Industrial Heartland Designated Industrial Zone

Non-methane Hydrocarbons as an Additional Indicator

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Alberta

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General Information

Background

Atmospheric hydrocarbons are a mixture of organic compounds containing mostly hydrogen and carbon. There are two broad classes of atmospheric hydrocarbons: non-reactive (i.e. methane) and reactive (i.e. non-methane). Non-methane hydrocarbons (NMHC) include volatile alkane, alkene, alkyne, and aromatic hydrocarbons. The Industrial Heartland (IH) is a dense area of industrial development and is Canada's largest hydrocarbon processing region. The IH contains several large chemical and petrochemical manufacturing and processing facilities that report emissions of hydrocarbons to the National Pollutant Release Inventory. In addition, the IH is within Alberta's Capital Region (City of Edmonton, City of St. Albert, Elk Island National Park, Lamont County, Leduc County, Parkland County, Strathcona County, and Sturgeon County), which contains other emitters of hydrocarbons including several other large hydrocarbon processing facilities as well as ancillary urban sources of hydrocarbon emissions from activities such as transportation and home heating. Non-methane hydrocarbon compounds can participate in chemical reactions that can result in the formation of ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$). The North Saskatchewan Air Zone, which includes the entirety of the IH, has consistently been determined to be in the Canadian Ambient Air Quality Standards[1] orange management level for both $PM_{2.5}$ and O_3. Non-methane hydrocarbons are an ideal candidate for an additional indicator (see definition below) to be implemented in the IH due to the prevalence of known sources of NMHC in the IH, as well as its participation in reactions that can contribute to the formation of key pollutants already under management in the IH and broader Capital Region; A management plan for $PM_{2.5}$ was developed for the Capital Region in 2014, and continues to be implemented. There is also a history of elevated measurements of NMHC in the IH as well as periodic odour complaints associated with hydrocarbons. The local air monitoring organization in the IH, the Fort Air Partnership (FAP), monitors NMHC to achieve the following monitoring objectives at each respective station:

- Characterize emerging issues: impact of emissions from sources related to oil and gas production, transport, and storage (Bruderheim)
- Government specifies parameter under contract (Fort Saskatchewan)
- Operating approval condition or legacy from previous approval (Lamont County, Range Road 220)
- On the portable depending on individual project objectives (Keith Purves Portable)

Monitoring of ambient concentrations of hydrocarbons and volatile organic compounds have occurred in various permutations in the IH for more than two decades. Monitoring has predominantly occurred in two forms, by continuous analyzers and through evacuated canister samples as part of targeted monitoring studies. The Fort Air Partnership operates continuous NMHC analyzers at 5 of its 10 monitoring stations (noted above). Continuous measurements of NMHC are reported to Alberta's Air Data Warehouse as hourly averaged concentrations. Continuous measurements of NMCH are non-specific and represent the summative concentrations of all NMHC compounds in the ambient air. Therefore, this information is of use as a surrogate for overall summative concentrations of volatile organic compounds. However, specific hydrocarbons or volatile organic compounds of concern need to be investigated using methods capable of resolving individual constituent compounds.

Concentrations of NMHC at stations operated by FAP range from locations where concentrations are above detection limit (method detection limit of 0.05 ppm) for less than 5% of the time (e.g. Fort Saskatchewan), to locations impacted by industrial emissions where concentrations on a monthly basis can be above detection limit for more than 30% of the time (e.g. Range Road 220). Over the last

[1] Since 2015, Alberta has been implementing the air zone management framework for fine particulate matter ($PM_{2.5}$) and ozone (O_3), as part of Alberta's commitment to implement the national Air Quality Management System. Under this framework, the Canadian Ambient Air Quality Standards are used to determine the condition of ambient air quality and set a management intent for air quality. The goal of the orange management level is to establish management plans to prevent exceedance of the CAAQS, and to maintain or improve air quality wherever possible.

two decades, several monitoring studies, led by various organizations including FAP have also utilized evacuated canisters to further investigate hydrocarbon and volatile organic compound concentrations in the IH (see Bruderheim Volatile Organic Compound Speciation Study Report, Fort Air Partnership, 2021; and Fort Saskatchewan VOC Monitoring Study, Environment Canada, 2006).

As described in the most recent study (Bruderheim Volatile Organic Compound Speciation Study Report, Fort Air Partnership, 2021) continuous monitoring of summative NMHC concentrations can aid in the analysis of the current state and trends of hydrocarbon and volatile organic compound concentrations. However, in-depth investigation of individual constituent compounds, as collected by evacuated canister samples, are required to gain additional insight into potential sources of measured NMHC concentrations. This most recent study notes that concentrations of NMHC should be examined for trends and changes that may identify when elevated conditions exist and warrant additional investigation. Implementing a statistical measure for NMHC as part of IH-DIZ implementation supports the management of hydrocarbon emissions and related secondary pollutants in the region.

Definitions

For the purpose of this document:

a. **Designated Industrial Zone (DIZ):** is a provincially-approved area of clustered industrial development established through municipally-led collaborations where facilities benefit from consistent, coordinated regulatory approvals, share access to infrastructure and resources, and minimize cumulative environmental impacts through participative governance of the zone and a commitment to continuous improvement.

b. **Industrial Heartland (IH):** is Canada's largest hydrocarbon processing region, and home to world-scale oil and gas refineries, chemical and petrochemical facilities. Its industrial zoned land extends into five different municipalities, including 533 km^2 within the City of Fort Saskatchewan and the Counties of Lamont, Strathcona and Sturgeon, in addition to 49 km^2 in the City of Edmonton (industrial area known as the Edmonton Energy and Technology Park). The Industrial Heartland is zoned for heavy industrial development and benefits from extensive regional collaboration between industry, government, and other regional stakeholders.

c. **Industrial Heartland Designated Industrial Zone (IH-DIZ):** the Industrial Heartland has been selected as the pilot project location for the Designated Industrial Zone concept of clustered industrial development and cumulative effects management. The spatial boundary of the Industrial Heartland is congruent with the boundaries for the pilot project.

d. **Additional indicator:** is an ambient air quality indicator that supplements Alberta's Implementation of the Air Zone Management Framework. It is a substance of concern but it is not a substance with an established Canadian Ambient Air Quality Standard. An additional indicator is significant for regional air quality management and an investigation may be initiated in the case of substantial increase and/or increasing trend in ambient concentration. Additional indicators may also be used to evaluate the effectiveness of implemented management actions. Additional indicators generally do not have triggers, thresholds, limits, or standards associated with their use.

Implementation

Statistical Measure

- Change in the 90th percentile of ambient NMHC concentrations over time
  - Calculated as the five-year trend of de-seasonalized monthly 90th percentile hourly-averaged NMHC concentrations using the Theil–Sen estimator.

Statistical Measure Calculation

- De-seasonalizing monthly data should be accomplished using the seasonal trend decomposition using loess method. This method applies locally fitted linear regression modelling to decompose time series data that have seasonal variations, like ambient air quality data. This method allows the observation of underlying variability in the dataset that is not the result of seasonal influences, such as the effects of ambient meteorology on dispersion.
- Monthly data completeness of hourly averaged measurements, for inclusion into the statistical measure calculation, should be greater than 75%. Months with data completeness less than 75% should be excluded from the statistical measure calculation. Excluded months should not exceed six total months in a given year or four consecutive months in a given year.

Rationale

- Ambient upper percentile concentrations can be considered as an indicator of somewhat elevated hydrocarbon concentrations, acting to highlight influence from nearby emissions sources. Note that elevated NMHC concentrations as determined by this statistical measure are relative to the magnitude and distribution of measured ambient concentrations and are not a direct indicator of human or environmental risk.
- Statistical measures utilizing very high percentiles (e.g. 99.9th, etc.) can have larger year-to-year variability due to influences from meteorology and variations in emission sources themselves. This variability makes these percentiles less suitable to establishing and interpreting trends over time.
- The change in an upper percentile (i.e. 75th percentile) of ambient total hydrocarbons has been proposed for adoption as part of reporting of hydrocarbons in Alberta's oil sands region, and this statistical measure aligns with that approach.
- The statistical measure aligns with existing monitoring objectives in FAP's monitoring plan, namely the characterization of emerging issues associated with hydrocarbon emissions.
- The spatial distribution of monitoring stations with a continuous NMHC analyzer in the FAP network is broad and covers a range of settings and exposure to ambient hydrocarbon concentrations. Stations with lower concentrations are Fort Saskatchewan (an urban site) and Lamont County (a downwind regional site). Stations with higher concentrations are Range Road 220 (nearby an industrial facility with reported hydrocarbon emissions) and Bruderheim (impacted by sources related to hydrocarbon production, transport, and storage). This range of station locations and exposure to hydrocarbon emissions will enable the observation of emerging trends in various settings in the vicinity of the IH.
- The Theil-Sen estimator is able to accurately analyze trends with appropriate confidence intervals for datasets that are non-normal, have non-constant error variance, and have large outliers; a common condition of ambient air datasets. Bootstrap resampling can be used to provide an estimated p value for the calculated trend.

Scope

- The statistical measure for NMHC is to be applied to data from the four permanent stations within or adjacent to the IH that are operated by FAP: Bruderheim, Fort Saskatchewan, Lamont County, Range Road 220. The statistical measure may be applied to data from the portable Keith Purves station if it is located at one site for a period of 5 years or more.
- If additional permanent monitoring stations are supplemented with NMHC continuous analyzers within the IH or within the FAP network in future, this statistical measure may apply to data from these stations.

Management Response Approach

- Triggers, thresholds, limits, objectives, and standards are the quantitative basis for evaluating air quality condition. There are no standards or objectives associated with NMHC, therefore triggers, thresholds, limits, objectives, or standards will not be established.
- Instead, statistical significance of trends identified using the statistical measure will signal the need for a more in-depth investigation of ambient hydrocarbon concentrations. Note that due to the nature of the statistical measure, a statistically significant trend does not necessarily identify a corresponding change in environmental or human risk.
- Statistically significant increases ($p < 0.05$) in the statistical measure will be investigated using an array of potential approaches including but not limited to:
  - A review of the monitoring data's meta-data to identify any potential for statistical significance because of a change in instrumentation (e.g. analyzer model, analyzer type, analyzer sampling method, etc.)
  - Analysis of existing NMHC concentration data using additional statistical tools to examine variation in percentiles, maximum, and minimum concentrations as well as temporal variability in concentrations at various time scales
  - Review of historical evacuated canister sample based studies in the IH to build a broader understanding of concentrations of specific hydrocarbons and thus knowledge of potential sources
  - Review of monitoring information from other jurisdictions with similar industrial activities (e.g. Houston-Galveston area) to characterize the impact of reactive hydrocarbons on the formation of secondary air pollutants
  - The development of a supplemental monitoring project such that the collected data support investigation of the increasing trend. Funding and delivery of a supplemental monitoring will be determined should the need for such a project arise, but may incorporate FAP and could utilize continuous analyzers such as those deployed in the Keith Purves Portable.
  - The development of a detailed hydrocarbon sampling project, using methods such as evacuated canisters designed to support investigation of the increasing trend, and not duplicating other studies already competed in the IH.
- The results of any additional investigations, as described above, may be used to develop a management response if there is an emerging hydrocarbon concentration issue that threatens to exceed an ambient objective for a specific hydrocarbon or volatile organic compound with an associated objective, or is substantively shown to be contributing to the formation of secondary pollutants in the IH.

Evaluation

- The implementation of NMHC as an additional indicator and the associated statistical measure will need to be evaluated with respect to its support of the management of hydrocarbon emissions and related secondary pollutants in the region. The intention is to revisit the indicator and statistical measure at regular intervals, revising as needed, as more information is learned. As long-term oversight of the implementation of the IH-DIZ is established, revisiting and revision of the additional indicator will aim to align with other evaluation and reporting intervals.
- The current additional indicator and statistical measure were based on a number of factors outlined in this document and its appendix. However, it must be recognized that this document is not exhaustive. Rather, this document aims to pilot the additional indicator and statistical measure to align with initial

implementation of the IH-DIZ, providing opportunity in the future to further probe the indicator and statistical measure, revising as necessary.

- A number of considerations have been documented, including input from stakeholders, with respect to potential future investigations to explore the form and function of the additional indicator and statistical measure. Several of these considerations are described in brief below:
  - Time-period of analysis – It is recognized that only the most recent five complete years of data were analyzed to determine the form of the statistical measure. It is recommended that the much more extensive historical record of measured NHMC concentrations in the IH are considered to understand historical variations in concentrations and their effect on the statistical measure.
  - Treatment of near-zero concentrations – Concentrations of NMHC in the IH are frequently near-zero, which can be problematic for data analysis and the treatment of data reported as 0.0 or 0.000 ppm. Methods for treating data below Method Detection Limit (MDL) were explored, but were determined to be not applicable to NMHC for reasons described in the appendix. Future investigations may probe other novel methods for treating data below MDL that are more appropriate for NMHC. Alternatively, obtaining the original monitoring data with a higher degree of precision (prior to truncation and reporting to AEP) and associated calibration data may enable the determination of a region-specific practical detection limit, which may differ from the analyzer's specified MDL.

Reporting

- The Fort Air Partnership publishes an "Ambient Air Quality Monitoring Annual Network Report and Data Summary." In the report FAP summarizes hydrocarbon concentrations using the following statistical measures:
  - Hydrocarbon concentrations are summarized in three categories, total hydrocarbons, methane, and non-methane hydrocarbons.
  - For each station with a hydrocarbon analyzer, data are reported as:
    - monthly averages for the most recent year
    - annual averages in comparison to the previous 5 years
    - and maximum 1-hour averaged concentration in each moth for the most recent year

  It is not expected that FAP will adopt the NMHC statistical measures for the IH as part of their reporting, unless otherwise decided by their board and stakeholders.

- Alberta Environment and Parks has recently released its Condition of the Environment webpage. Currently reporting for air quality is focused on the four key criteria contaminants of: fine particulate matter, nitrogen dioxide, ground-level ozone, and Sulphur dioxide. Additional parameters such as NMHC could be added in the future and may support reporting against this statistical measure.
- Moving into implementation in Fall 2022, reporting of ambient environmental outcomes will be considered as part of the ongoing oversight of the IH-DIZ pilot. Opportunities to include the statistical measure for NMHC into new reporting products associated with the IH-DIZ will be sought moving forward.

Appendix

Analysis to determine statistical measure

Non-methane hydrocarbon concentrations are often near-zero. Data reported to the Alberta Air Data Warehouse for Bruderheim, Fort Saskatchewan, Lamont County, and Range Road 220 stations include time periods when concentrations were reported in ppm to one decimal place and three decimal places. The method detection limit for NMHC analyzers utilized at these stations is 0.05 ppm.

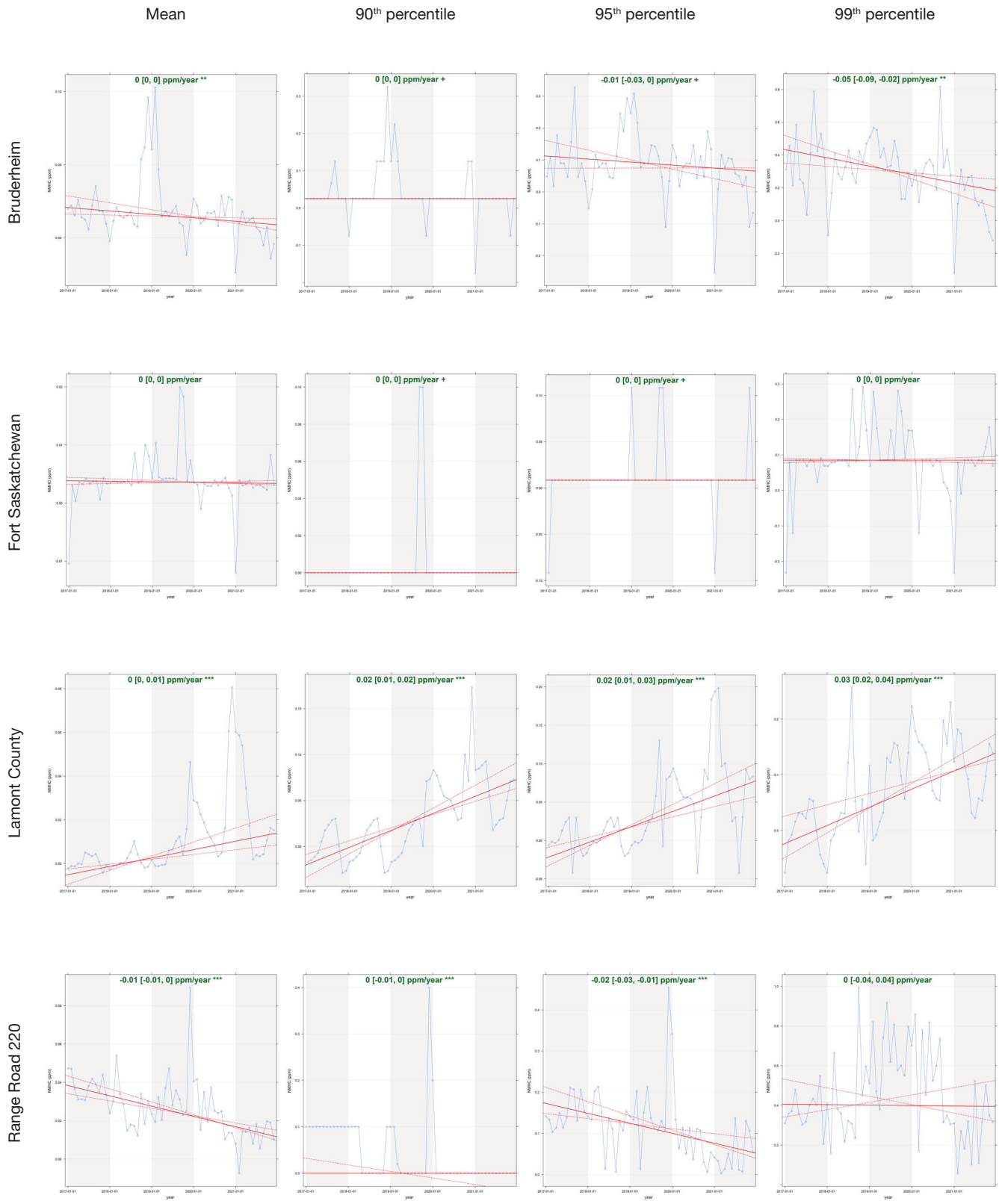
In order to determine an appropriate upper percentile for the statistical measure, an exploratory analysis of data from Bruderheim, Fort Saskatchewan, Lamont County, and Range Road 220 stations was performed. The five most recent complete years of data were analyzed: 2017-2021. For consistency, all data reported to three decimal places were rounded to one decimal place. Consideration was given to two common approaches to manage data below detection limit, however due to the reasons noted below, these considerations were not followed through:

- *Replace concentrations reported as 0.0 ppm or 0.000 ppm with half of the MDL (i.e. 0.025 ppm)* – In practice, when rounded to one decimal place, for consistency with the remainder of the dataset, half of the MDL remains 0.0 ppm. Therefore this approach does not significantly change the way near-zero concentrations are managed in the dataset.
- *Only analyze concentrations greater than the MDL* – For most stations in FAP, concentrations greater than MDL are a small subset of the data and would fail to meet generous 75% monthly data completeness requirements at most stations for most months. The variability in the number of hours analyzed could have implications for the impacts of periodic non-zero concentrations and would not give an accurate representation of dataset trends.

A brute force approach was used to determine an appropriate upper percentile for the statistical measure. To do this, the five years of NMHC data from Bruderheim, Fort Saskatchewan, Lamont County, and Range Road 220 stations were analyzed using the “Theil-Sen” function from the “openair” package for R. The “Theil-Sen” function was parameterized to use monthly averages, seasonal decomposition using loess method, and monthly data completeness of at least 75%. Four different iterations of the “Theil-Sen” function were computed: mean, 90th percentile, 95th percentile, and 99th percentile (Figure A1). The mean iteration of the “Theil-Sen” function was used to understand the overall trend slope of the dataset and the associated significance of the determined trend. The three upper percentile iterations (i.e. 90th, 95th, and 99th percentiles) were compared against the trend slope and trend significance of the mean iteration to determine whether a given upper percentile diverged from the overall trend of the dataset exhibited by the mean iteration. Divergence from the overall trend of the dataset is likely indicative that a given upper percentile is unduly influenced by year-to-year variability such as due to influences from meteorology and variations in emission sources.

For the period and stations identified, the trend slope and trend significance are generally similar to the mean for the statistical method evaluated using 90th or 95th percentile. However, using the 99th percentile for the statistical method, divergence of trend slope and trend significance is greater, indicating that the 99th percentile is less suitable for an appropriate upper percentile for the statistical measure. The 90th percentile was selected as the appropriate upper percentile for the statistical measure given the similarity in trend slope and trend significance for the stations and period of data analyzed.

FIGURE A1: Trend Slope and Trend Significance Figures for the Statistical Measure Evaluated on 2017-2021 NMHC Data for Bruderheim, Fort Saskatchewan, Lamont County, and Range Road 220 Stations Using the Mean, 90th, 95th, and 99th Percentiles.

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