Northwest Territories Air Quality Report

2014

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 Smith 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 regional air quality trends throughout Canada. A secondary overall objective of the stations is to establish baseline levels of SO_2, NO_x, O_3 and PM ahead of development as well as track the trends and cumulative impacts from source emissions should they occur.

Deposition monitoring is also conducted in the NWT, in cooperation with the federal Canadian Air and Precipitation Monitoring Network (CAPMoN). One station is located in Wood Buffalo National Park and the other at the Snare Rapids Hydro Facility; the latter operated in partnership with the Northwest Territories Power Corporation (NTPC).

The 2014 Annual Air Quality Report summarizes the air quality information collected in 2014, 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 'near real-time' air pollutant readings, can be found by visiting the NWT Air Quality Monitoring Network web site 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 Smith 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), 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 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	Meteorlogical Monitoring	
	$PM_{2.5}$ – Fine Particulate	PM_{10} – Coarse Particulate	SO_2 – Sulphur Dioxide	NO_x – Nitrogen Oxides	O_3 – Ground Level Ozone	CO – Carbon Monoxide	Deposition	Wind Speed and Direction	Air Temperature
Yellowknife	√	√	√	√	√	√		√	√
Inuvik	√	√	√	√	√	√		√	√
Norman Wells	√	√	√	√	√			√	√
Fort Smith	√	√	√	√	√	√		√	√
Snare Rapids					√		√		
Wood Buffalo					√		√		

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.

The Yellowknife and Inuvik stations are part of a larger national network that monitors the criteria air pollutants in communities 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 of 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 Smith and Norman Wells stations are territorial stations that were set up in response to increasing resource development activity in the NWT and Alberta, and the potential for the associated emissions to affect air quality. The primary territorial objective of these stations is to establish baseline levels of SO_2, NO_x, O_3 and PM ahead of development as well as to track the trends and cumulative impacts from source emissions as or should they occur. Although not NAPS-designated, these stations also fulfill the national urban monitoring objective. Fort Smith annual data will be reported for the first time for the 2014 sampling year.

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 35 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. Two CAPMoN stations are operated in the NWT, located in the Wood Buffalo National Park approximately 80 km northwest of Fort Smith, and at the Snare Rapids Hydro Facility located approximately 150 km northwest of Yellowknife. ENR, with assistance from the NTPC staff, operates the Snare Rapids CAPMoN station, consisting of an acid precipitation collector and ozone analyzer. The Wood Buffalo station uses an automated precipitation collector and also monitors continuous ozone. 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 partnerships and affiliations involved with the air quality monitoring stations in the NWT.

Table 2 – NWT Air Quality Network

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

Air quality monitoring in the NWT has evolved over time, beginning with a single particulate 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 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 2014

ENR strives for continuous improvement of the monitoring network to ensure we are current with technology advancements and are serving the needs of the NWT. The upgrades that were conducted throughout the network in 2014 include:

- Hydrogen sulphide monitoring was discontinued at the Norman Wells station in October. A review of the H_2S monitoring to date (approximately 10 years) determined that the readings observed were within the detection limits or 'noise' range of the analyzer, thus indicating that H_2S in this location is not of concern.
- The Yellowknife station was upgraded to a larger facility as part of the longer-term plan to increase the suite of monitoring parameters at this location. The larger station also accommodates space for instrument repairs and special monitoring projects.
- Three new instruments were acquired as part of the life-cycle plan of the network, including two (2) O_3 analyzers and one (1) NO_x analyzer.

Future Plans

ENR plans to conduct the following updates to the air quality monitoring network in 2015:

- The Yellowknife station has been identified by NAPS for advancement to Tier 1 status in the national network, which essentially means that specific additional parameters will be added to the station's existing monitoring suite. This includes the addition of volatile organic compounds (VOC) monitoring and particulate speciation monitoring. The Yellowknife station would be the only station in the NWT to operate such equipment.
- Black carbon monitoring is in the early stages of deployment across the NAPS network, and Yellowknife has been slated as one of the stations to implement it. Black carbon is a light-absorbing, carbon-containing component of particular matter in air pollution that has effects on both human health and on climate change. Some sources of black carbon in the NWT are from forest fires, vehicle exhaust and other diesel combustion sources. A Black Carbon Aethalometer will be installed at the Yellowknife station in 2015.
- ENR's data acquisition system (DAS) is a vital component of the monitoring network and is slated for life-cycle capital and software upgrades in 2015.

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 (µg/m³)*	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	126	63
Total Suspended Particulate (TSP)		
24-hour average	120	
Annual geometric mean	60	
Fine Particulate Matter ($PM_{2.5}$)		
24-hour average	28	
Annual Arithmetic mean	10	
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, Oct/14
Ground Level Ozone (O_3) 1-hour average	82ppb	Canadian National Ambient Air Quality Objectives, 1989
8-hour running average, 4th highest annually	63ppb	Canadian Ambient Air Quality Standards, 2013

Yellowknife Air Quality

ENR, in partnership with the Canadian 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, O3, 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.

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.

Figure 2 – Sir John Franklin Station

Particulate Matter

Yellowknife's greatest source of particulate is typically dust from roads, especially in the spring when the snow cover disappears and exposes winter sand and gravel on city streets. Once the sand and gravel is exposed, wind and vehicle activity can cause the dust to become suspended in the air. Forest fires, combustion products from vehicles, and heating and electricity generation also raise particulate levels. *Please note that forest fire events are observed and documented by regional ENR staff as they occur (i.e. visible smoke and olfactory indications of smoke), and this qualitative data serves as a validation to the conclusions drawn from measured $PM_{2.5}$ readings.*

ENR currently uses Beta Attenuation Mass Monitors (BAM) to sample for both the fine ($PM_{2.5}$) and coarse (PM_{10}) fractions of particulate matter in Yellowknife. The BAM methodology provides continuous, near real-time (hourly) analysis of particulate concentrations, in both the fine and coarse particle sizes. The BAM technology measures hourly concentrations on a mass basis. Non-continuous particulate monitoring is also conducted at the Sir John Franklin station, and uses a Partisol 2000i-D filter-based sampler.

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 39 episodes of $PM_{2.5}$ readings at the Sir John Franklin station in 2014 that exceeded the NWT 24-hour standard (28µg/m^3); all of these were a result of forest fire smoke. The annual $PM_{2.5}$ average was 15.7ug/m^3, which exceeded the standard of 10ug/m^3; for which the summer concentrations were again the driving force. Major impacts to $PM_{2.5}$ levels from forest fires were observed mainly in June, July and August, and remained at typical background levels throughout the rest of the year.

Yellowknife during extreme smoke event – August 16, 2015. Image courtesy of John McKay.

Figure 3 –
2014 Yellowknife $PM_{2.5}$

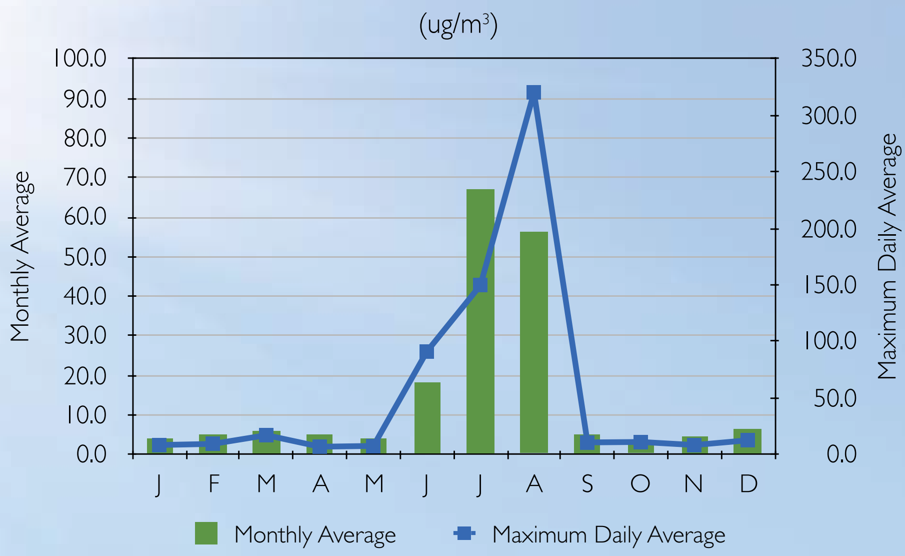


Figure 3 shows the monthly averages and maximum daily average per month, measured at the Sir John Franklin station in 2014 on the FEM BAM $PM_{2.5}$. The highest daily average concentration was 320.4 μg/m³, measured in August.

Figure 4 –
2011 to 2014 Summary: Yellowknife Monthly Average $PM_{2.5}$

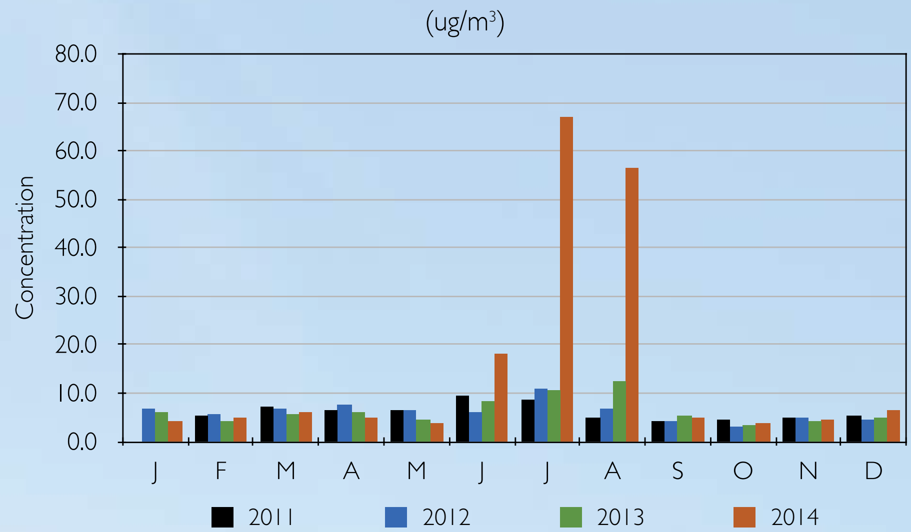


Figure 4 summarizes the monthly average $PM_{2.5}$ data over the last four years. The overall trends indicate that $PM_{2.5}$ levels increase during the summer months, which is typically attributed to forest fires that occur during this time of year. The 2014 summer season recorded the highest $PM_{2.5}$ levels experienced in Yellowknife since continuous $PM_{2.5}$ monitoring began in 2003.

Coarse Particulate (PM_{10})

The NWT does not have a standard for PM_{10}, but instead adopts a 24-hour average criterion of 50µg/m³. This level is used in several Canadian jurisdictions, including British Columbia and Ontario.

Figure 5 presents the $PM_{2.5}$ data for 2014. Generally, the annual spring-time "dust event" is typical during the month of April and is responsible for the highest levels seen in the year; this is due to residual gravel on the roads following the spring snow thaw. In 2014, however, the forest fire season resulted in higher levels of PM_{10} than those experienced from the spring-time dust event. There were 33 exceedances of the adopted standard of 50µg/m³ in 2014. Unlike most years, only four (4) of these occurred in April and the rest occurred during the summer months. Unfortunately, data had to be invalidated for the months of October and November due to an instrument malfunction.

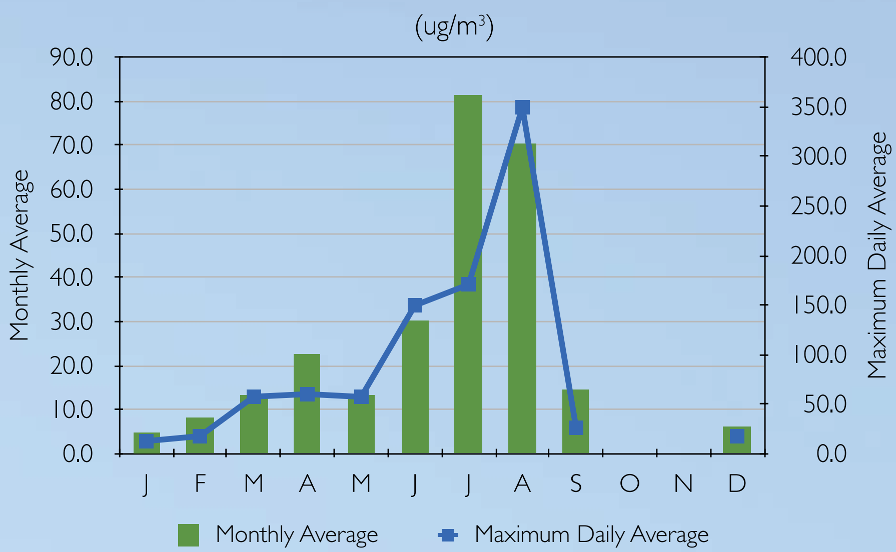


Figure 5 – 2014 Yellowknife BAM PM_{10}

Figure 5 shows the PM_{10} monthly averages and maximum daily averages per month measured at the Yellowknife station in 2014. The highest maximum daily concentration was 349.5µg/m³, occurring in August.

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 using an API 100 series UV fluorescence analyzer.

There were no exceedances of the NWT hourly (172ppb) or 24-hour (57ppb) standards in 2014 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 2014 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 – 1998 to 2014 Summary: Yellowknife Sulphur Dioxide

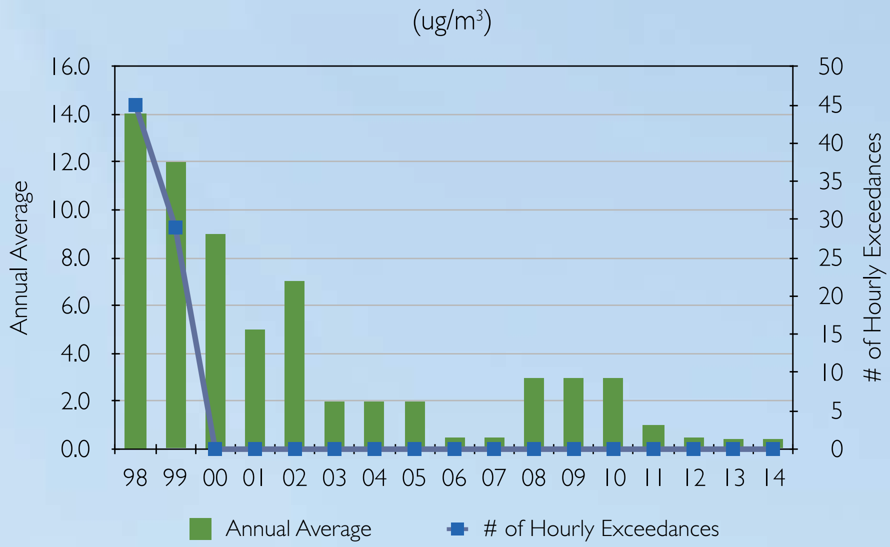


Figure 6 shows the general trends in SO_2 levels measured in Yellowknife air from 1998 to 2014. As illustrated, the number of exceedances has fallen to zero since the closure of Giant Mine in 1999. The 2014 data continues the trend of recent years.

Ground Level Ozone (O_3)

Continuous ozone monitoring has been conducted in Yellowknife since 1998, while the current location has been in operation at the Sir John Franklin station since February of 2003. Ozone is monitored with an API 400 series UV absorption analyzer.

The maximum 8-hour average in 2014 was 48.2ppb, which occurred in July, and was below the 8-hour NWT standard (63ppb). The maximum 1-hour average was 59.6ppb, which occurred in June, and was below the national maximum acceptable level (82ppb). The 2014 annual hourly average was 23.9ppb.

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**).

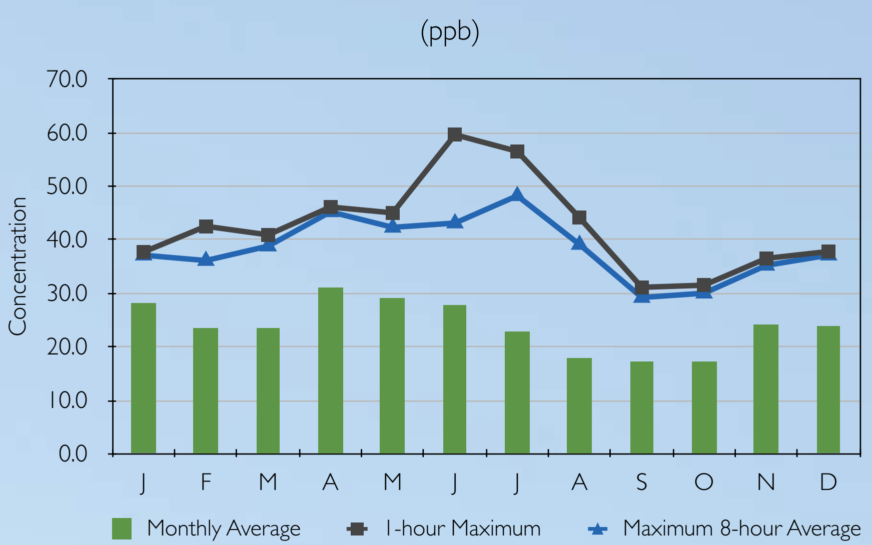


Figure 7 – 2014 Yellowknife Ozone

Figure 7 shows the maximum hourly ozone readings and maximum 8-hour averages per month as well as the monthly averages recorded in 2014.

Typically, ozone concentrations in Yellowknife and across the north are highest in the spring-time, coinciding with the increased sunlight, and natural and anthropogenic sources of precursor compounds. **Figure 7** illustrates that 2014 was not a typical year, and that the forest fire season had a major influence on short-term ozone levels, as indicated by the 1-hour and 8-hour maximums. Note that the highest monthly average did in fact occur in the spring (April), which commonly occurs at remote monitoring stations located in mid to high latitudes in the Northern hemisphere. Typical monthly ozone concentrations at remote sites in Canada range between 20 and 45ppb[1], and Yellowknife concentrations in 2014 fell within or below this range.

1. 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 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**). NO_x is monitored with an API 200 series chemiluminescence analyzer.

The 2014 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 54.1ppb, the maximum 24-hour average was 15.9ppb, while the annual average was 2.8ppb.

Figure 8 – 2014 Yellowknife Nitrogen Dioxide

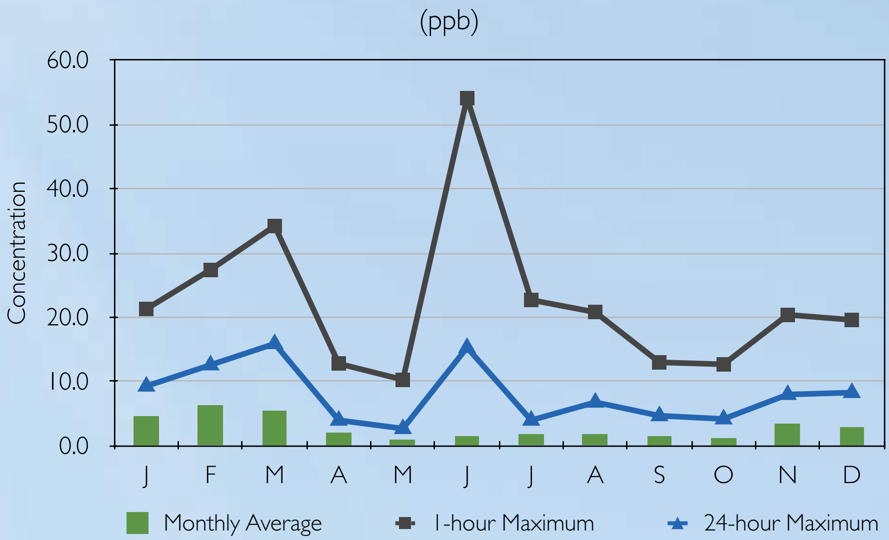


Figure 8 shows the 2014 maximum hourly, maximum daily and monthly averages of NO_2 in Yellowknife. Generally, both the highest monthly averages and the highest hourly concentrations occurred during the winter months. This is likely due to increased emissions from fuel combustion for residential and commercial heating and idling vehicles as well as short-term "rush hour" traffic influences. The March and June hourly spikes were caused by work being conducted at the City Lift Station located next to the air quality station. The effects of these combustion 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)

CO has been monitored in Yellowknife since 2003, using the API 300 series gas filter correlation analyzer. The 2014 data continued the pattern of low CO readings measured in 2013, with the exception of elevated concentrations throughout July and August. CO is often attributed to mobile sources; however, forest fire smoke can also contain CO due to the fire conditions and incomplete combustion within the blaze, as evidenced in the 2014 CO results.

The overall concentrations were below the NWT 1-hour and 8-hour average standards (13ppm and 5ppm respectively). In 2014, the maximum 1-hour average was 7.806ppm and coincided with one of the highest $PM_{2.5}$ concentrations of the year, which was directly attributed to forest fire smoke. The maximum 8-hour average for CO was 4.914ppm, occurring in early August, and was just below the standard of 5ppm. This period in August resulted in the highest 8-hour CO readings in Yellowknife since the inception of CO monitoring in 2003, which further emphasize the significance of the forest fire season experienced in 2014. The annual CO average was 0.262ppm.

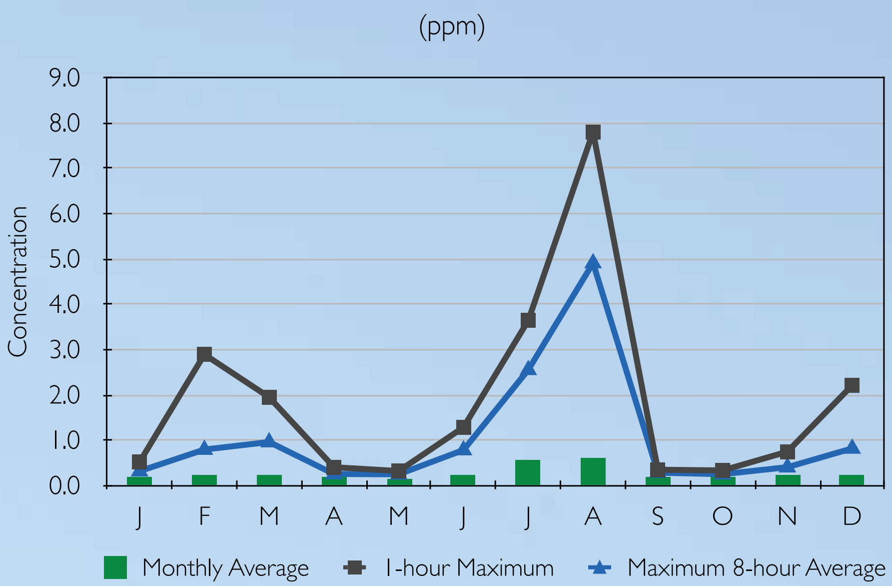


Figure 9 – 2014 Yellowknife Carbon Monoxide

Figure 9 shows the 2014 monthly averages and highest hourly and 8-hour 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.

This station has been in operation since 2003, but was moved from its original location at Samuel Hearne School to its present location 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 CO.

Figure 10 – Inuvik Station

Fine Particulate ($PM_{2.5}$)

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

The 2014 annual $PM_{2.5}$ average was 3.7µg/m³, which is below the standard of 10ug/m³. There were no exceedances of the NWT 24-hour standard (28µg/m³) for $PM_{2.5}$, as the highest daily average concentration was 12.2µg/m³, measured in November (attributed to a short-term, localized emission source). Impacts from forest fires in Inuvik were negligible during the summer of 2014.

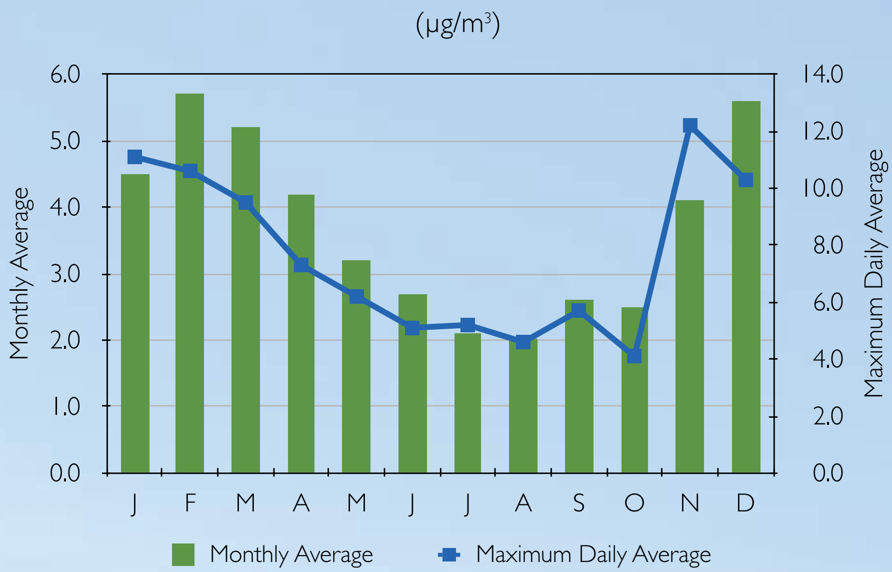


Figure 11 – 2014 Inuvik $PM_{2.5}$

Figure 11 shows the monthly averages and maximum daily average per month, measured at the Inuvik station in 2014 on the FEM BAM $PM_{2.5}$. The figure shows that unlike the other three regions, forest fire smoke did not affect the Inuvik region during the summer of 2014. The 2014 summer levels are relatively low compared to previous years where smoke from forest fires significantly impacted the region.

Coarse Particulate (PM_{10})

The maximum daily average measured from the PM_{10} BAM in Inuvik in 2014 was 85.4µg/m^3, which occurred in May, and the highest hourly maximum was 502µg/m^3, which occurred in June. There were 13 exceedances of the adopted 24-hour standard (50µg/m^3), which all occurred during the spring and summer months. Similar to previous years, the spring-time levels were elevated and were representative of the typical spring-time thaw and exposure of the residual winter gravel and dirt roads, a source that persisted throughout the summer months, given the dirt roads in the Inuvik area in proximity to the monitoring station.

Figure 12 – 2014 Inuvik PM_{10}

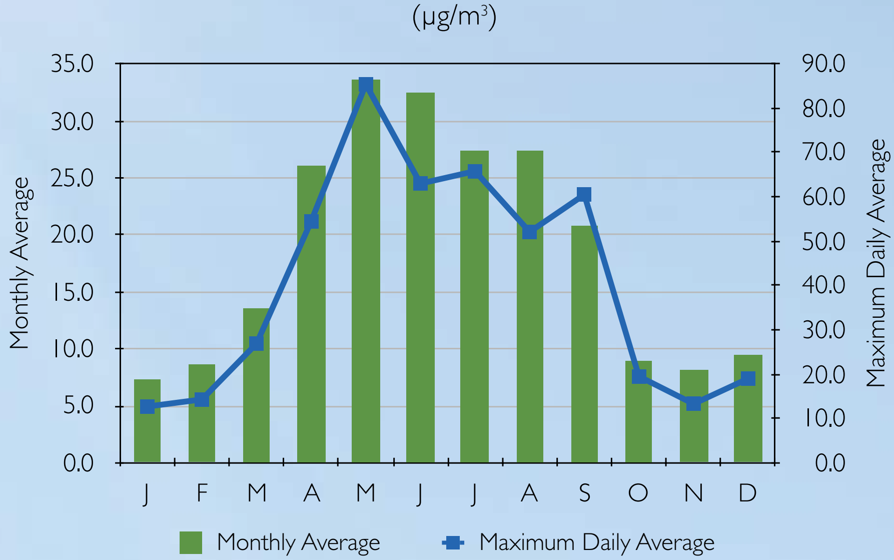


Figure 12 shows the monthly averages and the maximum daily average concentrations of PM_{10} in Inuvik.

Sulphur Dioxide (SO_2)

The annual average of SO_2 in Inuvik was less than 1ppb, and the maximum 1-hour average was 1.9ppb. The SO_2 concentrations measured in 2014 were very low and similar to previous years' results, which did not exceed the NWT hourly (172ppb), 24-hour (57ppb) or annual average (11ppb) standards.

Ground Level Ozone (O_3)

The maximum 1-hour average in 2014 was 52.6ppb, while the maximum 8-hour average was 49.1ppb. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (63ppb) for ground level ozone was exceeded in 2014. The annual average was 23.5ppb, which is typical of background levels.

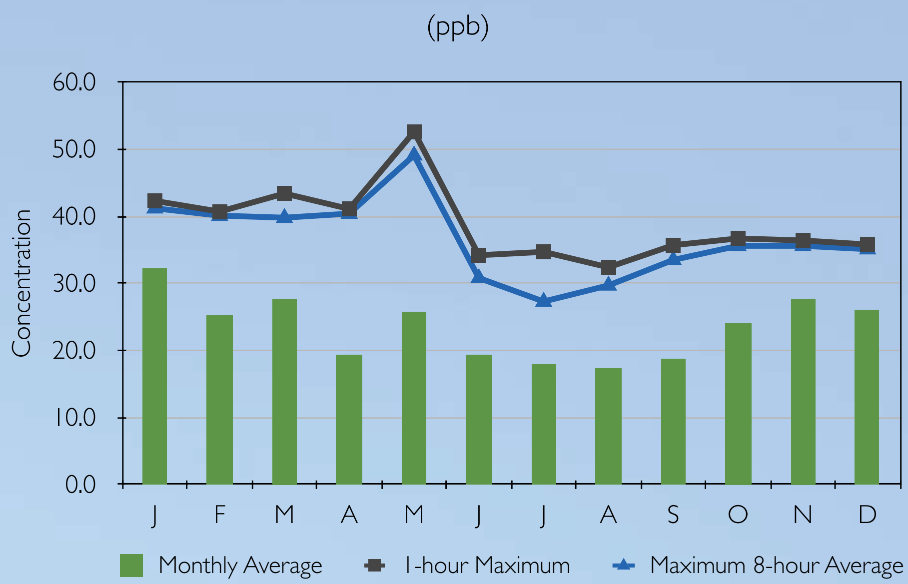


**Figure 13 –
2014 Inuvik Ozone**

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 2014 in Inuvik.

Nitrogen Dioxide (NO_2)

The NO_2 results for Inuvik in 2014 show that the maximum 1-hour average was 33.0ppb, the maximum 24-hour average was 14.3ppb, and the overall annual average was 2.2ppb; all of which were within the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 14 – 2014 Inuvik Nitrogen Dioxide

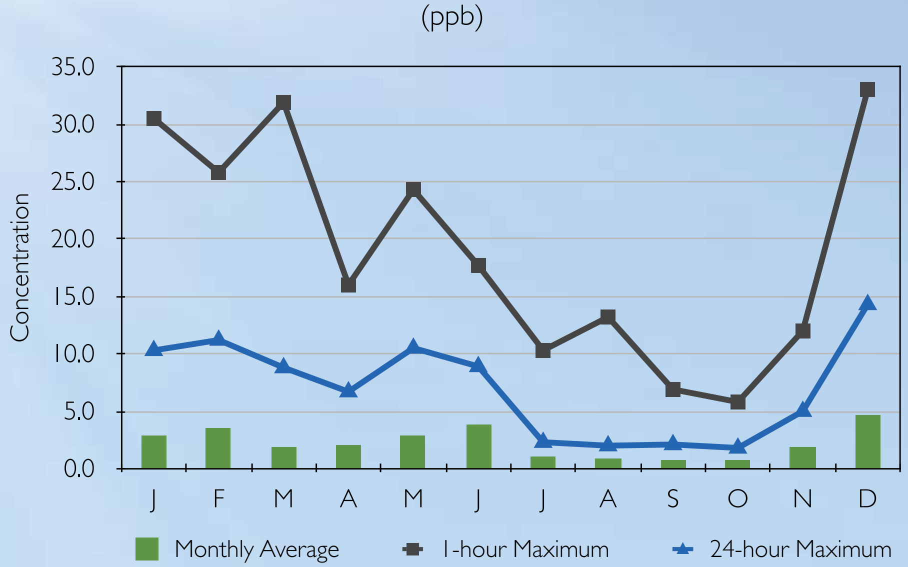


Figure 14 shows the maximum hourly, maximum daily and monthly averages of NO_2 in Inuvik in 2014. Average concentrations are observed to be higher in the colder months and when there is activity (i.e. vehicle or construction) near the station, similar to previous years, likely as a result of idling and other combustion sources during inversions (stagnant air masses).

Carbon Monoxide (CO)

The levels of CO were extremely low and were well below the NWT 1-hour and 8-hour average standards (13ppm and 5ppm respectively). In 2014, the maximum 1-hour average was 1.111ppm, the maximum 8-hour average was 0.802ppm, and the annual average was 0.166ppm. Low levels of CO are typically expected due to the limited combustion sources in Inuvik, such as low traffic volumes, and the absence of forest fire smoke influences in 2014.

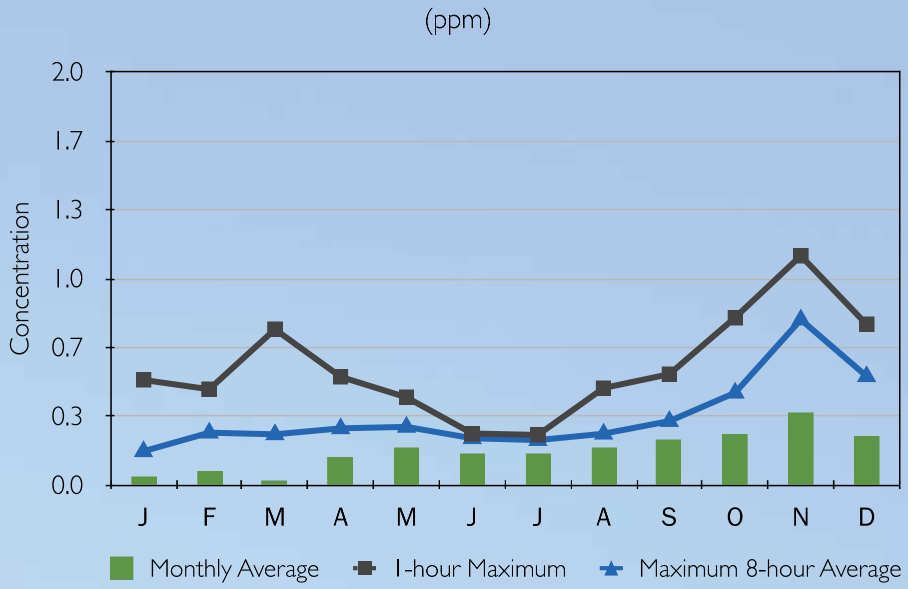


Figure 15 – 2014 Inuvik Carbon Monoxide

Figure 15 shows the 2014 monthly averages, and highest hourly and 8-hour concentrations for CO in Inuvik.

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 and NO_2. It has been in operation since 2003.

Fine Particulate ($PM_{2.5}$)

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

There were two (2) exceedances of the NWT 24-hour standard for $PM_{2.5}$ (28µg/m^3), both of which occurred in June and are attributed to the forest fire activity observed during the summer in Norman Wells. The annual average was 3.5µg/m^3, which is below the standard of 10ug/m$_3$.

Figure 16 –
Norman Wells Station

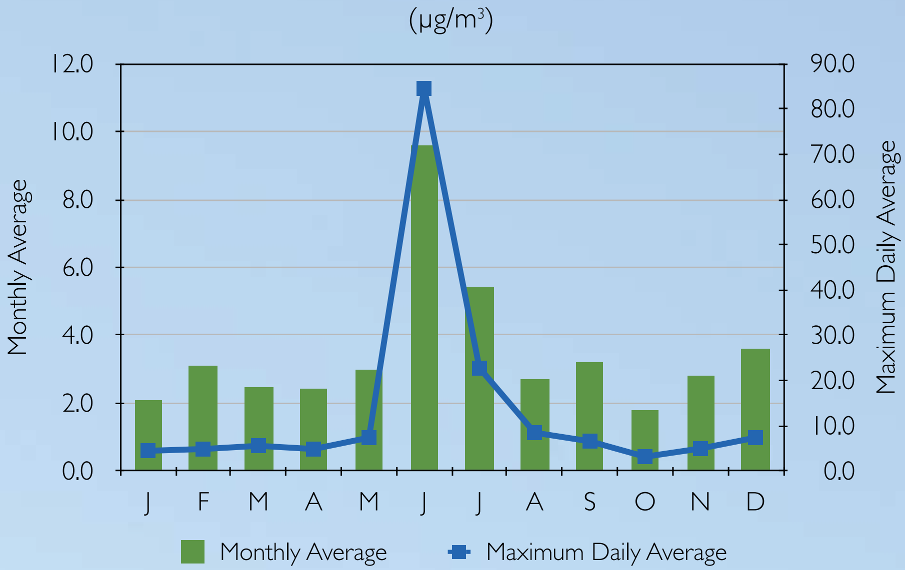


Figure 17 –
2014 Norman Wells $PM_{2.5}$

Figure 17 shows the monthly averages and maximum daily averages of $PM_{2.5}$ measured from the BAM at the Norman Wells station in 2014. The elevated readings in the summer are typical and are associated with the forest fire season. The maximum daily average concentration of $PM_{2.5}$ was 84.6µg/m$_3$, occurring in June.

Coarse Particulate (PM_{10})

The PM_{10} 1-hour maximum concentration measured in Norman Wells was 718µg/m³, and the 24-hour maximum concentration was 175.8µg/m³, both of which occurred in June and coincided with a forest fires burning in proximity to town. The annual average concentration of PM_{10} was 14.4µg/m³. There were 14 exceedances of the adopted 24-hour average standard of 50µg/m³. The majority of these exceedances occurred in the months of June and July, and although PM_{10} levels in the snow-free months are typically attributed to gravel from the roads, the driving force in 2014 was forest fire smoke. Data was not available for the month of April due to a system malfunction; however, the spring dust event was captured in the May readings.

Figure 18 – 2014 Norman Wells PM_{10}

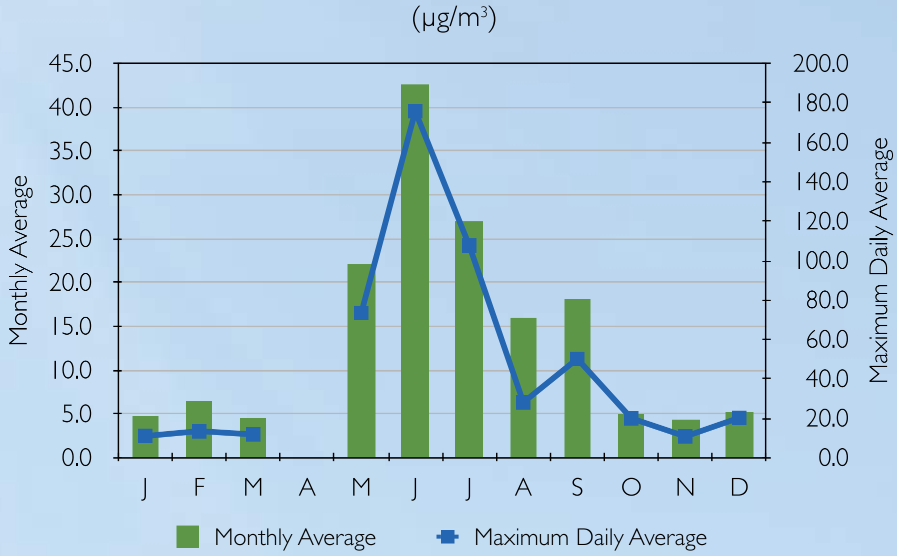


Figure 18 shows the monthly averages and the maximum daily average concentrations of PM_{10} measured in Norman Wells in 2014.

Sulphur Dioxide (SO_2)

Overall, SO_2 concentrations in Norman Wells were generally very low. The 1-hour maximum SO_2 reading was 1.4ppb, the maximum 24-hour average was 0.9ppb 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)

In 2014, the maximum 1-hour average for ozone was 52.3ppb, while the maximum 8-hour average was 46.8ppb. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (63ppb) for ground level ozone was exceeded in 2014. The annual average was 22.2ppb, which is within the range of what is considered background levels. Similar to Yellowknife, the forest fires of 2014 also had a major influence on ozone levels in Norman Wells, which is apparent in the short-term averages of June and July. Note that the highest monthly average occurred in the spring (May), which is typical of ozone at higher latitude locations and is consistent with historical data.

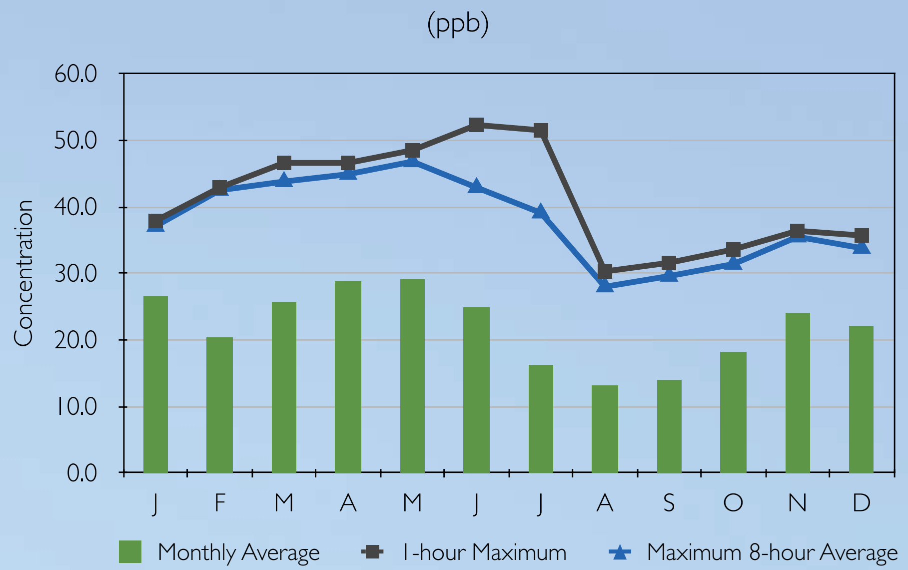


Figure 19 – 2014 Norman Wells Ozone

Figure 19 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 2014.

Nitrogen Dioxide (NO_2)

The 2014 NO_2 results for Norman Wells show that the maximum 1-hour average was 23.6ppb, the maximum 24-hour average was 9.8ppb, and the overall annual average was 1.4ppb, which were well below the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 20 –
2014 Norman Wells
Nitogen Dioxide

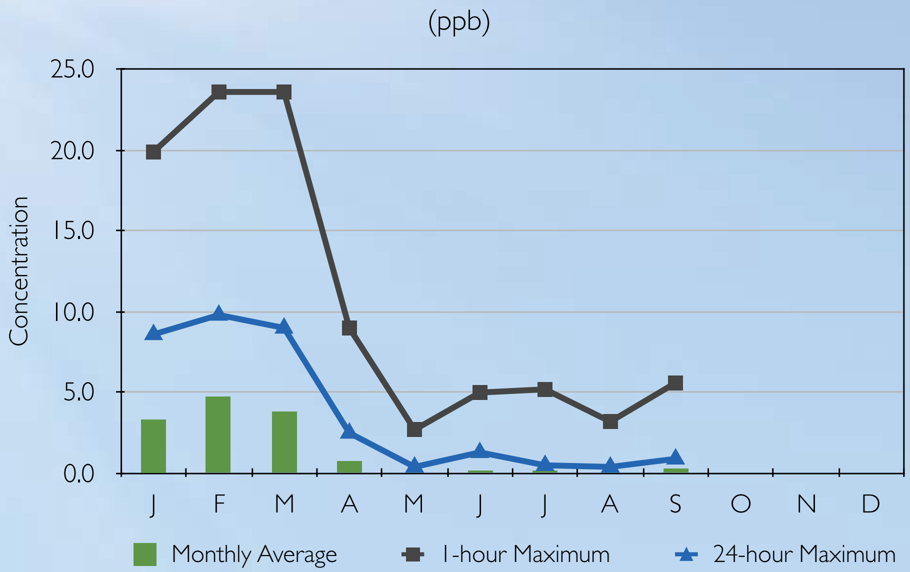


Figure 20 shows the 2014 monthly averages, maximum 24-hour averages, and maximum 1-hour concentrations of NO_2 in Norman Wells. As with previous years, NO_2 levels increased in the winter months as a function of vehicle idling and other combustion sources during inversions (stagnant air masses). Unfortunately, data was not available for the months of October to December due to instrument issues.

Hydrogen Sulphide (H_2S)

The maximum hourly H_2S concentration in 2014 was 2.0ppb and the maximum 24-hour average was 1.8ppb, with the vast majority of readings observed 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 of 10ppb and a 24-hour average of 3ppb). The 2014 results are consistent with previous years. The analyzer experienced major issues in October, which prompted a review of the H_2S monitoring in Norman Wells. Following the review, it was determined that years of non-detectable concentrations warranted the discontinuation of H_2S monitoring.

Fort Smith Air Quality

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

The station is located on the southwest end of the Paul William Kaeser High School property, and measures $PM_{2.5}$, PM_{10}, SO_2, O_3, NO_2 and CO. The station was installed in late 2013 and, therefore, 2014 is the first complete year of operation in Fort Smith.

Figure 21 – Fort Smith Station

Fine Particulate ($PM_{2.5}$)

There were 18 exceedances of the NWT 24-hour standard for $PM_{2.5}$ (28µg/m³) in Fort Smith in 2014, with a maximum daily average of 216.9µg/m³. The annual average was 9.7µg/m³, which was just below the standard of 10ug/m³. Forest fire activity was responsible for the elevated summer readings in 2014.

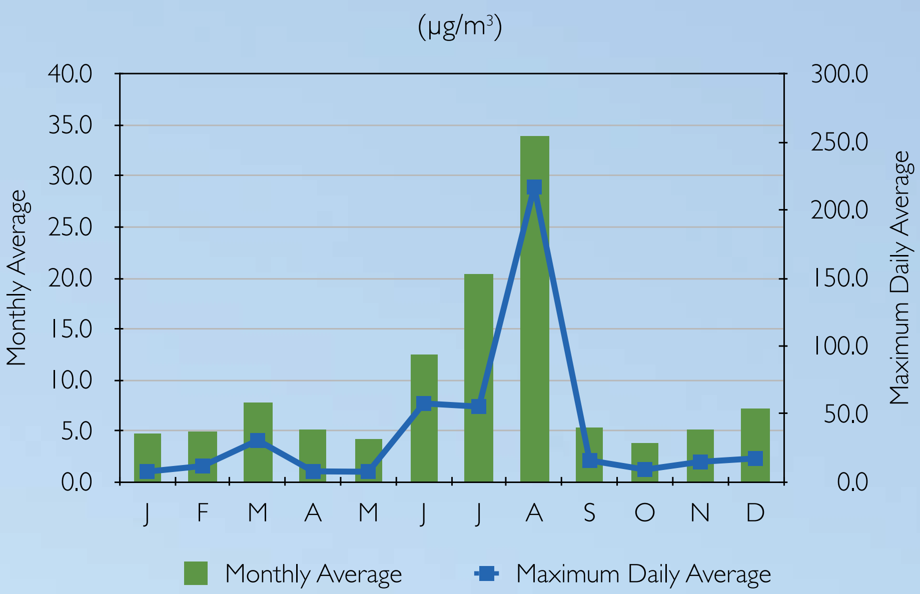


Figure 22 – 2014 Fort Smith $PM_{2.5}$

Figure 22 shows the monthly averages and maximum daily averages of $PM_{2.5}$ measured from the BAM at the Fort Smith station in 2014. The elevated readings in the summer are associated with the forest fire season and are typical of the trends observed in other monitored communities.

Coarse Particulate (PM_{10})

The 1-hour maximum concentration for PM_{10} in Fort Smith in 2014 was 501µg/m^3, which occurred in August and coincided with a forest fires burning in proximity to town. The 24-hour maximum concentration was 261.2µg/m^3, which also occurred in August. The annual average concentration was 17.8µg/m^3. There were 15 exceedances of the adopted 24-hour average standard of 50µg/m^3. These exceedances occurred in the months of June, July and August and were attributed to forest fire smoke. Data was not available for the months of November and December due to instrument damage sustained from water infiltration.

Figure 23 – 2014 Fort Smith PM_{10}

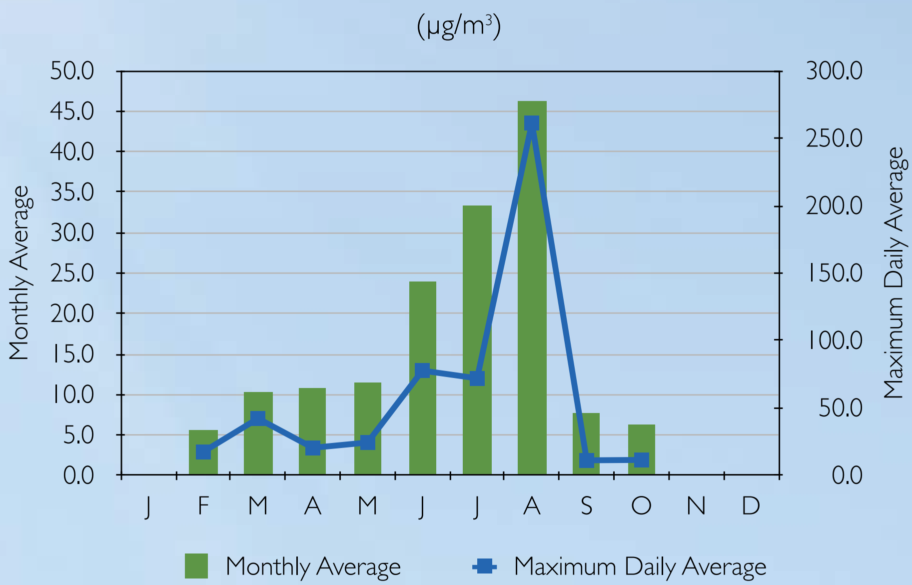


Figure 23 shows the maximum daily average per month as well as the monthly averages for PM_{10} recorded in Fort Smith in 2014.

Sulphur Dioxide (SO_2)

The first year of SO_2 data collection in Fort Smith returned similar results to the other NWT monitoring stations, which are generally very low. The 1-hour maximum SO_2 reading was 4.5ppb, 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).

Ground Level Ozone (O_3)

In 2014, only four months of ozone data were collected in Fort Smith as issues with the sampling outlet invalidated the data from the months of January through to August. Valid data was collected from September to December, but both the typical spring-time elevations and the potential elevations associated with the forest fire season were not captured. Based on only four months of data, the ozone maximum 1-hour average was 35.5ppb, while the maximum 8-hour average was 34.7ppb. Neither the 1-hour national maximum acceptable level (82ppb) nor the 8-hour NWT standard (63ppb) for ground level ozone was exceeded. The annual average was 19.1ppb, which is within the range of what is considered background levels.

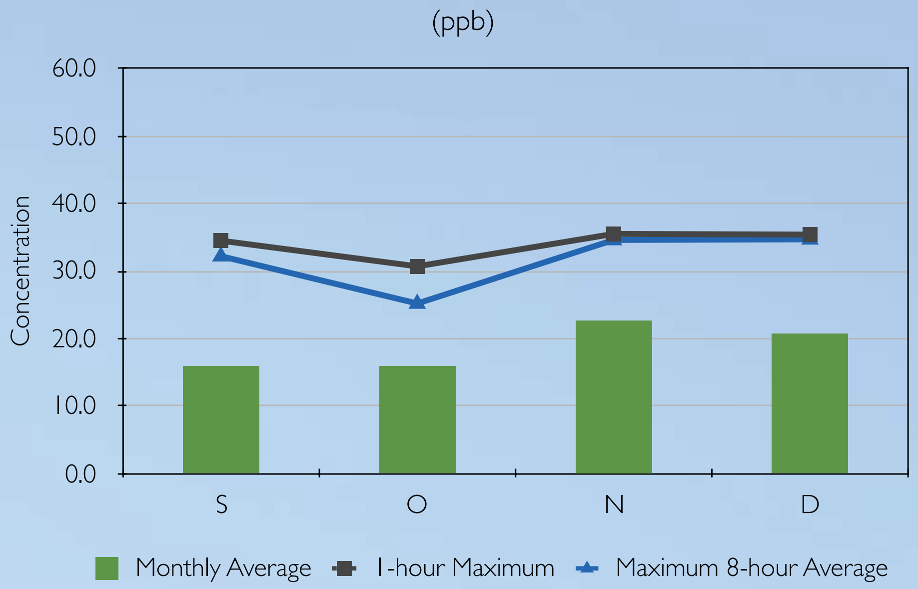


Figure 24 – 2014 Fort Smith Ozone

Figure 24 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in Fort Smith in 2014. Instrument error invalidated the data collected from January to August.

Nitrogen Dioxide (NO_2)

The 2014 NO_2 results for Fort Smith show that the maximum 1-hour average was 54.8ppb, the maximum 24-hour average was 24.5ppb, and the overall annual average was 2.8ppb, which were all below the NWT standards (213ppb, 106ppb, 32ppb, respectively).

Figure 25 – 2014 Fort Smith Nitogen Dioxide

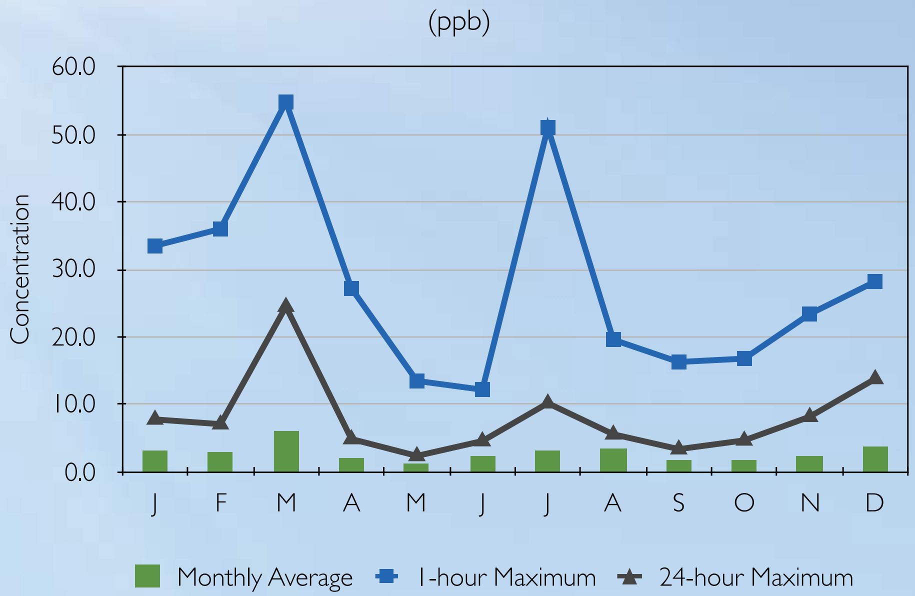


Figure 25 shows the 2014 monthly averages, maximum 24-hour averages, and maximum 1-hour concentrations of NO_2 in Fort Smith. As is the trend with the other three stations, NO_2 levels increased in the winter months as a function of vehicle idling and other combustion sources during inversions (stagnant air masses). The March and July spikes are most likely associated with localized activity near the station.

Carbon Monoxide (CO)

The CO analyzer wasn't installed in Fort Smith until September of 2014, resulting in only four months of monitoring data. The levels of CO during those four months were low, yielding a maximum 1-hour average of 1.014ppm and an 8-hour maximum of 0.555ppm, both of which are below the NWT 1-hour and 8-hour average standards (13ppm and 5ppm respectively). These results did not capture potentially elevated readings in the summer from forest fire influences; however, are otherwise typical of CO levels observed at the other NWT stations.

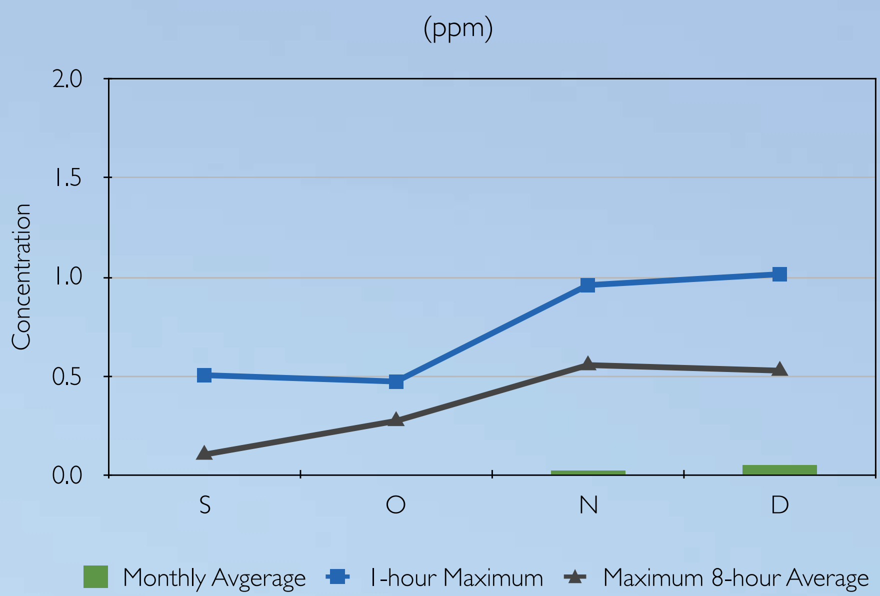


Figure 26 – 2014 Fort Smith Carbon Monoxide

Figure 26 shows the 2014 monthly averages and highest hourly concentrations for CO in Fort Smith. These low levels are typical of CO observed in the other monitored communities of the NWT.

Long-term Trends

The GNWT Ambient Air Quality Monitoring Network has been in operation for over a decade and, therefore, there is sufficient data to conduct longer term trend analyses. 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.

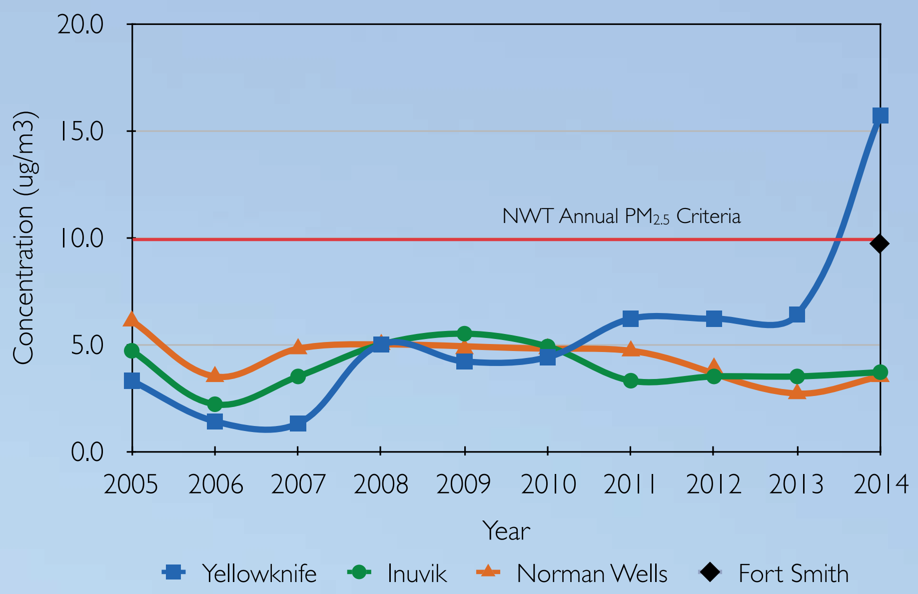


Figure 27 – 2005 to 2014 Annual $PM_{2.5}$ Averages

Figure 27 compares the annual $PM_{2.5}$ average concentrations from each of the NWT monitoring stations from 2005 to 2014. The Fort Smith station has only one year of data and, as such, is presented as a single point. 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, while the Norman Wells and Fort Smith stations became FEM in 2013.

The results demonstrate that the $PM_{2.5}$ levels in the NWT fluctuate annually, which could be due to the major influence of seasonal forest fires whose effects vary annually.

The Yellowknife station has the only data demonstrating an upward trend in $PM_{2.5}$ levels over the observed period, which could be attributed to a variety of factors, including the variation year to year in driving forces such as forest fire events. The 2014 year certainly represents that scenario well. In order to assess the data without the natural and variable/fluctuating influences from fires, the following figure presents the $PM_{2.5}$ averages for the years 2005 to 2014, excluding the May to August timeframes.

Figure 28 –
2005 to 2014 Annual $PM_{2.5}$ Averages (Excluding May to August)

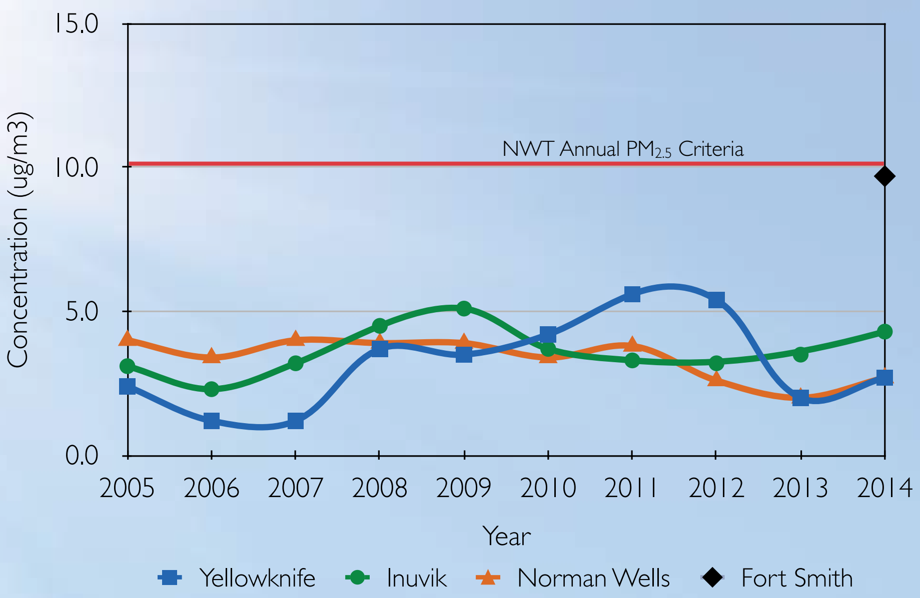


Figure 28 demonstrates that when the seasonal influences from forest fire smoke are eliminated, the $PM_{2.5}$ levels in each of the NWT communities are generally consistent from year to year. *Note that Fort Smith is not included in the trend analysis comparison since there is only a single year of data.*

Figure 29 –
2005 to 2014 Annual NO_2 Averages

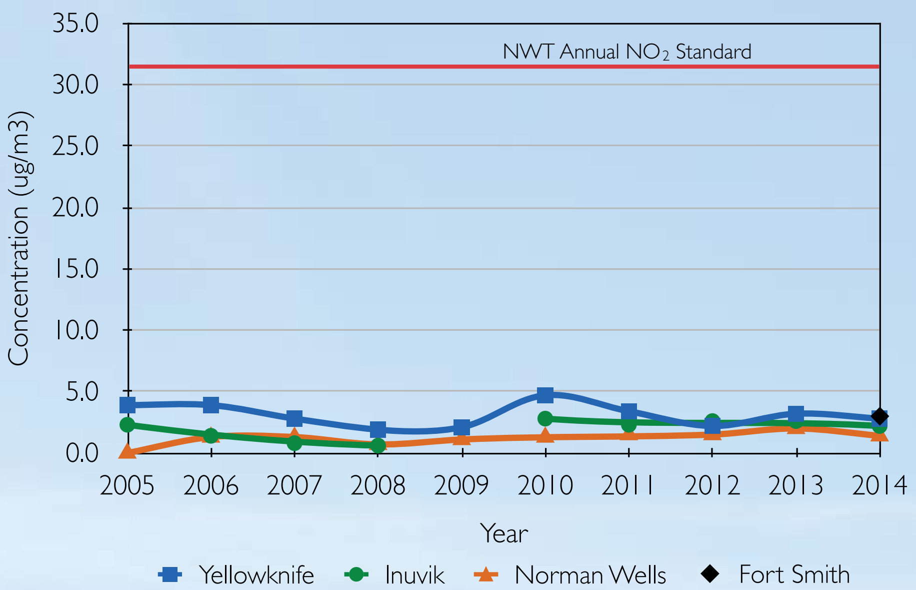


Figure 29 compares the annual NO_2 average concentrations from each of the NWT monitoring stations from 2005 to 2014. The Fort Smith data was included as a single point since 2014 was the first year data was collected from that station. Results indicate that, generally, Yellowknife has slightly higher 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. The trend over this time period for each monitoring station is relatively stable, which is to be expected given the absence of any major changes to emission sources or population growth in these communities.

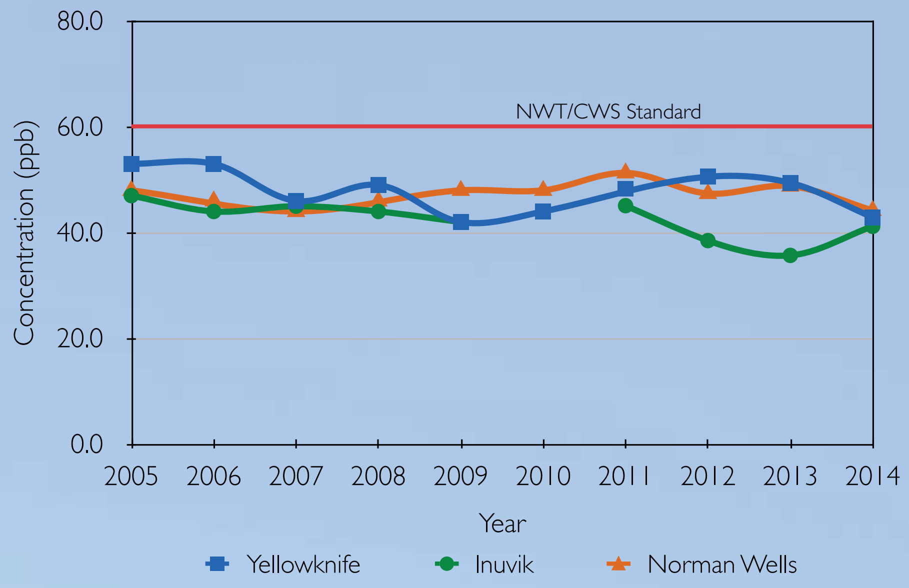


**Figure 30 –
2005 to 2014
4th Highest Daily
8-hour O_3**

Figure 30 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 63ppb. 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. The Fort Smith 2014 data was not included as total ozone data capture was less than 30%.

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 and density, 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.

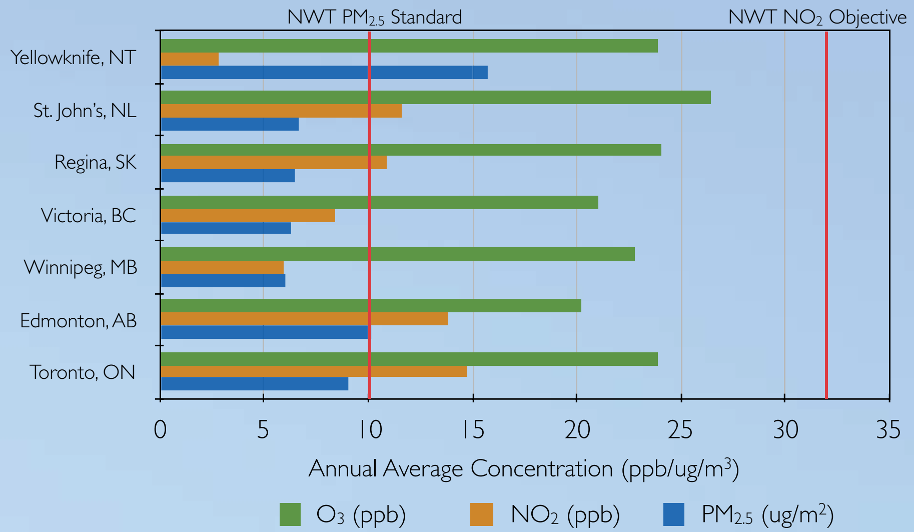


Figure 31 – 2014 National Comparisons, Jurisdictional Capitals

Figure 31 compares the 2014 annual average concentrations of O_3, NO_2 and $PM_{2.5}$ between select capital cities across Canada. The values are measured against the NWT air quality standards for $PM_{2.5}$ and NO_2; no criteria are available for annual O_3.

The data shows that Yellowknife O_3 levels in 2014 were slightly higher than half of the comparison cities. Yellowknife NO_2 levels, however, were significantly lower than all the comparison cities, presumably as a result of a much smaller size city with fewer combustion emission sources. 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. NO_2 levels for all comparison cities were below the NWT criteria.

The $PM_{2.5}$ levels in Yellowknife were the highest of the comparison cities as a result of one of the worse forest fire seasons in recent memory; Edmonton was the only other city that had $PM_{2.5}$ levels in exceedance of the presented criteria.

Figure 32 – 2014 National Comparisons, Similar Population Size

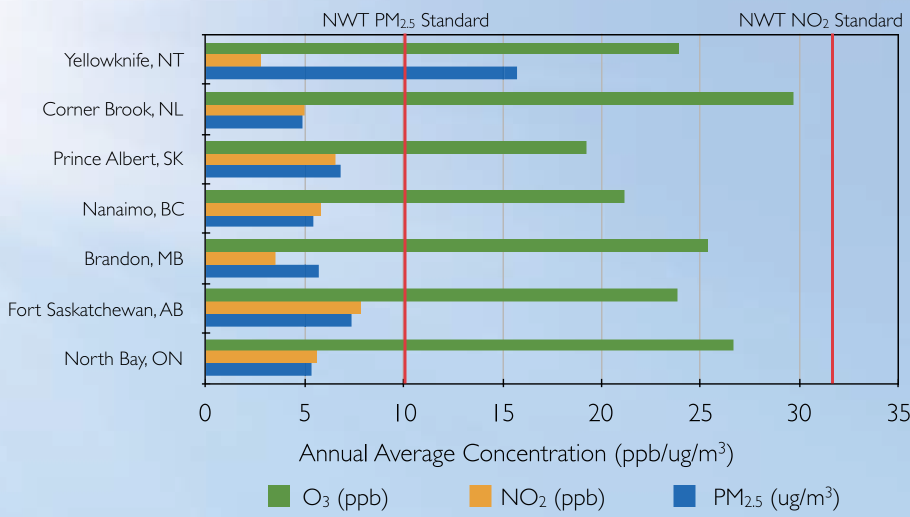


Figure 32 compares Yellowknife's annual average concentrations of O_3, NO_2 and $PM_{2.5}$ to select cities across Canada of a similar population size (<100,000). The results show that Yellowknife O_3 levels are middle of the range relative to the comparison cities, while Yellowknife NO_2 levels were lower than the comparison cities. All the NO_2 levels were below the NWT criteria. Yellowknife $PM_{2.5}$ levels in 2014 were significantly higher than the comparison cities, and the only city in exceedance of the NWT criteria. The $PM_{2.5}$ results are attributed to forest fire smoke.

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 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.

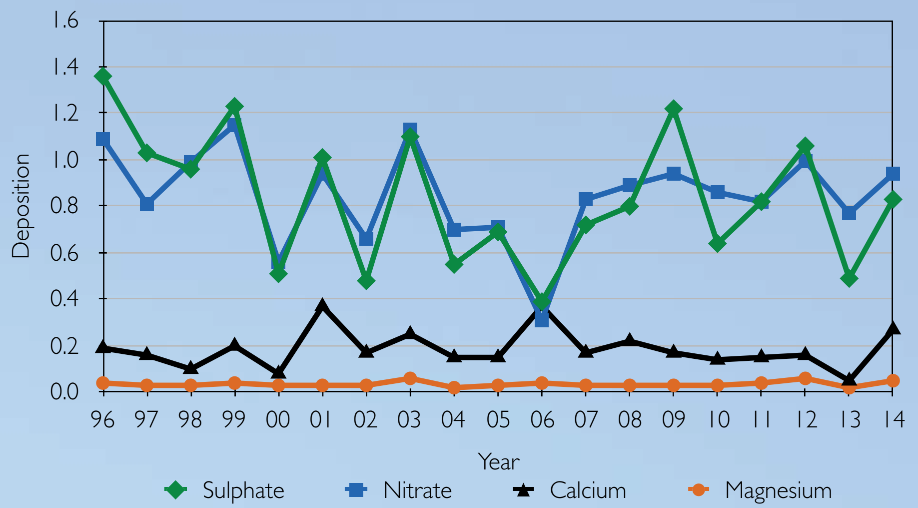


Figure 33 – Snare Rapids Acid Deposition

Figure 33 shows the deposition rates for sulphate, calcium nitrate and magnesium from 1996 to 2014.

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.

In 2014, a second CAPMoN station was opened in the NWT, located in the Wood Buffalo National Park, approximately 80 km northwest of Fort Smith. The area was of interest to CAPMoN due to the remote nature of the park, but also its location relative to the oil sands operations in Alberta. The site uses a state-of-the-art, automated daily collection sampler for precipitation chemistry and a continuous ambient analyzer for ozone monitoring. The first complete set of data results will be presented in 2015.

NWT 2014 Forest Fire Season

The NWT experienced an extraordinary wildfire season in the summer of 2014, with many of the fires occurring in the North and South Slave regions. This resulted in very high ambient particulate concentrations in various communities across the territory.

The southern NWT in the summer of 2014 experienced very low precipitation levels, causing extremely dry conditions. Whenever there was precipitation, it was minimal and was often accompanied by lightening, which was the main ignition source of the majority of the forest fires. The drought-like conditions persisted throughout most of the summer. This was exacerbated by the fact that the months of June and July were among the warmest in 73 years.[2] Total precipitation for June and July was the fifth lowest since 1942.[2] The inevitable outcome of all of these conditions was one of the most severe forest fire seasons ever recorded.

The impacts of forest fire smoke were felt throughout the NWT, with the exception of the Inuvik region. The most severe impacts were in the North Slave (Yellowknife), where the highest hourly $PM_{2.5}$ concentration (873 μg/m^3) was recorded on August 3. Impacts to the South Slave region (Fort Smith) were the second most severe, with the maximum hourly concentration of 417 μg/m^3 occurring on August 4. The Sahtu region (Norman Wells) also felt the impacts of forest fire smoke with its highest hourly concentration of 452μg/m^3, occurring on June 24. A comparison of the $PM_{2.5}$ and PM_{10} data throughout the summer, between the three smoke-affected monitored communities, is presented in the following figures.

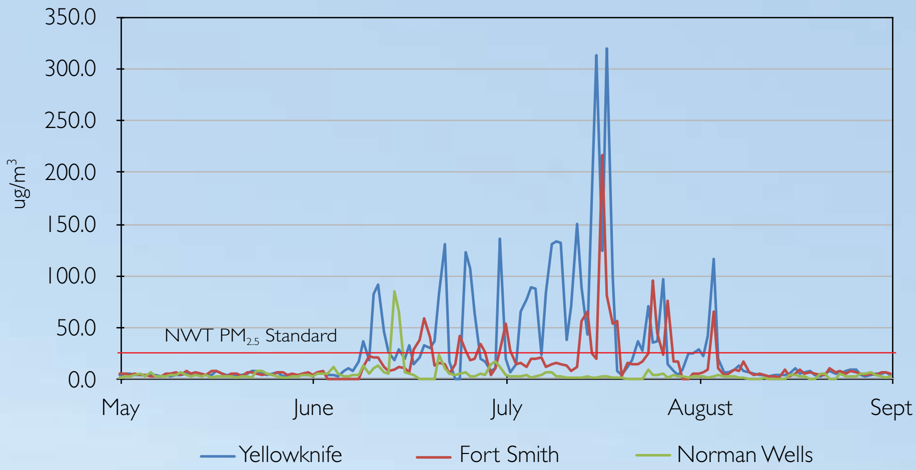
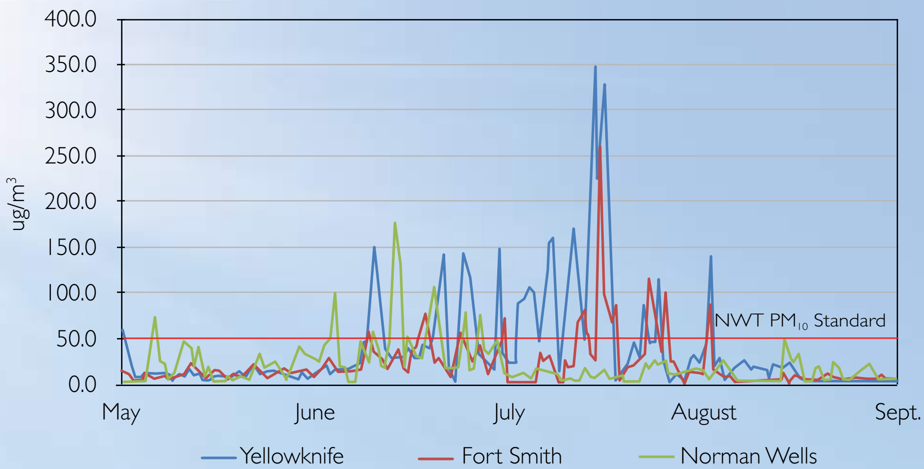


Figure 34 – Summer 2014 Daily $PM_{2.5}$ Concentrations for Yellowknife, Fort Smith and Norman Wells

2. Pankratz et al, "The Northwest Territories Up In Smoke: the summer of 2014", The Canadian Smoke Newsletter, 2015.

Figure 35 – Summer 2014 Daily PM_{10} Concentrations for Yellowknife, Fort Smith and Norman Wells



Figures 34 and 35 show the degree of elevated particulate concentrations throughout the summer months of 2014. Between the three affected communities, there were a total of 59 exceedances of the NWT $PM_{2.5}$ 24-hour standard and 62 exceedances of the adopted PM_{10} 24-hour standard.

Another effect from forest fire smoke is an increase in CO levels, which was observed at the Yellowknife station. The following figure illustrates the relationship between $PM_{2.5}$ and CO monitored in Yellowknife. *Note that the comparison could not be drawn at the Fort Smith or Norman Wells stations due to malfunctioning CO analyzers during that time period.*

Figure 36 – Hourly $PM_{2.5}$ and CO, Yellowknife, June to August 2014

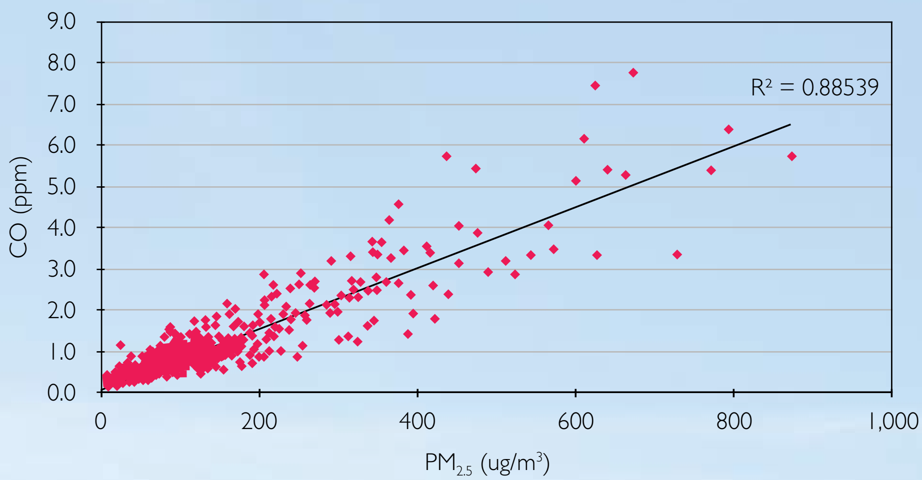


Figure 36 demonstrates that CO concentrations correlated well with $PM_{2.5}$ concentrations in Yellowknife during the forest fire events, between the months of June and August. Normal CO concentrations in this region are within the range of 0 to 2.0ppm, whereas the levels observed in the 2014 summer season reached an unprecedented 7.8ppm. This was also the highest hourly CO concentration ever recorded at the Yellowknife station. The elevated CO concentrations made this comparison possible and their correlation to the $PM_{2.5}$ levels demonstrate their association to forest fire smoke. Although the CO levels remained within the NWT criteria, these results demonstrate that exposure to CO concentrations are an additional consideration during forest fire events.

Health Messaging from Forest Fires

The Air Quality Health Index (AQHI) is a health risk communication tool developed by Environment Canada and Health Canada. The AQHI, which is available for Yellowknife and Inuvik, forecasts health risks related to air quality for the current and following day. It translates air quality monitoring data into a health scale from 1 to 10, and provides associated health-based messaging for the public, such as suggestions to adjust your activity level to protect yourself when the air quality is poor.

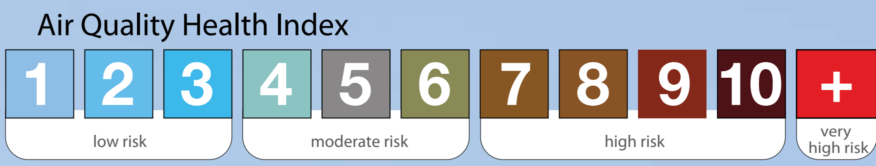


Figure 37 – Air Quality Health Index

The AQHI was a useful tool for the public during the 2014 forest fire season. The following figure presents the AQHI results for that timeframe.

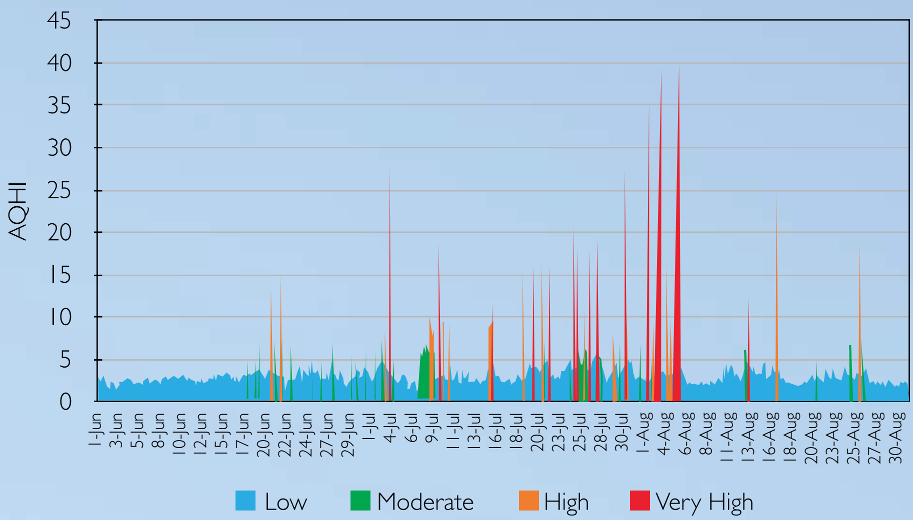


Figure 38 – Summer 2014 Hourly AQHI for Yellowknife

Figure 38[3] demonstrates the frequency that the AQHI reached the various levels of risk throughout the summer of 2014 in Yellowknife. The AQHI was in the high risk range for 215 hours and exceeded the index (i.e. 10+, very high risk) for a total of 88 hours during this time period. The extreme AQHI values observed during the fire season have prompted action to develop additional tools within the GNWT and at Environment Canada to assist with health messaging and public awareness.

3. Pankratz et al, "The Northwest Territories Up In Smoke: the summer of 2014". The Canadian Smoke Newsletter, 2015.

Since the AQHI is only available in two communities, Yellowknife and Inuvik, there is a gap in health-related messaging for the rest of the territory. Environment Canada is continuing to develop and expand on the Public Weather Alerts system, which will help to address that gap. The Public Weather Alerts system is a tool that provides weather-related, as well as air quality-related information, for regions across Canada, including all the regions of the NWT. It uses meteorological information and smoke modeling software to predict and disseminate real-time and predicted conditions for a geographic area.

The following link demonstrates the Public Weather Alerts system for the NWT: https://weather.gc.ca/warnings/index_e.html?prov=nt

This tool will be valuable to complement ENR's air quality monitoring network, and assist the GNWT and residents of the NWT to make health-related decisions based on air quality during forest fire seasons.

Future Monitoring Activities for Forest Fire Events

ENR operates four comprehensive air quality monitoring stations in Fort Smith, Yellowknife, Norman Wells and Inuvik; however, the remaining communities of the NWT do not currently have any air monitoring coverage. Although there are tools available to assist with estimating particulate levels in all areas of the NWT during forest fire seasons, such as smoke forecasting models, precise, real-time data is not available at this time. Such data would be useful to assist Health and Emergency Management officials with understanding population exposure and ensuing decision-making during forest fire smoke events. As such, ENR will undertake to acquire portable particulate monitoring equipment for the coming years, to use for deployment to affected communities in the NWT during smoke events. The equipment type, deployment decision matrix, unit operations and data dissemination protocols will be established in 2015.

Appendix A: 2014 Data Capture

$PM_{2.5}$ Data

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Max 24-hr	Percentile (24-hr) 25	50	75	>28 ug/m³ # days	% days
Yellowknife	353	96.7	8494	97.0	15.7	873.0	320.4	3.8	4.9	7.8	39	10.7
Inuvik	346	94.8	8395	95.8	3.7	30.0	12.2	2.2	3.3	4.7	0	0.0
Norman Wells	320	87.7	7752	88.5	3.5	452.0	84.6	1.8	2.5	3.6	2	0.5
Fort Smith	344	94.2	8298	94.7	9.7	417	216.9	3.9	5.2	8.4	17	4.7

PM_{10} Data

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Max 24-hr	Percentile (24-hr) 25	50	75	>50 ug/m³ # days	% days
Yellowknife	292	80.0	7058	80.6	26.2	772	349.5	6.0	11.8	25.1	33	9.0
Inuvik	333	91.2	8131	92.8	18.9	502	85.4	8.8	13.6	25.6	13	3.6
Norman Wells	291	79.7	7125	81.3	14.4	718	175.8	3.2	7.2	17.6	14	3.8
Fort Smith	234	64.1	5847	66.9	17.8	501	261.2	6.8	10.2	19.7	15	4.1

O_3

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Max 8-hr	Percentile (8-hr) 25	50	75	>63 ppb # 8-hrs	% 8-hrs
Yellowknife	359	98.4	8683	99.1	23.9	59.6	48.2	17.7	24.4	29.8	0	0.0
Inuvik	318	87.1	7514	85.8	23.5	52.2	49.1	17.3	22.8	29.9	0	0.0
Norman Wells	340	93.2	7905	90.2	22.2	52.3	46.8	15.4	21.7	28.6	0	0.0
Fort Smith	113	31	2602	29.7	19.1	35.5	34.7	14.2	19.6	23.8	0	0.0

NO_2

Location	Valid Days	% Valid Days	Valid Hrs	% Valid Hrs	Mean	Max 1-hr	Percentile (1-hr) 25	50	75	>213 ppb # 1-hrs	% 1-hrs
Yellowknife	360	98.6	8698	99.3	2.8	54.1	0.6	1.4	3.4	0	0.0
Inuvik	346	94.8	8049	91.9	2.2	33	0.3	0.9	2.7	0	0.0
Norman Wells	248	67.9	5799	66.2	1.4	23.6	0.0	0.1	1.3	0	0.0
Fort Smith	360	98.6	8296	94.7	2.8	54.8	0.9	1.8	3.1	0	0.0

NO_2		Percentile (24-hr)			>106 ppb	
Location	**Max 24-hr**	**25**	**50**	**75**	**# days**	**% days**
Yellowknife	15.9	0.9	1.9	3.8	0	0.0
Inuvik	14.3	0.6	1.4	3.1	0	0.0
Norman Wells	9.8	0.1	0.3	2.1	0	0.0
Fort Smith	24.5	1.3	2.3	3.3	0	0.0

SO_2							Percentile (1-hr)			>172 ppb	
Location	**Valid Days**	**% Valid Days**	**Valid Hrs**	**% Valid Hrs**	**Mean**	**Max 1-hr**	**25**	**50**	**75**	**# 1-hrs**	**% 1-hrs**
Yellowknife	338	92.6	8212	93.7	0.41	3.0	0.0	0.30	0.78	0	0.0
Inuvik	294	80.5	6900	78.8	0.3	1.9	0.0	0.1	0.5	0	0.0
Norman Wells	332	91.0	7765	88.6	0.2	1.4	0.0	0.0	0.3	0	0.0
Fort Smith	347	95.1	7995	91.3	0.6	4.5	0.2	0.5	0.9	0	0.0

SO_2		Percentile (24-hr)			>57 ppb	
Location	**Max 24-hr**	**25**	**50**	**75**	**# days**	**% days**
Yellowknife	1.3	0.0	0.42	0.78	0	0.0
Inuvik	1.7	0.0	0.1	0.5	0	0.0
Norman Wells	0.9	0.0	0.0	0.3	0	0.0
Fort Smith	2.2	0.2	0.5	0.9	0	0.0

CO								Percentile (1-hr)			>13 ppm	
Location	**Valid Days**	**% Valid Days**	**Valid Hrs**	**% Valid Hrs**	**Mean**	**Max 1-hr**	**Max 24-hr**	**25**	**50**	**75**	**# 1-hrs**	**% 1-hrs**
Yellowknife	358	98.1	8670	99.0	0.262	7.806	2.775	0.160	0.184	0.228	0	0.0
Inuvik	348	95.3	8206	93.7	0.166	1.111	0.557	0.098	0.171	0.222	0	0.0
Fort Smith	111	30.4	2677	30.6	0.021	1.014	0.223	0.000	0.000	0.000	0	0.0

CO		Percentile (8-hr)			>5 ppm	
Location	**Max 8-hr**	**25**	**50**	**75**	**# 8-hrs**	**% 8-hrs**
Yellowknife	4.914	0.165	0.189	0.230	0	0.0
Inuvik	0.802	0.102	0.172	0.221	0	0.0
Fort Smith	0.555	0.102	0.172	0.000	0	0.0

Appendix B: Monitoring History

History of Air Quality Monitoring in the Northwest Territories

1974	• Government of the NWT starts monitoring air quality in Yellowknife with the installation of a high-volume 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 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.
2002	• Daring Lake summer sampling of PM_{10} begins. • City Hall SO_2 analyzer relocated to new air monitoring trailer located at École 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 trailers 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 SO2 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 fine particulate sampler at the Yellowknife Post Office station is relocated indoors at the Sir John Franklin station. • The Yellowknife Post Office station is officially closed after the last TSP sample ran on December 6, 2005. • Development of an Air Quality web site begins. The web site 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 Air Quality Monitoring Network web site 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 web site, 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. • Daring Lake particulate monitoring temporarily discontinued due to 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 STP, 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 web site launched to provide current and historic data to users (http://aqm.enr.gov.nt.ca/).
2013	• AQHI launched for the City of Yellowknife. • $PM_{2.5}$ FEM installed in Norman Wells. • Fort Liard Station closed in November 2013. • New air quality station installed in Fort Smith in December 2013. • Yellowknife and Inuvik stations equipped with trace level CO analyzers. • Filter-based particulate sampler (Partisol 2000i-D) installed at the Yellowknife station.
2014	• H_2S monitoring discontinued at Norman Wells station. • Replaced Yellowknife station with a larger 10' x 25' building. • AQHI launched in Inuvik.

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.

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.

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

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.

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 Canadian Ambient Air Quality Standards (CAAQS) has set a limit for $PM_{2.5}$, but has not yet established a limit for PM_{10}. The CAAQS 24-hour average limit for $PM_{2.5}$ is 280µg/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.