12th International Environmental Specialty Conference
12ième conférence internationale spécialisée sur le génie de l'environnement

Edmonton, Alberta
June 6-9, 2012 / *6 au 9 juin 2012*

Source Identification for Odours in the Downtown of City of Medicine Hat

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Abstract: This paper discusses the results of an air quality monitoring program at the City of Medicine Hat. The objective of this study was to identify the potential contribution sources of odours in the downtown area. Total hydrocarbons (THC) and nitrogen dioxide (NO_2) were used as the indicator pollutants for organic emission sources and combustion sources. Pollutant rose analysis indicated that the potential source region might be in the south side of downtown for both THC and NO_2. Within this region, potential sources include the downtown rail yard, assorted business operations, traffic emissions, and space heating exhaust. Time-series analysis provided extra evidence to refine the list of candidate sources. THC time-series data indicated that the high concentration events were mostly detected between the late night and early morning hours. The unique timing pattern indicated that the downtown rail yard could be the potential contribution source. In winter, diesel locomotives require increased idling during night and early morning hours. The rail yard may be preparing for morning trains as well. The diurnal trend of NO_2 data was characterized by a double-crest pattern during a 24-hour period. The two peaks were detected during the morning and evening rush hours, indicating traffic emissions could be the major contribution source of NO_2.

1. Introduction

The City of Medicine Hat is located beside the South Saskatchewan River in the southeastern part of Alberta. During winter cold days, the atmosphere in the downtown area tends to be stable due to formation of inversion layers and/or calm wind conditions. Stable atmosphere limits pollutant dispersion and dilution, the City occasionally receives odour complaints from the residents. In response to the complaints, the Palliser Airshed Society (PAS) coordinates with the City and Alberta Environment (AENV) conducting a three-month monitoring program from December 1, 2010 to February 28, 2011. The objective was to identify the potential sources causing the odours. Because there was no record for the odour complaints, for example odour scent property, the air quality monitoring program used total hydrocarbon (THC) and nitrogen oxides (NOx) as the indicator pollutants for organic emission sources and combustion sources, respectively.

Prior to this study, AENV had conducted two air monitoring programs (AENV 1997; 1998) at downtown of City of Medicine Hat. Both studies analyzed 24-hour intermittent PAHs samples to investigate whether diesel exhaust, specifically from locomotive exhaust, could be the causes of odours and health concerns.

The 1997 AENV study collected six 24-hours intermittent PAH samples between late winter and early spring (February 10 to April 2, 1997). The study found when wind blew from the eastern directions, total PAHs were about four times higher than when wind blew from the southwest and south-southwest directions. The major PAHs source on the east side of the monitoring station was locomotive exhaust of the downtown rail yard (see Figure 1). The average of total PAHs for the six samples was 62% of the average of five other Alberta stations. The concentrations of three individual PAHs (anthracene, fluoranthene, and pyrene) were higher than the Alberta averages.

The 1998 AENV study collected six 24-hours intermittent PAH samples between winter and early spring (January 7 to March 25, 1998). The findings were similar to the 1997 study. The total PAHs was three times higher when the prevailing wind was from the east and east-northeast directions. The average total PAHs of the six samples was approximately 65% of Alberta average. The concentrations of four individual PAHs (anthracene, benzo [ghi] perylene, fluoranthene, and indeno [1,2,3-cd] pyrene) were higher than Alberta averages.

AENV conducted a monitoring program at the Mirror hamlet in the spring of 2010 and during the winter between 2010 and 2011 in response to complaints for impact on air quality from idling diesel engines of the Mirror rail yard (AENV 2011). This project included both continuous monitoring and intermittent samples. Directional trend analysis indicated that rail yard emissions could be the potential contribution sources of nitrogen oxides, while THC did not show a directional trend. The 2010 spring samples indicated that contribution sources could be existent near the monitoring station other than locomotive idling. To distinguish rail yard emissions from other contribution sources, the winter samples were collected when the monitoring station was downwind of the rail yard. Due to moderately high wind speed during the sampling period, the concentrations of volatile organic compounds and PAHs were lower than the spring samples.

The study presented in this paper used a different monitoring approach and data analysis methods as compared to the Alberta Environment studies. Two continuous monitoring stations, located at different orientation from the downtown area, were included. The design improved the capability for source region identification. Spatial trend analysis used high concentration events only. These events are more likely related to pollutant episodes and major source emission activities. This study also examined the time-series trends of continuous monitoring data. The detected time-series pattern may be associated with source activities.

2. Methodology

2.1 Air Quality Monitoring

Figure 1 presents locations of air quality monitoring stations and the rail yard at downtown of City of Medicine Hat. The Firehall monitoring station was installed on top of a one-story building. This station was at the east side of the downtown rail yard across the monitoring station used by the aforementioned AENV studies (AENV 1997, 1998). The Firehall station monitors total hydrocarbons (THC), nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NOx), wind speed, wind direction, and ambient temperature. The monitoring program was from December 1, 2010 to February 28, 2011.

During winter cold days, the atmosphere in the downtown area tends to be stable. Wind speed is slow and wind direction is unstable (i.e. standard deviation of wind direction is high). Unstable wind direction implies that an air parcel may circulate around the monitoring station. Using a pollutant rose to track potential contribution sources may be less informative.

To improve the capability and reliability of pollutant rose analysis, the monitoring data of the Crescent Heights station of the Palliser Airshed Society was included in this study. The Crescent Heights station is located 1.3 km northwest of the Firehall station across the South Saskatchewan River on top of the north bank. The elevation is approximately 30 m to 40 m above the downtown area. The monitoring data was obtained from the CASA Data Warehouse (Clean Air Strategic Alliance, 2011).

Figure 1: Locations of air monitoring stations and rail yard in the downtown of City of Medicine Hat

2.2 Data Analysis

This study analyzes spatial trend and time-series trend of pollutant concentration data to extract evidence for source identification. Spatial trend analysis identifies the potential source area, while time-series analysis examines the timing pattern which may be associated with source activities.

Pollutant rose analysis included 1-hour average concentration data for THC and NO_2. Only high concentration events (i.e. concentration higher than station average) were included in the analysis. The objective was to exclude background events. High concentration events are more likely to be associated with pollutant episodes. The time-series analysis included both 1-minute average data and 1-hour average data of THC and NO_2.

In using the Crescent Heights station to assist in source identification, it was assumed that the potential sources in the downtown area would impact the air quality at this station. This assumption was validated to ensure the data set would achieve the study objectives.

3. Results and Discussion

3.1 Validity of Crescent Heights Data for Source Identification

Paired monitoring data of the Crescent Heights station and the Firehall station were examined to validate the assumption that the potential sources in the downtown area would impact the air quality at the Crescent Heights station. Figure 2 illustrates scatter plots of paired monitoring data at the two air monitoring stations. The solid line represents an equivalent–concentration line. A data point falling on the line indicating both stations detected the same concentration for that 1-hour monitoring period.

The NO_2 scatter plot shows a general trend that the higher the concentration at the Firehall station, the higher the concentration at the Crescent Heights station. This pattern suggests that both stations could be affected by common contribution sources. Using the Crescent Heights station to assist in identification of potential sources at the downtown area is validated. Most of the data points were distributed above the equivalent-concentration line, indicating the Firehall station tends to detect a higher concentration of NO_2. The potential contribution sources might be located closer to the Firehall station.

For THC, the paired data points form a cluster parallel to the equivalent-concentration line. The pattern indicted both air monitoring stations could be affected by common contribution sources as well. Most data points were scattered above the equivalent-concentration line, indicating the Firehall station tended to detect a higher concentration than the Crescent Heights station. The potential contribution sources might be closer to the Firehall station.

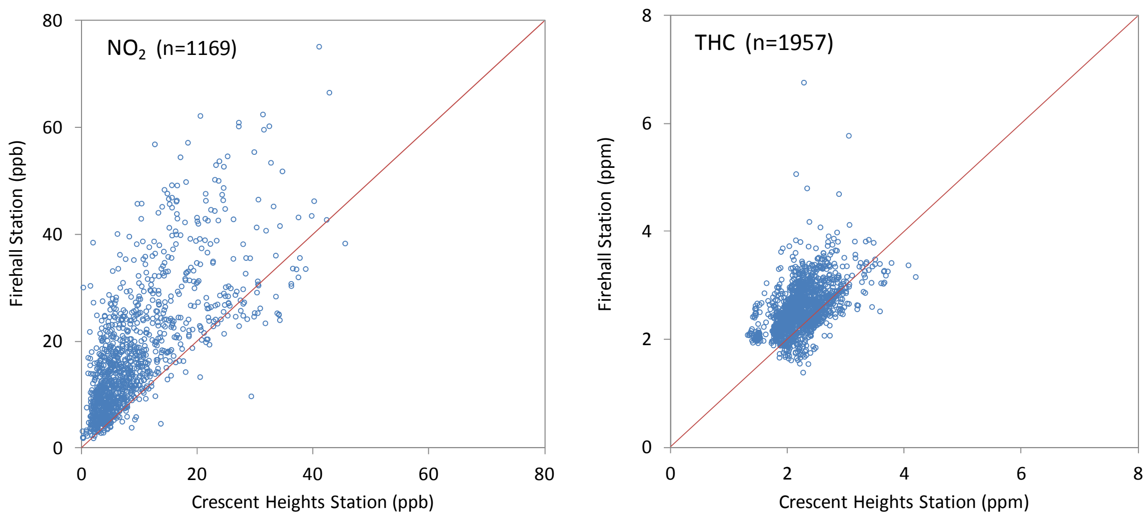

Figure 2: Paired one-hour average concentrations at the Crescent Heights station and Firehall station (December 1, 2010 to February 28, 2011)

3.2 Wind Roses

Figure 3 presents the wind roses of one-hour observation data at the Crescent Heights station (n=2155) and the Firehall station (n=2094). During the three-month monitoring period, the prevailing wind speed at the Firehall station was less than 5 km/hr (average wind speed 1.7 ± 1.4 km/hr). The prevailing winds were from the northwest to southeast directions. There was only 21% of time wind blew from the directions of the downtown business area and the rail yard.

The wind speed at the Crescent Heights station was higher (11.2 ± 7.0 km/hr) than at the Firehall station, and wind direction was more stable. The prevailing winds were from the southwest to west-southwest directions, as well as the north to north-northeast directions. There was only 10% of time during which wind blew from the downtown area.

Although wind seldom blew from the downtown area to both air monitoring stations, it is interesting to find whenever wind blew from the downtown area, both air monitoring stations detected an increased probability of high concentration events for THC and NO_2, as discussed in Section 3.3.

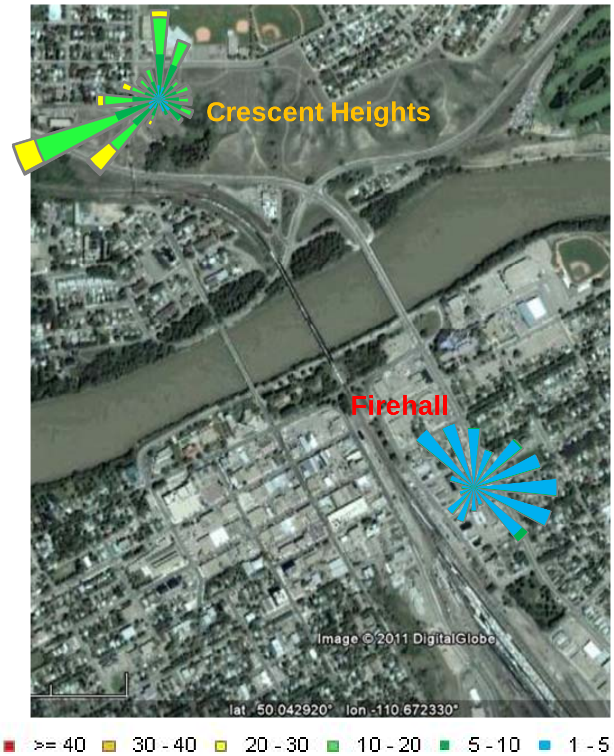

Figure 3: Wind roses at the Crescent Heights and Firehall stations (unit: km/hr; December 1, 2010 to February 28, 2011)

3.3 THC Pollutant Roses

During the three-month study period, the 1-hour average concentration of THC was 2.5 ± 0.4 ppm. The pollutant rose analysis only included the high concentration data, i.e. concentration higher than the station average. The total sample size was 1304 hours.

Figure 4 presents the THC pollutant roses. The length of a pollutant rose petal represents the probability for detecting a high concentration event for that wind direction. The longer the rose petal, the more likely THC would be originated from that direction. As a result, the shaded area represents the region where potential contribution sources could be located.

At the Firehall station, when wind blew from the south-southwest to west-southwest directions, there was a probability of 73% to 79% that THC concentration would exceed the station average of 2.5 ppm. When wind blew from the east to south-southwest directions, the probability was 60% to 68%. These were significantly higher than the remaining wind directions (probability ranged from 20% to 52%). The shaded region in the south side of the downtown area could be the source region. The potential sources within the area include the rail yard, assorted business operation activities, traffic emission, and space heating.

A similar directional trend was found at the Crescent Heights station. When wind blew from the southeast to south directions, there was a probability of 50% to 64% that THC concentration would exceed the station average of 2.5 ppm. The probability was significantly higher than the wind remaining directions (6% to 32%). The shaded region could be the source region. The potential sources in the area include the rail yard, assorted business operation activities, traffic emission, and space heating.

Combining the spatial trend information at the two air monitoring stations, the overlapped shade region was the most probable area where the THC contribution sources could be located. Within this area, the potential sources include the rail yard, assorted business operation activities, traffic emission, and space heating.

The above directional trend was not detected in the Mirror rail yard study (AENV, 2011). The Mirror rail yard report concluded that there were no significant THC sources near the air monitoring station. While possibly true for the Mirror site, there is another potential cause leading to different results between the two studies, and that is the data analysis methodology. The Mirror Lake study included all THC monitoring data in the directional trend analysis, while this paper analyzed high concentration events only. High concentration events typically account for a small portion of the entire data set. If all data is used in trend analysis, the analysis would be dominated by background data. The directional trend would be less relevant to the major emission sources. Take this study as an example; the analyzed THC data set (1304 hours) was about one-third of the entire data set (3877 hours). If all THC data was included in pollutant rose analysis, the pollutant rose would be dominated by background events.

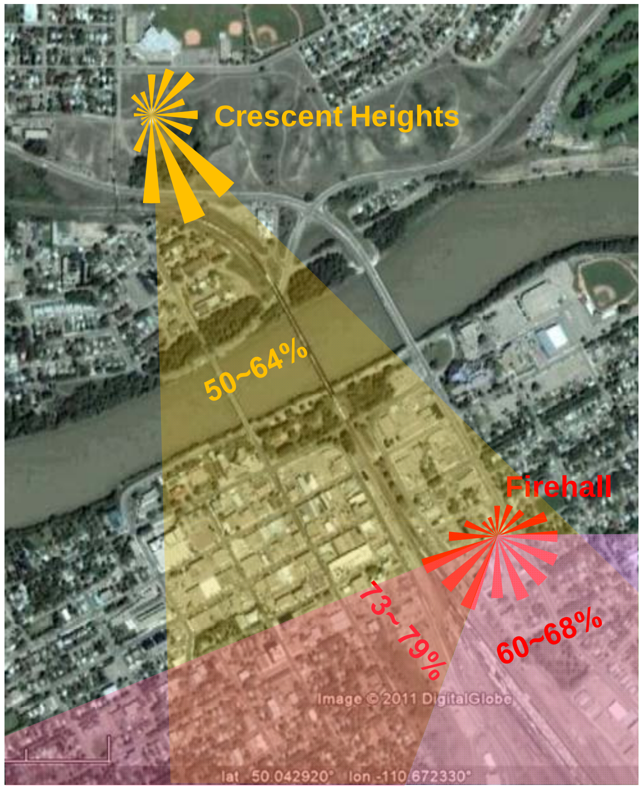

Figure 4: THC pollutant roses at the Crescent Heights station and Firehall station (December 1, 2010 to February 28, 2011)

3.4 NO_2 Pollutant Roses

During the three-month study period, the 1-hour average concentration of NO_2 was 14 ± 11 ppb. The pollutant rose analysis presented here only includes the high concentration data, i.e. concentration higher than the station average. The sample size was 1023 hours.

Figure 5 presents the NO_2 pollutant roses. Similar to the THC pollutant roses, when winds blew from the downtown area, both air monitoring stations detected an increased probability of high concentration events. It is interesting to examine the southwest and west-southwest components of the pollutant rose at the Firehall station. During this study, there were 132 hours wind blew from these two directions. For these time periods, NO_2 concentrations were always higher than the station average concentration (i.e. 100% probability). The evidence indicates a strong source-receptor relationship in these two directions.

A similar trend was found at the Crescent Heights station. During the 3-month study period, there were 48 hours during which wind blew from the south-southeast direction. For these time periods, 98% of NO_2 concentration data exceeded the station average. The evidence again indicates a strong source-receptor relationship in this direction.

Combining the spatial trend information at the two stations, the overlapped shade area would be the most probable region where the major NO_2 emission sources could be located. Within this area, the potential sources include the rail yard, downtown business operation, traffic emissions, and space heating.

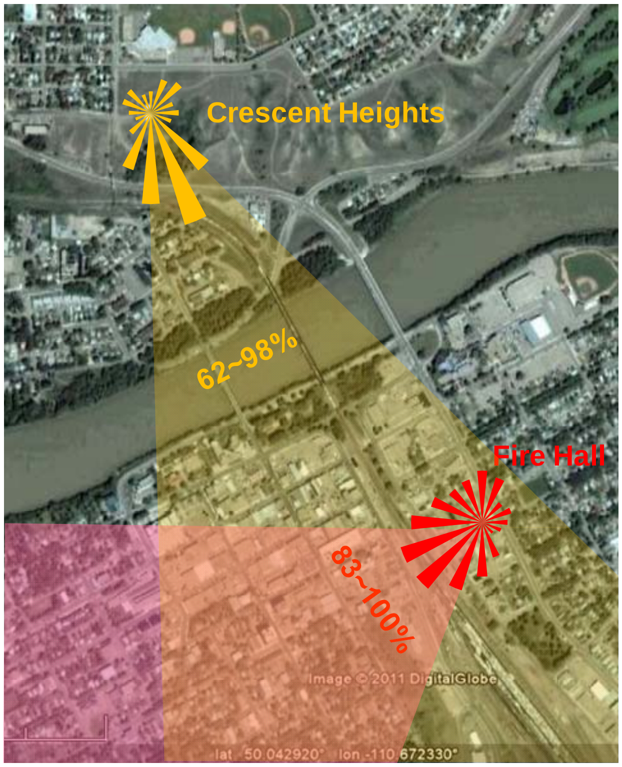

Figure 5: NO_2 pollutant roses at the Crescent Heights station and Firehall station (December 1, 2010 to February 28, 2011)

3.5 Time-Series Analysis

Figure 6 illustrates a time-series chart of 1-hour average concentration for THC at the Firehall station. During this study, the seven highest concentration events were detected between 10 pm and 5 am of a day. The timing pattern occurred frequently. Among the 89-day study period, there were 48 days (or 54%) the maximum 1-hour average concentration of a day was detected during the eight-hour period between 10 pm and 5 am. An in-depth review of the 1-minute average data found that the maximum 1-hour concentration of a day was frequently due to a high concentration event for 15 to 30 minutes. Some of the events were characterized by a double-crest pattern.

The above timing evidence provides valuable information in source identification because the pattern may reflect the operation schedule of the contribution sources. In this case study, for example, small industry, downtown business operation activities, and space heating could be excluded because these sources were less likely to release significantly more air pollutants between 10 pm and 5 am than during the daytime hours. On the other hand, the rail yard could be a possible contribution source. During winter days, diesel locomotives require increased idling during night and early morning hours. In addition, the yard may be preparing for morning trains. The conclusion that the rail yard could be a potential contribution source is consistent with the 1997 study at the City of Medicine Hat (AENV, 1997). The AENV study found that total PAH concentrations were about four times higher when prevailing winds of the sampling day were from the rail yard directions.

Figure 7 presents the diurnal trends of 1-hour average NO_2 data. Both air monitoring stations were characterized by a double-crest pattern, which is similar to the trend in urban area. The occurrence time of the peaks matched the morning and afternoon rush hours. Traffic emissions could therefore be the major contributors of NO_2

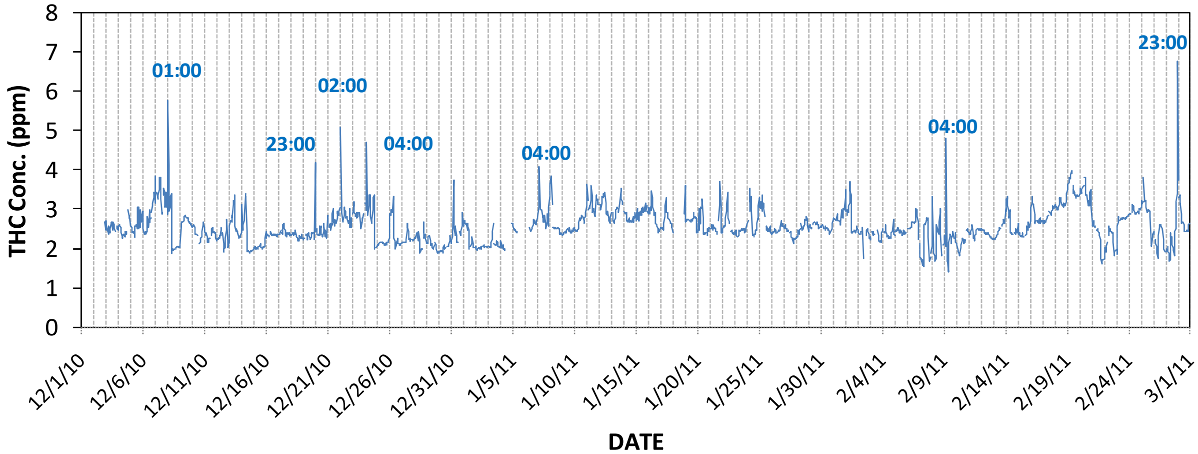

Figure 6: Time-series chart of 1-hour average THC observed at the Firehall station

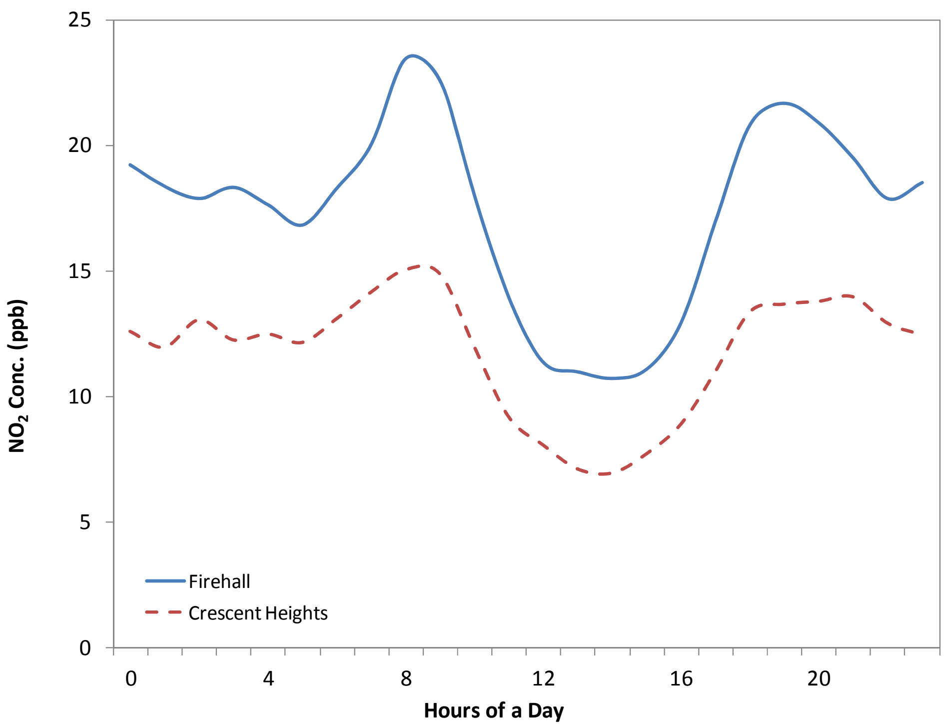

Figure 7: Average diurnal trends of 1-hour average NO_2 for the three month study period

4. Conclusion

This study was designed to investigate the potential sources of odours in the downtown area of City of Medicine Hat in winter. THC and NOx were used as indicator pollutants for organic emission sources and combustion sources, respectively. Pollutant rose analysis found the potential source area for THC and NO_2 could be located in the south side of the downtown. THC time-series data found that the daily maximum were frequently detected between the late night and early morning hours. The unique timing pattern would exclude most sources in the downtown area. The downtown rail yard seems to be a potential candidate source within the area. Time-series trends of NO_2 data indicate traffic emissions could be the major contribution source of NO_2. The City was recommended to establish a database for odour complaints. The database should include the records for type of odour, as well as location, timing, and duration of odour complaints. The City was also recommended to collect source operation records. The time-series data of THC found a unique temporal trend which could be associated with source operation activities. The timing records might be an important evidence for source confirmation. The City was recommended to collect a pollutant profile database for both the potential sources and receptor sites. The information can be used as fingerprint for source confirmation.

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