Condition of Environment – Air Indicators

Data Analysis/Visualization Methodology

1 NO_2, SO_2, O_3, and $PM_{2.5}$ Indicators

1.1 Data Source

Data used in the data analysis and visualization is from Alberta's long-term air quality monitoring network, which is publicly available through the Alberta Air Data Warehouse at https://www.alberta.ca/access-air-data.

1.1.1 Limitations of the Dataset

The spatial coverage of the current long-term monitoring network is concentrated in central and northeastern Alberta and the majority of stations are located in/near communities. Therefore, data is not available for all parts of the province. The types and number of monitoring stations used for each indicator are given below:

- **NO_2:** 60 monitoring stations met completeness criteria for annual average and peak NO_2 in 2024.
  - 37 Community monitoring stations, 12 Regional monitoring stations, and 11 Near Industrial Facility monitoring stations.
- **O_3:** 46 monitoring stations met completeness criteria for annual average and peak O_3 in 2024.
  - 34 Community monitoring stations, 9 Regional monitoring stations, and 3 Near Industrial Facility monitoring stations.
- **$PM_{2.5}$:** 52 monitoring stations met completeness criteria for annual average and peak $PM_{2.5}$ in 2024.
  - 34 Community monitoring stations, 9 Regional monitoring stations, and 9 Near Industrial Facility monitoring stations.
- **SO_2**: 68 monitoring stations met completeness criteria for annual average and peak SO_2 in 2024.
  - 34 Community monitoring stations, 14 Regional monitoring stations, 17 Near Industrial Facility monitoring stations, and 3 Local Issues monitoring stations.

1.2 Annual Average and Peak Metric Calculations

The annual average and peak metrics for the indicators were calculated for each continuous ambient air monitoring station in Alberta's long-term air monitoring network using the statistical forms shown in Table 1. All indicator metrics, except O_3 annual average, are derived from the Canadian Ambient Air Quality Standards (CAAQS) metrics and follow the calculation methodology detailed in the Guidance Documents for each pollutant published by the Canadian Council of Ministers of Environment (CCME) (CCME, 2012; 2020a; 2020b; 2021).

Table 1: Statistical form for the annual average and peak metrics for each pollutant.

Metric	Parameter	Statistical Form
Annual Average	NO_2	annual average of all valid hourly data in a year
	SO_2	annual average of all valid hourly data in a year
	$PM_{2.5}$	annual average of all valid daily average values in a year
	O_3	Annual average of all valid daily maximum 8-hour rolling average concentrations
Peak	NO_2	annual 98th percentile of the daily maximum 1-hour average concentrations
	SO_2	annual 99th percentile of the daily maximum 1-hour average concentrations
	$PM_{2.5}$	annual 98th percentile of the daily 24-hour average concentrations
	O_3	annual 4th highest daily maximum 8-hour rolling average concentrations

1.2.1 Data Completeness Criteria Used in the Calculation of Each Metric:

- **NO_2:**
  - Daily maximum = at least 75% valid hours in a day, except if the daily maximum based on the available hours exceeds 60 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the year and 60% in each quarter, except if the 98th percentile based on the available daily maximums exceeds 60 ppb, then the year is included.
  - Annual average = at least 75% valid hours in a year and 60% valid hours in each quarter, except if the annual average exceeds 17 ppb and at least 50% valid hours are available in each quarter.

- **SO_2:**
  - Daily maximum = at least 75% valid hours in a day, except if the daily maximum based on the available hours exceeds 70 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the year and 60% in each quarter, except if the 98th percentile based on the available daily maximums exceeds 70 ppb, then the year is included.
  - Annual average = at least 75% valid hours in a year and 60% valid hours in each quarter, except if the annual average exceeds 5 ppb and at least 50% valid hours are available in each quarter.

- **$PM_{2.5}$:**
  - Daily average = at least 75% valid hours in a day.
  - Peak value = at least 75% valid daily averages in a year and 60% in each quarter
  - Annual average = at least 75% valid daily averages in a year and 60% in each quarter.

- **O_3:**
  - 8-hour rolling average = at least 75% of hours in 8-hour period.
  - Daily maximum = at least 75% of valid 8-hour rolling averages in a day, except if the daily maximum based on the available hours exceeds 62 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the combined 2nd and 3rd quarter of the year, except if the 4th highest value based on the available daily maximums exceeds 62 ppb, then the year is included.
  - Annual average = at least 75% valid daily maximums in the combined 2nd and 3rd quarter of the year.

1.3 Time Series Graphs

1.3.1 All Indicators

Provincial average = for each year, the annual average/peak concentration was averaged across all stations in the long-term air quality monitoring network that monitored a valid annual average/peak concentration.

10th and 90th percentiles = for each year, the 10th and 90th percentile in annual average/peak concentration across all stations in the long-term air quality monitoring network monitoring a valid metric were calculated.

Results for major population centres = The average concentration across all stations in a given large population centre (Calgary, Edmonton, Fort McMurray, Grande Prairie, Lethbridge, Medicine Hat, and Red Deer) was calculated to give one averaged concentration value for each city each year. All stations in the long-term air quality monitoring network within the municipal boundaries of the city were included in each spatial average.

1.3.2 For SO_2 Indicator only

The average concentration across each station type (Community, Near Industrial Facility, and Regional) were calculated to give one averaged concentration value for each station type each year. For more information on the monitoring station types see the "Five-year provincial air quality and deposition monitoring, evaluation and reporting (MER) plan (2021-2025)" (Aklilu, et al., 2021).

1.4 Trend Estimates

Trends in annual average/peak concentrations were estimated for each indicator using the openair package (Carslaw and Ropkins, 2012) in R (R Core Team, 2024) and TheilSen function therein. For information on this package and function, see the OpenAir user manual https://openair-project.github.io/book/. For NO_2, SO_2, and O_3, trend estimates for the provincial average and large population centres were calculated beginning in 2000 or the earliest date with monitoring data using the annual average/peak concentration and required at least 10 years of data.

Trends in more recent years (2014-2023) for monthly average concentrations of NO_2, SO_2, and O_3 were estimated using the methodology outlined in Nunifu and Fu (2019). Two trend estimation approaches were used:

1. Non-parametric approach where the Theil-Sen and Mann-Kendall methods are used to estimate trend and test for significance.
2. Parametric approach where linear regression is used to estimate trend and the generalized autoregressive conditional heteroscedasticity (GARCH) method is used to estimate the standard error to test the null hypothesis that the estimated trend is not statistically significant.

The 10-year monthly average trend results are provided in the maps in Figures 1a and 1b on the NO_2, SO_2, and O_3 indicator webpages. These results can be viewed for each station when the station's symbol is selected. The threshold to report a significant trend was a p-value <0.05.

1.5 Seasonal Variation Box Plots for $PM_{2.5}$ and O_3

Monthly average concentration from each station monitoring during the year(s) included in the box plot were included. The data completeness criteria for monthly average concentration calculation was at least 50% of hourly data available in a given month. The box represents the middle 50% of the data with the horizontal line inside the box indicating the middle value of the dataset. Vertical lines extending from the top and bottom of the box show the overall spread of the data.

1.6 Comparison to Alberta's Ambient Air Quality Objectives

Comparison to Alberta's Ambient Air Quality Objectives (AAAQOs) followed the rounding and comparison rules stipulated in Section 3.1.2 of the "Air Monitoring Directive Chapter 9: Reporting" (Alberta Environment and Parks [AEP], 2016). For a summary of the AAAQOs in effect in Alberta and used in this assessment, see the "Alberta Ambient Air Quality Objectives and Guidelines 2024" (Alberta Environment and Protected Areas, 2024).

1.7 References

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2 Wildfire Smoke Indicator

2.1 Data Sources

2.1.1 Wildfire Burn Area

Estimated wildfire burn area for Canadian jurisdictions (1990 to 2023) was accessed from the National Forestry Database at http://doi.org/10.5281/zenodo.3690046. Data for United States jurisdictions (2002 to 2023) was accessed from the National Interagency Fire Centre at https://www.nifc.gov/fire-information/statistics.

2.1.2 Trend Estimates

Trends in annual area burned in Alberta were calculated beginning in 1990 using the openair package (Carslaw and Ropkins, 2012) in R (R Core Team, 2024) and TheilSen function therein. For information on this package and function, see the OpenAir user manual at https://openair-project.github.io/book/. The threshold to report a significant trend was a p-value <0.05.

Limitations of the datasets:

- Different jurisdictions might vary in their reporting of area burned due to differences in land use, among others.
    - For example, Alberta reports area burned within the province's Forest Protection Area, while Saskatchewan reports area burned data under the Intensive Protection Zone.
- U.S. data from the National Interagency Fire Center is only available from 2002 onward. Additionally, U.S. data beyond 2018 does not include prescribed burns (which are not expected to be significant in size).

Note: Megafires are fires greater than 40,500 ha, as defined by the U.S. Interagency Fire Center (National Geographic, 2023).

2.1.3 Wildfire Smoke Influenced Days

Data collected at select monitoring stations in Alberta are evaluated for wildfire smoke impact using multiple datasets:

- satellite imagery (https://worldview.earthdata.nasa.gov);
- back trajectories (obtained from Environment Climate Change Canada);
- maps of past wildfires and smoke forecasts (https://firesmoke.ca);
- time series analysis of $PM_{2.5}$, other pollutants and meteorological variables; and
- information gathered throughout the year as part of the Air Quality Health Index and associated air quality advisories, and through communication with station operators.

This process identifies wildfire smoke with notable impact on $PM_{2.5}$ concentrations (daily average concentrations > 15 µg m^{-3}); marginal impacts may not be recognized.

EPA has used this analysis to determine wildfire impacted days for select stations, chosen for this indicator to represent the areas of the province with air monitoring in place, going back as far as 2015.

Limitations of the dataset:

- Only days with daily average $PM_{2.5}$ concentration greater than 15 µg/m^3 were included in the identified wildfire smoke impacted days. There may be additional days with lower $PM_{2.5}$ concentrations that were impacted by wildfire smoke but not included in the results. For data showing total number of impacted days, only urban stations were included due to limited data in rural regions.
- Long-term air quality monitoring stations do not cover all regions of Alberta, therefore monitoring gaps may incorrectly suggest that wildfire smoke impacts do not occur in those areas.

2.2 References

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3 Ions in Precipitation

3.1 Data Source

Data used in the data analysis and visualization from 2013-2020 is publicly available on the National Atmospheric database at https://data-donnees.az.ec.gc.ca/data/air/monitor/monitoring-of-atmospheric-precipitation-chemistry/major-ions/. Data collected prior to 2013 are available upon request (epa.aws-rsd-admp@gov.ab.ca).

3.1.1 Data Completeness Criteria Used in the Calculation

The data quality control and assurance performed on 2011-2020 precipitation chemistry data are described in the Alberta Precipitation Chemistry Data Handling Manual.

Additional data completeness criteria:

- Excluding samples with a collection period of 35 days or more,
- Excluding samples with a volume less than 75 ml,
- Excluding samples with missing ion concentrations, and
- Must have valid data for at least 60% of the period of study

3.1.2 Limitation of the Dataset

Atmospheric deposition stations did not have independent co-located precipitation depth monitoring (i.e., precipitation gauge data) for 2011-2020. Instead, precipitation depth was calculated based on sample volume to conduct quality control.

To account for the impact of precipitation sample volume on reported concentration, volume-weighted concentrations were used in the analysis instead of the arithmetic mean concentration. Volume-weighted concentrations are less likely to be skewed by collected precipitation sample volume, which varies in time and location. The volume-weighted concentrations (VWC; mg/l) for a given period (e.g., monthly, annual) are calculated based on:

$$VWCs = \frac{\sum_{i=1}^{n} v_i * x_i}{\sum_{i=1}^{n} v_i} \qquad \text{Equation 1}$$

Where v_i is the sample precipitation volume (ml) for period *i*, x_i is the ion concentration for period *i* (mg/l) and there are *n* periods (either 12 months or 10 years) over which the concentrations are being averaged.

3.2 Variation Across Alberta Plot

The average of volume-weighted concentrations of ions and pH in precipitation over 2011-2020 from each selected station in the bar plot were included.

3.3 Changes Over Time Plot

3.3.1 Annual Volume-weighted Concetrations

The annual volume-weighted concentrations of ions and pH in precipitation from selected stations (i.e., 7 stations) over the 10-year study period. The box represents the middle 50% of the data with the horizontal line inside the box indicating the middle value of the dataset. Vertical lines extending from the top and bottom of the box show the overall spread of the data.

3.3.2 Trend Estimates

Trends in annual average were estimated for ions and pH using the openair package (Carslaw and Ropkins, 2012) in R (R Core Team, 2021) and TheilSen function therein. For information on this package and function, see the OpenAir user manual at https://openair-project.github.io/book/. The threshold to report a significant trend was set with a probability of less than 10% for falsely detecting a trend when the pattern was random (i.e., p-value < 0.1).

3.4 Monthly Volume-weighted Concentration

The monthly volume-weighted concentrations of ions and pH in precipitation from selected stations (i.e., 7 stations) over the 10-year study period. The box represents the middle 50% of the data with the horizontal line inside the box indicating the middle value of the dataset. Vertical lines extending from the top and bottom of the box show the overall spread of the data.

3.5 Reference

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