The July and August 2017 Wildfire Smoke Events in Kamloops, BC

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ABSTRACT

This report examines the air quality measurements made at the downtown Federal Building and the higher elevation Aberdeen monitoring stations in Kamloops to assess the impact on air quality from the recent forest fires. The report also compares the July 2017 data to those in other months of July over the period 1998 to 2016. The focus is on measurements of concentrations of fine particulates in the air, $PM_{2.5}$ (in micrograms per cubic meter, $\mu g/m^3$). Data from the first half of August 2017 are also analyzed and discussed.

The limitations of the Air Quality health Index (AQHI) to describe the particulate concentrations in the air during smoke events are discussed in some detail. This has implications for managing health risks for the population of the city of Kamloops. The literature concerning health risks related to elevated $PM_{2.5}$ values is not examined in this report.

The monthly average $PM_{2.5}$ concentration for July 2017 at the Federal Building, 28.6 $\mu g/m^3$, was the highest of any month of July since records began in 1998. The monthly average $PM_{2.5}$ concentration for August 2017 at the Federal Building, 67.9 $\mu g/m^3$, was the highest of any month of August since records began in 1998. August 2017 had the highest monthly $PM_{2.5}$ average of any of the approximately 240 months in the 20 year history of records for the city of Kamloops. The July, 29.4 $\mu g/m^3$, and August, 71.7 $\mu g/m^3$, average values for the Aberdeen Monitoring Station were also the highest in the short period of record and similar to those at the Federal Building site in the valley bottom.

In July, $PM_{2.5}$ concentrations were generally below those in Williams Lake, located in the Cariboo region close to the major wildfires; however, in August the $PM_{2.5}$ concentrations at both

Kamloops locations exceeded the values in Williams Lake despite the major wildfires being more than 60 km away from the city of Kamloops.

The mean value of $PM_{2.5}$ at the Federal Building site for July 2017, 28.6 $\mu g/m^3$, was much higher than the long-term average for July from the 1998-2016 Brocklehurst (decommissioned) and downtown Kamloops stations, 8.0 $\mu g/m^3$. All July records between 1998 and 2016 have had $PM_{2.5}$ values in the range from 5.4 in 2016 to 12.4 $\mu g/m^3$ in 2014. The July average $PM_{2.5}$ value for 2017 was more than twice the previous high value recorded for a month of July

The average $PM_{2.5}$ value at the Federal Building for the full period of study, from 1 July to 16 August, was 57.5 $\mu g/m^3$. The average value at Aberdeen from 1 July to 16 August was 60.7 ug/m3.

Peak hourly average values of $PM_{2.5}$ at the two sites in Kamloops reached extreme values on occasion. The maximum at the downtown Federal building site was 862 $\mu g/m^3$ on 3 August at 2 PM PDT. The maximum at the higher elevation Aberdeen site was 364 $\mu g/m^3$ on 5 August at 10 AM PDT.

There were numerous smoke episodes during the month of July 2017 when 24-hour average concentrations of $PM_{2.5}$ far exceeded the provincial Air Quality Objective (AQO) value of 25 $\mu g/m^3$ and every day in the period from 31 July to 16 August 2017 exceeded this AQO.

The high values for fine particulate concentrations in July were a precursor to even higher values that were experienced in early August 2017. The average for the period from 1 to 16 August was 113.7 $\mu g/m^3$ at the Federal Building site and 121.3 $\mu g/m^3$ at the Aberdeen site.

The rare topographical positioning of Kamloops, with major valleys from the east, from the west, and from the north meeting in the centre of the city plays a significant role in the transport of pollutants into the city and their residence time once in the city. The geography, coupled with wind directions during the measurement period, and the size and location of the wild fires, all contributed to the high $PM_{2.5}$ values experienced in the city. Already in 2017 the area burned by wildfires has set a new record for the province of British Columbia.

Due to the demonstrated limitations of the AQHI it is recommended that the BC Ministry of the Environment, the Interior Health Authority, and the City of Kamloops, together with relevant local groups and individuals, should develop guidelines for public advisories in Kamloops based directly on measured $PM_{2.5}$ concentrations or a careful re-examination of the ranking of the AQHI risk categories.

1. Introduction and Overview of the Data

This is the seventh in a series of reports (previously, Tsigaris and Schemenauer, 2014a, 2014b, 2015, 2016a,b,c) that have been written to inform the public, politicians and government decision makers on the quality of the air in Kamloops.

A set of air quality measurements were made at the Federal Building Monitoring Station (FBMS) in downtown Kamloops in July 2017 but only $PM_{2.5}$ ($\mu g/m^3$) is discussed in this report. Hourly meteorological data were not collected at the FBMS and are not available for comparison to the air quality data. Similar $PM_{2.5}$ data are available for the Aberdeen Monitoring Station (AMS). PM10 data will also be briefly discussed for the AMS. The FBMS is at an elevation of 385 m and the AMS is at an elevation of 860 m.

All of the data are from the British Columbia Ministry of the Environment (BC MOE) monitoring sites and BC MOE maintains the instrumentation, does the quality control of the data, and archives the data. This report presents an analysis of the archived data (as downloaded on 16 August 2017). In June 2017 the measurement of $PM_{2.5}$ data at the FBMS was switched to the SHARP 5030 instrument from the previous Met One BAM instrument. They are both FEM (Federal Equivalent Method) instruments. The SHARP 5030 uses both beta attenuation and nephelometry technologies. The two instruments should produce consistent data.

The main focus of this report is on the fine particulate matter in the air generated by large forest fires to the west and north of the city. $PM_{2.5}$, is particulate matter with aerodynamic diameters less than 2.5 μm (micrometers). These data have been available from the downtown monitoring station since 1998. Both $PM_{2.5}$ and PM_{10} (particulate matter with aerodynamic diameters less than 10 μm) are available from the AMS since 2015.

All measurements of $PM_{2.5}$ concentrations for the period from 1998 to 2010 at the FBMS using the old TEOM instrument have been adjusted according to the methodology of Tsigaris and Schemenauer (2014b) to produce a data set consistent with the measurements made by the new BAM instrumentation. This important work provides the basis for working with a consistent data set through the entire period from 1998 to 2017 and is, to our knowledge, unique for cities in British Columbia.

2. Brief Overview of the 2017 Wildfire Season to Early August 2017

The 2017 British Columbia wildfire season has been reported to be the worst in terms of area burned, though not in terms of total number of fires at this point in time. This may change as there are many weeks left in the period during which significant fires can be present in the Interior of British Columbia. The fires that have been the primary smoke producers for the city of Kamloops are located to the west and northwest of the city. The Elephant Hill fire, north of Cache Creek, has burnt approximately 175,000 ha of land at the time of writing this report. Figure 1 shows the outlines of the areas of the major fires and their relationship to the city of Kamloops as of 9 August 2017.

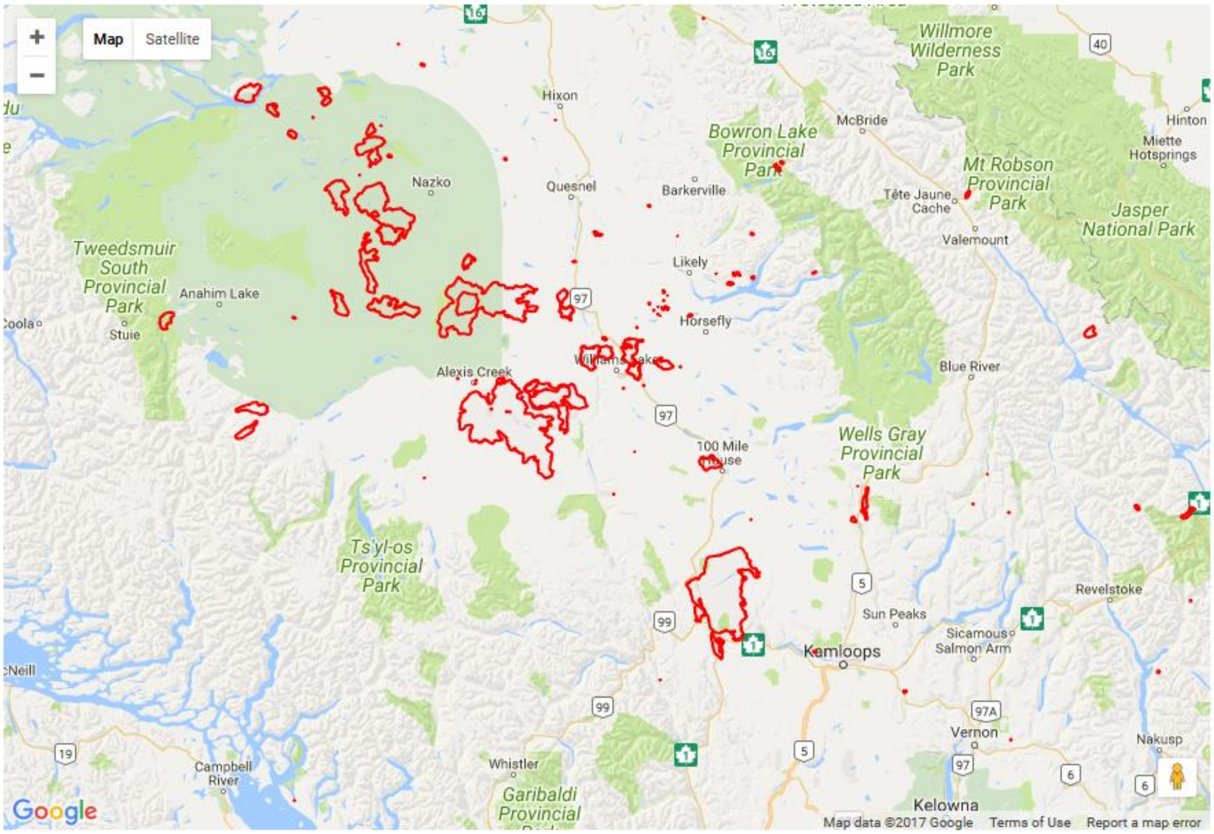

Figure 1. The outlines of the perimeters of the major fires on 9 August 2017 and their positions relative to the city of Kamloops. The Elephant Hill fire is the large area 75 km WNW of Kamloops. Source: BC Wildfire Service.

The initial large fires in July had plumes of smoke that produced elevated $PM_{2.5}$ and PM_{10} readings in Kamloops (Figures 3, 4 and 6) when winds were from the quadrant defined as West to North. By the time of the major event, which began on 31 July and stretched into August, the entire southern interior of the province was covered in smoke and particulate concentrations stayed high in the City of Kamloops regardless of wind direction.

3. How July and August 2017 $PM_{2.5}$ Values Compare to Data for Previous Years

Monthly Averages

Table 1 shows the July 2017 averages of $PM_{2.5}$ at the two Kamloops stations and at Williams Lake for comparison purposes. Also shown are the historical averages for the months of July and August at the Federal Building Monitoring Station. In addition, Table 1 shows the same values for the three stations, for the full period being examined in this report, from 1 July to 16 August 2017, plus a breakdown of the data for the period from 1 – 16 August.

	Federal Building	Aberdeen		Williams Lake	
	PM2.5	PM2.5	PM10	PM2.5	PM10
1 July to 16 Aug	57.5	60.7	62.2	84.6	68.2
1 – 31 July	28.6	29.4	32.7	89.5	55.4
1 – 16 August	113.7	121.3	119.0	75.0	85.3
Maximum	861.7	364.0	328.0	945.9	547.1
	3 Aug 17	5 Aug 17	7 Aug 17	16 Jul 17	15 Jul 17
	1400 PDT	1000 PDT	1500 PDT	0300 PDT	1100 PDT
Historical average for July*	8.0				
Historical average for Aug*	11.0				

*Calculations by Tsigaris and Schemenauer as per previous reports. All values are in μg/m^3.

Table 1. A summary of the measured $PM_{2.5}$ and PM_{10} concentrations, at the two Kamloops monitoring stations, and Williams Lake, for specific periods in the summer of 2017.

For the entire period being examined, 1 July to 16 August, the average of the hourly $PM_{2.5}$ values at the FBMS, 58 μg/m^3, was similar to that at the AMS, 61 μg/m^3, and both were below the average for the period at Williams Lake, 85 μg/m^3. Looking more closely at the data we see that this is related to lower values for the month of July at the FBMS, 29 μg/m^3, and at the AMS, 29 μg/m^3, than at Williams Lake, 90 μg/m^3. The situation was reversed for the first half of August, with the average at the FBMS, 114 μg/m^3, and the AMS, 121 μg/m^3, being considerably higher than at the Williams Lake Monitoring Station, 75 μg/m^3.

The average of the hourly $PM_{2.5}$ values for July 2017 at the FBMS, 28.6 μg/m^3, is far above the long-term average for July at the site, 8.0 μg/m^3.

The average of the hourly $PM_{2.5}$ values for the first half of August 2017 at the FBMS, 113.7 μg/m^3, is extremely high and guarantees that the average for the entire month will far exceed the historical average of 11 μg/m^3. It also ensures that August 2017 in Kamloops will have the highest average $PM_{2.5}$ value of any month in the 20 years of records in downtown Kamloops.

A plot of the historical July and August monthly averages of $PM_{2.5}$ in Kamloops for the period 1998 to 2017 is given in Figure 2. It makes use of the simple adjustment developed to bring the measurements made with the TEOM instrument prior to 2011 in line with those made using the modern BAM monitor. This protocol has been discussed extensively in a previous report (Tsigaris and Schemenauer, 2014b).

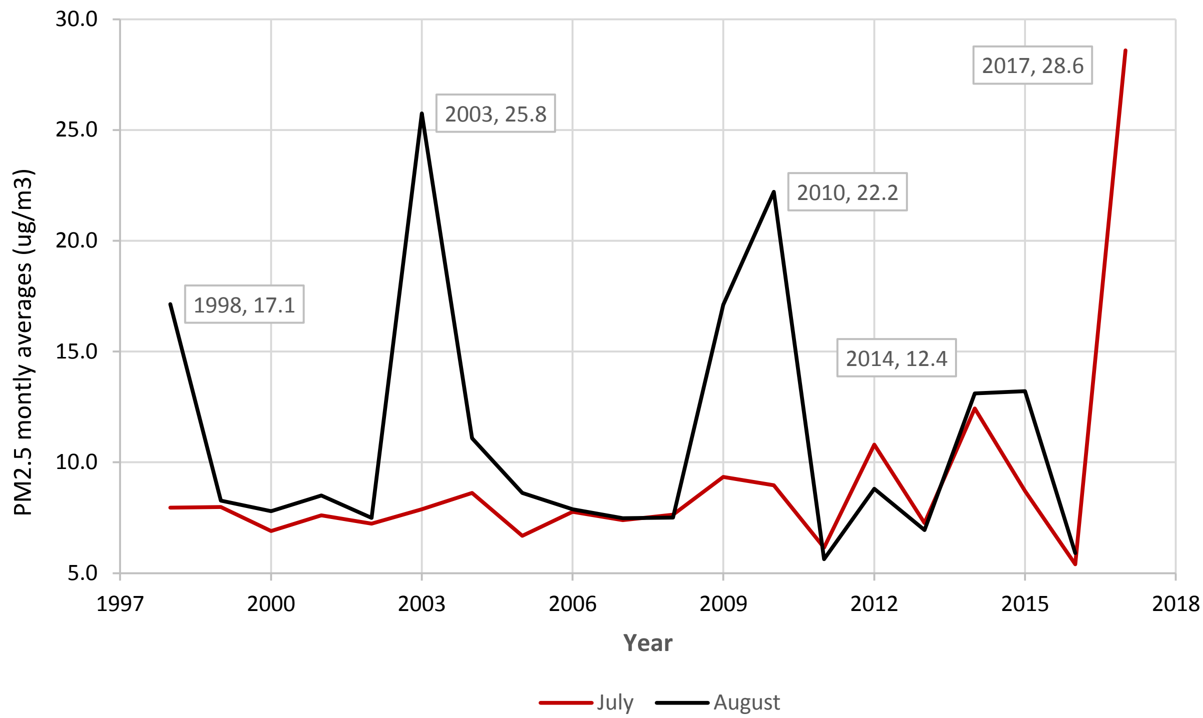

Figure 2. $PM_{2.5}$ monthly averages for July and August, from 1998 to 2017, at the Federal Building Monitoring Station in Kamloops.

The figure shows that the July average of 28.6 $\mu g/m^3$ is the highest for this 20 year period. It is more than double the 2014 July average value of 12.4 $\mu g/m^3$, which was the previous high for the month. It is also higher than the value for August 2003, which was previously the worst forest fire month in Kamloops during this 20 year period. However, given that the average $PM_{2.5}$ at the FBMS for the first 16 days of August 2017 was 114 $\mu g/m^3$, the July figure will be exceeded by the August 2017 average. As it stands, the August monthly average at the FBMS cannot be less than 64 $\mu g/m^3$. Hence, over the period 1998 – 2017 we are experiencing the worst air quality for the months of July and August.

Multiyear Cycle in the August Fine Particulate Concentrations in Downtown Kamloops

A casual glance at Figure 2 will show there is not an evident pattern in the July $PM_{2.5}$ concentrations over the period of record, 1998 – 2017. It is quite different for the month of August. There are significant peaks in the August averages about every seven years. Since August is the month with the most pronounced wildfire problem in the Interior of British Columbia, it is a reasonable working hypothesis to relate the peaks in particulate concentrations in Kamloops to the occurrence of forest fires. The peak years are 1998 (or earlier), 2003, 2010, and 2017. We don't know the concentrations in airborne particulates in Kamloops before 1998 and we do not know for sure whether 2017 is a peak or might be exceeded next year. We do know that 2017 is the highest value ever recorded.

The exact reason for peaks approximately every seven years in the fine particulate (smoke) concentrations in Kamloops is unclear. The August particulate concentrations in Kamloops will not be directly related to any one parameter describing the forest fires in that month. The impact on air quality in Kamloops will depend on the location of the fires, the area of the fires, the volume of material burned, wind direction, and meteorological factors on the regional and local scale. There are also large-scale meteorological and oceanographic factors such as major El Niño occurrences that vary with a timescale of 5 to 10 years. In addition there are well-known meteorological and oceanographic cycles of 30 and 60 years. Some or all of these cycles and meteorological factors may be at play and may provide part of the explanation for the peaks seen in particulate concentrations in Kamloops. It is also possible that such periodicity in August smoke in Kamloops could be caused by random chance given the small sample period

Hourly and Daily $PM_{2.5}$ Values in Kamloops

The maximum one hour average values for $PM_{2.5}$ are also shown in Table 1 for the three sites. The highest values occurred at the FBMS and the AMS in Kamloops in early August and in Williams Lake in the middle of July. These extreme values, reaching 946 $\mu g/m^3$ in Williams Lake, and their relationship to potential negative health impacts should be investigated further.

The distribution of daily values of $PM_{2.5}$ at the downtown FBMS and the hillside AMS are shown in Figure 3. Most of the values are low but a number of discrete periods of high concentrations are evident. These are associated with periods when wind directions were such that smoke from large wildfires was transported into the city of Kamloops.

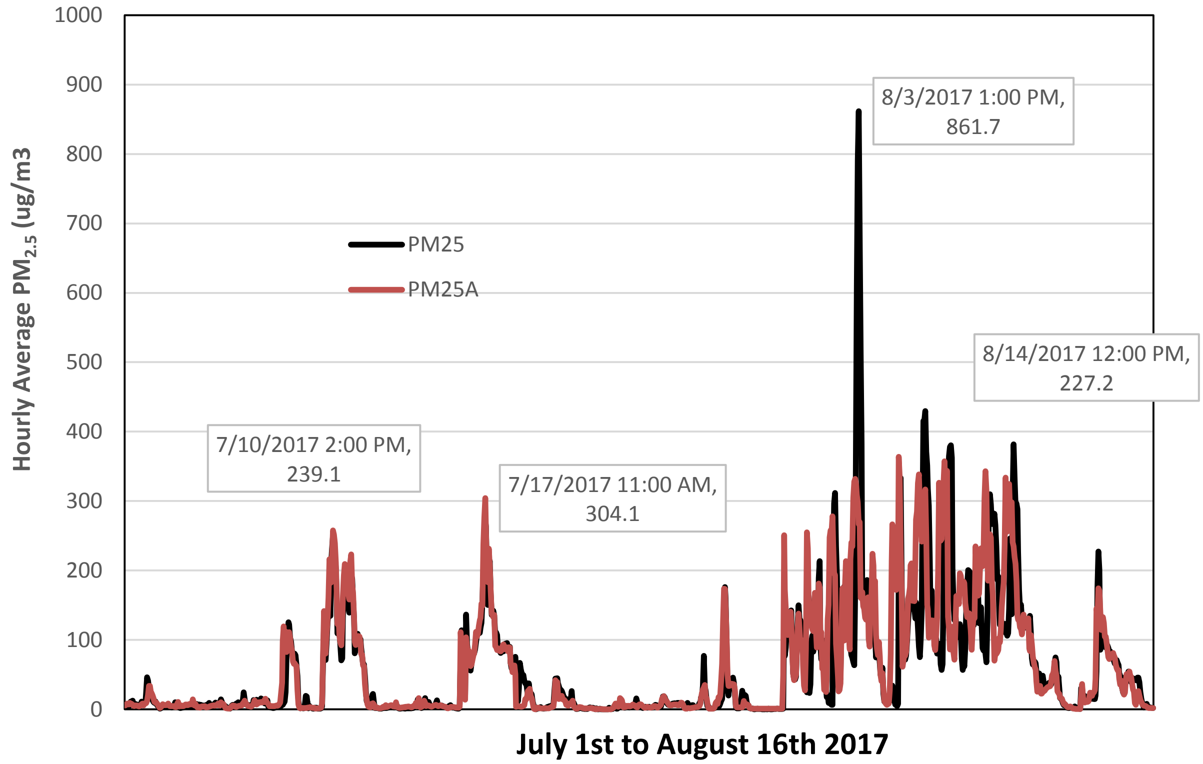

Figure 3. Federal Building and Aberdeen $PM_{2.5}$ concentrations for the period 1 July to 16 August 2017.

We see in Figure 3 that during the July smoke episodes the $PM_{2.5}$ concentrations were generally higher at the AMS than at the FBMS in the Valley bottom. They typically exceeded 100 μg/m^3 during the worst parts of the episodes. The largest smoke event began on 31 July and ended on 12 August. It appears on the right-hand side of Figure 3 and is followed by another significant smoke event several days later. During this period values at the two monitoring sites were similar. One value stands out and that is at 1400 PDT on 3 August when the measurements at the FBMS peaked at a tremendously high value of 862 μg/m^3.

The British Columbia Air Quality Objective for short time periods is the 24 hour average value. In Figure 4 we see the history of the 24 hour average from 1 July to 16 August 2017 at the three sites discussed in this report. The B.C. Air Quality objective for $PM_{2.5}$, which should not exceed an average of 25 μg/m^3 for a 24 hour period, was broken for 16 days over this 39 day window at the FBMS. In Williams Lake a health advisory was issued for 23 days. The maximum 24 hour average $PM_{2.5}$ in Kamloops occurred on 3 August 2017 at the FBMS with a value of 274 μg/m^3.

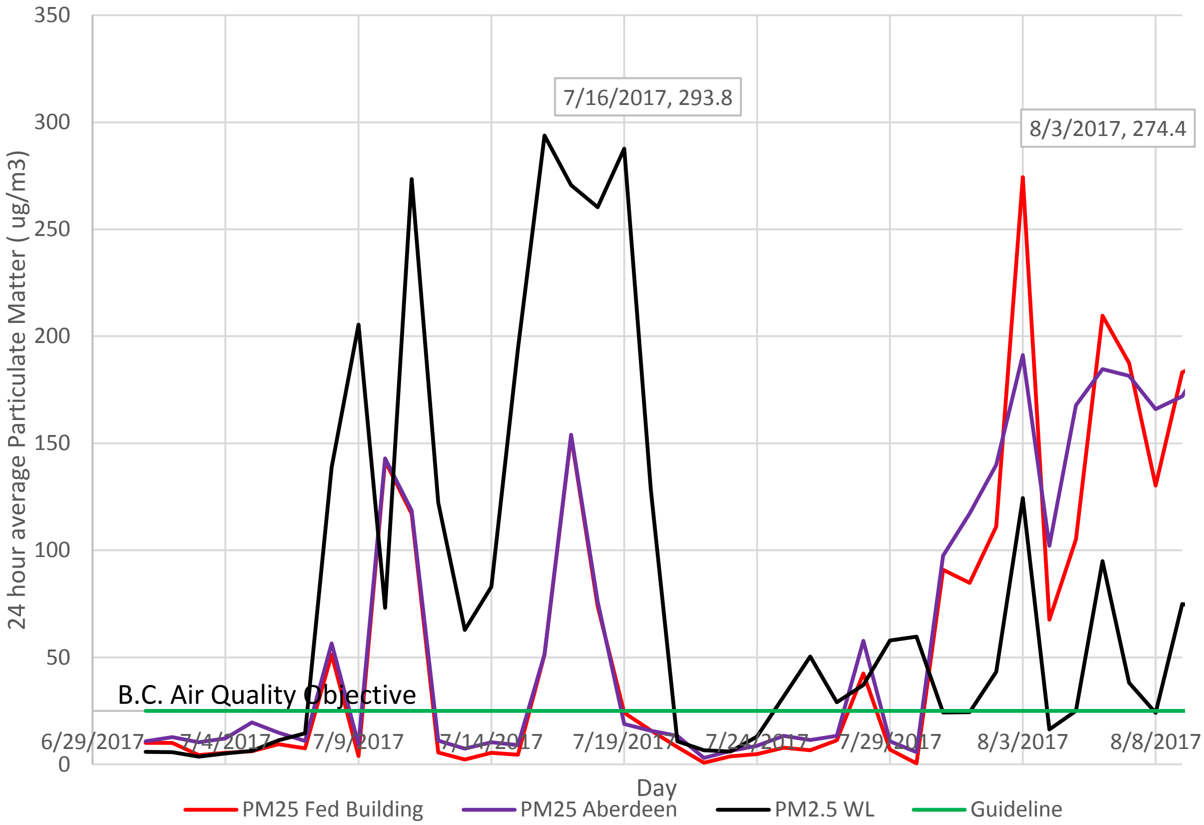

Figure 4: 24 hour Average $PM_{2.5}$ at the Federal Building and Aberdeen in Kamloops, and in Williams Lake, 1 July to 16 August, 2017.

The values in Table 1 can be better understood by examining the visual presentation in Figure 4. In the first part of July, the 24 hour average $PM_{2.5}$ was much higher at Williams Lake, near the fires, than it was at the two monitoring stations in Kamloops. During the long event that ran from 31 July to 16 August values were higher at the Kamloops monitoring stations than in Williams Lake. Notable is the coincidence in the peak values of the 24 hour average at all three monitoring stations on 3 August. The highest value on this day, 274 $\mu g/m^3$ as a 24 hour average, was recorded at the FBMS. This far exceeds the British Columbia Air Quality objective of 25 $\mu g/m^3$ for a 24 hour period. It needs to be kept in mind that the AQO was set to protect the health of the people of the province.

5. Comparison of PM 2.5 Values in Kamloops and Williams Lake:

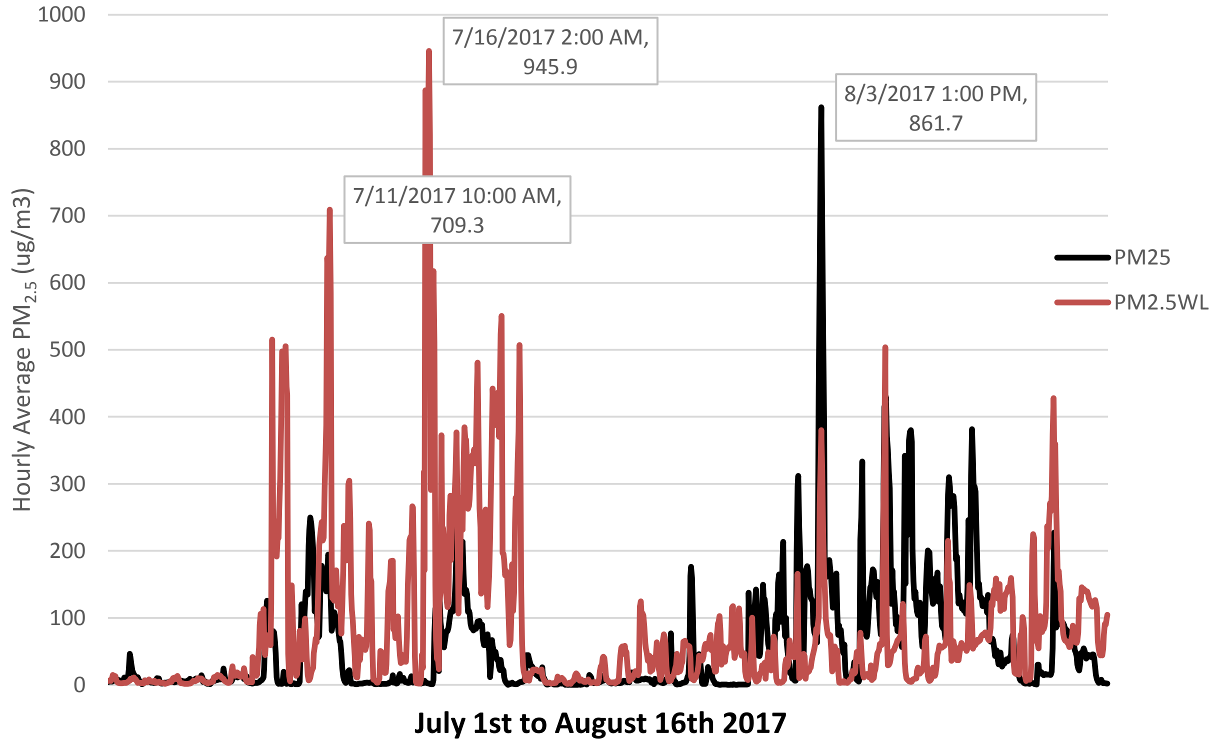

Figure 5. Hourly averaged $PM_{2.5}$ at the Federal Building in Kamloops and in Williams Lake, 1 July to 16 August, 2017.

The hourly values for $PM_{2.5}$ in both downtown Kamloops and in Williams Lake are plotted in Figure 5 for the period from 1 July to 16 August 2017. Again, as for the 24 hour average values, the $PM_{2.5}$ concentrations were higher in Williams Lake in early and mid July and then generally higher in Kamloops from the end of July through early August. Notable is the hourly value in Williams Lake on 16 July when it reached 946 μg/m^3. This is higher than the peak value reached in Kamloops on 3 August of 862 μg/m^3.

6. Comparison of July and August 2017 to the 2003 Forest Fire Season

The following two paragraphs regarding the 2003 forest fire season are quoted directly from the BC wildfire service website.

a) Okanagan Mountain Park

"The Okanagan Mountain Park fire was the most significant interface wildfire event in BC history. The fire's final size was 25,600 hectares. Much of BC was affected by the fire but the communities of Naramata and Kelowna suffered the largest effect when the blaze caused the evacuation of 33,050 people (4,050 of these people were also evacuated for a second time) and 238 homes were lost or damaged. The fire also claimed 12 wooden trestles and damaged two other steel trestles in the historic Myra Canyon."

b) McLure

"The McLure fire caused the devastating loss or damage of 72 homes and nine businesses. Due to this fire, 3,800 people were evacuated (880 of these people were also evacuated for a second time) from the small communities of McLure, Barriere and Louis Creek. The fire reached a final size of 26,420 hectares."

In Kamloops, in 2003, measurements of the $PM_{2.5}$ concentrations were made at the station located in the Brocklehurst region of Kamloops on the north side of the Thompson River. Figure 6 shows a plot of the measurements for the month of August 2003. The measured data obtained with the TEOM instrument have been adjusted according to Tsigaris and Schemenauer 2014b to be compatible with modern measurements made in 2017 in Kamloops at the downtown Federal Building. As shown in Table 1, the average value of the $PM_{2.5}$ measurements in 2017 in downtown Kamloops was 114 $\mu g/m^3$ for the first half of the month of August, with the peak value of 862 $\mu g/m^3$ on three August. In 2003 with fires much closer to the centre of Kamloops, the average value for the first 16 days of August was 28.2 $\mu g/m^3$ and the peak value was 322 $\mu g/m^3$ on 8 August 2003.

Wild fires in the late summer of 2003 resulted in severe damage to forests and property in the southern interior of British Columbia but, in terms of smoke in downtown Kamloops, the conditions were not as severe as during the same period in 2017. During the month of August 2003 Kamloops experienced eight smoke events each typically lasting from 1 to 3 days. The most severe events were early in the month as was the case in August 2017; however, in 2017 the severe smoke event in early August in Kamloops lasted for 12 days.

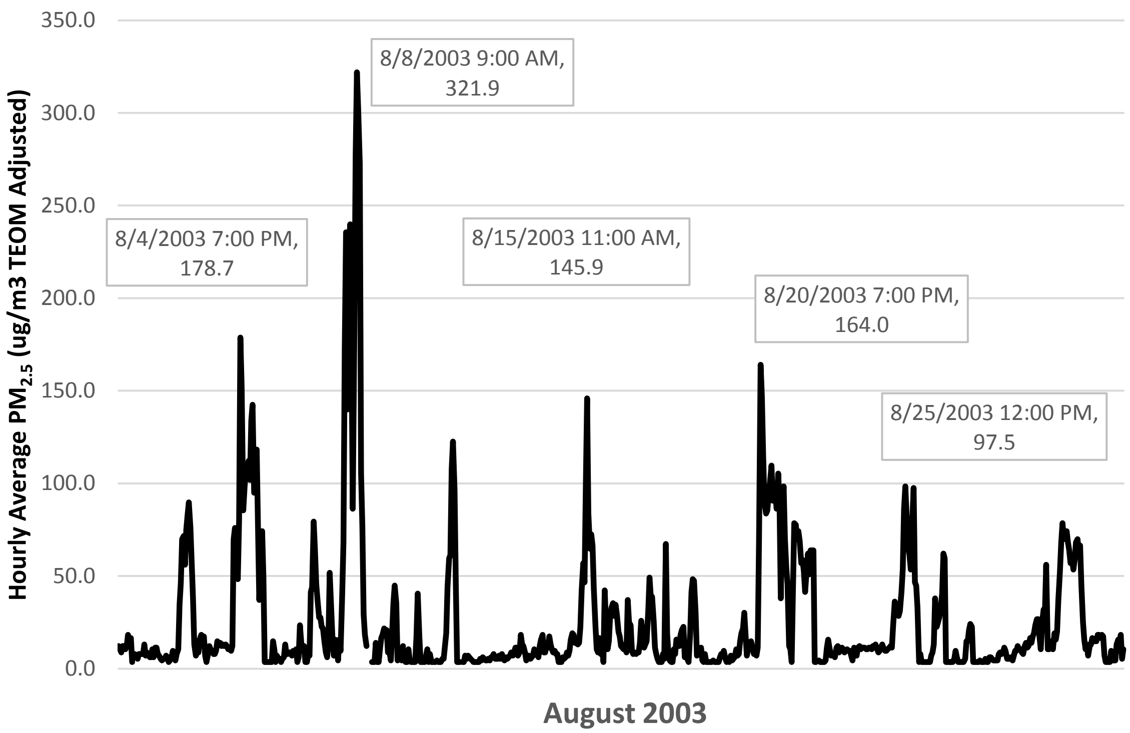

Figure 6. Brocklehurst, $PM_{2.5}$ in August 2003 adjusted for TEOM instrument offset according to Tsigaris and Schemenauer 2014b.

7. The AQHI and AQI indexes of air quality

This report discusses the air quality in Kamloops during the smoke events in July and August 2017 using measurements of the fine particulates in the air ($PM_{2.5}$) as measured by the BC Ministry of the Environment. The public, however, very often receives media reports and smoke advisories based on the Air Quality Health Index (AQHI) or sometimes the Air Quality Index (AQI).

The AQHI and the AQI are not equivalent, they are calculated in completely different ways, and one cannot be converted into the other.

a) The Air Quality Health Index (AQHI)

The AQHI is calculated from an equation with three input parameters, NO_2, O_3 and $PM_{2.5}$ (nitrogen dioxide, ozone and fine particulate matter less than 2.5 microns in aerodynamic diameter, respectively) expressed as concentrations averaged over three consecutive hours. Units are parts per billion for each gas and micrograms per cubic meter for $PM_{2.5}$. The equation was developed from health studies and is calculated and used by Environment Canada. Its primary application is in large urban areas where the three components may be present in large quantities. According to Chen et al, (2014):

> "The AQHI is calculated based on the excess mortality risk of a combination of three air pollutants that time series studies have shown to be associated with increased mortality: ozone, PM2.5, and NO2. This calculation employs rolling 3-h average pollutant concentrations (average of the current and 2 previous hours), as the trailing 3-h average concentrations had been seen as being more stable than a 1-h average."

The major problem with Kamloops air quality is the airborne fine particulate concentrations. Because this pollutant makes up only one component of the publicly reported AQHI, the AQHI under normal circumstances is almost always low in Kamloops and it provides the public with limited useful information on the health risks associated with particulates in the air. It takes large increases (see discussion in Appendix 1) in the $PM_{2.5}$ concentrations to move the AQHI into the extreme risk category. It is demonstrated in Appendix 1 that even in the case of the intense smoke events experienced in July and August 2017 the AQHI provided limited actionable information to the public.

b) The Air Quality Index (AQI)

The Air Quality Index (AQI) was developed in the United States about 50 years ago and can be seen displayed on certain websites describing the air quality in Kamloops. It is calculated in a completely different way than the AQHI is calculated. The numbers in the two indexes are unrelated to each other.

Six different air pollution measurements can be used to generate the AQI. The AQI can be calculated from different pollutants in different locations. It could be O_3, $PM_{2.5}$, PM_{10}, CO, SO_2, or NO_2. If it is a measure of the $PM_{2.5}$ that is used, then the AQI requires a 24 hour average of the PM2.5 values. The Environmental Protection Agency (EPA) in the USA, when it calculates the AQI for a particular time, would use the measurements from the 12 hours before this moment in time and the model calculations of what the measurements might be in the 12 hours to come.

Because the concentration of the pollutants such as $PM_{2.5}$ in future hours is unknown and is difficult to estimate accurately, a computation called the NowCast is used. This mixture of measurements and modelled results produce the value that is published as the AQI. Sometimes people run the calculation for a shorter time periods but this should not be called the AQI.

Recommendations

In situations such as Kamloops has recently experienced, with dense smoke and high $PM_{2.5}$ concentrations, there are a number of new options that might be considered. The $PM_{2.5}$ concentrations could be reported directly to the population, the AQHI could be recalculated using the actual hourly data instead of an average of the previous three hours, the coefficients could be changed within the AQHI equation to give a greater weight to the fine particulate concentrations or the current hourly concentration, and consideration could be given to reassigning the levels for the various health risk categories.

The BC Ministry of the Environment, the Interior Health Authority, and the City of Kamloops, together with relevant local groups and individuals, should develop guidelines for public advisories based on measured $PM_{2.5}$ concentrations. The newer instruments are capable of a time resolution better than hourly average measurements and the time interval for reporting particulate concentrations during smoke events should be determined based on existing research related to causation of acute respiratory symptoms.

8. Influence of Valley Air Circulations on PM2.5

Air circulations within the valley contribute to a variation in particulate concentrations both in the vertical and the horizontal. This is a complex subject that cannot be discussed in detail here. It contributes to the observed differences in airborne fine particulate concentrations at the AMS and the FBMS and will play a role in explaining the differences between $PM_{2.5}$ concentrations in Kamloops and locations closer to the fires themselves.

One example of valley meteorology is temperature inversions, which can have a direct bearing on fine particulate concentrations in valleys. An inversion occurs when temperatures increase with elevation leading to a suppression of vertical motion of the air. When a large high pressure area is persistent over the southern interior of British Columbia there will be a subsidence inversion that covers the entire region. This inhibits deep convection that might produce precipitation and also traps smoke below the subsidence inversion. There can also be inversions at lower levels depending on the topography of valleys and the local meteorological conditions. Some brief examples from the major smoke event in early August will be given below.

10 August 2017 - $PM_{2.5}$ Gradient

At 6 AM on the morning of 10 August the temperature at the airport, at 345 m elevation, was 14.6°C and at 865 m elevation at the Aberdeen Monitoring Station it was 18.1°C. These measurements indicate an inversion was present in the Kamloops valley. This inversion was associated with a $PM_{2.5}$ concentration of 123 µg/m3 at the downtown FBMS and 238 µg/m3 at the AMS. This is an example of how the fine particulate concentrations can be higher on the hillside near the probable base of the local inversion than at the valley bottom.

11 August 2017 - $PM_{2.5}$ Mixed

At 6 AM on the morning of 11 August the temperature at the airport was 11.9°C and at the AMS it was 17.7°C. Again an inversion was present but in this case the $PM_{2.5}$ concentrations were identical at both locations, 122 µg/m3. This indicates the inversion base was higher and the air was well mixed below the inversion.

13 August 2017 - No Inversion

The major smoke event that began on 31 July ended overnight. The valley inversion was no longer present and it was now warmer at the valley bottom, 16.9°C, than at the higher Aberdeen site, 14.5°C. The PM 2.5 concentrations had now dropped dramatically and were 4.4 µg/m3 at the AMS and 3.0 µg/m3 at the downtown FBMS. The breakdown of the inversion was associated with the passage of a weak front and a strong airflow from the southwest.

The valley meteorology in Kamloops and how it is linked to our specific topography has not, to our knowledge, been extensively studied but likely plays a significant role in trapping pollutants such as smoke from forest fires.

9. Discussion

This report summarizes the concentrations of fine particulates in the air in Kamloops from 1 July to 16 August 2017. This was a period with intense wildfires and a record amount of forest area burned in the province. This report does not examine the extent or causes of the wildfires. Clearly there is a linkage between the presence of the wild fires and the record high concentrations of particulates in the air in the City of Kamloops. The primary factors such as location and area of the fires, wind directions, presence of inversions, lack of precipitation, condition of the forest ecosystems, and so on, can be listed but their relative importance to the production of the smoke and the nature of the interaction of these factors will be complex and require extensive study.

The major results of this study have been summarized in the abstract at the beginning of the report and will not be repeated here. The monthly average $PM_{2.5}$ values in downtown Kamloops, in July and August 2017, were the highest recorded for those months since measurements began in 1998. In addition, the August monthly average was the highest average $PM_{2.5}$ value for any month since records began.

The Kamloops Physicians for a Healthy Environment Society (KPHES) conducted an online survey of the impacts of the smoke during July and August on both the health and activities of people in Kamloops. The results of the survey are presently online at https://www.surveymonkey.com/r/KPHEalthAir .

The Air Quality Health Index (AQHI) and its application during the smoke events of July and August 2017 have been discussed in the body of this report and in an appendix below. This issue should be explored at greater length and will be addressed in a future report.

There are numerous private users in Kamloops of an inexpensive instrument to measure particulate concentrations in the air. The Purple Air Monitor (PAM) provides a fast response to changing concentrations of $PM_{2.5}$. The PAM instrument will also be examined in a future report and it is planned to compare the data obtained to that from instruments at the BC MOE monitoring sites.

The rare topographical positioning of Kamloops, with major valleys from the east, from the west, and from the north meeting in the centre of the city plays a significant role in the transport of pollutants into the city and their residence time once in the city centre. This again is a complex subject and to understand it would require a dedicated and thorough investigation.

The impacts of the wild fires on the City of Kamloops extend far beyond the high particulate concentrations in the air in Kamloops that is the focus of this report. It must must be kept in mind that other communities, especially those close to the actual fires, experienced more severe disruptions including evacuation of populations, destruction of rangeland and loss of homes and other structures.

Source for the Data

The hourly measurements were made and archived by the British Columbia Ministry of the Environment who also did the quality assurance and quality control of the measurements. As these data were downloaded from the archive on 17 August, it is possible that some small changes may be made in the final archived data set. With respect to the data, BC MOE says "Data found on this web site is accessible in raw form before all quality assurance reviews are complete. This data is preliminary and is subject to change during the review process. Final data reviews for a given calendar year are usually completed by June 1st of the following year."

Authorship

The authors of this report, Prof. Peter Tsigaris and Dr. Robert Schemenauer, have prepared this and previous reports on a volunteer basis with no direction from any organization and no remuneration in terms of salary or any other form. The work is a contribution to the community, with the hope that it leads to a better understanding of the environment in which we live.

References

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APPENDIX 1. The AQHI Values in Kamloops in July and August 2017

In situations such as Kamloops has experienced, with dense smoke and high $PM_{2.5}$ concentrations, one option is that it is these fine particulate concentrations that should be reported directly to the people. If that is not done, then consideration should be given to reporting the AQHI based on actual hourly data for $PM_{2.5}$, NO_2 and O3 (or a higher weight placed on current PM2.5 values) rather than the currently employed three-hour average of the measurements for the three pollutants. In other words, instead of equally weighting current values and the past two hourly values during forest fires, more weight be placed on the current $PM_{2.5}$ value. Although one sacrifices some stability of the AQHI, the benefit is the increased warning and precaution to the people at risk. It could be updated as frequently as the $PM_{2.5}$ and other measurements, and be a reflection of current conditions.

Alternatively, consideration should be given to lowering the high risk level AQHI from 7+ to 6+ or 5+. If the high risk is set to 6+ values, then it would occur 59 percent of the total hours while with the current 7+ level high risk occurred 50 percent of the total hours. Reducing it further to 5+ as high risk would include 67 percent of the hours. Using this adjustment the 3-hour averaging could be maintained. The U.S. EPA for the AQI as it relates to $PM_{2.5}$ 24 hour average (https://www.epa.gov/sites/production/files/2016-04/documents/2012_aqi_factsheet.pdf) has done something similar.

The following three figures compare the AQHI and the actual hourly averaged $PM_{2.5}$ when the AQHI is reported. The AQHI was computed by the authors from the original measurements because historical data on AQHI are not available on the BC air quality website. The NO_2, O_3 and $PM_{2.5}$ data for the FBMS, from the BC air quality archive, were downloaded for the period from 1 to 16 August in order to do the calculations.

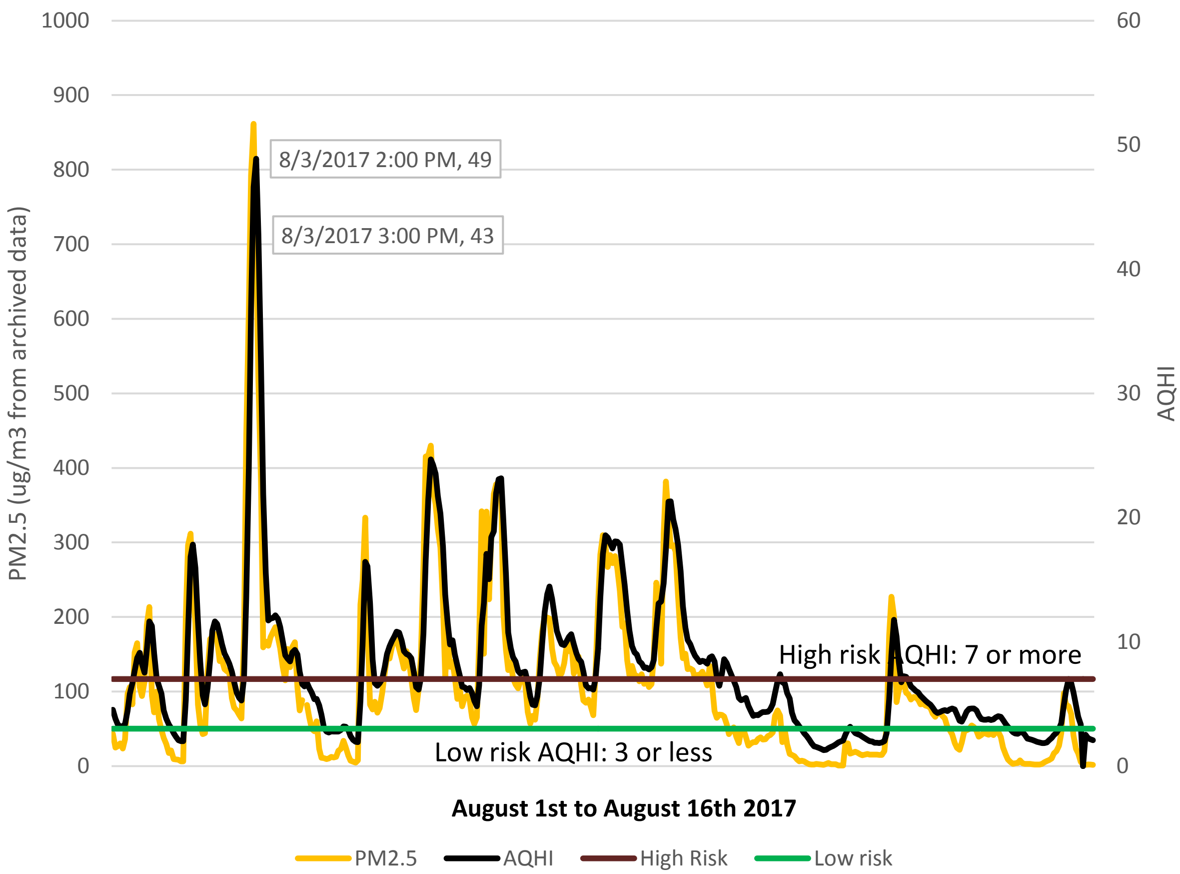

Figure 7. A comparison of the AQHI values as calculated in this report to the actual average hourly $PM_{2.5}$ reported value in the hour of reporting the AQHI. Note the two different vertical scales being used to show the data.

In Figure 7 the vertical axis on the left reports the $PM_{2.5}$ occurring at the time the AQHI is being reported while the vertical axis on the right reports the AQHI values. The green horizontal line separates low risk AQHI with the moderate or higher risk warning AQHI, while the brown horizontal line separates the high risk from the moderate or less risk warning category. Because the AQHI is calculated using $PM_{2.5}$ data for three hours the rise and fall during this period of extreme smoke concentrations in the city would be expected to correlate well with the posted hourly $PM_{2.5}$ measurement.

A good correlation is evident in Figure 7. This is because the AQHI is computed using the average of the current and past two hourly $PM_{2.5}$ values (Chen et. al (2014)). Sometimes, however, it does not have much relevance to what the actual measured $PM_{2.5}$ is in the current hour, given that this hour receives only 1/3 weight. For example, $PM_{2.5}$ values in the range of moderate risk are very high, often even higher than 100 µg/m^3, and many are higher than 50 µg/m^3. Measured values are sometimes as high as 216.9 µg/m^3, with an AQHI of 5 showing moderate risk when it should be high risk. Why is that? Because the previous two hourly values for $PM_{2.5}$ were very low at 4.7 and 7.7 µg/m^3, averaging 76.4 µg/m^3 for use in the AQHI reported value whereas the actual $PM_{2.5}$ when the AQHI is being reported has jumped to 216.9 µg/$m^{3.}$ After the next hour when the $PM_{2.5}$ increased to 249.6 µg/m^3, the AQHI jumped to 10. Had the AQHI been based only on the current $PM_{2.5}$ value then the AQHI would have been 11 and 15 respectively.

One can see in Figure 8 that as $PM_{2.5}$ increases above 100 µg/m^3 the AQHI can take on a wide range of values for a given $PM_{2.5}$ value. For example at a $PM_{2.5}$ of 216.9 µg/m^3 the AQHI could be anywhere from 5 (moderate risk) to 18 (extremely high risk). What determines the AQHI value is not the current $PM_{2.5}$ value but an average of the current period with the earlier period of two hours. The AQHI does not provide information on the high spikes in $PM_{2.5}$ values that occur over time periods as short as one hour, which are frequent in smoke events and could potentially cause acute respiratory problems.

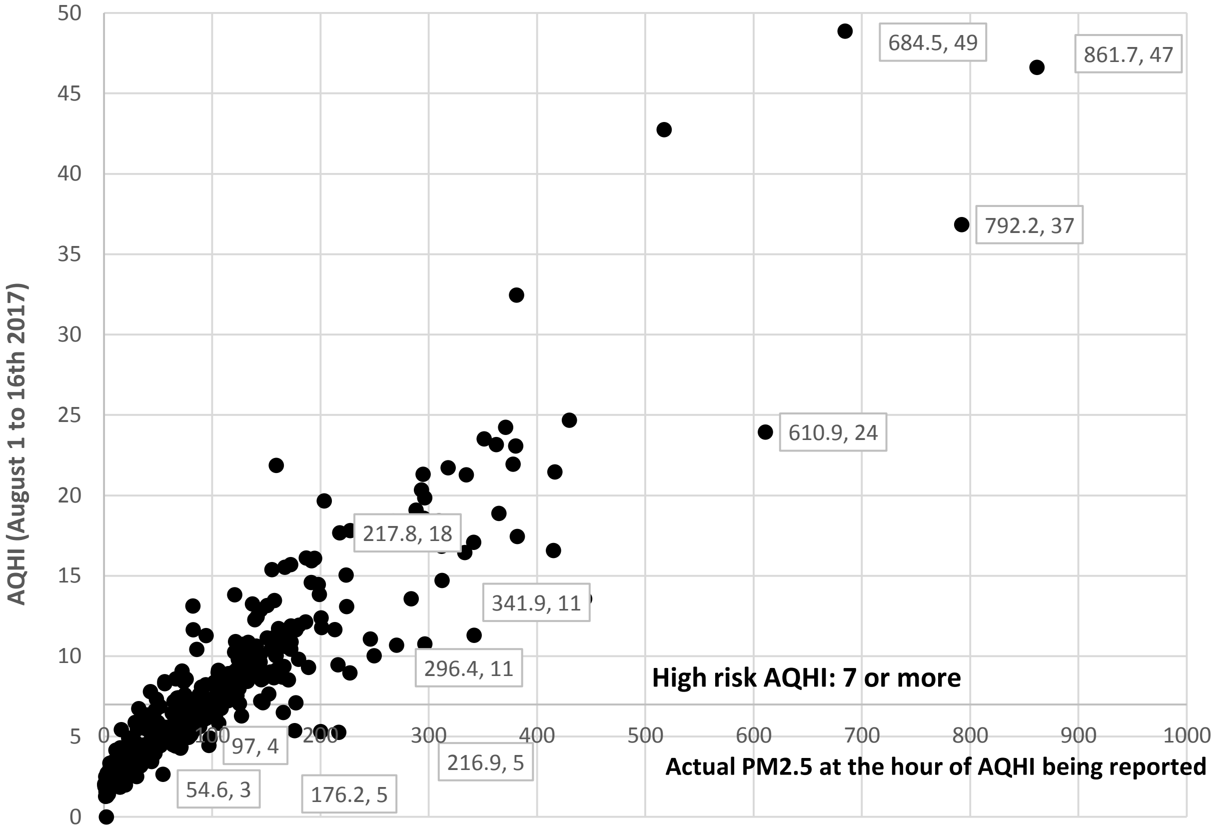

Figure 8. A comparison of the calculated AQHI values for the period from 1 to 16 August 2017, as a function of the actual $PM_{2.5}$ value at the hour of AQHI being reported. The data are from the Federal Building Monitoring Station in Kamloops

Figure 9 magnifies Figure 8 and shows the AQHI at the moderate risk levels which are in the region of 4 to 7. There are seven hours which have PM2.5 exceeding100 µg/m^3. Also a significant amount of hours are in the 50-100 µg/m^3 range. However, Figure 10 shows a relatively large fraction of PM2.5 values in the 50-100 µg/m^3 range for the high risk category as well. We think that all hourly values in the 50-100 µg/m^3 range should be in the high risk category and not in the moderate risk category, in order to best protect the population most at risk. For the population at risk, the moderate risk category recommendation is to “Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.” while for the general population it recommends that there is: “No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.” At levels of over 50 µg/m^3, for precautionary purposes, we think it is more advisable to consider recommending the following to the population at risk: “Reduce or reschedule strenuous activities outdoors. Children and the elderly should also avoid vigourous activity.”

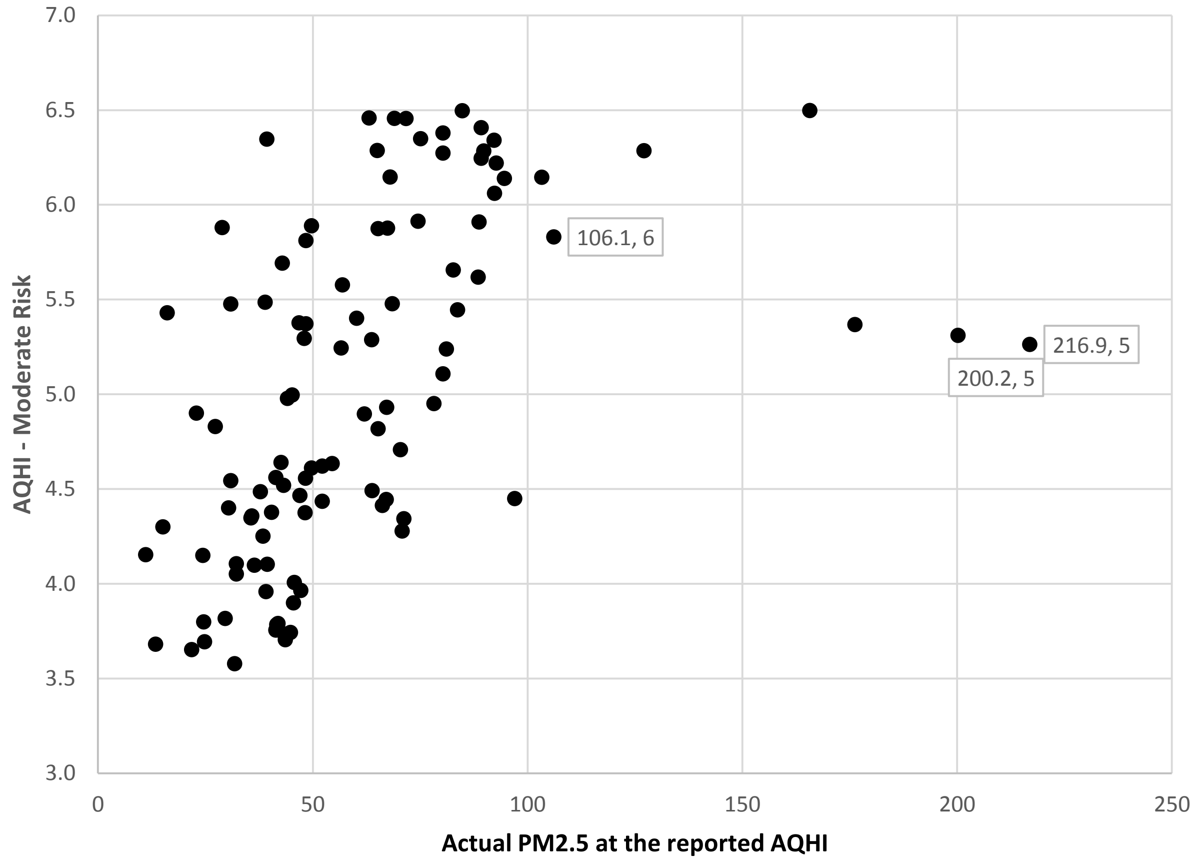

Figure 9. A comparison of the calculated AQHI values for the period from 1 to 16 August 2017, as a function of the actual $PM_{2.5}$ value at the hour of AQHI being reported for what is considered moderate risk. The data are from the Federal Building Monitoring Station in Kamloops.

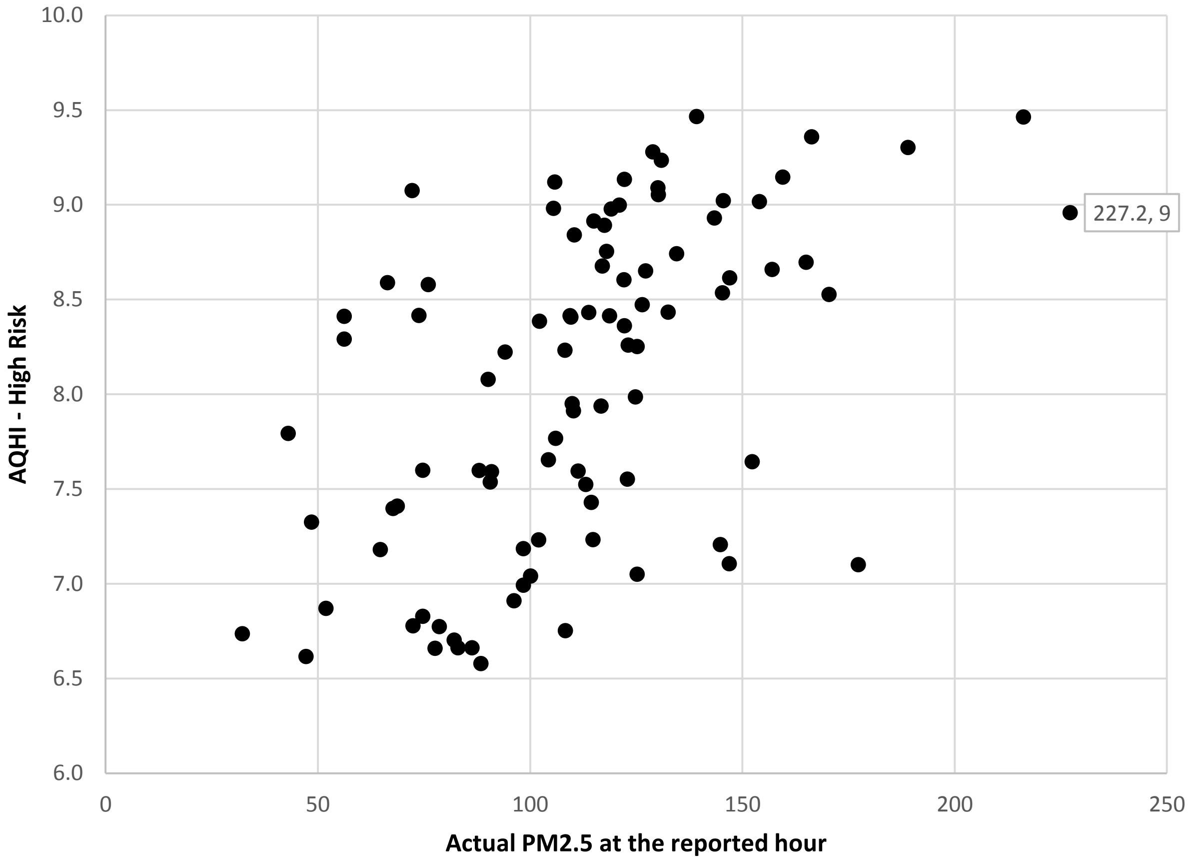

Figure 10. A comparison of the calculated AQHI values for the period from 1 to 16 August 2017, as a function of the actual PM2.5 value at the hour of AQHI being reported for what is considered high risk. The data are from the Federal Building Monitoring Station in Kamloops.

APPENDIX 2 The PM_{10} Values in Kamloops in July and August 2017

PM_{10} values are shown in Table 1 for the Aberdeen Monitoring Station in Kamloops and the Williams Lake Columneetza site. The PM_{10} values at Aberdeen, Figure 11, followed the pattern for $PM_{2.5}$, which was discussed above. The PM_{10} values were very high and also exceeded the regulatory values where they exist. The AQO of 50 µg/m3, for the 24 hour average $PM_{10,}$ was exceeded on multiple days and especially during the period of the smoke event that began on 31 July 2017. The average PM_{10} at the AMS for the full month of July was 32.7 µg/m^3 and for the full month of August was 72.9 µg/m^3 .

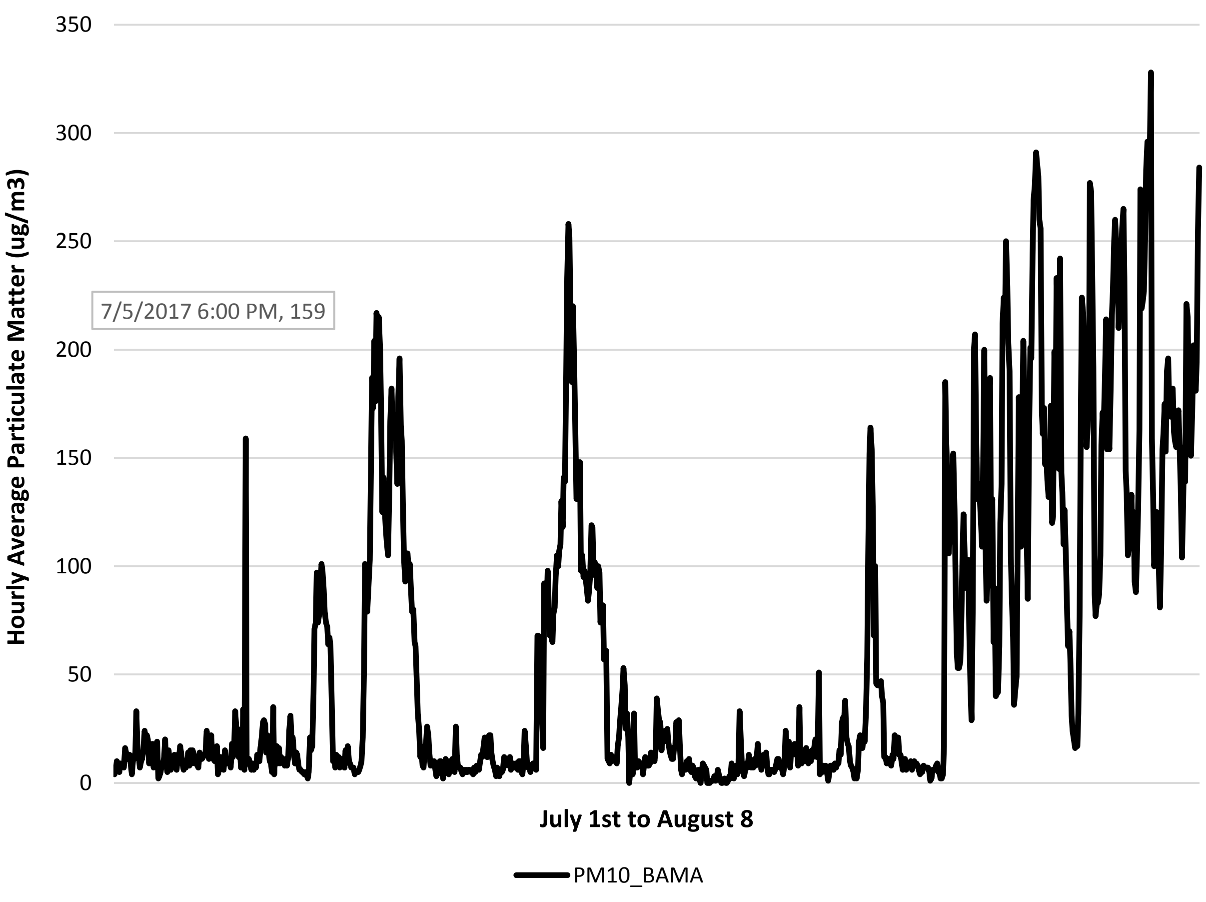

Figure 11: Aberdeen Large Particulate Matter, PM_{10} for the period 1 July to 8 August 2017.