Dmax 1-hour is 100 ppb. Since this 98^{th} percentile exceeds the standard, it has to be used in the calculation of the metric value at the station even though the completeness criterion was not satisfied.

Table 5-3: Data completeness and exceptions criteria

Parameter (Column 1)	**Data completeness criteria** (Column 2)	**Exceptions to the data completeness criteria** (This parameter will always be considered in the calculation of metric values if the following conditions are satisfied) (Column 3)
NO_2 Dmax 1-hour	At least 18 of the 24 (75%) NO_2 1-hour are available in the day[11].	The NO_2 Dmax 1-hour exceeds the standard.
Annual 98th percentile of the NO_2 Dmax 1-hour	The NO_2 Dmax 1-hour are available for at least: 1. 75% of the days in a year; and 2. 60% of the days in each calendar quarter*.	The 98th percentile based on the available NO_2 Dmax 1-hour exceeds the standard.
1-hour metric value	Two of the possible three annual 98th percentiles are available[12].	No exceptions
Annual metric value	1. at least 75% of the NO_2 1-hour are available in the year; and 2. at least 60% of the NO_2 1-hour are available in each calendar quarter*.	1. at least 50% of the NO_2 1-hour are available in each calendar quarter; and 2. the annual average exceeds the standard.

*The calendar quarters (Q) are: **Q1 -** January 1 to March 31; **Q2 -** April 1 to June 30; **Q3 -** July 1 to September 30; **Q4 -** October 1 to December 31.

As indicated in Table 5-3, the 1-hour metric value is considered to be based on complete data if two of the three annual 98th percentiles of the NO_2 Dmax 1-hour are available. However, for cases when a 1-hour metric value is based on only two annual 98th percentiles, provinces and territories can nevertheless identify them as such in the air zone report. Cases where one or more of the exceptions criteria listed above were applied can also be indicated in the report. Section 7 provides suggestions on how to communicate CAAQS exceedances based on incomplete data.

[11] The data completeness and other information for the NO_2 1-hour are provided in the Ambient Air Monitoring and Quality Assurance and Quality Control Guidelines: NAPS Program (CCME 2019c).

[12] If only two annual 98th percentiles are available, the divisor in equation 5.1 will be 2 instead of the indicated 3.

When a standard is exceeded under exceptions to the data completeness criteria, provinces and territories could evaluate if an exceedance would also have occurred had the data been complete. The evaluation may be important since the exceedance of a standard means that the air zone could be managed at the Red management level. The result of the evaluation could be used to inform the decision whether to manage at the Red management level under exceedances associated with incomplete data. Text box 2 below provides an example of an evaluation.

Text Box 2: Example for evaluating the potential of an exceedance

An air zone has a single NO_2 CAAQS-reporting station and the achievement status for the 1-hour standard is evaluated for the 3-year period 2018 to 2020. The completeness criteria for the 98th percentile of the NO_2 Dmax 1-hour are satisfied for 2018 and 2019 but not for 2020. For 2020 the 98th percentile based on the available NO_2 Dmax 1-hour is 70.9 ppb and since it is greater than the 2020 standard it is retained for the calculation of the metric value. The 98th percentiles for 2018 and 2019 are 65.6 and 53.8 ppb respectively. The 1-hour metric value at the station is the average of the three annual 98th percentiles or 63 ppb. Since the metric value exceeds the 2020 standard, the jurisdiction opts to evaluate if the 98th percentile in 2020 could also have been greater than the standard had the data been complete.

For this, the jurisdiction first determines the time of year where the NO_2 Dmax 1-hour are missing in 2020 and it finds that they were missing in January and February. The jurisdiction next looks at the historical NO_2 Dmax 1-hour for these two months and finds that in the previous five years there were up to eight days per year where the NO_2 Dmax 1-hour was greater than the standard. The jurisdiction next conducts analyses of the general weather conditions in January and February 2020 and it concludes that they were mostly similar to those in the previous five years for the same two months. The jurisdiction also evaluates the emissions of NO_2 from sources known to influence the monitoring station. Since the emission information was not available on a monthly basis, the jurisdiction evaluates the annual emissions and it concludes that they were mostly similar to those in the previous five years.

Considering all this information, the jurisdiction concludes that the missing 1-hour NO_2 in January and February 2020 likely included some concentrations which were greater than the standard and that, therefore, the metric value for 2018-2020 would also have exceeded the standard had the data been complete.

5.4 Decimal Places and Rounding Rules

Calculated values, such as the 1-hour average concentrations[13] and the CAAQS metric values can be reported to various decimal places. Table 5-4 specifies the number of decimal

[13] For most NO_2 monitors, the 1-hour average concentrations correspond to the average of concentrations measured over shorter time periods.

places that 1-hour average concentrations and metric values are to be reported, together with the rules for rounding the values to the specified decimal places.

The NO_2 1-hour are to be reported to one decimal place. The NO_2 CAAQS metric values are to be reported to the same number of decimal places as their corresponding CAAQS, which is a whole number for the 1-hour CAAQS and one decimal place for the annual CAAQS. It should be noted that the NO_2 Dmax 1-hour and their 98th percentiles are not calculated values but are instead directly obtained from the NO_2 1-hour. As such, the NO_2 Dmax 1-hour and their 98th percentiles are both to be reported to one decimal place. Text Box 3 provides an example for rounding the 1-hour CAAQS metric values to whole numbers.

Table 5-4: Decimal place and rounding rules

<table>
<tr><th>Parameter</th><th>Decimal place of parameter</th><th>Rounding rule for the parameter</th></tr>
<tr><td>NO_2 1-hour*</td><td rowspan="2">One decimal place</td><td rowspan="2">For the calculated average, first discard all numbers after the second decimal. This results in a number with two decimal places (a calculated average of 65.4599 ppb becomes 65.45 ppb). For the resulting number, if its second decimal is:
1. ≥ 5, round upward to one decimal place (65.45 ppb is rounded upward to 65.5 ppb)
2. ≤ 4, round downward to one decimal place (65.44 is rounded downward to 65.4 ppb).
The rounded number is then the NO_2 1-hour or annual metric value.</td></tr>
<tr><td>Annual metric value
(annual average of the NO_2 1-hour)</td></tr>
<tr><td>1-hour metric value
(average of three annual 98th percentiles)</td><td>No decimal place (whole number)</td><td>For the calculated 3-year average, first discard all numbers after the first decimal. This results in a number with one decimal place (a calculated 3-year average of 65.4999 ppb becomes 65.4 ppb). For the resulting number, if its decimal is:
1. ≥ 5, round upward to a whole number (65.5 ppb is rounded upward to 66 ppb)
2. ≤ 4, round downward to a whole number (65.4 ppb is rounded downward to 65 ppb).
The rounded number is then the 1-hour metric value.</td></tr>
</table>

* The NO_2 Dmax 1-hour and their 98th percentile are also reported to one decimal place since they are directly obtained from the NO_2 1-hour.

Text Box 3: Example for rounding the 1-hour CAAQS metric value to a whole number

The annual 98th percentiles of the NO_2 Dmax 1-hour at a monitoring station for the years 2018, 2019 and 2020 are 72.5, 60.5 and 55.9 ppb respectively. Their calculated 3-year average is 62.966…ppb*.

According to Table 5-4, the 1-hour metric values are to be reported as a whole number (no decimal place) based on the specified rounding procedure.

The procedure specifies to first discard all numbers after the first decimal place in the calculated 3-year average. Therefore, the calculated 3-year average of 62.966…ppb becomes 62.9 ppb. For the resulting number, the rounding rule then specifies that if its decimal is:

1. ≥ 5, round upward to a whole number
2. ≤ 4, round downward to a whole number.

Accordingly, 62.9 ppb is rounded upward to 63 ppb, which becomes the 1-hour metric value.

*The three dots signify that the number 6 repeats indefinitely.

6.0 TRANSBOUNDARY FLOWS AND EXCEPTIONAL EVENTS

Transboundary flows (TF) and exceptional events (EE) are influences on concentrations from sources over which a jurisdiction has little to no direct control and they are discussed in the CCME Guidance Document on Transboundary Flows and Exceptional Events (CCME 2019b). Under AQMS, provinces and territories can consider influences from TF and EE on CAAQS exceedances and management levels and the procedures for doing so are provided in CCME 2019b. Consideration of TF-EE can also be applied to exceedances resulting from exceptions to the data completeness criteria discussed in section 5.3

7.0 COMMUNICATION AND REPORTING

Communicating with the Canadian public is an important component of AQMS. Each jurisdiction will regularly publish reports on air quality containing information for each of their air zones. With respect to CAAQS metric values, these reports should include the following information:

1. the NO_2 CAAQS metric values at each NO_2 CAAQS reporting station
2. the NO_2 CAAQS achievement status for each CAAQS reporting station
3. the NO_2 CAAQS achievement status for the air zone.

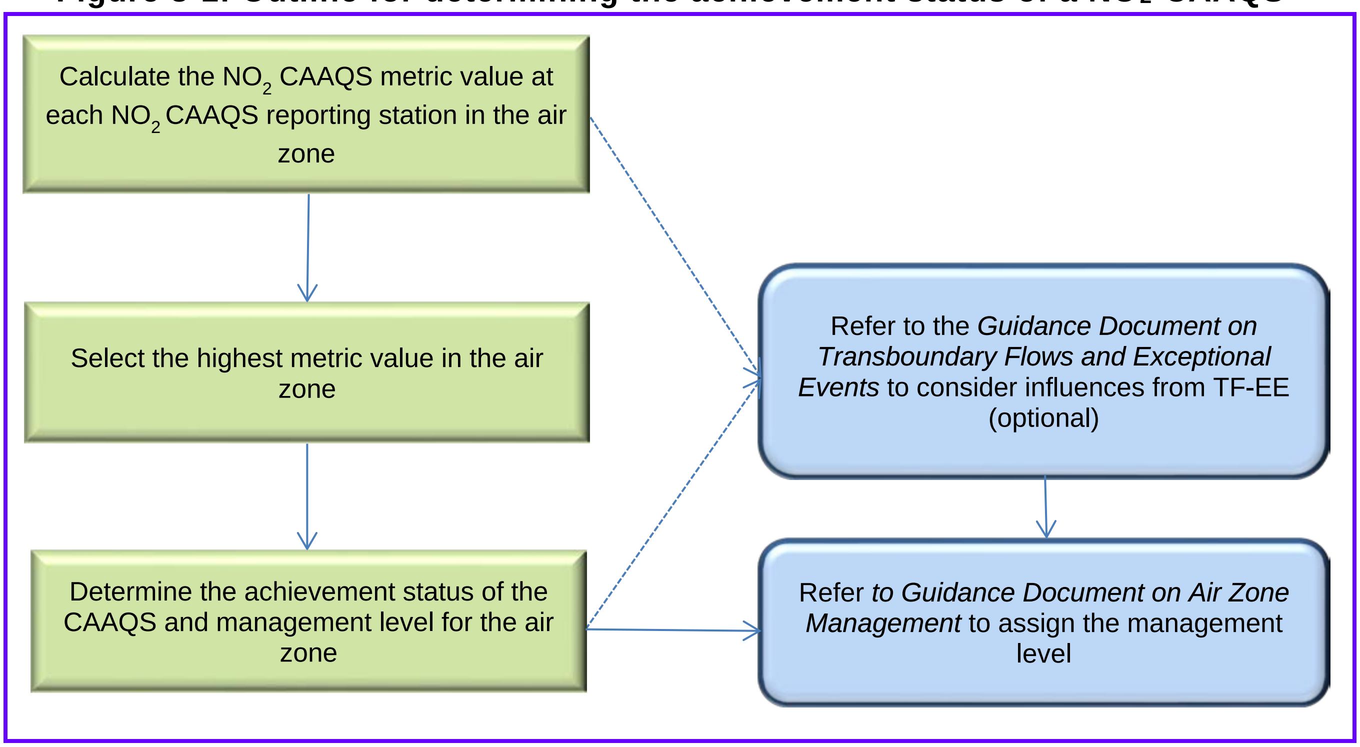
Including the metric values at each station will show the spatial variation in concentrations and will also serve to show that an exceedance may be limited to only some areas instead of the entire air zone. If an air zone has no NO_2 CAAQS-reporting station, the air zone report would clarify that the NO_2 CAAQS achievement status could not be determined. Exceedances of a standard under incomplete data may be identified as such in the air zone reports and be accompanied with a cautionary note. Information may also be included in regard to which concentration was based on the exceptions criteria outlined in Table 5-3.

The reporting requirements for air zone management levels are discussed in CCME 2019a.

8.0 SUMMARY OF GUIDANCE

The guidance provided in this document for the determination of the NO_2 CAAQS achievement status is summarized schematically in Figure 8-1.

Figure 8-1: Outline for determining the achievement status of a NO_2 CAAQS



9.0 REFERENCES

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APPENDIX A – EXAMPLE CALCULATION OF THE 1-HOUR CANADIAN AMBIANT AIR QUALITY STANDARDS METRIC VALUE

This appendix provides an example of the procedures for calculating the NO_2 1-hour CAAQS metric value at a monitoring station for the three-year period 2018 to 2020.

Based on equation 5.1, the 1-hour metric value is:

$$\text{1-hour CAAQS metric value}_{2018\text{-}2020} = (98P_{2018} + 98P_{2019} + 98P_{2020}) \div 3$$

The 98^{th} percentiles for each of the years 2018 to 2020 are obtained by applying the three-step procedure described in section 5.1 and an example is provided below for the $98P_{2018}$.

Step 1 – Select the NO_2 Dmax 1-hour for each day.

The NO_2 Dmax 1-hour was selected for each day in 2018 as shown by the fourth column in Table A-1. For January 1, 2018 the data completeness criterion of at least eighteen NO_2 1-hour was not satisfied. However, since the NO_2 Dmax 1-hour for this day (125.7 ppb) exceeds the standard, this maximum was retained as per the exception specified in Table 5-3.

Table A-1: Selecting the NO_2 Dmax 1-hour per day

Day	Hour of the day	NO_2 1-hour average concentration (ppb)	NO_2 Dmax 1-hour (ppb)	# of available NO_2 Dmax 1-hour
1-Jan-2018	1	2.1		
1-Jan-2018	2	3.9		
1-Jan-2018	3	4.1		
1-Jan-2018	4	10.1		
1-Jan-2018	5	4.4		
1-Jan-2018	6	4.1		
1-Jan-2018	7	12.5		
1-Jan-2018	8	55.5		
1-Jan-2018	9	125.7		
1-Jan-2018	10	100.9		
1-Jan-2018	11	40.4		
1-Jan-2018	12	10.4		
1-Jan-2018	13	8.3		
1-Jan-2018	14	4.5		
1-Jan-2018	15	55.6		
1-Jan-2018	16	Not available		
1-Jan-2018	17	Not available		
1-Jan-2018	18	Not available		
1-Jan-2018	19	Not available		
1-Jan-2018	20	Not available		
1-Jan-2018	21	Not available		
1-Jan-2018	22	Not available		
1-Jan-2018	23	Not available		
1-Jan-2018	24	4.5	125.7	16
…	…	…		
31-Dec-2018	1	3.2		
31-Dec-2018	2	2.3		
31-Dec-2018	3	4.5		
31-Dec-2018	4	6.6		
31-Dec-2018	5	10.1		
31-Dec-2018	6	8.9		
31-Dec-2018	7	5.6		
31-Dec-2018	8	12.5		
31-Dec-2018	9	22.5		
31-Dec-2018	10	55.1		
31-Dec-2018	11	20.1		
31-Dec-2018	12	23.1		
31-Dec-2018	13	9.1		
31-Dec-2018	14	2.3		
31-Dec-2018	15	5.5		
31-Dec-2018	16	6.6		
31-Dec-2018	17	4.4		
31-Dec-2018	18	1.1		
31-Dec-2018	19	2.1		
31-Dec-2018	20	1.5		
31-Dec-2018	21	Not available		
31-Dec-2018	22	Not available		
31-Dec-2018	23	3.5		
31-Dec-2018	24	1.2	55.1	22

Step 2 – Select the eight highest NO_2 Dmax 1-hour in the year and rank them in decreasing order of magnitude and repeating common values as often as they occur.

From all the NO_2 Dmax 1-hour in the year, the eight highest were selected and common values were repeated as often as they occurred (Table A-2).

Table A-2: The eight highest NO_2 Dmax 1-hour in 2018 ranked in decreasing order

NO_2 Dmax 1-hour (ppb)	Rank	Date measured
125.7	Highest	1-01-2018
125.7	Second highest	15-02-2018
72.5	Third highest	3-03-2018
70.9	Fourth highest	5-01-2018
65.6	Fifth highest	6-03-2018
60.1	Sixth highest	31-01-2018
55.3	Seventh highest	17-05-2018
51.9	Eighth highest	11-04-2018

Step 3 – Use Table 5-2 to determine the annual 98^{th} percentile value depending on the number of NO_2 Dmax 1-hour available in the year.

For this example, it is assumed that there are 300 NO_2 Dmax 1-hour in 2018. With N_{DM} = 300, the 98^{th} percentile is the value of the 6^{th} highest NO_2 Dmax 1-hour (Table 5-2), or 60.1 ppb. Therefore, $98P_{2018}$ = 60.1 ppb.

Calculation of the NO_2 1-hour CAAQS Metric Value

The same three steps were repeated for each of 2019 and 2020 and the obtained 98^{th} percentiles are 60.5 and 55.9 ppb respectively. Using equation 5.1 and the rounding rule in Table 5-4, the 1-hour metric value for the three-year period from 2018 to 2020 is calculated to be 59 ppb as shown below.

$$\textbf{1-hour CAAQS metric value}_{\textbf{2018-2020}} = (98P_{2018} + 98P_{2019} + 98P_{2020}) \div 3$$

$$= (60.1 + 60.5 + 55.9) \div 3$$

$$= 58.8333$$

$$\mathbf{= 59\ ppb}$$

APPENDIX B – THE PERCENTILE RANKING APPROACH

This section explains the derivation of Table 5-2.

In the percentile ranking approach, the 98th percentile of the NO_2 Dmax 1-hour is the K^{th} highest concentration (C) in the decreasing ordered array (e.g. $C_1 \geq C_2 \geq C_3 \cdots \geq C_n$). The K^{th} highest is obtained using the equation below for any number (N_{DM}) of the daily-maximum 1-hour average concentrations:

$$\mathbf{K^{th}\ highest = N_{DM} - Truncated\ (N_{DM} \times 0.98)}$$

“Truncated” means that the value of the product (N_{DM}x0.98) is converted to a whole number by discarding (not rounding) the decimal part of the value. If the value of the product $N_{DM}\times 0.98$ is a whole number, no truncation is needed.

For example, with N_{DM} = 355:

$$\begin{aligned}
K^{th}\ \text{highest} &= N_{DM} - \text{Truncated}\ (N_{DM} \times 0.98) \\
&= 355 – \text{Truncated}\ (355 \times 0.98) \\
&= 355 – \text{Truncated}\ (347.9) \\
&= 355 – 347 \\
&= \text{Eighth highest}
\end{aligned}$$

Applying the equation for N_{DM} from 1 to 366 provides the results of Table 5-2.