Northwest Territories Air Quality Report 2012

Northwest Territories Environment and Natural Resources

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INTRODUCTION

The Environment Division (ED) of the Department of Environment and Natural Resources (ENR) monitors air quality in the Northwest Territories (NWT). ENR maintains and operates the NWT Ambient Air Quality Monitoring Network, consisting of four monitoring stations located in Yellowknife, Inuvik, Fort Liard and Norman Wells. Each station is capable of continuously sampling and analyzing a variety of air pollutants and meteorological conditions. The Yellowknife and Inuvik stations are operated in partnership with the National Air Pollution Surveillance (NAPS) program – a joint federal/provincial/territorial monitoring network with the objective of tracking urban air quality trends throughout Canada. A secondary overall objective of the stations is to establish baseline levels of SO_2, H_2S, NO_x, O_3 and PM ahead of development as well as track the trends and cumulative impacts from source emissions should they occur.

ENR also monitors acid precipitation at Snare Rapids, in cooperation with the Canadian Air and Precipitation Monitoring Network (CAPMoN) and the Northwest Territories Power Corporation (NTPC).

The 2012 Annual NWT Air Quality Report summarizes the air quality information collected in 2012, along with some discussion of trends. *Data capture and select statistical information is provided in Appendix A*. The report also provides information on network operations, the air pollutants monitored and the air quality standards used in assessing the monitoring results. Further information, including 'almost real-time' air pollutant readings, can be found by visiting the NWT Air Quality Monitoring Network website at http://air.enr.gov.nt.ca.

After reading this report, if you have questions or require further information, you can contact:

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This report is also available on the Internet at
http://www.enr.gov.nt.ca/_live/pages/wpPages/Air_Quality.aspx

OPERATIONS (NETWORK)

The NWT Air Quality Monitoring Network consists of four permanent monitoring stations located in Yellowknife, Inuvik, Fort Liard and Norman Wells. The stations are climate-controlled structures and include state-of-the-art monitoring equipment capable of continuously sampling and analyzing a variety of air pollutants and meteorological conditions. Pollutants monitored vary by station, but include sulphur dioxide (SO_2), hydrogen sulphide (H_2S), fine particulate ($PM_{2.5}$), coarse particulate (PM_{10}), ground level ozone (O_3), carbon monoxide (CO) and nitrogen oxides (NO_x). Wind speed, wind direction and temperature are also monitored. For additional information on air pollutants see **Appendix C**.

Figure 1: Map of the NWT Air Quality Monitoring Network

Table 1 shows the breakdown of the NWT Air Quality Monitoring Network by substances and meteorological parameters monitored at each station.

Table 1 – Substances Monitored by Station

Stations	**Particulate Matter**		**Gaseous**					**Precipitation**	**Meteorological Monitoring**	
	$PM_{2.5}$ – Fine Particulate	PM_{10} – Coarse Particulate	SO_2 – Sulphur Dioxide	H_2S – Hydrogen Sulphide	NO_x – Nitrogen Oxides	O_3 – Ground Level Ozone	CO – Carbon Monoxide	Acidic Deposition	Wind Speed and Direction	Air Temperature
Yellowknife	√	√	√		√	√	√		√	√
Inuvik	√	√	√	√[1]	√	√	√[2]		√	√
Norman Wells	√	√	√	√	√	√			√	√
Fort Liard	√	√	√	√	√	√			√	√
Snare Rapids						√		√		

Using a sophisticated data acquisition system (DAS) and communications software, data from each station is automatically transmitted every hour to ENR headquarters in Yellowknife, allowing almost real-time review of community air quality by ENR staff. The data also undergoes a series of 'on the fly' validity checks before being archived by ENR's data management, analysis and reporting system.

[1] H_2S monitoring in Inuvik discontinued at the end of 2012.
[2] CO monitoring commenced in late 2012 at the Inuvik station – first data set to be presented in the 2013 report.

The Yellowknife and Inuvik stations are part of a larger national network that monitors the common or criteria air contaminants in urban centres across Canada. The National Air Pollution Surveillance (NAPS) Network is a joint federal/provincial/territorial program, incorporating approximately 286 stations located in 203 communities, which monitor similar particulate and gaseous substances as those sampled in Yellowknife and Inuvik. ENR operates the Inuvik station in partnership with the Aurora Research Institute (ARI), who provide on-the-ground technical operations to the station. Data from both these NWT stations, along with data from other cities, is summarized and assessed, with results published in the NAPS annual data reports available at http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=77FECF05-1#reports

The NAPS Network has a stringent quality assurance/quality control (QA/QC) program that ensures Canada-wide data is comparable. Participation in the NAPS program requires ENR to follow these QA/QC procedures at the Yellowknife and Inuvik sites, and ENR, in turn, applies these procedures at the other NWT stations.

The Fort Liard and Norman Wells stations are territorial stations that were set up in response to increasing resource development activity in the NWT and the potential for the associated emissions to affect air quality. The NAPS Inuvik station still fulfills its original territorial goals, along with its national urban monitoring objective. The primary territorial objective of these stations is to establish baseline levels of SO_2, H_2S, NO_x, O_3 and PM ahead of development as well as track the trends and cumulative impacts from source emissions should they occur.

ENR is involved in a second federal monitoring system; the Canadian Air and Precipitation Monitoring Network (CAPMoN). CAPMoN is a non-urban monitoring network with, as of 2010, 33 measurement sites in Canada and one in the United States that are designed to study the regional patterns and trends of atmospheric pollutants such as acid rain, smog, particulate matter and mercury, in both air and precipitation. Unlike NAPS, CAPMoN locates sites to limit the effect of anthropogenic sources. Most sites are remote and data is considered representative of background values. ENR, with assistance from the Northwest Territories Power Corporation staff, operates the NWT's sole CAPMoN station at the Snare Rapids hydro-electric site, consisting of an acid precipitation collector and ozone analyzer. Daily rain and snow samples are collected and forwarded to the CAPMoN laboratory for analysis, and the data is used by both Environment Canada and ENR.

Table 2 presents the various government affiliations involved with the air quality monitoring stations in the NWT.

Table 2 – NWT Air Quality Network

	Partnership/ Contract	Stations	Network
Environment and Natural Resources – Environment Division		Yellowknife	Environment Canada / Environnement Canada National Air Pollution Surveillance
	Aurora Research Institute	Inuvik	
		Fort Liard and Norman Wells	Northwest Territories stations
	NWT Power Corporation	Snare Rapids	Environment Canada / Environnement Canada Canadian Air and Precipitation Monitoring

Air quality monitoring in the NWT has evolved over time, beginning with a single TSP monitor in Yellowknife back in 1974, and progressing through various monitoring locations and equipment to reach the current stage of development.

Appendix B traces the history of ENR's air quality monitoring in the NWT, while previous ENR Annual Air Quality Reports can be found at http://www.enr.gov.nt.ca/_live/pages/wpPages/Air_Quality.aspx

DEVELOPMENTS IN 2012

The upgrades that were conducted throughout the network in 2012 were made to remain current with monitoring technology advancements and to conform with the NAPS operating standards:

- A new and improved GNWT Air Quality Monitoring website was launched in 2012 to replace the previous version. This website provides more user-friendly features in accessing current and historic air quality monitoring data and associated statistics as well as air quality information and associated resources. The link to the website can be found at http://air.enr.gov.nt.ca/.
- The Yellowknife SO_2 analyzer was replaced with a Trace Level analyzer; this analyzer can accurately measure low level sulphur dioxide concentrations, which are typical of the NWT environment.
- In October, ENR entered into a partnership with the Aurora Research Institute (ARI) to provide technical operations of the Inuvik air quality monitoring station, under the guidance of ENR's Air Quality Technologist. A full training session was conducted for ARI, by both the GNWT and Environment Canada, to provide the necessary skills and resources required to effectively and efficiently operate the station.
- H_2S monitoring was removed from the Inuvik station. H_2S is not a standard Criteria Air Contaminant, but was originally installed due to potential oil and gas activities in the region. Given the lack of oil and gas development in that area, and that years of non-detectable levels have been observed, continued H_2S monitoring was determined to be no longer necessary.
- CO monitoring was added to the Inuvik station at the end of 2012, bringing both NWT NAPS stations (Yellowknife and Inuvik) up to the same suite of monitored parameters.

FUTURE PLANS

ENR plans to conduct the following updates to the NWT Air Quality Monitoring Network in 2013:

- Install a new air monitoring station in Fort Smith, with the following suite of parameters: $PM_{2.5}$, PM_{10}, NO_x, SO_2, O3 and CO, and wind speed, wind direction and temperature. This station will be the first ambient air quality monitoring station in the South Slave Region and is intended to provide data for tracking urban air quality trends and to monitor any cumulative impacts from source emissions should they occur. The proximity of Fort Smith to the Alberta border and the upwind oil sands operations may also provide the potential for identifying transboundary air pollution at this monitoring location.
- The Fort Liard station operations will be suspended following the implementation of the Fort Smith station. The Fort Liard site was established based on the predicted oil and gas activities in the area and the potential associated air quality effects; however, these activities have not yet been realized at the scale originally predicted. Operational challenges at this station, due to remoteness and lack of personnel resources in the area, have also contributed to the decision to suspend this station.

NWT AIR QUALITY STANDARDS

The Government of the NWT has adopted a number of concentration limits for protection of ambient (outdoor) air quality in the NWT. These limits apply to select pollutants and are contained in the "Guideline for Ambient Air Quality Standards in the Northwest Territories", established under the NWT *Environmental Protection Act*. They are summarized in **Table 3** below.

The NWT standards are used in the assessment of air quality monitoring data as well as determining the acceptability of emissions from proposed and existing developments. Where NWT standards are not available for a particular pollutant, the Canadian National Ambient Air Quality Objectives (national standards) or limits established in other jurisdictions are used.

Table 3 – NWT Ambient Air Quality Standards

Parameter and Standard	Concentration ($\mu g/m^3$)*	Concentration (ppbv)**
Sulphur Dioxide (SO_2)		
1-hour average	450	172
24-hour average	150	57
Annual arithmetic mean	30	11
Ground Level Ozone (O_3)		
8-hour running average	130	65
Total Suspended Particulate (TSP)		
24-hour average	120	
Annual geometric mean	60	
Fine Particulate Matter ($PM_{2.5}$)		
24-hour average	30	
Nitrogen Dioxide (NO_2)		
1-hour average	400	213
24-hour average	200	106
Annual arithmetic mean	60	32
Carbon Monoxide (CO)		
1-hour average	15,000 *(15mg/m³)*	13,000
8-hour average	6,000 *(6mg/m³)*	5,000

* Micrograms per cubic metre
** Parts per billion by volume

The “Guideline for Ambient Air Quality Standards in the Northwest Territories” provides additional information on the application of the NWT standards and the pollutants of concern. For additional information on air pollutants see **Appendix C**.

Additional criteria from other jurisdictions used in this report are presented in Table 4.

Table 4 – Additional Ambient Air Quality Standards

Parameter and Standard	Concentration	Source
Coarse Particulate Matter (PM_{10}) 24-hour average	50 ug/m^3	Ontario Ambient Air Quality Criteria, Apr/12 B.C. Ambient Air Quality Objectives, Aug/13
Ground Level Ozone (O_3) 1-hour average	82ppb	Canadian National Ambient Air Quality Objectives, 1989
Annual average	15ppb	B.C. Ambient Air Quality Objectives, Aug/13
8-hour running average, 4th highest annually	65ppb	Canada-Wide Standards for $PM_{2.5}$ and O_3, Jun/00
Hydrogen Sulphide (H_2S) 1-hour average 24-hour average	10ppb 3ppb	Alberta Ambient Air Quality Objectives, Aug/13
Fine Particulate Matter ($PM_{2.5}$) Annual average	10 ug/m^3	B.C. Ambient Air Quality Objectives, Aug/13
	12 ug/m^3	US EPA National Ambient Air Quality Standards, Dec/12

YELLOWKNIFE AIR QUALITY

ENR, in partnership with the NAPS Program, operates the air quality monitoring station in Yellowknife.

This station is located at the École Sir John Franklin High School (Sir John Franklin) and continuously monitors criteria air contaminants (CACs) fine particulate ($PM_{2.5}$), coarse particulate (PM_{10}), SO_2, O_3, NO_x and CO. The station also monitors wind speed, wind direction and temperature, which assist in identifying possible sources of unusual or elevated readings.

Figure 2: Sir John Franklin Station

The previous operations of a non-continuous (discrete) monitor for particulate sampling have been temporarily suspended due to equipment malfunctions and NAPS program-wide replacements. ENR anticipates that the discrete PM sampling will be resumed in the near future.

The air quality monitoring results from the Sir John Franklin station are discussed in the following sections, and historical data is used to demonstrate trends where applicable.

Particulate Matter

Yellowknife's greatest source of particulate is dust from roads, especially in the spring when the snow cover disappears and exposes winter sand and gravel on city streets to the effects of wind and vehicle disturbance. Forest fires, combustion products from vehicles, and heating and electricity generation also raise particulate levels.

ENR currently uses one method of sampling the particulate size fractions of PM in Yellowknife – Beta Attenuation Mass Monitors (BAM). The BAM methodology provides continuous, almost real-time (hourly) analysis of particulate concentrations, in both fine and coarse particle size. The technology measures hourly concentrations on a mass basis.

Fine Particulate ($PM_{2.5}$)

The BAM operating in Yellowknife for the $PM_{2.5}$ fraction is a Federal Equivalency Method (FEM) model.

There were two $PM_{2.5}$ BAM readings at the Sir John Franklin station in 2012 that exceeded the NWT 24-hour standard (30µg/m^3), both of these were a result of forest fire smoke. Impacts to $PM_{2.5}$ levels from forest fires were observed mainly during the month of July. Specifically, forest fires burning north of Wekweeti and north of Lutsel'ke affected $PM_{2.5}$ readings in Yellowknife in the month of July.

Figure 3: 2012 Yellowknife BAM $PM_{2.5}$

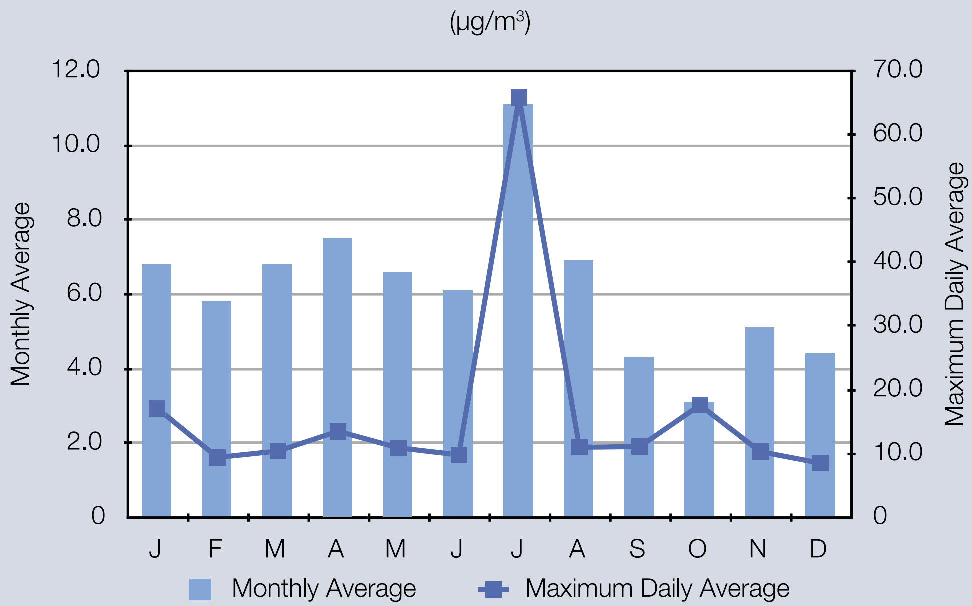


Figure 3 shows the monthly averages and maximum daily average per month measured at the Sir John Franklin station in 2012 on the FEM BAM $PM_{2.5}$. The highest daily average concentration was 65.8µg/m^3 measured in July.

Figure 4: 2009 - 2012 Summary: Yellowknife Monthly $PM_{2.5}$

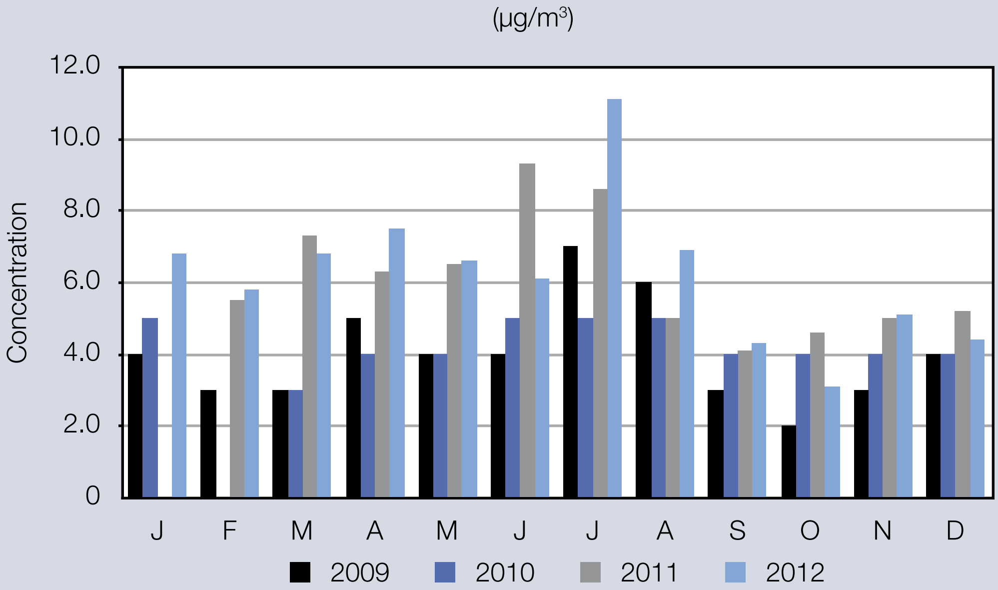


Figure 4 summarizes the monthly average BAM $PM_{2.5}$ data over the last four years. The overall trends indicate that $PM_{2.5}$ levels increase during the summer months, which is typically attributed to forest fires that occur during this time of year.

Coarse Particulate (PM_{10})

The NWT does not have a standard for PM_{10}, but instead adopts a 24-hour average criterion of 50µg/m^3. This level is used in several Canadian jurisdictions, including British Columbia and Ontario.

The graph in Figure 5 presents the PM_{10} data for 2012 and clearly shows the annual "dust" event, which is typical during the month of April. This is due to residual gravel on the roads following the spring snow thaw. There were 11 exceedances of the adopted standard of 50µg/m^3 in 2012. The majority of these occurred in April and correlate well with the spring-time "dust event". The other exceedances occurred during the month of July and were attributed to the previously mentioned smoke from forest fires.

Figure 5: 2012 Yellowknife BAM PM_{10}

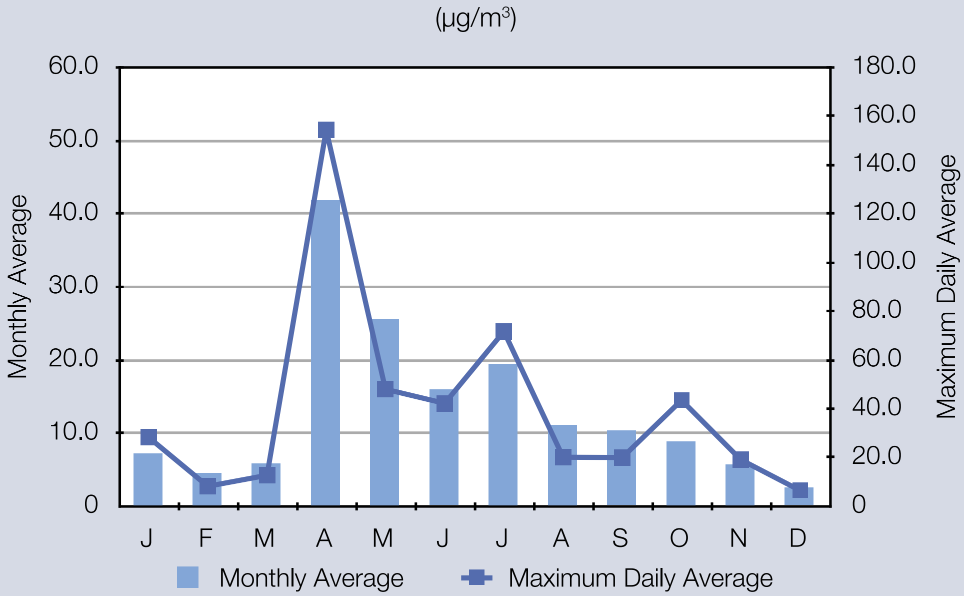


Figure 5 shows the BAM PM_{10} monthly averages and maximum daily averages per month measured at the Yellowknife station in 2012. The highest maximum daily concentration was 154.3µg/m^3, occurring in April.

Sulphur Dioxide (SO_2)

Continuous monitoring for SO_2 has been conducted in Yellowknife since 1992 at a variety of locations over the years, primarily to monitor the effects from the former gold mine operations. The current SO_2 monitoring location at the Sir John Franklin station has been in place since 2004.

There were no exceedances of the NWT hourly (172ppb) or 24-hour (57ppb) standards in 2012 in Yellowknife. The annual average was less than 1ppb, a level that is well below the NWT (11ppb) standard.

The majority of the hourly concentrations recorded in 2012 were only background or slightly greater. These concentrations are similar to the years since 1999 when the last gold mine in Yellowknife closed, and reflect naturally occurring SO_2 and/or small amounts from the burning of fossil fuels.

Figure 6: 1997 - 2012 Summary: Yellowknife Sulphur Dioxide

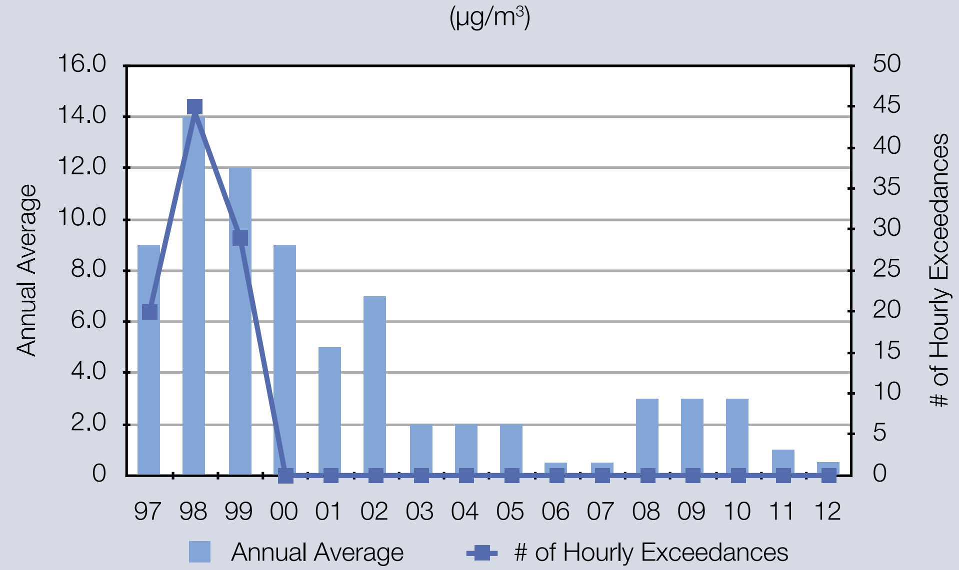


Figure 6 shows the general trends in SO_2 levels measured in Yellowknife air from 1997 to 2012. As illustrated, the number of exceedances has fallen to zero since the closure of Giant Mine in 1999. The 2012 data continued the trend of recent years.

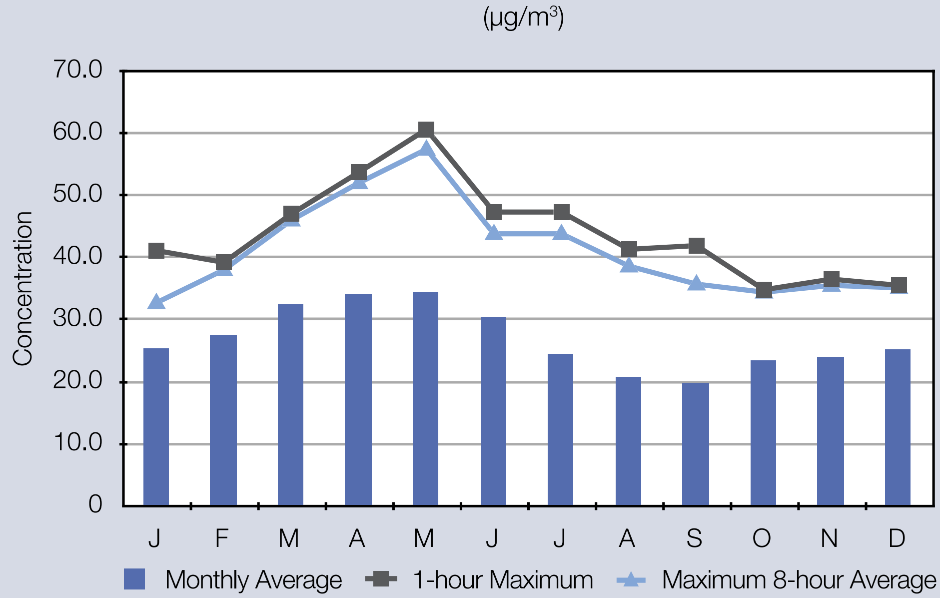
Ground Level Ozone (O_3)

Continuous ozone monitoring has been conducted in Yellowknife since 1998, while the current technology has been operating at the Sir John Franklin station since February of 2003.

The maximum 8-hour average in 2012 was 57.4ppb, which occurred in May and met the 8-hour NWT standard (65ppb). The maximum 1-hour average was 60.6ppb, which met the national maximum acceptable level (82ppb). The 2012 annual hourly average was 26.7ppb.

Detectable concentrations of O_3 exist even in remote areas due to naturally occurring sources of the precursor gases such as volatile organic compounds (VOC) emissions from trees and the introduction of stratospheric ozone to lower elevations resulting from atmospheric mixing processes. These background concentrations typically are in the range of 20 to 40ppb. In large urban areas (and areas downwind), ozone concentrations can be much higher than typical background due to the additional emissions of precursor gases from anthropogenic sources (see **Appendix C**).

Figure 7: 2012 Yellowknife Ozone



Figures 7 shows the maximum hourly reading and maximum 8-hour average Ozone level per month as well as the monthly averages recorded in 2012.

The Figure illustrates the typical spring maximum, which commonly occurs at remote monitoring stations located in mid to high latitudes in the northern hemisphere. The source of this spring maximum continues to be the subject of scientific debate as to how much is attributable to natural vs. anthropogenic sources. Typical monthly ozone concentrations at remote sites in Canada range between 20 and 45ppb[3] and Yellowknife concentrations in 2012 fell within or below this range.

[3] Vingarza, R. "A review of surface ozone background levels and trends". Atmospheric Environment, Vol 38, Issue 21, pp 3431-3442 (2004).

Nitrogen Dioxide (NO_2)

The NO_x gas analyzer provides continuous information on Nitric Oxide (NO), NO_2 and NO_x. However, the focus is on NO_2 due to the greater health concerns associated with this pollutant and the availability of national air quality standards for comparison (see **Appendix C**).

The 2012 results indicated that there were no exceedances of the 1-hour, 24-hour or annual NWT standards for NO_2 (213ppb, 106ppb, 32ppb, respectively). The maximum 1-hour average was 36.6ppb, the maximum 24-hour average was 15.8ppb, while the annual average was 2.2ppb.

Figure 8: 2012 Yellowknife Nitrogen Dioxide

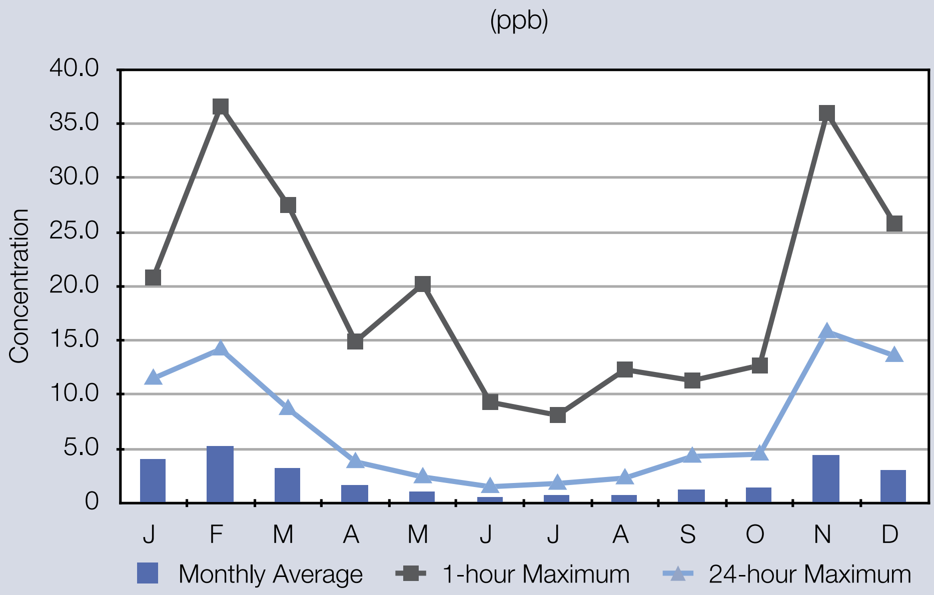


Figure 8 shows the 2012 maximum hourly, maximum daily and monthly averages of NO_2 in Yellowknife. Generally, both the highest monthly averages and the highest hourly concentrations occurred during the winter months. This is likely caused by increased emissions from fuel combustion for residential and commercial heating and idling vehicles as well as short-term “rush hour” traffic influences. The effects of these emissions on winter-time air quality can be increased when combined with stagnant meteorological conditions. Cold, calm days can result in an atmospheric situation where the normal decrease in air temperature with elevation is reversed and a zone of colder air is present at ground level. This zone of colder air and the lack of wind act to restrict dispersion and trap pollutants close to the ground.

Carbon Monoxide (CO)

The 2012 data continued the pattern of low CO readings measured in 2011 and were well below the NWT 1-hour and 8-hour average standards (13ppm and 5ppm, respectively). In 2012, the maximum 1-hour average was 2.909ppm and the annual average was 0.419ppm. The presence of CO is often attributed to mobile sources and, given the absence of heavy traffic volumes in Yellowknife, low levels of CO are expected.

Figure 9: 2012 Yellowknife Carbon Monoxide

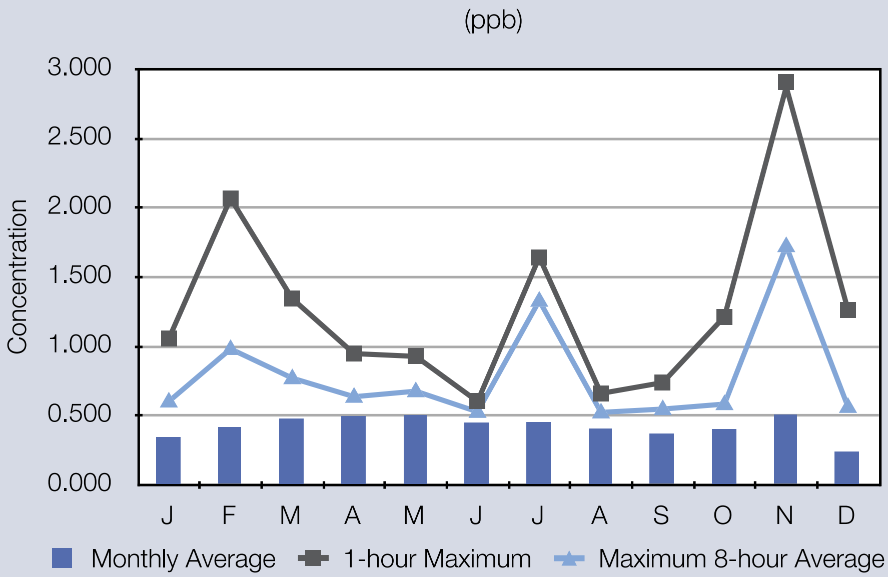


Figure 9 shows the 2012 monthly averages and highest hourly concentrations for CO in Yellowknife.

INUVIK AIR QUALITY

The focus of the monitoring station in Inuvik is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time. In January 2006, the station was incorporated into the National Air Pollution Surveillance (NAPS) Network to provide air quality information for comparison to other communities in Canada.


Figure 10: Inuvik Station

This station has been in operation since 2003, but was moved from its original location at Samuel Hearne School to its present site on Bompas Street in 2009. The following parameters are measured at the Inuvik station: $PM_{2.5}$, PM_{10}, SO_2, O_3, NO_2 and H_2S. Note that H_2S monitoring in Inuvik was discontinued at the end of 2012 and CO monitoring was commenced.

Fine Particulate ($PM_{2.5}$)

The BAM operating in Inuvik for the $PM_{2.5}$ fraction is a Federal Equivalency Method (FEM) model.

The 2012 BAM readings produced an annual $PM_{2.5}$ average of 3.5µg/m^3. There were no exceedances of the NWT 24-hour standard (30µg/m^3) for $PM_{2.5}$, as the highest daily average concentration was 12.1µg/m3, measured in July. Impacts from forest fires were negligible during the summer of 2012.

Figure 11: 2012 Inuvik BAM $PM_{2.5}$

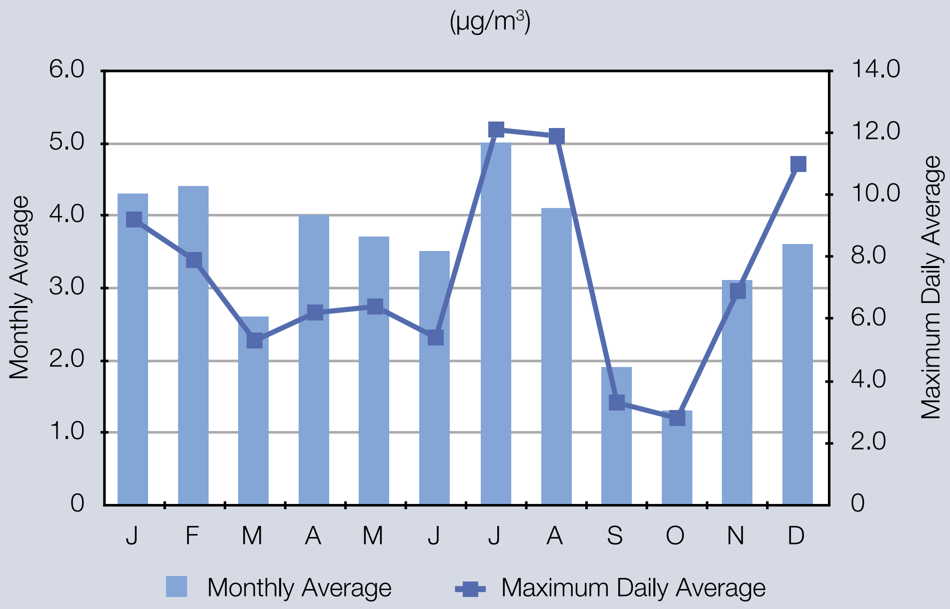


Figure 11 shows the monthly averages and maximum daily average per month measured at the Inuvik station in 2012 on the FEM BAM $PM_{2.5}$. Although the $PM_{2.5}$ concentrations were slightly elevated in the summer, they were not comparable to previous summer months when forest fires can cause monthly averages over twice these levels.

Coarse Particulate (PM_{10})

The maximum daily average measured from the PM_{10} BAM in Inuvik in 2012 was 73.8µg/m^3 and the highest hourly maximum was 242µg/m^3, both occurring in May. There were 7 exceedances of the adopted 24-hour standard (50µg/m^3), which all occurred in the month of May as well. Similar to previous years, the spring time levels were elevated and were representative of the typical "spring-time dust event" associated with residual winter gravel. Given the dirt roads in the Inuvik area in proximity to the monitoring station, the dust events can persist into the summer months as well.

Figure 12: 2012 Inuvik BAM PM_{10}

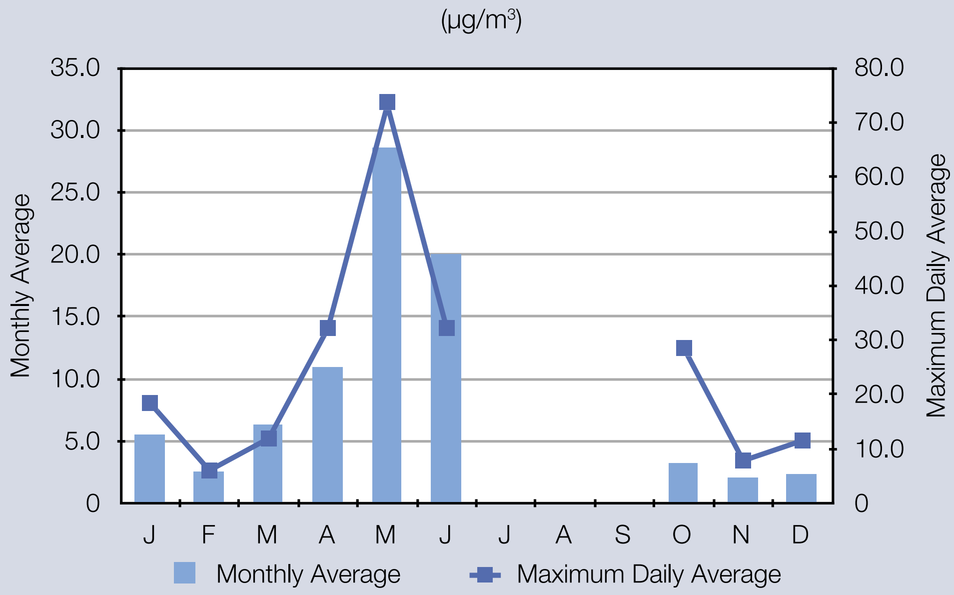


Figure 12 shows the monthly averages and the maximum daily average concentrations of PM_{10} from the BAM in Inuvik. The spring spike is attributed to the residual winter gravel on the roads following the thaw. Unfortunately, significant data loss occurred during the months of July through to September due to logger communication issues as well as a critical monitor component malfunction. The equipment was replaced in October.

Sulphur Dioxide (SO_2)

The annual average of SO_2 in Inuvik was less than 1ppb and the maximum 1-hour average was 1.0ppb. The SO_2 concentrations measured in 2012 were very low and, similar to previous years' results, had no exceedances of the NWT hourly (172ppb), 24-hour (57ppb) and annual average (11ppb) standards.

Ground Level Ozone (O_3)

Ozone data was available for nine months during 2012; unfortunately, valid data could not be collected during the peak level spring months (April, May and June) due to an analyzer component failure that compromised the data for these months. From the available nine months of data, the maximum 1-hour average was 52.1ppb, while the maximum 8-hour average was 39.4ppb. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (65ppb) for ground level ozone was exceeded in 2012. The annual average was 19.6ppb, which is typical of background levels.

Figure 13: 2012 Inuvik Ozone

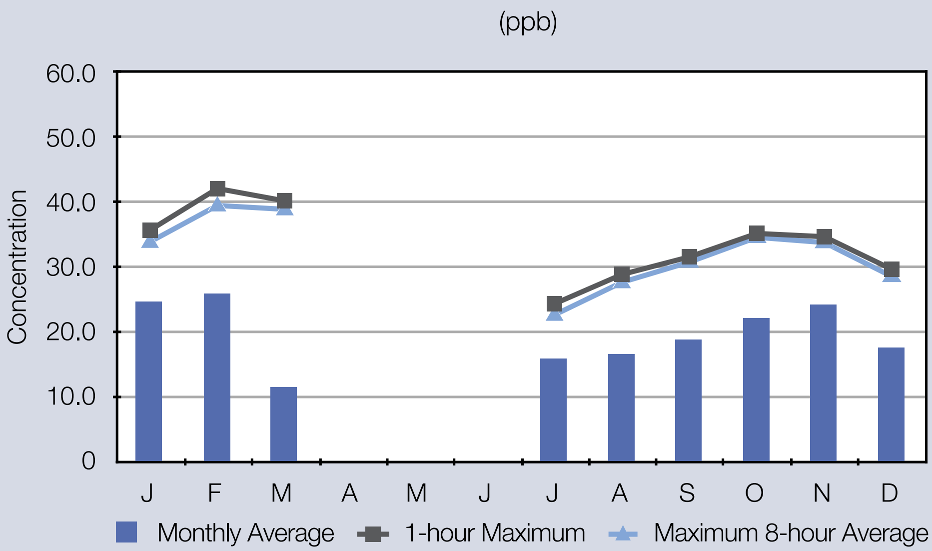


Figure 13 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in 2012 in Inuvik.

Nitrogen Dioxide (NO_2)

The NO_2 results for Inuvik in 2012 show that the maximum 1-hour average was 70.1ppb, the maximum 24-hour average was 16.5ppb and the overall annual average was 2.6ppb, all of which were within the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 14: 2012 Inuvik Nitrogen Dioxide

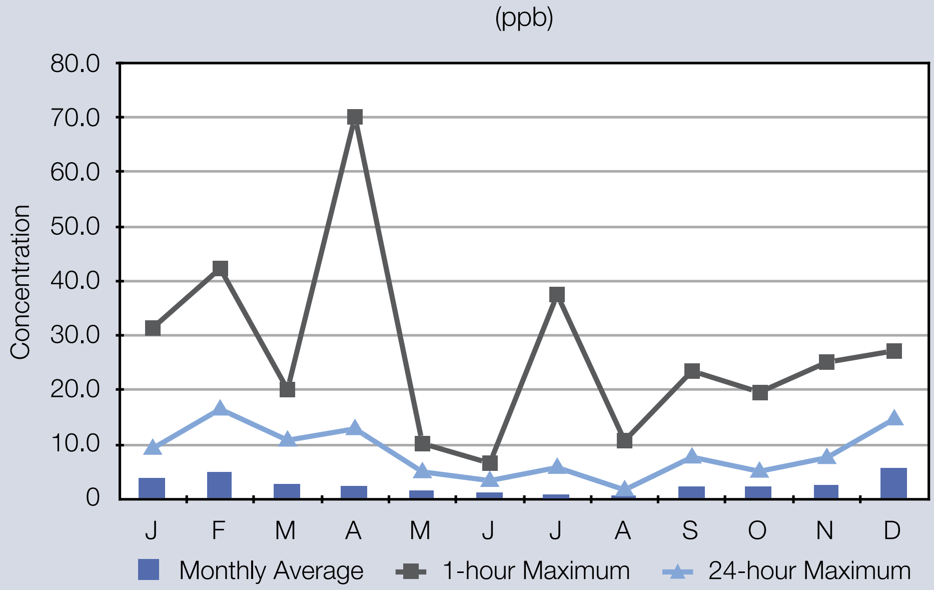


Figure 14 shows the maximum hourly, maximum daily and monthly averages of NO_2 in Inuvik in 2012. Average concentrations are observed to be higher in the colder months, similar to previous years, likely as a result of idling and other combustion sources during inversions (stagnant air masses). A higher than normal 1-hour maximum occurred in the month of July due to some short-term localized emissions near the air monitoring station.

Hydrogen Sulphide (H_2S)

The data collected in 2012 continued to indicate very low H_2S concentrations in Inuvik – essentially non-detectable. Most of the readings were less than 1ppb, which is below the detectable limitations of the instrumentation and considered to be within the “noise” range. As noted in the “Developments in 2012” section of this report, 2012 was the final year of H_2S monitoring at the Inuvik station.

The maximum recorded 1-hour average was 1ppb, while the maximum 24-hour average was 0.2ppb. There were no exceedances of the adopted Alberta Guidelines (1-hour average 10ppb and a 24-hour average of 3ppb). These results are consistent with the readings collected in previous years.

FORT LIARD AIR QUALITY

The focus of the monitoring station in Fort Liard is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time, including potential oil and gas development in the region.

The station is located near the Fort Liard Airport and measures $PM_{2.5}$, PM_{10}, SO_2, O_3, NO_2 and H_2S. Monitoring has been conducted for select parameters since 2000; however, this station was established in 2004. *Note that the O_3 analyzer was installed in 2007.*

Fine Particulate ($PM_{2.5}$)

The 2012 annual $PM_{2.5}$ average concentration was 4.6µg/m^3, while the maximum daily average was 34.4ug/m^3. There was only one exceedance of the NWT 24-hour standard for $PM_{2.5}$ (30µg/m^3), occurring in September as a result of forest fire activity in the area.

Figure 15: 2012 Fort Liard BAM $PM_{2.5}$

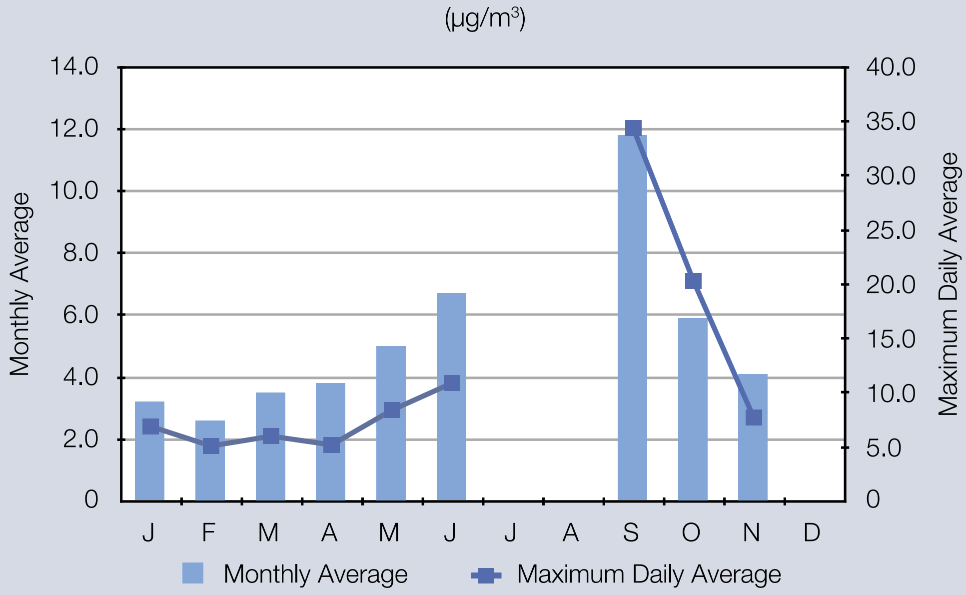


Figure 15 shows the monthly averages and maximum daily averages for $PM_{2.5}$ measured from the BAM at the Fort Liard station in 2012. Unfortunately, data loss occurred over the summer months when we would typically expect to see elevated levels as a result of forest fire effects. This was due to equipment malfunctions, which were repaired in September. The highest concentrations occurred in September and were attributed to forest fires burning just west of Fort Liard.

Coarse Particulate (PM_{10})

Limited PM_{10} data collection occurred in 2012 as a result of repetitive issues with the monitoring instrument. Of the available data (approximately four months), the maximum 24-hour average was 54.3ug/m^3, occurring in September during the forest fire events. This was the only recorded exceedance of the 24-hour standard for PM_{10} (50ug/m^3).

Sulphur Dioxide (SO_2)

There were no exceedances of the NWT hourly (172ppb), 24-hour (57ppb) or annual average (11ppb) standards for SO_2 in Fort Liard. The maximum 1-hour average value was only 2.0ppb. The monthly averages were also low, with values less than 1ppb. These readings are consistent with those measured in previous years.

Ground Level Ozone (O_3)

Ozone data was available for eight months during 2012. Valid data could not be collected during the peak level spring and summer months, with the exception of May, due to an analyzer component failure that invalidated the data. The maximum 1-hour average was 52.0ppb, while the maximum 8-hour average was 50.6ppb. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (65ppb) for ground level ozone was exceeded in 2012. The annual average was 22.9ppb, which is typical of background levels.

Figure 16: 2012 Fort Liard Ozone

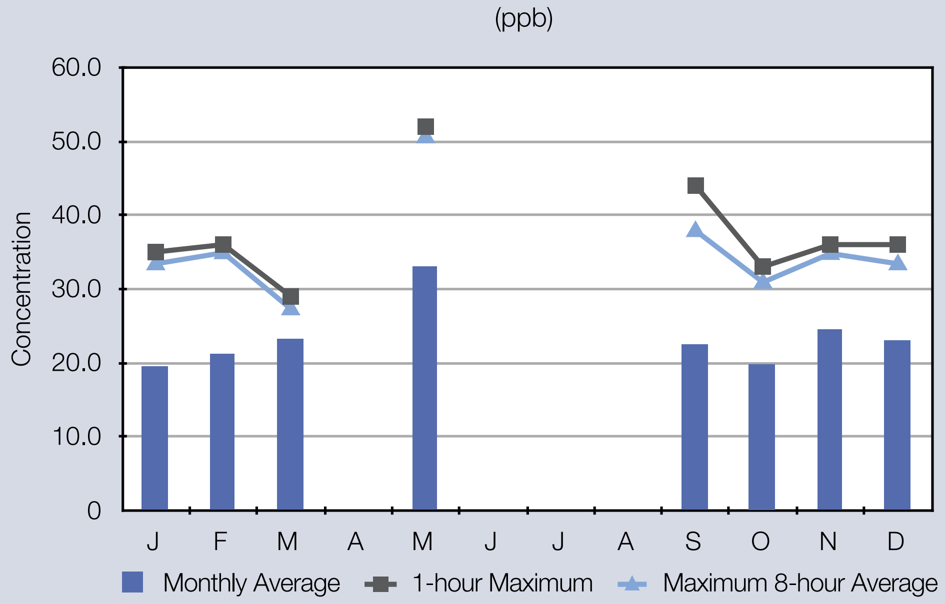


Figure 16 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in Fort Liard in 2012.

Nitrogen Dioxide (NO_2)

The 2012 results for Fort Liard show that the maximum 1-hour average was 28.0ppb, the maximum 24-hour average was 23.0ppb and the overall annual average was 3.0ppb, which were within the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 17: 2012 Fort Liard Nitrogen Dioxide

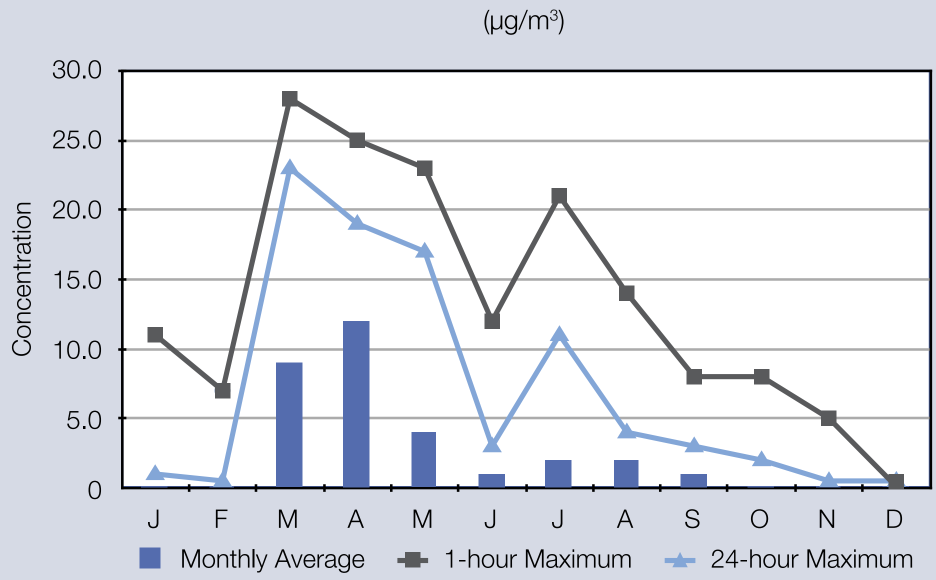


Figure 17 shows the maximum hourly, maximum daily and monthly averages of NO_2 in Fort Liard in 2012. Levels are typically higher in the cold months than the summer due to more combustion sources such as home heating and idling vehicles coupled with inversions; the higher than normal 1-hour maximum reading in July is likely attributed to an intermittent, localized source.

Hydrogen Sulphide (H_2S)

The maximum hourly H_2S concentration in 2012 was 2ppb and the vast majority of readings were less than 1ppb, essentially within the detection limits or "noise" range of the analyzer. H_2S in Fort Liard was within the limits of the adopted Alberta Guidelines (1-hour average 10ppb and a 24-hour average of 3ppb).

NORMAN WELLS AIR QUALITY

The focus of the monitoring station in Norman Wells is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

The station is located at the ENR compound on Forestry Drive and measures $PM_{2.5}$, PM_{10}, SO_2, O_3, NO_2 and H_2S. It has been in operation since 2003.

Fine Particulate ($PM_{2.5}$)

The maximum daily average concentration of $PM_{2.5}$ in Norman Wells in 2012 was 35.2µg/m^3 and the annual average was 3.9µg/m^3. There was one exceedance of the NWT 24-hour standard for $PM_{2.5}$ (30µg/m^3), which occurred in August. The elevated readings measured in June and July are attributed to smoke from forest fires burning in and around Tulita, Deline, Fort Good Hope and Colville Lake. The elevated readings in August were caused by a fire located about 20 kilometres northwest of Norman Wells near the Carcajou River.

Figure 18: 2012 Norman Wells BAM $PM_{2.5}$

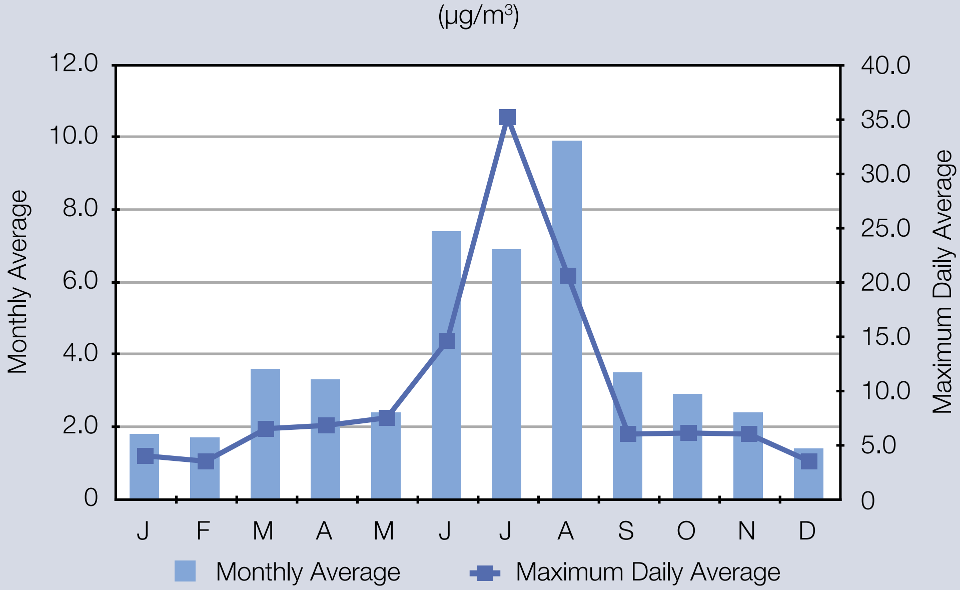


Figure 18 shows the monthly averages and maximum daily averages of $PM_{2.5}$ measured from the BAM at the Norman Wells station in 2012. The elevated readings in the summer are typical and are associated with the forest fire season.

Coarse Particulate (PM_{10})

Eight months of data was collected in 2012 as a result of instrument malfunctions. The 1-hour maximum concentration was 401µg/m³, which occurred in August and coincided with a forest fire burning in proximity to the town of Norman Wells. The 24-hour maximum concentration was 60.8µg/m³, which occurred in April when spring-time dust levels were elevated. The annual average concentration was 20.9µg/m³. There were two exceedances of the adopted 24-hour average standard of 50µg/m³, both occurring in April.

Figure 19: 2012 Norman Wells BAM PM_{10}

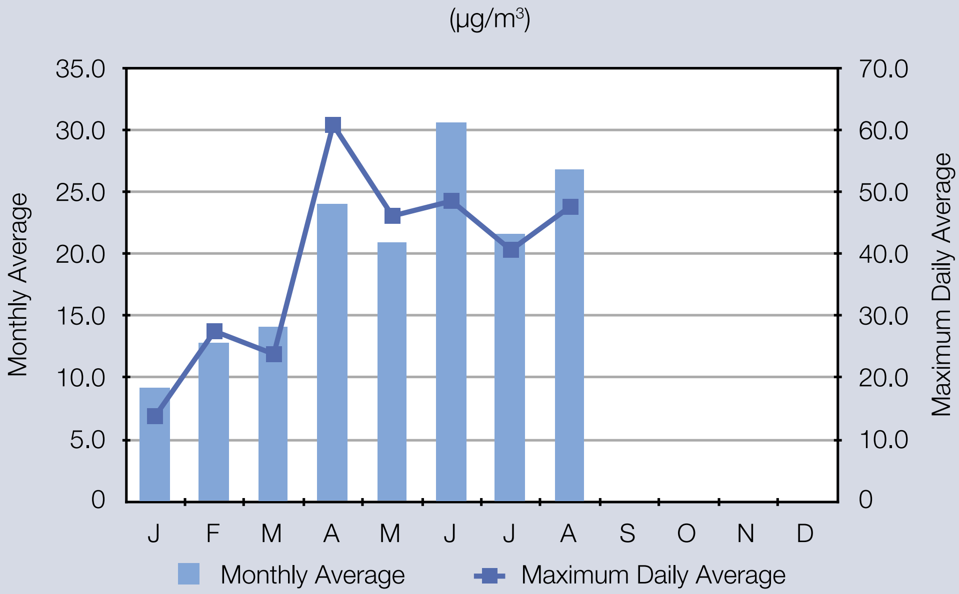


Figure 19 shows the monthly averages and the maximum daily average concentrations of PM_{10} measured from the BAM in Norman Wells in 2012. The snow-free months were affected by dusty conditions throughout the summer from the gravel roads and construction activities, in addition to forest fire influences.

Sulphur Dioxide (SO_2)

Overall, SO_2 concentrations in Norman Wells were generally very low. The 1-hour maximum SO_2 reading was 4.7ppb, the maximum 24-hour average was 2.2ppb and the annual average was less than 1ppb. No exceedances of the NWT standards occurred (1-hour average of 172ppb, 24-hour average of 57ppb and annual average of 11ppb). This is consistent with previous years.

Ground Level Ozone (O_3)

The maximum 1-hour average was 53.0ppb, while the maximum 8-hour average was 50.8ppb, both occurring in May. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (65ppb) for ground level ozone was exceeded in 2012. The annual average was 22.3ppb, which is within the range of what is considered background levels. The typical elevated readings in the spring-time were observed, which is consistent with historical data.

Figure 20: 2012 Norman Wells Ozone

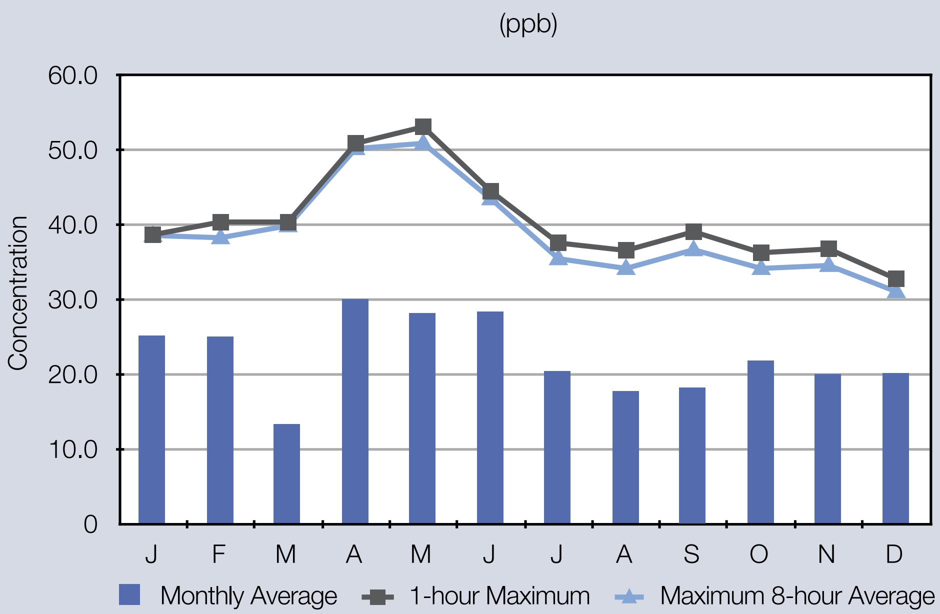


Figure 20 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in Norman Wells in 2012.

Nitrogen Dioxide (NO_2)

The 2012 NO_2 results for Norman Wells show that the maximum 1-hour average was 42.9ppb, the maximum 24-hour average was 10.5ppb and the overall annual average was 1.5ppb, which were within the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 21: 2012 Norman Wells Nitrogen Dioxide

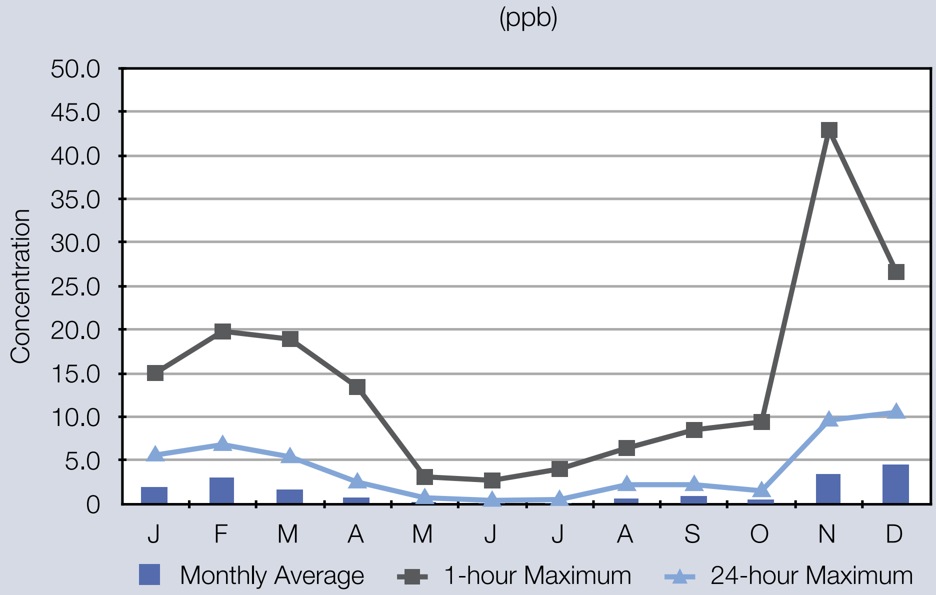


Figure 21 shows the 2012 monthly averages, maximum 24-hour averages and maximum 1-hour concentrations of NO_2 in Norman Wells. As with previous years, NO_2 levels were observed to increase in the winter months as a function of idling and other combustion sources during inversions (stagnant air masses).

Hydrogen Sulphide (H_2S)

The maximum hourly H_2S concentration in 2012 was 0.1ppb and the vast majority of readings were less than 1ppb, essentially within the detection limits or "noise" range of the analyzer. H_2S in Norman Wells was within the limits of the adopted Alberta Guidelines (1-hour average 10ppb and a 24-hour average of 3ppb). The 2012 results are consistent with previous years.

LONG-TERM TRENDS

The NWT Ambient Air Quality Monitoring Network has been in operation for a decade and, therefore, it is appropriate timing to look back at the available data for longer term trends. Comparisons of the annual averages of select parameters are presented below. In cases where no GNWT annual air quality objective exists, another jurisdiction's has been adopted for reference.

Figure 22: 2005 to 2012 – Annual $PM_{2.5}$ Averages

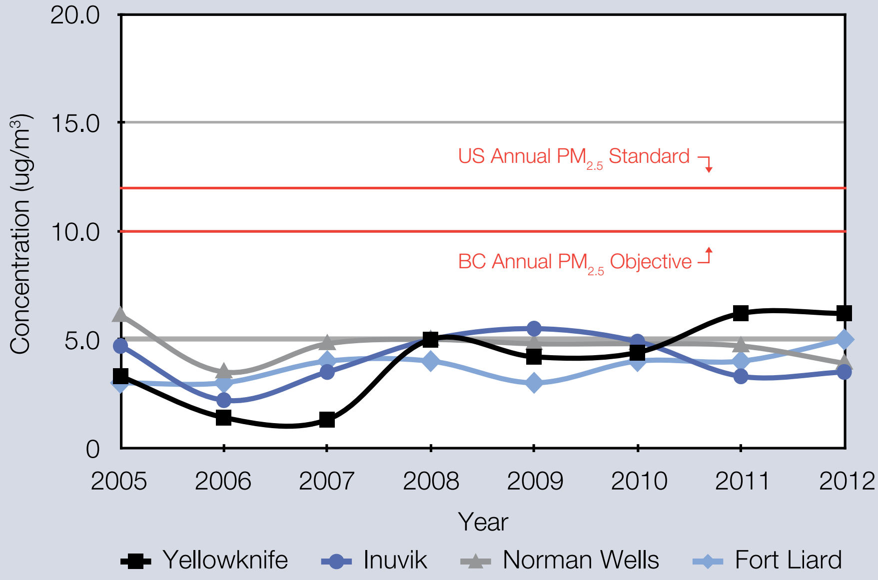


Figure 22 compares the annual $PM_{2.5}$ average concentrations from each of the NWT monitoring stations from 2005 to 2012. The results demonstrate that the $PM_{2.5}$ levels in the NWT fluctuate annually, which could be due to the influence by seasonal forest fires whose effects vary annually. The instruments in use over the time period presented were consistent (BAM1020), with upgrades conducted as required. The Yellowknife and Inuvik stations were upgraded to a Federal Equivalency Method (FEM) version between 2010 and 2011.

The Yellowknife station is demonstrating a slight upward trend in $PM_{2.5}$ levels, which could be attributed to a variety of factors, including localized sources or natural causes (e.g. forest fire). We will continue to examine if this trend continues and review potential causes accordingly.

The BC Ambient Air Quality Objective of 10ug/m^3 and the US EPA National Ambient Air Quality Standard for $PM_{2.5}$ annual mean of 12ug/m^3 were used for comparison. The results demonstrate that $PM_{2.5}$ levels at each of the four NWT communities are consistently within the criteria.

Figure 23: 2005 to 2012 – Annual NO_2 Averages

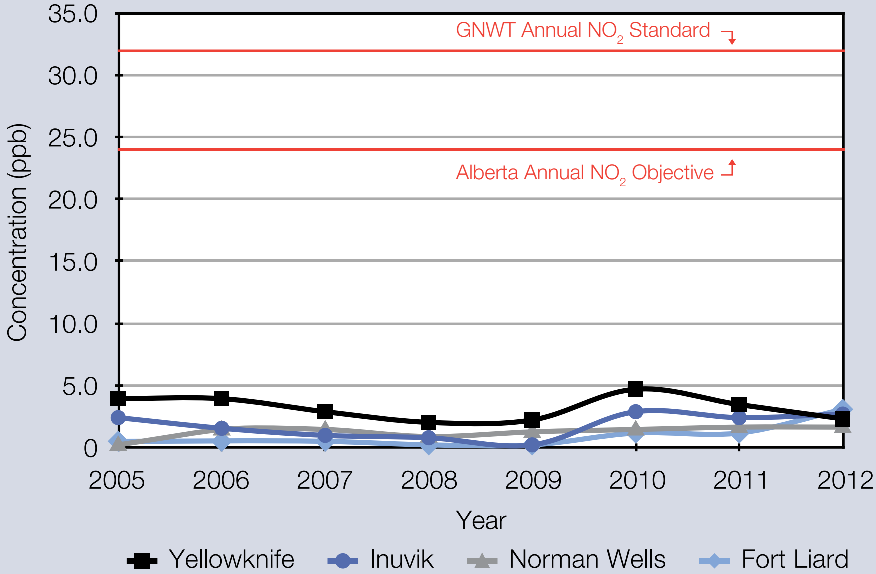


Figure 23 compares the annual NO_2 average concentrations from each of the NWT monitoring stations from 2005 to 2012. Note that data from Fort Liard for 2008 and 2009, and from Inuvik for 2009, are not included due to low data capture. Results indicate that generally Yellowknife has slightly higher NO_2 levels than the other communities, which is to be expected given the larger population size and resulting combustion sources. All results are below the GNWT standard of 32ppb and the Alberta Ambient Air Quality Objectives NO_2 annual average of 24ppb.

Figure 24: 2005 to 2012 – 4th Highest Daily 8-hour O_3

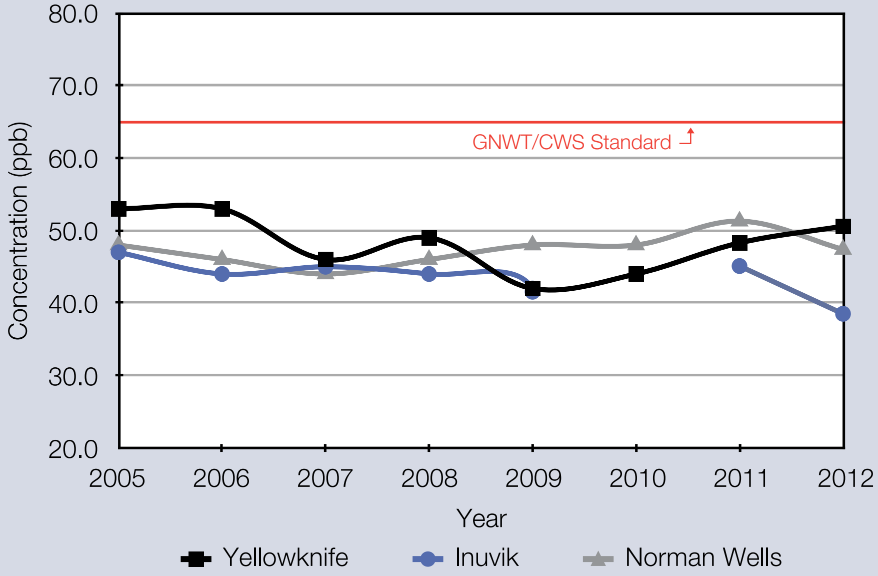


Figure 24 shows the O_3 comparison according to the Canada-Wide Standards (CWS) method of calculation; the year's 4th highest 8-hour average is compared to the GNWT and CWS standard of 65ppb. *Fort Liard was not included in the comparison due to multiple years of insufficient data capture.* The results indicate that O_3 levels are fairly consistent from year to year and between the communities, and are consistently below the applicable air quality standard.

NATIONAL COMPARISONS

In addition to comparison of our air quality data within the NWT, this report compares NWT air quality against other parts of the country. When looking at ambient air data between different locations, it is important to note that there are many influences to local air quality, including geographic considerations, population size, local industrial sources, transboundary considerations and others. For comparison purposes, ENR has presented Yellowknife air quality against select jurisdictional capitals, followed by a comparison to cities of similar population, regardless of the types and sources of their air emissions. *Results for other jurisdictions were calculated from data available on provincial websites.* In cases where no GNWT annual air quality objective exists, another jurisdiction's has been adopted for reference.

Figure 25: National Comparisons – Jurisdictional Capitals

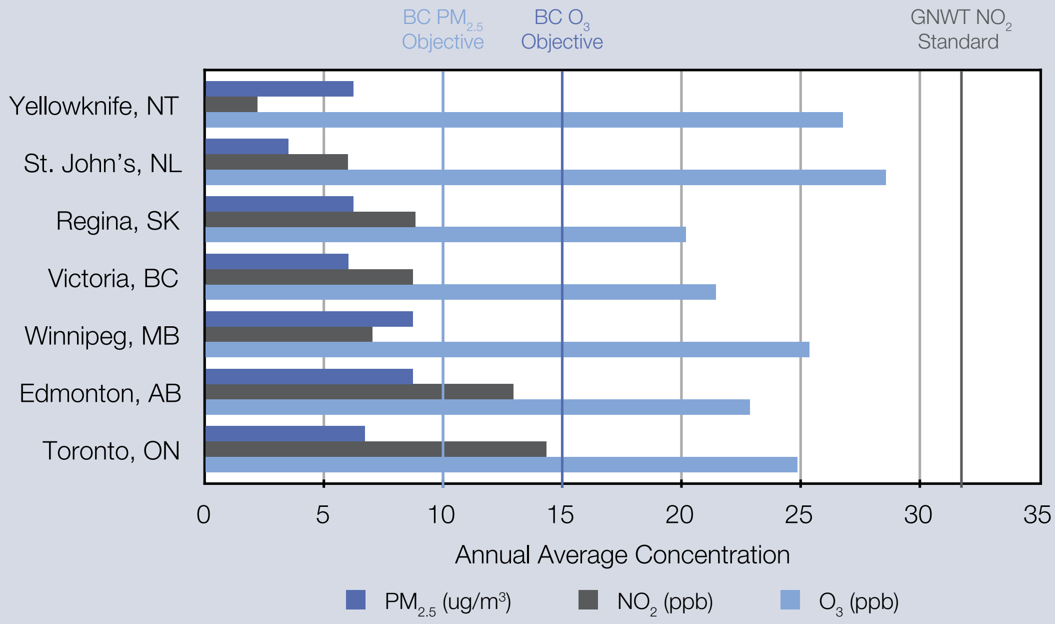


Figure 25 compares the 2012 annual average concentrations of O_3, NO_2 and $PM_{2.5}$ between select capital cities across Canada. The values are measured against the GNWT air quality standards for NO_2 and the BC Provincial Ambient Air Quality Objectives for O_3 and $PM_{2.5}$ (BC is one of few jurisdictions that has criteria for annual averages of these parameters).

The data shows that Yellowknife O_3 levels in 2012 were higher than the comparison cities, with the exception of St. John's. Conversely, Yellowknife NO_2 levels were significantly lower than all the comparison cities. The reverse ranking between Yellowknife's O_3 and NO_2 concentrations is generally to be expected, in part since localized NO_x levels contribute to ozone reduction through a chemical process known as scavenging. Therefore, higher O_3 levels may be expected in areas with lower NO_2 concentrations. All O_3 levels were in exceedance of the presented criteria, while NO_2 levels were all below the GNWT criteria.

The $PM_{2.5}$ levels in Yellowknife were middle of the range of the comparison cities, and similar to Regina and Victoria. Only Winnipeg and Edmonton $PM_{2.5}$ levels were in exceedance of the presented criteria.

Figure 26: National Comparisons – Similar Population Size

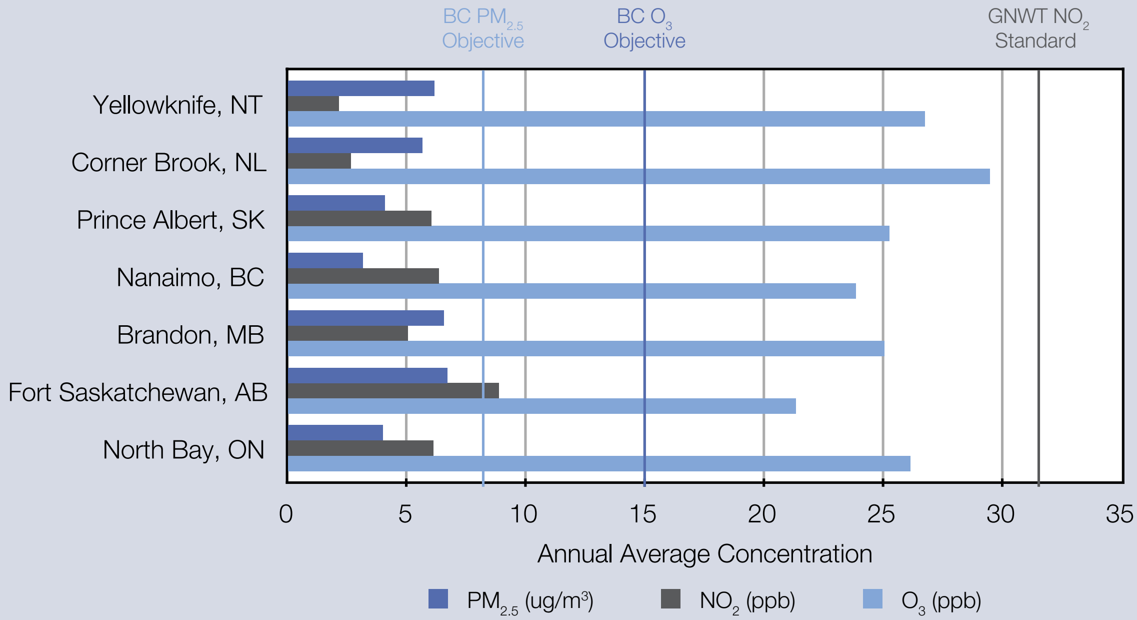


Figure 26 compares Yellowknife annual average concentrations of O_3, NO_2 and $PM_{2.5}$ between select cities across Canada of a similar population size (<100,000). The results show that Yellowknife O_3 levels in 2012 were again higher than the comparison cities, with the exception of Corner Brook. Conversely, Yellowknife NO_2 levels (as well as Corner Brook's) were significantly lower than the comparison cities. This inverse relationship between O_3 and NO_2 levels is generally evident between the selected cities, likely in part as a result of O_3 scavenging. All O_3 levels were in exceedance of the presented criteria, while NO_2 levels were all below the GNWT criteria.

Yelllowknife $PM_{2.5}$ levels in 2012 were among the higher concentrations of the comparison cities, with similar levels as Brandon and Fort Saskatchewan. All $PM_{2.5}$ results were below the presented criteria.

SNARE RAPIDS

Since 1989, ENR has operated a Canadian Air and Precipitation Monitoring (CAPMoN) station at the Northwest Territories Power Corporation's Snare Rapids hydro-electric site. This site is located approximately 150 kilometres northwest of Yellowknife. Rain and snow samples are collected on a daily basis and sent to Environment Canada's CAPMoN laboratory in Toronto for analysis of precipitation chemistry. Select results are presented below.

Figure 27: Snare Rapids Acid Deposition

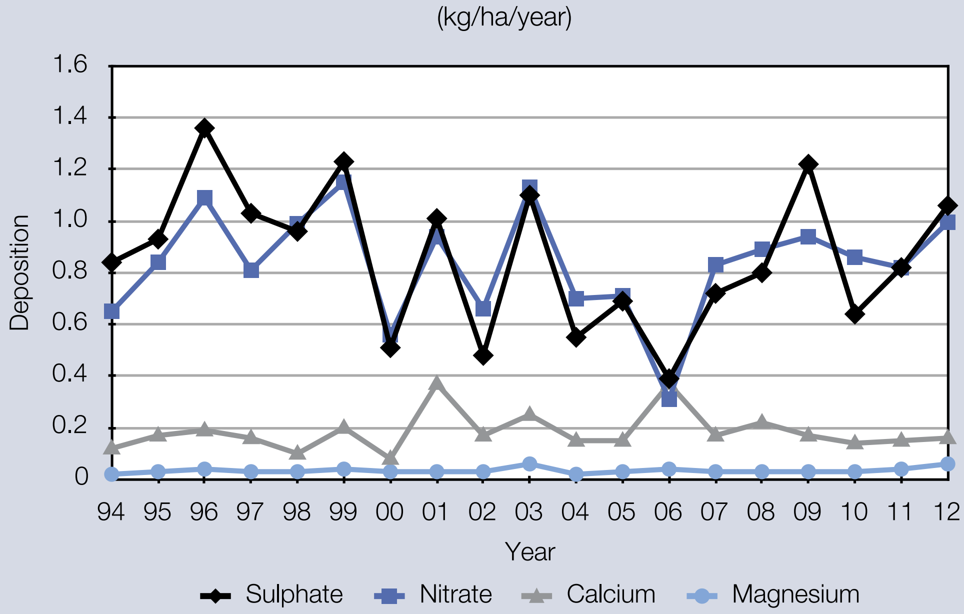


Figure 27 shows the deposition rates for sulphate, calcium, nitrate and magnesium from 1994 to 2012.

The geology of the NWT is mostly characterized by non-carbonate bedrock resistant to weathering and/or shallow, coarse-textured soils with low cation exchange capacity, low sulphate adsorption capacity and low pH. The sulphate level of deposition that is considered to be protective of sensitive ecosystems in the NWT is 7 kg/ha/yr. In areas of eastern Canada where acid rain is a more serious environmental problem, sulphate deposition has been measured by CAPMoN in excess of 20 kg/ha/yr. Nitrate deposition at Snare Rapids is also low relative to eastern Canada.

Sulphate and nitrate deposition rates measured at Snare Rapids remain below levels that would be expected to cause a significant environmental effect in sensitive ecosystems.

APPENDICES

APPENDIX A: 2012 DATA CAPTURE

$PM_{2.5}$								Percentile (24-hr)			>30 ug/m^3	
Location	**Valid Days**	**% Valid Days**	**Valid Hrs**	**% Valid Hrs**	**Mean**	**Max 1-hr**	**Max 24-hr**	**25**	**50**	**75**	**# days**	**% days**
Yellowknife	338	92.6	8170	93.3	6.2	158.0	65.8	4.2	5.6	7.1	2	0.5
Inuvik	307	84.1	7400	84.5	3.5	64.0	12.1	2.0	3.1	4.7	0	0.0
Norman Wells	310	84.9	7554	86.2	3.9	329.0	35.2	1.8	2.8	4.6	1	0.3
Fort Liard	201	55.1	4951	56.5	4.6	172.8	34.4	2.9	3.7	5.1	1	0.3

PM_{10}								Percentile (24-hr)			>50 ug/m^3	
Location	**Valid Days**	**% Valid Days**	**Valid Hrs**	**% Valid Hrs**	**Mean**	**Max 1-hr**	**Max 24-hr**	**25**	**50**	**75**	**# days**	**% days**
Yellowknife	358	98.1	8554	97.6	13.3	360	154.3	4.3	8.1	15.8	11	3.0
Inuvik	224	61.4	5393	61.6	7.8	242	73.8	1.2	3.4	8.2	7	1.9
Norman Wells	189	51.8	4615	52.7	20.9	401	60.8	13.3	17.6	24.9	2	0.5
Fort Liard	169	46.3	4147	47.3	9	262	54.3	4.2	6.1	11.1	1	0.3

0_3								Percentile (8-hr)			>65 ppb	
Location	**Valid Days**	**% Valid Days**	**Valid Hrs**	**% Valid Hrs**	**Mean**	**Max 1-hr**	**Max 24-hr**	**25**	**50**	**75**	**# 8-hrs**	**% 8-hrs**
Yellowknife	362	99.2	8632	98.5	26.7	60.6	57.4	21.0	26.6	32.0	0	0.0
Inuvik	238	65.2	5587	63.8	19.7	42.0	39.4	14.7	19.6	24.9		0.0
Norman Wells	0	0.0	7554	86.2	3.9	329.0	35.2	1.8	2.8	4.6	1	0.3
Fort Liard	259	71.0	8174	93.3	22.3	53.0	50.8	15.9	22.3	28.0	0	0.0
	191	52.3	4444	50.7	22.9	52.0	50.6	17.9	22.4	27.5	0	0.0

NO_2

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Percentile (1-hr)			>213 ppb	
							25	50	75	# 1-hr	% 1-hr
Yellowknife	360	98.6	8614	98.3	2.2	36.6	0.3	1.0	2.6	0	0.0
Inuvik	332	91.0	7677	87.6	2.6	70.1	0.0	1.2	3.3	0	0.0
Norman Wells	359	98.4	8166	93.2	1.5	42.9	0.0	0.3	1.6	0	0.0
Fort Liard	366	100.3	8417	96.1	3.0	28.0	0.0	0.0	2.0	0	0.0

NO_2

Location	Max 24-hr	Percentile (24-hr)			>106 ppb	
		25	50	75	# days	% days
Yellowknife	15.8	0.5	1.3	2.8	0	0.0
Inuvik	16.5	0.5	1.8	3.6	0	0.0
Norman Wells	10.5	0.2	0.6	1.9	0	0.0
Fort Liard	23.0	0	0	2.0	0	0.0

$S0_2$

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Percentile (1-hr)			>172 ppb	
							25	50	75	# 1-hr	% 1-hr
Yellowknife	310	84.9	7404	84.5	0.17	2.75	0.00	0.00	0.00	0	0.0
Inuvik	197	54.0	4796	54.7	0.1	1.0	0.0	0.0	0.1	0	0.0
Norman Wells	298	81.6	7121	81.3	0.7	4.7	0.2	0.6	1.1	0	0.0
Fort Liard	365	100.0	8407	96.0	0.0	2.0	0.0	0.0	0.0	0	0.0

SO_2

Location	Max 24-hr	Percentile (24-hr) 25	50	75	>57 ppb # days	% days
Yellowknife	1.28	0.00	0.00	0.03	0	0.0
Inuvik	0.5	0.0	0.0	0.1	0	0.0
Norman Wells	2.2	0.2	0.6	1.1	0	0.0
Fort Liard	1.0	0.0	0.0	0.0	0	0.0

CO

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Max 24-hr	Percentile (24-hr) 25	50	75	>13 ppm # days	% days
Yellowknife	364	99.7	8682	99.1	0.419	2.909	0.937	0.361	0.420	0.479	0.0	0.0

CO

Location	Max 8-hr	Percentile (8-hr) 25	50	75	>5 ppm # days	% days
Yellowknife	1.723	0.365	0.423	0.481	0.0	0.0

APPENDIX B: MONITORING HISTORY

History of Air Quality Monitoring in the Northwest Territories	
1974	• GNWT starts monitoring air quality in Yellowknife with the installation of a high-volume TSP air sampler at the Post Office site.
1989	• Monitoring of acid precipitation at the Snare Rapids hydro-electric site begins.
1992	• SO_2 analyzer installed at the Yellowknife City Hall site.
1997	• SO_2 monitoring in N'dilo begins and continues until 2000.
1998	• O_3 analyzer added in Yellowknife to the City Hall site.
2000	• A SO_2 analyzer was installed in the ENR building in Fort Liard in March, followed by a H_2S analyzer in October. • Installed a partisol dichotomous particulate sampler at the Yellowknife Post Office station in January.
2002	• Summer sampling of PM_{10} begins at ENR's Daring Lake Research Station. • Yellowknife City Hall SO_2 analyzer relocated to new air monitoring trailer located at Ècole Sir John Franklin High School.
2003	• Daring Lake summer sampling of $PM_{2.5}$ begins (the same sampler is used for PM_{10} and $PM_{2.5}$ monitoring). • Air monitoring stations are installed in Inuvik, Norman Wells and Fort Liard. • CO and NO_x analyzers added to the Yellowknife station as well as a continuous fine particulate sampler ($PM_{2.5}$). • Norman Wells station monitors SO_2 and H_2S. • Inuvik station monitors SO_2, H_2S, NO_x and $PM_{2.5}$. • Fort Liard station monitors SO_2 and H_2S. A $PM_{2.5}$ sampler is installed late in the year. • The O_3 analyzer that was operating at the Yellowknife City Hall location is relocated to the new Sir John Franklin station. • ENR initiates the upgrade of the Data Acquisition System moving to a specialized air monitoring system, which will allow more efficient and quality controlled data collection. • Continuous $PM_{2.5}$ samplers are installed in Inuvik and Fort Liard. • A second high-volume sampler is installed at the Sir John Franklin station in Yellowknife.
2004	• $PM_{2.5}$ sampler is installed in Norman Wells. • Data Acquisition System (DAS) is significantly upgraded. New components are installed inside the stations and a new data management, analysis and reporting system is brought on-line.
2005	• NO_x analyzer is installed in March at the Fort Liard station. • O_3 and NO_x analyzers are installed at the Norman Wells station in April. • O_3 analyzer purchased by Environment Canada (Yellowknife office) is installed at the Inuvik station in April. • Due to years of significant data loss caused by extreme cold, the partisol dichotomous particulate sampler at the Yellowknife Post Office station is relocated indoors at the Sir John Franklin station.

History of Air Quality Monitoring in the Northwest Territories (cont.)	
2005	• The Yellowknife Post Office station is officially closed after the last TSP sample ran on December 6, 2005. • Development of an air quality website begins. The website will link with the data management, analysis and reporting system to provide public access to air quality data for each monitoring location. Access to archived data will also be available by querying the database using web-based tools.
2006	• Yellowknife – A BAM particulate matter (PM_{10}) monitor is installed and begins collecting data in April. • Inuvik – A BAM particulate matter (PM_{10}) monitor is installed and begins collecting data in October. • The NWT Air Quality Monitoring Network website is officially released.
2007	• Fort Liard – A BAM particulate matter (PM_{10}) monitor and an ozone (O_3) analyzer are installed and begin collecting data in late August. • Completed the second phase of the Air Quality Monitoring Network website, which included database related modifications as well as web design improvements.
2008	• No significant changes to the network.
2009	• Norman Wells – PM_{10} BAM installed to complete particulate sampling throughout the network. • Yellowknife – Hi-vol sampler discontinued from all NAPS stations. • Daring Lake particulate monitoring temporarily discontinued due to equipment malfunction.
2010	• Norman Wells – PM_{10} BAM installation completed. • Inuvik – Entire station is relocated to a more representative location due to ongoing construction activities in the original location. • Yellowknife – $PM_{2.5}$ monitor upgraded to BAM FEM (Federal Equivalency Method).
2011	• Inuvik – $PM_{2.5}$ monitor upgraded to BAM FEM (Federal Equivalency Method). • Data acquisition and management system upgraded in Yellowknife, Norman Wells and Inuvik, including Envista ARM software and PC-based industrial data-loggers. • Manual partisol dichotomous sampler installed in Yellowknife. • BAMs at all stations begin reporting in actual conditions instead of standard conditions, as per federal protocol.
2012	• Entered into partnership with Aurora Research Institute (ARI) to provide technical operations of the Inuvik station. • Installed CO monitoring in Inuvik (end of 2012). • Discontinued H_2S monitoring in Inuvik (end of 2012). • Switched to trace level SO_2 monitoring in Yellowknife. • New air quality monitoring network website launched to provide current and historic data to users (http://aqm.enr.gov.nt.ca/).

APPENDIX C: AIR POLLUTANTS

The NWT Air Quality Monitoring Network tracks a number of different air pollutants. With the exception of H_2S, these pollutants are known as Criteria Air Contaminants (CACs). They represent the gases and compounds most often affecting community air quality and targeted by monitoring programs.

H_2S is monitored at the air quality stations in Inuvik, Norman Wells and Fort Liard due to its association with oil and gas development activities. *Note that 2012 was the final year of H_2S monitoring in Inuvik.*

Total Suspended Particulate (TSP)

Total Suspended Particulate (TSP) is a general term for dust. TSP includes a wide variety of solid and liquid particles found floating in the air, with a size range of approximately 50 micrometers (µm) in diameter and smaller (a human hair is approximately 100 µm in diameter). While TSP can have environmental and aesthetic impacts, it is the smaller particles contained within TSP that are of concern from a human health perspective (see Particulate Matter ($PM_{2.5}$) and (PM_{10}) later in section). Road dust, forest fires, mining activities and combustion products from vehicles, heating and electricity generation contribute to TSP levels.

The NWT Ambient Air Quality Standard for TSP is 120µg/m^3 over a 24-hour period. The standard for the annual average is 60µg/m^3 (geometric mean).

TSP monitoring has not been conducted in the NWT network since 2005, since particulate monitoring has instead been focused on $PM_{2.5}$ and PM_{10} monitoring.

Particulate Matter ($PM_{2.5}$) and (PM_{10})

A sub-portion of TSP, these very small particulates are named for the diameter size of the particles contained within each group – PM_{10} contains particles with a diameter of 10 microns (1 millionth of a metre) or less, while $PM_{2.5}$ (a sub-portion of PM_{10}) contains particles with a diameter of 2.5 microns or less. The significance of these microscopic particles is that they can be inhaled and are associated with health effects, including aggravation of existing pulmonary and cardiovascular disease. Generally, the smaller the particle, the greater the penetration into the lung and the greater the associated health risk.

Sources of particulates that can be inhaled include road dust and wind-blown soil, which make up the majority of the PM_{10} particles. Particles in the $PM_{2.5}$ size range primarily result from combustion of fossil fuels for industrial activities, commercial and residential heating as well as vehicle emissions, forest fire smoke and chemical reactions between other gases emitted to the air.

The national Canada-Wide Standards (CWS) process has set an acceptable limit for $PM_{2.5}$, but has not yet established a limit for PM_{10}. The CWS 24-hour average acceptable limit for $PM_{2.5}$ is 30µg/m^3 and this concentration has been adopted under the NWT *Environmental Protection Act* as the NWT Ambient Air Quality Standard for $PM_{2.5}$. Several Canadian jurisdictions (e.g. BC, Ontario, Newfoundland and Labrador) have adopted a PM_{10} concentration of 50µg/m^3 (24-hour average) as an acceptable limit.

Sulphur Dioxide (SO_2)

SO_2 is a colourless gas, with a pungent odour at elevated concentrations, which can have negative effects on human and environmental health. Certain types of vegetation (especially lichens) are very sensitive to SO_2 impacts. SO_2 also plays a role in acid deposition and formation of secondary fine particulate through chemical reactions with other pollutants in the air.

There are some natural sources of SO_2 in ambient air (forest fires, volcanoes), but human activity is the major source. Emissions of SO_2 primarily result from the burning of fossil fuels containing sulphur. Sources include natural gas processing plants, gas plant flares and oil refineries, metal ore smelting, power generating plants and commercial or residential heating.

The NWT Ambient Air Quality Standards for SO_2 are 172ppb (1-hour average), 57ppb (24-hour average) and 11ppb (annual average).

Hydrogen Sulphide (H_2S)

Hydrogen sulphide (H_2S) is a colourless gas with a characteristic rotten egg odour. At high concentrations (parts per million range), it can be toxic, but typical ambient (outdoor) concentrations, even in areas impacted by industrial sources, tend to fall in the parts per billion (ppb) range. However, due to its low odour threshold, the presence of H_2S can be offensive and it has been associated with eye irritation and triggering feelings of nausea in sensitive individuals.

Industrial sources include oil and gas extraction, petroleum refining, sewage treatment facilities, and pulp and paper mills. Natural sources include sulphur hot springs, swamps and sloughs, which release H_2S as a by-product of organic decomposition.

There are no NWT standards for H_2S. The Alberta Ambient Air Quality Objectives provide an hourly limit of 10ppb and a 24-hour limit of 3ppb, based on avoidance of odour.

Nitrogen Oxides (NO_X)

Nitrogen oxides (NO_x) consist of a mixture of nitrogen-based gases, primarily nitric oxide (NO) and nitrogen dioxide (NO_2). Emissions of both NO and NO_2 results from the high temperature combustion of fossil fuels. The predominant emission is NO, which then rapidly converts to NO_2 through chemical reaction in the atmosphere. NO is a colourless and odourless gas, whereas NO_2 is a reddish-brown colour with a pungent, irritating odour. NO_2 is considered the more toxic and irritating of the two gases and, at elevated concentrations, is associated with both acute and chronic respiratory effects. Both gases play a role in the atmospheric reactions, resulting in acid deposition and secondary pollutant formation (i.e. O_3 and fine particulate).

Because of the greater health effects of NO_2, development of air quality standards has focused on this gas, rather than NO or total NO_x. The NWT standards are reflective of national maximum desirable levels of 213ppb (1-hour average), 106ppb (24-hour average) and 32ppb (annual average).

Ground Level Ozone (O_3)

Ground level ozone (O_3) should not be confused with stratospheric O_3, which occurs at much higher elevations and forms a shield that protects life on the planet from the sun's harmful ultraviolet radiation. The gas is the same, but at ground level O_3 is regarded as undesirable due to its association with a variety of human health concerns, environmental impacts and property damage. O_3 is a highly reactive gas and is defined as a secondary pollutant. It is not emitted in large quantities from any source, but is formed through a series of complex chemical reactions involving other pollutants called precursors (e.g. NO_x and volatile organic compounds or VOCs) in the presence of sunlight.

The national standards provide a maximum acceptable level of 82ppb for O_3 based on a 1-hour average and an annual maximum acceptable level of 15ppb. The Canada-Wide Standards (CWS) process has also set an acceptable limit of 65ppb based on an 8-hour average. The CWS 8-hour limit has been adopted under the NWT *Environmental Protection Act* as the NWT Ambient Air Quality Standard for O_3.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. The primary source is vehicle exhaust, especially in cities with heavy traffic congestion. Other sources include industrial processes and fuel combustion for building heating. One natural source is wildfires.

CO affects humans and animals by interfering with the ability of the blood to transport oxygen around the body.

The NWT standards for CO reflect the national maximum desirable levels of 13ppm (1-hour average) and 5ppm (8-hour average). CO values are reported in ppm as opposed to other gaseous pollutants, which are reported in ppb.

Acid Deposition

Acidity in precipitation is measured in pH units on a scale of 0 to 14. A value of seven indicates neutral, values less than seven indicate acidic conditions and values greater than seven indicate alkaline conditions. Even clean precipitation is slightly acidic – around pH5.6 – due to the presence of naturally occurring concentrations of carbon dioxide and minor amounts of sulphate and nitrate ions. The introduction of sulphur dioxide and nitrogen oxide emissions from combustion of fossil fuels for industrial, commercial and individual activities can result in an increase in acidic compounds in the atmosphere – often in areas far removed from the original emission sources. The removal of these sulphur and nitrogen compounds through atmospheric washout is reflected in the increased acidity (lower pH values) of precipitation. Calcium and magnesium ions – mostly from natural sources – act to neutralize acidity in precipitation.

Generally, precipitation with a pH value of 5.0 or less is termed “acidic”. However, assessment of acid precipitation is usually based on deposition to an area over a specified time period (e.g. kilograms per hectare per year, kg/ha/yr) rather than review of specific precipitation event parameters. Also, the degree of impact to a particular environment is influenced by its “buffering” capacity or ability to tolerate the acidic inputs. Therefore, determination of acceptable limits usually requires a range of values to reflect the differing tolerances of various areas.