ENVIRONMENTAL MONITORING AND SCIENCE

Air Quality Monitoring

A tale of two air quality metrics

The Canadian Ambient Air Quality Standards (CAAQS) and the Air Quality Health Index (AQHI) are metrics used in the assessment of air quality in Alberta:

- CAAQS are air quality standards used to identify persistent air quality issues due to anthropogenic emissions within a jurisdiction (assessments are completed annually). Exceedances of the CAAQS can lead to management actions, such as emissions reductions.
- AQHI is a communication tool used to inform the public about current air quality and what it means to their health. The AQHI is not used as an indicator for the management of air quality.

	CAAQS	AQHI
Purpose	Air quality standards used to manage pollutants based on their risk to human health and the environment	Communication tool that is designed to help the public make day-to-day decisions to protect their health when air quality is poor
Reporting	Annual reporting based on monitoring data from the previous three years	Real-time hourly data and health messaging based on current monitoring data and forecasts
Management	Management action depends on assigned management levels, with more stringent action taken if CAAQS are approached or exceeded	No direct management response, besides communication to the public
Pollutants considered	Currently there are CAAQS for ozone and fine particulate matter. CAAQS for sulphur dioxide are effective in 2020 and CAAQS for nitrogen dioxide currently are in development	Cumulative influence of a mixture of pollutants on health (ozone, fine particulate matter and nitrogen dioxide), with hourly concentrations of carbon monoxide, sulphur dioxide and hydrogen sulphide also considered

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What is Fine Particulate Matter?

Fine particulate matter, or $PM_{2.5}$, are particles that are less than 2.5 micrometres in diameter, small enough to penetrate the lungs. These particles are about one-twentieth the size of a human hair and can remain suspended in the air for long periods of time. Fine particles can be emitted directly from emission sources or formed in the atmosphere by the transformation of gaseous emissions from industrial or domestic sources of air pollutants.

The major sources of particulate matter include all types of combustion activities, such as motor vehicle operation, power plants, and industrial processes. Road dust and construction operations can also contribute particulate matter to the air. Natural sources of particulate matter include forest fire smoke.

What is Ozone?

Ozone is not emitted directly by human activities, but is produced by a complex set of chemical reactions with nitrogen dioxide and volatile organic compounds. Ozone is also transported to the ground from the ozone rich stratosphere by weather and also can be carried downwind from urban centres and industrial complexes.

What is Nitrogen Dioxide?

Nitrogen dioxide occurs naturally in the environment as a result of forest fires, atmospheric lightning discharges and biogenic oxidation of nitrogen containing compounds present in soil. Anthropogenic emissions of nitrogen dioxide are mainly the result of combustion processes, such as the combustion of fuel for vehicles and home heating or the combustion of coal, oil and natural gas for industrial processes. Nitrogen dioxide can lead to the formation of ozone, nitric acid and particulate matter. Nitrogen dioxide is partially responsible for the brownish discolouration of the lower atmosphere near urban centres.

Figure 1: Instruments to monitor and collect particulate matter data used in CAAQS and AQHI reporting.

What Are the Canadian Ambient Air Quality Standards (CAAQS)?

The CAAQS are national air quality standards that are designed to protect human health and the environment. The CAAQS inform the development of management plans and appropriate management actions required to improve air quality.

The CAAQS are based on three years of data. Therefore, they target long-term air quality issues and not short-term air quality episodes. For fine particulate matter ($PM_{2.5}$), there are two CAAQS metrics: the $PM_{2.5}$ 24-hour metric and the $PM_{2.5}$ annual metric. For ozone, there is one ozone metric, which is based on 8-hour average concentrations.

The CAAQS are targeted to assess air quality issues that can be controlled locally through management actions (such as emissions reductions). Therefore, when determining whether an air zone exceeds the CAAQS, events that are outside of the control of the jurisdiction are not included in the calculations. For example, transport of pollutants across provincial or national borders; natural emissions, such as forest fires or transport of ozone from the stratosphere; and exceptional events, such as windblown dust due to temporary construction, are excluded from the CAAQS.

Figure 2: CAAQS air zones with cities

How Are the Canadian Ambient Air Quality Standards Calculated

The methodology used to calculate the CAAQS metrics is explained in detail in the Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone[1]. The implementation of the CAAQS in Alberta is described in the Alberta Implementation of the Air Zone Management Framework for Fine Particulate Matter and Ozone[2].

CAAQS management levels are assigned within "air zones", which in Alberta are based on the Land Use Framework regional boundaries. For each air zone, management levels are assigned based on the numerical value of the CAAQS metric shown in Table 1.

The following steps are taken in order to calculate metrics and assign management levels to a given air zone.

1. CAAQS metrics for 24-hour $PM_{2.5}$[3], annual $PM_{2.5}$[4], and ozone[5] are calculated for each station within an air zone annually using the past three years monitoring data.
2. Events that are outside the control of the jurisdiction are identified and the CAAQS metrics are recalculated, excluding these events. In order to identify these "transboundary flow" and "exceptional events" various data sources are consulted, such as forest fire maps, satellite images of smoke, and back trajectory information.
3. The management levels for the air zone are assigned for 24-hour $PM_{2.5}$, annual $PM_{2.5}$, and ozone. The management level is assigned based on the station in the air zone with the highest CAAQS metric value, as calculated when events that are outside the control of the jurisdiction are excluded.

Table 1 CAAQS air zone management (effective 2015)

Management Level	Ozone (ppb)	$PM_{2.5}$ 24 hour ($\mu g/m^3$)	$PM_{2.5}$ Annual ($\mu g/m^3$)
Red	Actions for achieving CAAQS		
Threshold	63	28	10.0
Orange	Actions for preventing CAAQS exceedances		
Threshold	56	19	6.4
Yellow	Actions for preventing air quality deterioration		
Threshold	50	10	4.0
Green	Actions for keeping clean areas clean		

1 Canadian Council of Ministers of the Environment, Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone, 2012, available at: www.ccme.ca/files/Resources/air/aqms/pn_1483_gdad_eng.pdf

2 Alberta Environment and Parks, Alberta Implementation of the Air Zone Management Framework for Fine Particulate Matter and Ozone, Air Policy, 2015, No. 2, available at: http://aep.alberta.ca/air/management-frameworks/canadian-ambient-air-quality-standards/documents/ImplementationFramework-PM-Ozone-Sep2015.pdf

3 The 24-hour $PM_{2.5}$ metric is the three-year average of the 98th percentile of the daily 24-hour average $PM_{2.5}$ values for each year

4 The annual average $PM_{2.5}$ metric is the three-year average of the mean of the daily 24-hour average $PM_{2.5}$ values for each year

5 The ozone metric is the three year average of the 4th highest mean 8-hour ozone value for each year

What is the Air Quality Health Index (AQHI)?

The AQHI is used to inform the public about current and predicted air quality conditions and what it means to their health.The AQHI is not used as an indicator for the management of air quality.

The AQHI is calculated every hour and is reported to the public in real time, 24-hours a day. The AQHI is calculated every hour based on ambient concentrations of fine particulate matter, ozone and nitrogen dioxide, and can help the public make decisions to limit exposure or to adjust levels of physical activity when outdoor air quality is poor.

The AQHI provides a simple number from 1 to 10 to indicate the level of relative health risk associated with local air quality. The higher the AQHI number, the greater the health risk and need to take precautions. There are four health risk categories within the scale: 1 to 3, Low risk; 4 to 6, Moderate risk; 7 to 10, High risk; +10, Very High risk. Occasionally, when the amount of air pollution is extremely high, such as during a forest fire smoke event, the AQHI may exceed 10.

The national AQHI reflects the combined effect of various pollutants on overall air quality and health. The AQHI is reported across Canada and is calculated based on the cumulative contribution of ground level ozone, fine particulate matter, and nitrogen dioxide. The AQHI formulation was developed by Health Canada and is based on correlations between air pollution, epidemiological and morbidity data from major cities across Canada.[6]

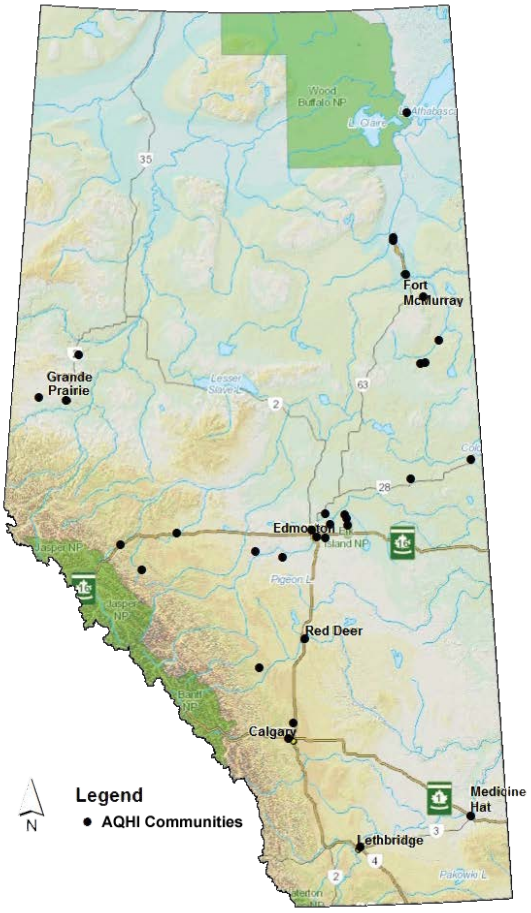


Figure 3: AQHI communities

Government of Alberta. (2016). Provincial Basemap B [GIS layer]. IMG-MS Database of the Central Layer Manager of the Government of Alberta GIS network. (Base Data provided by Spatial Data Warehouse Ltd., Alberta Road Network Data provided by GeoBase, Department of Natural Resources Canada.).

$$\textit{National AQHI} = \frac{1000}{10.4} \times \left[\left(e^{0.000537 \times \overline{O_3}} - 1\right) + \left(e^{0.000871 \times \overline{NO_2}} - 1\right) + \left(e^{0.000487 \times \overline{PM_{2.5}}} - 1\right)\right]$$

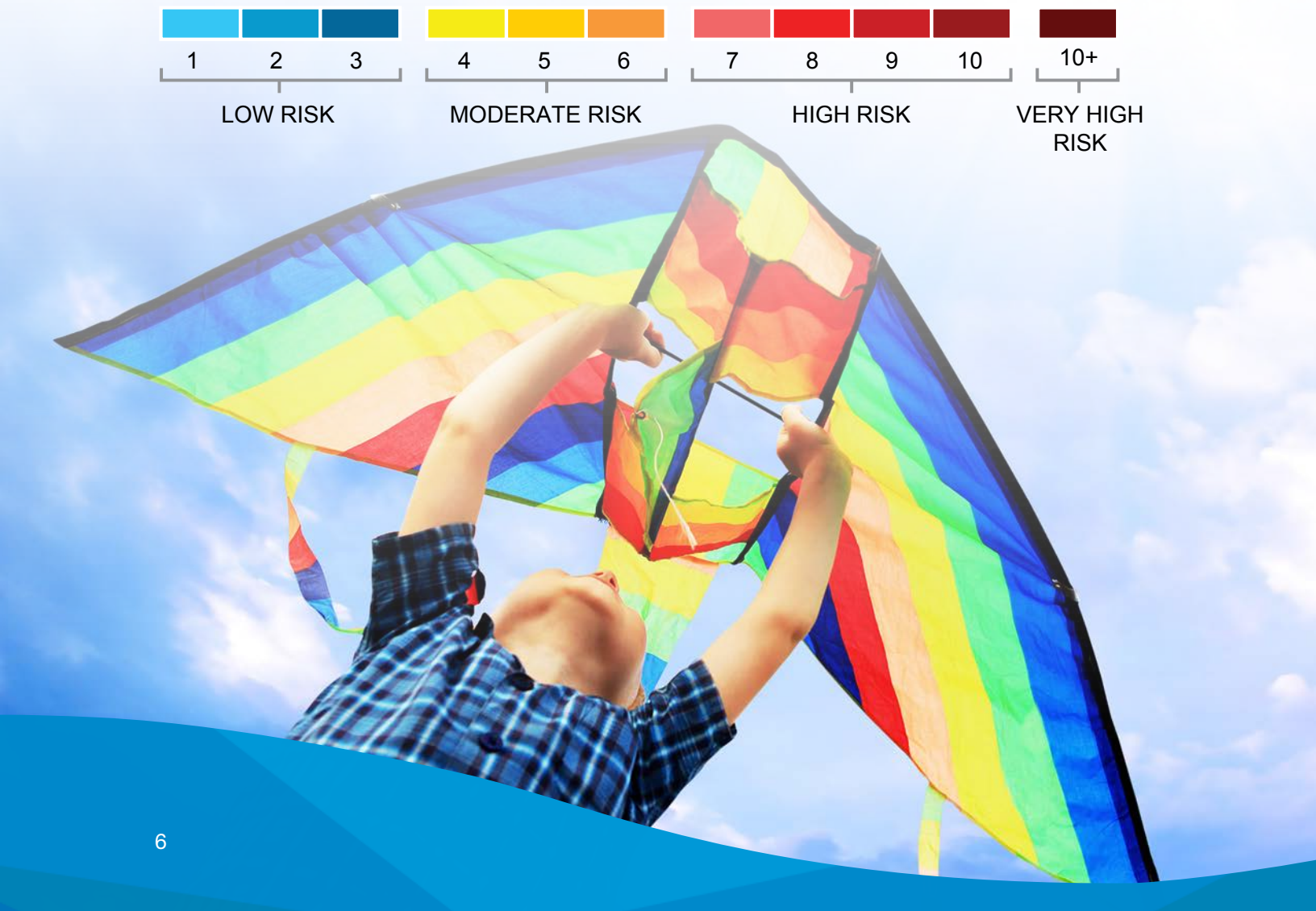
6 Stieb, D. M., Burnett, R. T., Smith-Doiron, M., Brion, O., Shin, H. H., Economou, V. A New Multipollutant, No-Threshold Air Quality Health Index Based on Short-Term Associations Observed in Daily Time-Series Analyses, Journal of the Air & Waste Management Association, 58(3), 2008. DOI: 10.3155/1047-3289.58.3.435, available at: www.tandfonline.com/doi/abs/10.3155/1047-3289.58.3.435

In Alberta, the national AQHI is augmented to include additional pollutants and thresholds (Alberta AQHI). Baseline Alberta AQHI risk categories are calculated using the national AQHI formula. If hourly air pollutant concentrations are higher than Alberta's Ambient Air Quality Objectives or other pollutant thresholds, the AQHI is adjusted. If any of the following pollutant thresholds are exceeded when the national AQHI is Low or Moderate risk (6 or less), then the Alberta AQHI is assessed at the appropriate High or Very High risk value (7 or greater):

- 80 micrograms per cubic metre for fine particulate matter
- 82 parts per billion for ozone
- 159 parts per billion for nitrogen dioxide
- 172 parts per billion for sulphur dioxide
- 13 parts per million for carbon monoxide
- 1 part per million for hydrogen sulphide and total reduced sulphur

Special messaging is also available for visibility (based on levels of particulate matter) and for odour (based on levels of hydrogen sulphide, sulphur dioxide, and total reduced sulphur).

Figure 4: AQHI scale



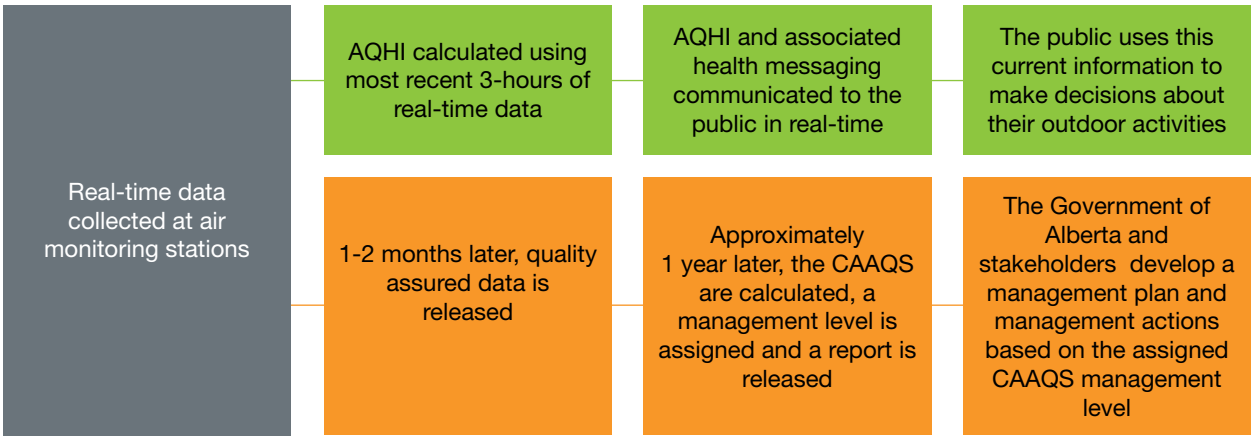


Figure 5: Primary flow of data, reporting and decision making for the AQHI and CAAQS

How are the AQHI and CAAQS Reported?

Figure 5 shows the primary[7] flow of data, reporting, and decision making for the AQHI and the CAAQS. AQHI data, forecasts, and associated health messaging are reported in real-time. Therefore, the public can make decisions for their health based on the current air quality. On the other hand, the CAAQS are calculated using reviewed, quality assured data collected over the entire year and reported to the public as a part of an annual cycle. The Management Levels assigned through the CAAQS are then used to inform the selection of management actions for a given air zone.

Application of the CAAQS Versus AQHI – Simplified Example

Two simplified examples can be used to understand the different applications of the CAAQS versus the AQHI.

- City A has very good air quality most of the year, but is affected by smoke from forest fires for several days in the summer. During the forest fires, the calculated AQHI leads to health messaging informing the public that air quality is at Very High risk. The public in City A can then make decisions based on the associated health messaging, for example, to limit outdoor physical activity, during this period. A year later, the CAAQS report that City A is at the Green Management Level. The CAAQS reflect the good overall air quality in City A and the fact that air pollution due to forest fires cannot be controlled through environmental management actions within the jurisdiction.
- City B has somewhat elevated levels of particulate matter for a large part of the year caused primarily by local sources such as automobiles and industrial emissions. The AQHI throughout the year is in the Low risk or Moderate risk categories. This reflects the fact that air quality on any given day is never poor enough to require the real-time health messaging associated with the High risk or Very High risk categories. However, the persistent levels of elevated particulate matter lead to an exceedance of the CAAQS. The CAAQS therefore reflect the long-term effect of these levels of particulate matter on health and can be used for the management of air quality in the region. Management actions could take many forms (emissions reductions, educating the public, enhancement of transit systems) and could be led by various parties (provincial government, local industrial facilities, municipal governments).

7 Occasionally these data are also used in other secondary forms of reporting. For example, yearly summaries of AQHI data can be reported to the public in community reports.

Application of CAAQS Versus AQHI in Red Deer

For reporting periods between 2011 and 2015, the only air zone to exceed the CAAQS was the Red Deer air zone during 2011-2013. This exceedance was based on both the 24-hour $PM_{2.5}$ and annual $PM_{2.5}$ metrics at the Red Deer Riverside station. The distribution of the AQHI risk categories calculated over the same time period is shown in the top panel of Figure 6.

86.7% of the time, the AQHI was in the Low risk category, with events in the High risk category occurring only 0.1% of the time and no events in the Very High risk category.

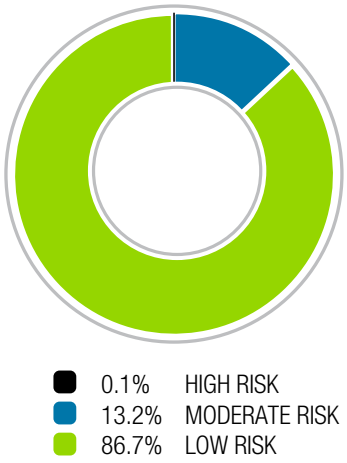
The bottom panel of Figure 6 shows the distribution of AQHI risk categories on days when levels of PM were high (24-hour $PM_{2.5}$ greater than 28 µg/m^3)[8].

During these periods with higher levels of $PM_{2.5}$, the AQHI was in the Moderate risk category 89.8% of the time and in the High risk category 4.8% of the time. Therefore, on the days that contributed to the exceedance of the 24-hour $PM_{2.5}$ CAAQS metric, the AQHI risk categories were higher than usual, but were not often High risk.

How could Red Deer exceed the CAAQS but have so few AQHI values in the High risk or Very High risk categories?

As described above, the AQHI and the CAAQS have different purposes. The CAAQS are air quality standards used to identify persistent air quality issues. The exceedance of the CAAQS in Red Deer shows that the levels of particulate matter have a long-term negative effect on human health and the environment, and that the Government of Alberta and stakeholders must undertake management actions to improve air quality in the area. The AQHI is a tool used to communicate acute health risks to the public in real-time. Persistent AQHI values in the moderate category, as observed during PM events in Red Deer, could result in chronic health effects, whereas the AQHI High risk or Very High risk categories focus on acute health effects. Furthermore, the AQHI assesses the cumulative influence of a pollutant mixture on health, while the CAAQS $PM_{2.5}$ metrics are based only on levels of $PM_{2.5}$. Therefore, if a pollution event is primarily caused by elevated $PM_{2.5}$, it may be somewhat muted by the cumulative nature of the AQHI.

All AQHI Health Risk Categories for 2011-2013
N=26304 hours



AQHI Health Risk Categories for 2011-2013
for 24-hr $PM_{2.5}$ > 28 µg/m^3 N=600 hours

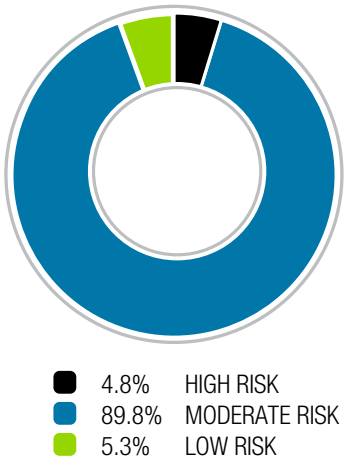


Figure 6: Pie charts of AQHI risk categories for 2011-2013 in Red Deer for (top panel) all measurements and (bottom panel) only days with 24-hour average $PM_{2.5}$ > 28 µg/m^3.

N = total number of hourly AQHI calculations included in the pie chart.

8 28 µg/m^3 is the CAAQS threshold for the 24-hour $PM_{2.5}$ metric.