Analysis of the Air Quality and Meteorological Data from the Aberdeen Monitoring Station in Kamloops, BC, October to December 2015

prepared by

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ABSTRACT

The British Columbia Ministry of the Environment (BC MOE) established a new air quality and meteorological monitoring station in Kamloops in October 2015. The location is on the south side of the valley about 300 m above the previously established downtown monitoring station. This report examines the archived hourly data for the last two-and-a-half months of 2015. The wind direction data show that 74% of the time winds were from the southern half of the terrain and 26% from the northern half. The most frequent wind direction was from the south, followed by southeast, east, west, southwest, northwest, northeast, and north, in that order. The highest concentrations of $PM_{2.5}$ (fine particulate matter) in the air were associated with winds from the northwest and north. An analysis of these data is given in the text along with information on wind speeds and concentrations of ozone, sulphur dioxide, nitrogen oxide and nitrogen dioxide at the Aberdeen site.

These data have implications for the city in light of the proposed application by KGHM Ajax to establish an open-pit mine on the southern border of the city. Presently, cleaner air enters the upper part of the city from the south. It is also the predominant direction from which winds come. The BC MOE monitoring site is on the property of the Pacific Way Elementary School about 1 km away from the edge of the proposed mine; therefore, the school and homes in upper Aberdeen are most often receiving air that has passed over the proposed site of the future mine. These data on wind directions must be given careful consideration in every evaluation of the application for the proposed mine. In addition, any dispersion models used by the proposed KGHM Ajax mine must demonstrate that they can produce wind direction and $PM_{2.5}$ values, for the upper Aberdeen site, that are in agreement with the summaries of the measurements that are presented in this report for the observation period in 2015. If they cannot, the models will have no value in describing scenarios for conditions in coming years.

Introduction and Overview of the Data

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

Hourly meteorological data for wind speed in meters per second (m/s), wind direction (degrees), mean hourly temperature (°C) and humidity (% RH) were collected at the new Aberdeen monitoring site by the BC MOE. The air quality measurements were $PM_{2.5}$ ($\mu g/m^3$), PM_{10} ($\mu g/m^3$), ozone (O_3) (in ppb), sulphur dioxide (SO_2) (in ppb), nitrogen oxide (NO) (in ppb) and nitrogen dioxide (NO_2) (in ppb). These measurements are discussed below. Archived data are available from October 16th 2015 at 4:00 PM to December 31st 2015, 11:00 PM.

A brief discussion is given for the gases but they are not discussed in detail, since the main focus is on the fine particulate matter in the air. The focus of the previous reports has been on $PM_{2.5}$, particulate matter with aerodynamic diameters less than 2.5 μm (micrometers). These data have been available from the downtown monitoring station since 1998 and are now available from the Aberdeen site for comparison. $PM_{2.5}$ concentrations have important implications for public health and are typically produced in large amounts by open-pit mining operations (Environment Canada, National Pollutant Release Inventory database). For these reasons the focus will be on $PM_{2.5}$ in this report.

All of the data are from the British Columbia Ministry of the Environment monitoring site 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 January 1st 2016).

Weather in Aberdeen

Overview

In this section we examine measurements of specific meteorological parameters during the period from the middle of October to the end of December 2015. It is not a study of the synoptic or large-scale weather features. Obviously, this does not produce values that can be considered typical for the entire year but it does present a tremendously valuable first look at what is happening near the high elevation, southern boundary of Kamloops.

Table 1 shows the average temperature, wind speed, and humidity for the months of November and December. The data show no major differences between these two months in 2015.

Table 1: Monthly Average Temperature, Wind Speed and Humidity in Aberdeen

Parameter	November 2015	December 2015
Temperature (°C)	-2.1	-2.0
Wind speed (m/s)	2.2	2.6
Humidity (%)	78	81

Detailed look at the meteorological data

Figure 1 shows the wind direction by octants, i.e. everything has been grouped into eight bins. Each bin has 45° of wind directions in it. For example, the northern winds would be from 337.5° to 22.5°, northeast from 22.6 – 67.5°, east from 67.6 – 112.5°, etc. The most frequent wind direction was from the south (21.9%), followed by southeast (18.2%), east (17.3%), west (14.9%), southwest (13.3%), northwest (7.4%), northeast (3.7%), north (3.2%). Looking at the overall wind pattern in Aberdeen, where everything is divided into two categories, northern winds from 270.1 to 360° plus from 0 – 90° and southern winds from 90.1 – 270°, the wind direction in Aberdeen during this period is predominately from the south. Winds from the south account for 74% of the 1820 hourly observations, while those from the north account for 26% of the observations.

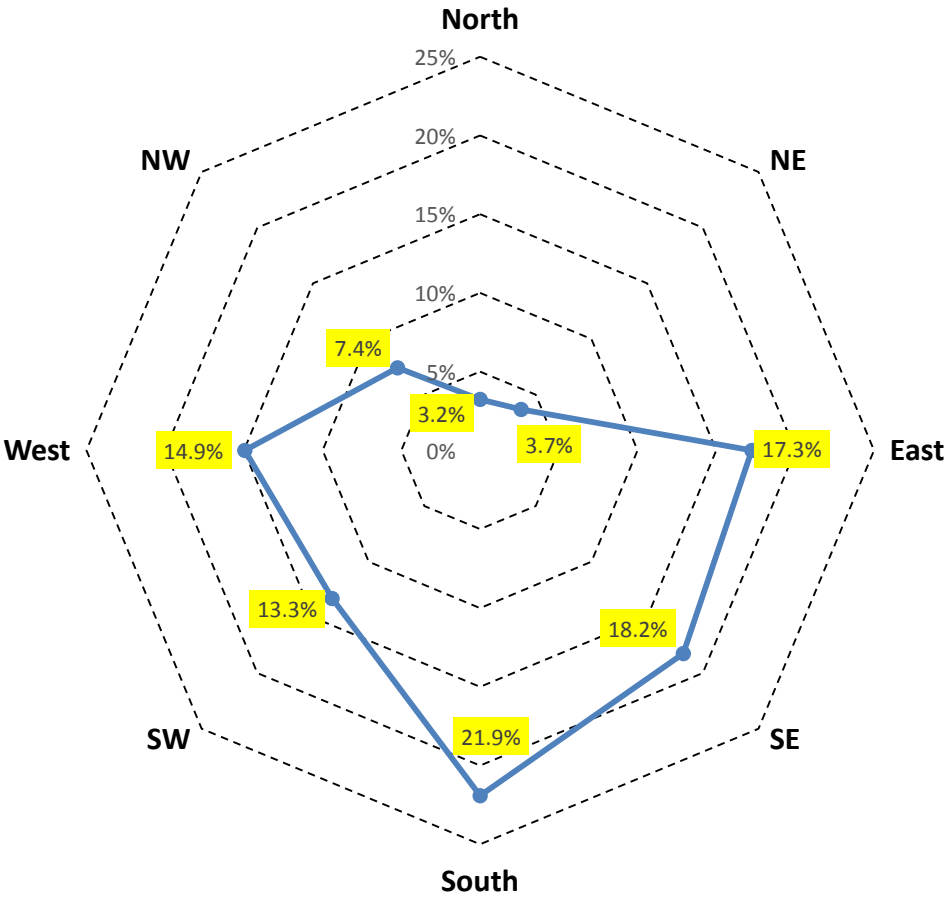

Figure 1: Percentage of time the wind is from each direction in Aberdeen during the period from mid-October to the end of December 2015

Figure 2 shows the wind speed during the measurement period. The mean is 2.3 m/s (8.3 km per hour) and the median is 1.9 m/s, which is lower than the mean as the distribution is skewed towards lower speeds. The speed varies from 0 to 8 m/s (from 0 to 29 km/hr). The mode is less than 1 m/s. North (averaging 0.8 m/s), northwest (0.85 m/s) and northeast (1.2 m/s) winds are calmer than those from the east (3.3 m/s) and southeast (3 m/s), while those from the west (2.2 m/s) southwest (1.8 m/s) and south (1,8 m/s) are in between.

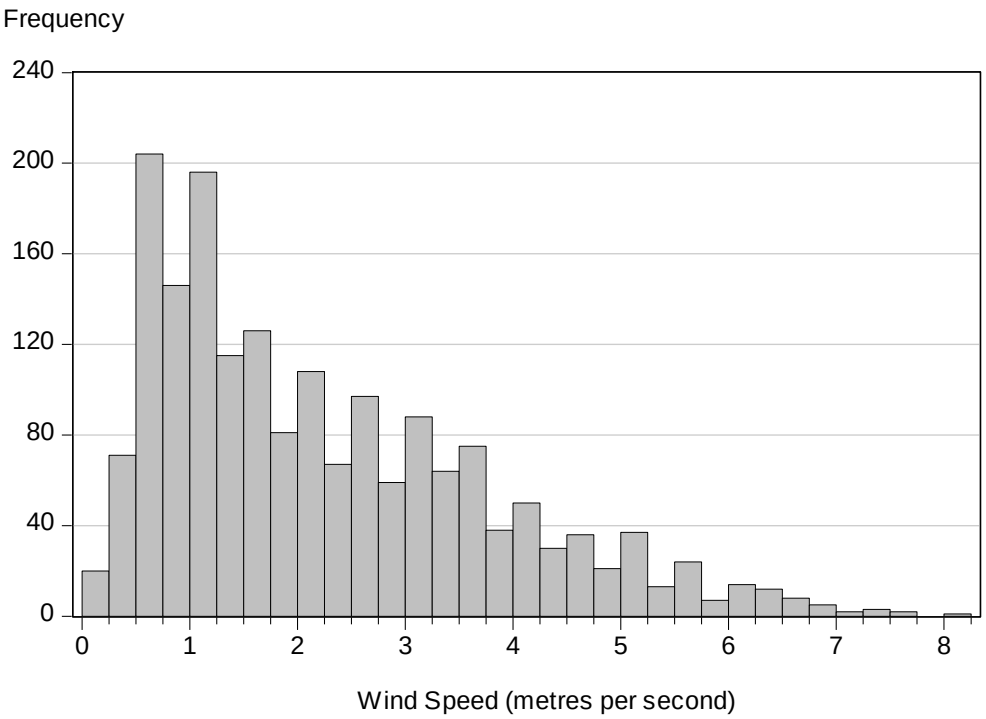

Figure 2: Wind speed in Aberdeen. The number of hours each wind speed occurred during the two-and-a-half month period of record is shown.

Figure 3 shows the histogram of the mean hourly temperature. The mean temperature is -0.67°C during this time period, with a standard deviation of 6.2°C. The median is -0.3°C. The maximum mean hourly temperature is 14.9°C and the minimum mean hourly temperature is -15.5°C.

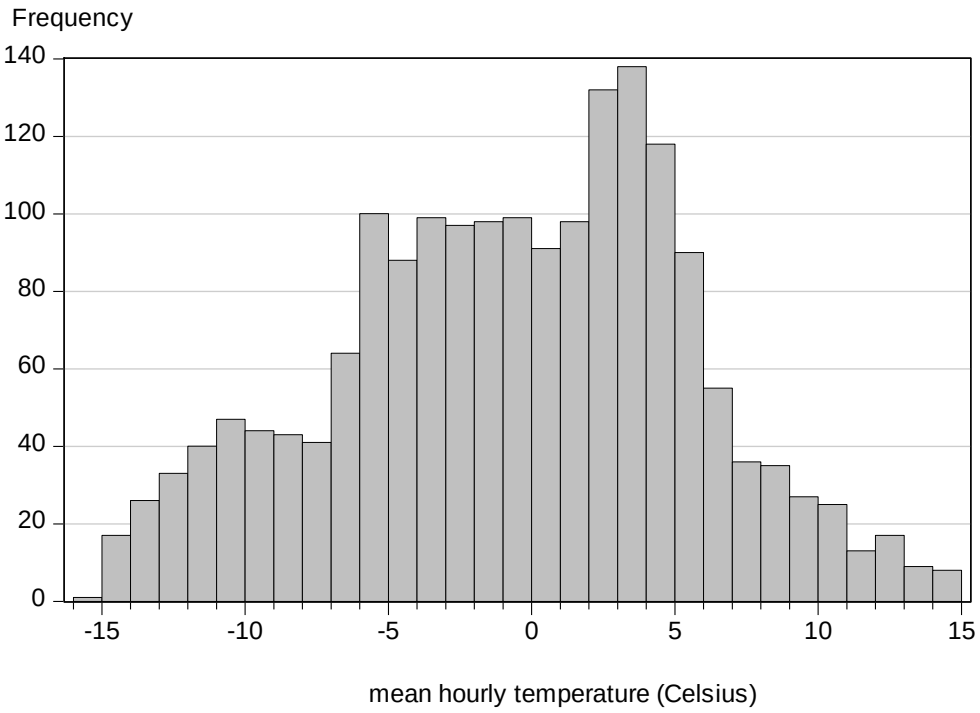

Figure 3: Distribution of mean hourly temperatures at the Aberdeen monitoring site for the period from mid-October to the end of December 2015.

The histogram of humidity values is shown in Figure 4. Clearly, during this time at the end of the fall and the start of the winter season the humidity values are very high, with most values above 60% RH. The mean value is 78.9% and the median is 79.2%.

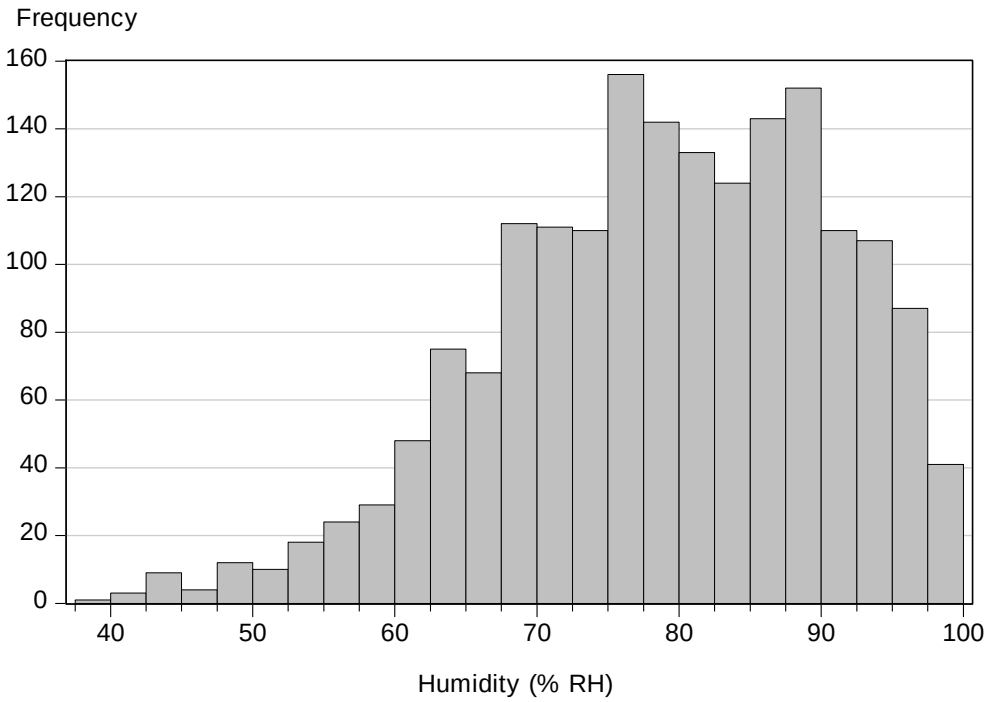

Figure 4: Distribution of mean hourly values of relative humidity at the Aberdeen monitoring site for the period from mid-October to the end of December 2015.

Impact of Meteorological Variables on Concentrations of Fine Particulates

In this section air quality information will be examined. Table 2 shows the monthly average values of six air contaminants in Aberdeen:

Table 2: Monthly Average Values of Air Contaminants in Aberdeen

	$PM_{2.5}$ $\mu g/m^3$	PM_{10} $\mu g/m^3$	SO_2 ppb	O3 ppb	NO ppb	NO_2 ppb
November	6.8	9.2	-0.1	26.1	1.6	1.9
December	3.2	4.1	0.1	27.8	0.9	1.9
All period	5.1	6.9	0.0	24.8	1.3	2.2

November is higher in particulate concentrations relative to December. This is likely related to the fact that the start of slash burning is in November and it is before the snow comes at higher elevations (Tsigaris and Schemenauer, 2015). For $PM_{2.5}$ most hourly values are relatively low, with a mean for the full period of 5.1 µg/m3, a median of 3.9, a minimum of 0.6 and a maximum

of 33.5. Factors such as wind speed, mean temperature and humidity (see Table 1) cannot explain the large difference in $PM_{2.5}$ in December relative to November.

Averages over months however hide hourly fluctuations and a more detailed look at the data is undertaken below. Figure 5 shows the distribution of hourly values of $PM_{2.5}$. It can be seen that the distribution is highly skewed towards low values. These low values are typically associated with the South and Southeast wind directions.

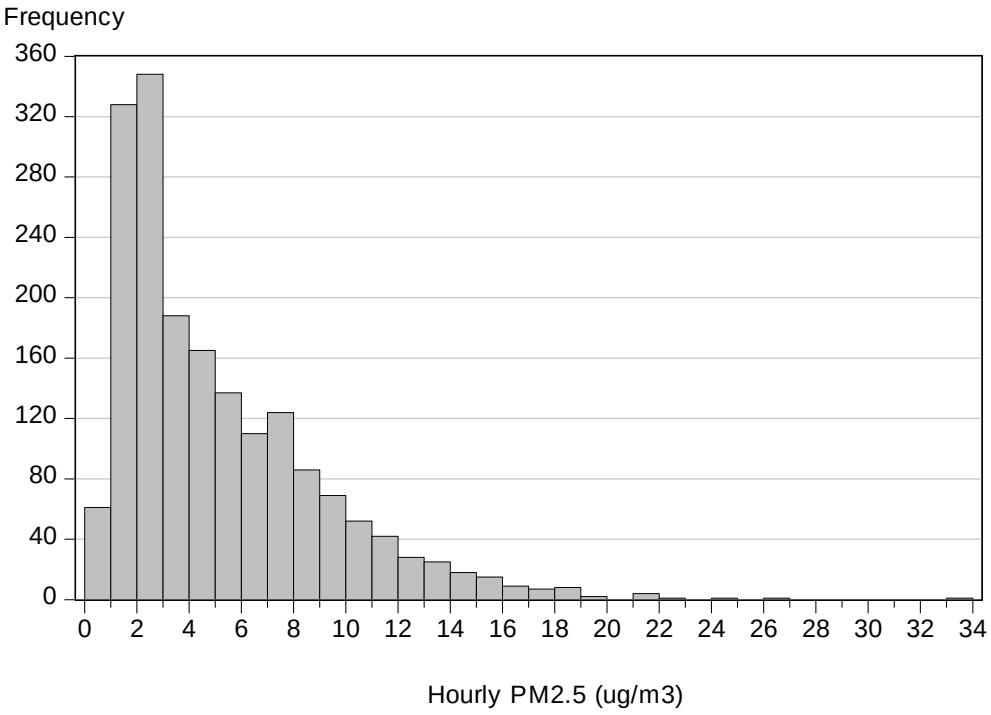

Figure 5: Distribution of hourly values of PM 2.5 for the full sample period from 16 October to 31 December 2015 at the Aberdeen monitoring site.

The Influence of Wind Direction on Airborne Particulate Concentrations

One of the objectives of this study is to go beyond the basic descriptive statistics and determine the impact of wind direction, wind speed, average temperature, and humidity on hourly $PM_{2.5}$, PM_{10} and the concentrations of the gaseous pollutants. Figure 6 shows the average concentrations of $PM_{2.5,}$ and PM_{10} for each of the different wind directions. The highest concentrations for both parameters are associated with wind directions from the north and northwest. This clearly indicates that Aberdeen's air quality is impacted by dirtier air coming from the urban and industrial areas to the north and northwest of Aberdeen. The wind is less frequent from those directions but because the highest concentrations of particulates come from the north and northwest they will have a significant impact on the monthly average values.

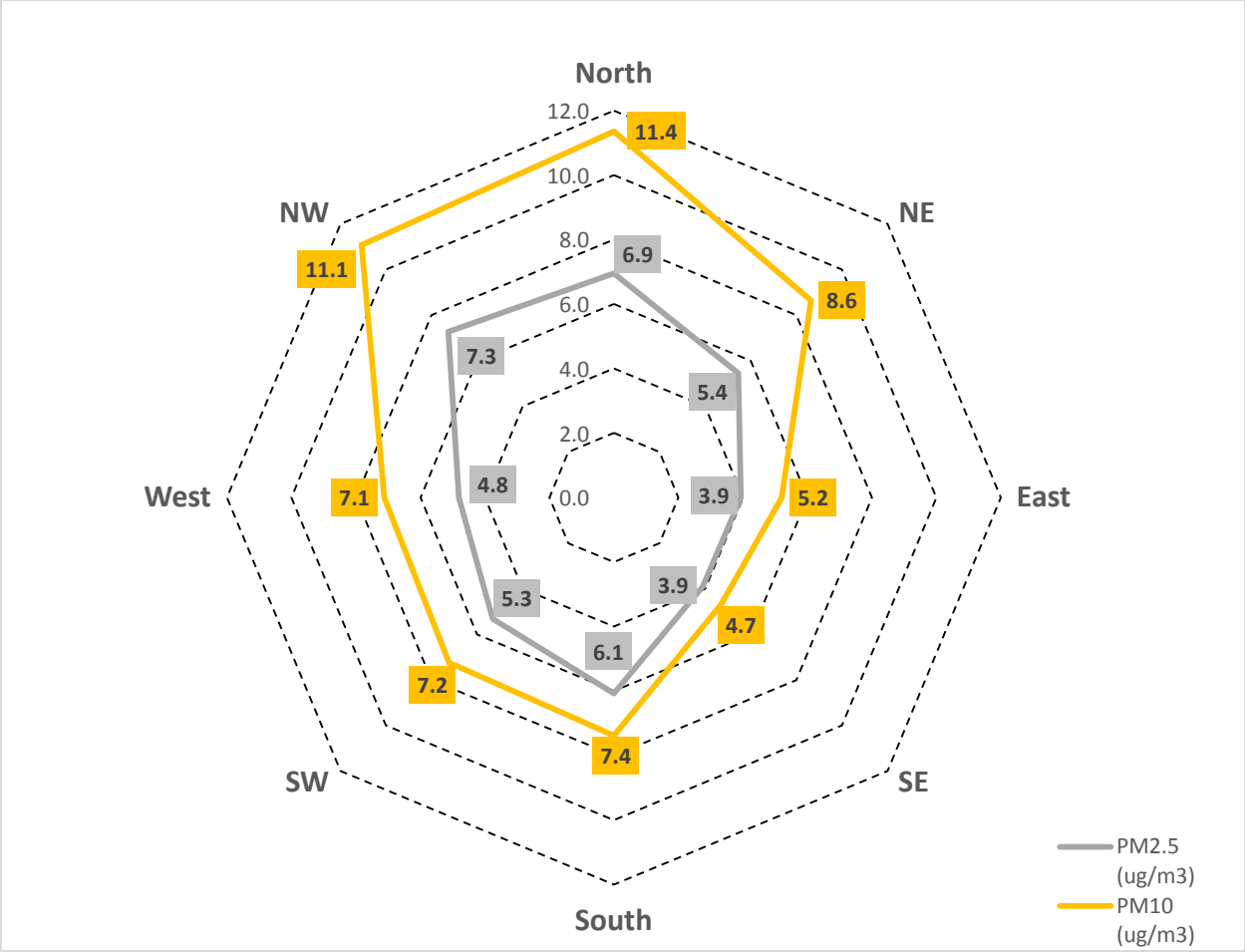

Figure 6: Average $PM_{2.5}$ (grey) and PM_{10} (yellow) in $\mu g/m^3$ for winds coming from each of eight wind directions in Aberdeen.

In order to look closer at the degree to which specific weather parameters may influence the hourly $PM_{2.5}$ in Aberdeen, a multivariate (multiple variables) regression analysis was carried out (See Appendix 1 for details). This is a technical statistical discussion and the assumptions and conclusions are discussed in the appendix.

The Importance of Wind Direction on the Impact of Airborne Fine Particulates

The total exposure to $PM_{2.5}$ of children at the Pacific Way Elementary School and residents of Aberdeen will depend on the number of hours each wind direction occurs during the course of the year. This is because, as we have shown, there are different concentrations of fine particulates coming in the air from different directions. If the October to December period was representative of the entire year, and if winds were consistently from the east or southeast, this would lead to the cleanest air, 3.9 µg/m3. In fact, Aberdeen during this time period had an overall average of 5.1 $\mu g/m^3$. This means the winds blowing from all the other directions into upper Aberdeen make this clean air average of 3.9 µg/m3 worse by 30%. The B.C. Air Quality Objective for $PM_{2.5}$ (24 hour average) is 25 µg/m3 and no days exceeded this value during the two-and-a-half month period of record.

We need to be concerned about three related issues when we consider impacts on populations. The first is the wind directions that produce the highest average values of fine particulates and also the highest peak values over short time periods. We now know these are winds from the north and northwest. The second consideration is that since most of the hours in the sample period are from the southern half of the terrain, these winds bring the majority of the particulates that people will breathe in during the course of the year. The third factor is what the chemical composition of the particulates from each wind direction is. We have no information on this but can suppose that there would be differences because of the urbanization and industry to the north of the monitoring site and the grasslands and forests found to the south of the monitoring site.

This discussion is of importance in terms of the impact the proposed open-pit mine would have on people living near southern edge of the city. The emissions of particulates and gases from the open-pit mining operations will be blown from the south to the north, with the southerly winds that are present most of the time. Because of the prevalence of southerly winds, any change in the average concentration of fine particulates in the air from that sector will result in significant increases in the average values at the Pacific Way Elementary School monitoring site.

Measurements of Large Particulate Matter (PM_{10})

The monitoring site in Aberdeen also reports airborne concentrations of the larger particulates in the atmosphere. PM_{10} includes all particles with an aerodynamic diameter less than 10 um (micrometers) in size. This includes the $PM_{2.5}$.

Figure 6 shows the concentrations of both PM_{10} and $PM_{2.5}$ as a function of wind direction. The highest concentrations come from the northwest and north and the cleanest air is associated with wind directions from the east and southeast. It is apparent from the figure that the pattern is the same as for $PM_{2.5}$. This would suggest similar emission sources for the two categories of particulates. The monthly average values for PM_{10} are given in Table 2 above. The November value of 9.2 $\mu g/m^3$ was considerably above the December average value of 4.1 $\mu g/m^3$.

Measurements of Gaseous Pollutants

i) Nitrogen Oxide (NO)

NO is called nitrogen oxide in the summary information provided on the B.C. Air Quality Site. It is also referred to as nitric oxide. The gas-phase chemistry will not be discussed here. It is very complicated and the presentation for all of the gases will be limited to showing the archived data. NO and N02 are products of high temperature combustion and may be emitted by vehicles, power plants, forest fires, slash burning and so on.

On Figure 7 the concentrations of NO, and $N0_2$, are plotted in concentrations of parts per billion (ppb). We see that NO comes primarily from the industrial and urban areas to the northwest and north and that the average concentrations from the other wind directions are low. There is not a B.C. Air Quality Objective for nitrogen oxide listed on the B.C. Air Quality Site. Table 2 shows the mean values for November (1.6 ppb) and December (0.9 ppb), with November having the higher value.

ii) Nitrogen Dioxide ($N0_2$)

Figure 7 shows the concentrations of $N0_2$ as a function of wind direction. The highest concentrations are from the northwest, north and northeast in that order. The other directions contribute only small amounts to the total nitrogen dioxide observed in Aberdeen. The B.C. Air Quality Objective for nitrogen dioxide (1 hour average) is 210 ppb. There were no hours exceeding the objective during the measurement period. Table 2 shows the mean values for November (1.9 ppb) and December (1.9 ppb), with no difference being seen between the months.

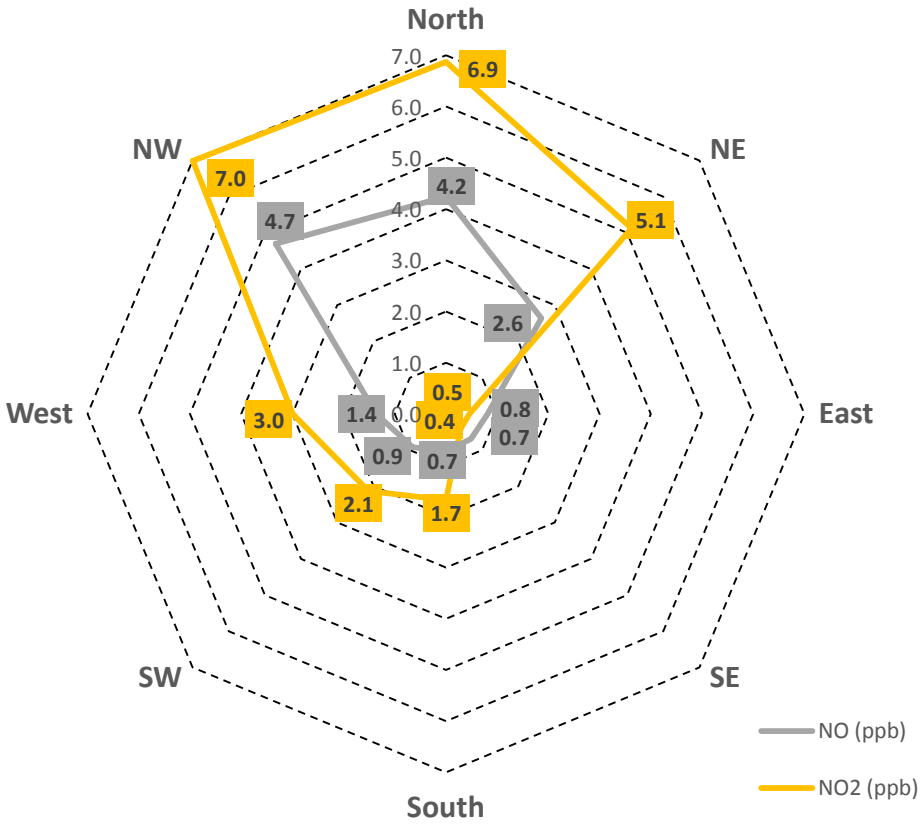

Figure 7: The concentrations of NO (grey) and $N0_2$ (yellow) plotted as a function of wind direction, in concentrations of parts per billion (ppb), for the full sample period from mid-October to the end of December 2015.

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iii) Sulphur Dioxide (SO_2)

Sulphur is present in fossil fuels and is converted to sulphur dioxide when the fuel is burnt. The hourly averaged SO_2 values at the Aberdeen monitoring site are consistently very low; however, even though the values are low, again winds from the northwest and north produce significantly

higher concentrations than from the other directions. The hourly values are often below 2 ppb whereas the B.C. Air Quality Objective for sulphur dioxide (1 hour average) is 75 ppb. There were no hours exceeding the objective during the measurement period.

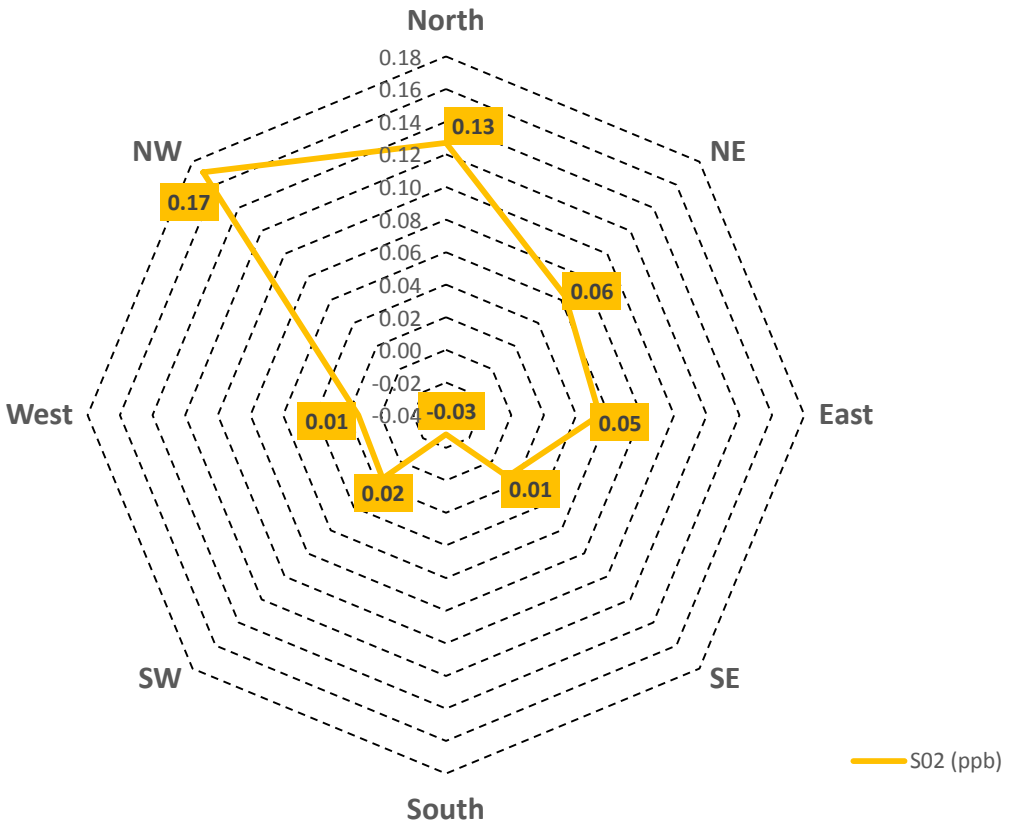

Figure 8: The average concentrations of $S0_2$ plotted as a function of wind direction, in concentrations of parts per billion (ppb), for the full sample period from mid-October to the end of December 2015.

iv) Ozone (O_3)

The ozone values are not greatly affected by wind direction. There are correlations to humidity, wind speed, and temperature but these will not be explored in this report. Ozone is generally formed downwind from sources of precursor gases from which the ozone forms in the presence of sunlight. In the case of the Aberdeen monitoring station, these sources may be quite some distance away. The monthly average values are moderately high with the November average being 26.1 ppb and the December average being 27.8 ppb. The B.C. Air Quality Objective for Ozone (1 hour average) is 82 ppb. There were no hours exceeding the objective during the measurement period.

Conclusions

Despite there being only two-and-a-half months of meteorological and air quality data from the new monitoring site in upper Aberdeen, it is vitally important to analyze the measurements and use the results to guide decisions related to the application for an open-pit mine on the southern edge of the city.

The results show that during this period, mid-October to the end of December 2015, the wind directions were overwhelmingly, 74% of the time, from the southern half of the terrain. The $PM_{2.5}$ values associated with these southerly winds were somewhat lower (cleaner) than for winds from the north or northwest. However, the relatively less frequent north and northwest winds have a measurable impact on Aberdeen air quality despite industry being relatively far from Aberdeen in that direction.

This report clearly shows that any new industry to the south or south east of Aberdeen has the potential to make the air quality worse in Aberdeen and the city of Kamloops. Three quarters of the time the wind is from the southern half of the terrain and the wind speeds are higher than they are for other wind directions. Aberdeen will get air pollution not only from the existing urban and industrial areas to the north and north-west but from the south as well, if an open-pit mine is located next to the city boundary. This means there will be a greater amount of fine particulate matter available to be inhaled by students, the population of Aberdeen and potentially everyone in the city.

Summary data are also presented from the Aberdeen monitoring station for various meteorological parameters, for larger particulates (PM_{10}), and for a set of pollutant gases. They were examined in a preliminary fashion to see if there were correlations with the concentrations of $PM_{2.5}$. Some of this information is presented in an appendix but no detailed study will be done until the end of 2016 when there is a full year of data available. What is evident is that the highest concentrations of the pollutant gases NO, NO_2 and SO_2 come with winds from the northwest and north of the Aberdeen site.

A comparison of these 2015 data from the Aberdeen monitoring station to those from the downtown Federal Building monitoring station, both operated by the BC MOE, will be done in a forthcoming report looking at the air quality for the entire year of 2015 using data from the downtown station. As in past years, this next report will compare data for the year 2015 to measurements from previous years at the downtown station.

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 immediately after the year end, it is possible that some small changes may be made in the final archived data set.

References

Tsigaris, P. and R.S. Schemenauer, 2014a: Statistical Study of $PM_{2.5}$ Measured at the Kamloops Federal Building for Years 2011, 2012 and 2013. Statistical Report prepared for Kamloops Physicians for a Healthy Environment Society, 27 June 2014, pp 8. Accessible at: www.kphe.ca.

Tsigaris, P. and R.S. Schemenauer, 2014b: Reconstructing the Historic Database of Annual $PM_{2.5}$ Values for Kamloops, B.C. by Calculating the Offset between TEOM and BAM Measurements. Prepared for Kamloops Physicians for a Healthy Environment Society (KPHES), 25 July 2014, pp 20. Accessible at: www.kphe.ca.

Tsigaris, P. and R.S. Schemenauer, 2015: The Influence of Prescribed Burning of Wood in the Kamloops Fire Centre on the PM2.5 Values in Kamloops in the Month of November, 2014. Prepared for Kamloops Physicians for a Healthy Environment Society (KPHES), 13 January 2015 (Minor Revisions from 10 December 2014), pp 16. Accessible at: www.kphe.ca.

Appendix 1: Regression analysis

In this appendix we explore the impact on the hourly $PM_{2.5}$ arising from a number of factors beyond wind direction as was done in the main text. Here the hourly mean temperature, wind speed, humidity are added to explain the variation of the hourly $PM_{2.5}$, which is not done in the main text. The magnitude of the effect of wind direction on PM2.5 changes slightly as it now depends also on temperature, wind speed and humidity. We find that the mean hourly temperature is negative associated with $PM_{2.5}$ after controlling for wind direction, speed and humidity at the 10% level of significance (p-value: 0.09). The most significant variable is wind speed (p-value 0.0). Higher wind speeds improve the air quality (lower $PM_{2.5}$) in Aberdeen and vice versa. An increase in wind speed by 1 m/s (i.e., 3.6 km per hour) is associated with a $PM_{2.5}$ fall by 0.7 ug/m^3 in Aberdeen. This may simply be a different way of quantifying the fact that stronger winds come from the south as do lower concentrations of $PM_{2.5}$. Humidity is only marginally significant (p-value of 0.16).

Table A1: Multiple regression for $PM_{2.5}$

Independent variables	Coefficients	SE Coef	T-Value	P-Value
Wind speed	-0.66	0.07	-9.34	0.00
Temperature	-0.03	0.02	-1.69	0.09
Humidity	0.01	0.01	1.40	0.16
NE	5.05	0.92	5.47	0.00
East	5.10	0.85	5.99	0.00
SE	4.91	0.83	5.93	0.00
South	6.20	0.79	7.86	0.00
SW	5.50	0.80	6.92	0.00
West	5.20	0.82	6.34	0.00
NW	6.76	0.84	8.00	0.00
North	6.44	0.91	7.06	0.00

Note: Standard error of regression 3.7

Table A2 conducts a sensitivity analysis of wind direction on $PM_{2.5}$. The last column is the impact as discussed in the main text. The first three columns give the results of impact of wind direction given specific values of wind speed, temperature and humidity. The first column gives the results if wind speed is at 2.3 m/s, temperature at -0.67 Celsius, and humidity at 78.9. Wind speed, temp and humidity are evaluated at their sample means. Values range from 4.6 to 6.3. Eastern winds have the lowest impact on PM2.5 and north, northwest the highest impact. Keeping humidity at the 78.9% and reducing the wind speed to 1.3 m/s, which is the mode of the distribution and reducing temperature to -5 C, we get very similar results to the sample averages for north and northwest but higher for the remaining directions relative to the average values in the last column. If we increase the temp to 10 C and keep the wind speed to 2.3 m/s, then we get (Table A2) lower $PM_{2.5}$ from any direction and the east and southeast are closer to 3.9 (Column 4). This shows that our results in the main text are not very sensitive to different assumptions. Namely the northwest and north winds move more particulates to Aberdeen than from the other directions even after controlling for wind speed, temperature and humidity in the area.

Table A2: Sensitivity summary

	Wind speed at 2.3 m/s, temp at -0.67 C	Wind speed at 1.3 m/s, temp at -5 C	Wind speed at 2.3 m/s, temp at +10 C	Sample average
NE	4.6	5.4	4.3	5.4
East	4.7	5.4	4.4	3.9
SE	4.5	5.2	4.2	3.9
South	5.8	6.5	5.5	6.1
SW	5.1	5.8	4.8	5.3
West	4.8	5.5	4.5	4.8
NW	6.3	7.1	6.0	7.3
North	6.0	6.7	5.7	6.9

Note: Humidity kept at 78.9 the sample mean