A Brief Comparison of the Air Quality and Meteorological Data from the Federal Building, the Aberdeen Monitoring Station in Kamloops, BC, and the KGHM Ajax Upwind Station

prepared by

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ABSTRACT

In the last half of March 2016, the British Columbia Environmental Assessment Office (EAO) provided to the Kamloops Physicians for a Healthy Environment Society (KPHES) air quality and meteorological data from the company (KGHM Ajax) proposing an open-pit copper-gold mine on the southern edge of the city of Kamloops. There are no meteorological data from within the proposed plant boundary. There are meteorological data from a compromised location (Ajax Met) to the northwest of the plant boundary and air quality data from a monitoring station (upwind site) on the southwest edge of the plant boundary.

Though the data from the upwind monitoring station are not used in the KGHM Ajax mine application, they can be assessed to see if the location indeed provides useful data to determine the air quality on the southwest edge of the proposed mine. This report also compared the conditions at the Aberdeen, Federal Building and upwind monitoring stations in order to provide an estimate of what the background concentrations of airborne fine particulate matter ($PM_{2.5}$) are in the areas south of the city of Kamloops. Over a full 12 month period (3 February 2015 to 2 February 2016) the upwind site averaged 2.5 μg/m3, which is consistent with this being a relatively remote site. This value is well below the background concentration of 3.8 μg /m³ used by KGHM Ajax in their application for the proposed mine.

During a period from mid-October 2015 to December 2015, when data are available from both sites, the Aberdeen site $PM_{2.5}$ average concentration was about 1.7 μg/m3 higher than at the upwind site. For a period of 12 months, the downtown Federal building $PM_{2.5}$ average concentration was about 6 μg/m3 higher than at the upwind site. This would be an initial estimate of the contribution of all emission sources to fine particulate concentrations in Kamloops using the 2015 annual average.

An understanding of both maximum wind speeds and wind gusts is important for the prediction of emissions of dust from a mine site. No measurements of these parameters are available from within the plant boundary of the proposed mine. A brief discussion of the data from the compromised location (KGHM Ajax Met) behind Sugarloaf Mountain is given. The maximum wind gust seen in a one-year period was 25.5 m/s (92 km/h).

1. Introduction and Overview of the Data

This is the sixth in a series of reports (Tsigaris and Schemenauer, 2014a, 2014b, 2015, 2016a, 2016b) that have been written to inform the public, politicians and government decision makers on the quality of the air in Kamloops. This report is a brief follow-up to the examination of the Aberdeen air quality and meteorological data collected from October to December 2015 (Tsigaris and Schemenauer, 2016 a). The British Columbia Ministry of the Environment (BC MOE) established this new air quality and meteorological monitoring station (Aberdeen) 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.

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). Similar air quality data are available for the KGHM Ajax upwind site and the downtown Federal Building site.

Due to the fact that the public comment period for the proposed mine is well advanced, the focus of this report will be limited to measurements of wind and on concentrations of $PM_{2.5}$ (particulate matter with aerodynamic diameters less than 2.5 μm (micrometers)). $PM_{2.5}$ 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).

2. Airborne Particulate Matter Concentrations at the three stations

Measurements of particulate matter in two size ranges are available from February 2015 at the KGHM Ajax upwind station and from the middle of October 2015 at the Aberdeen station. The upwind station is in a more remote location in the minor valley through which the Lac Le Jeune Road runs. The approximate coordinates of the site are 50^o 35’ 20”N, 120^o 26’ 08” W. The Aberdeen site is on the very upper south edge of the city of Kamloops and just below and about 1.5 km from the edge of the proposed mine site. The approximate coordinates of the site are 50^o 38’ 12” N, 120^o 22’ 13” W. The upwind site is 7 km at a bearing of 220° (Southwest) from the Aberdeen site.

It is very important to note at the outset that no calibration data are presently available for either the KGHM Ajax upwind instrumentation or the BC MOE instrumentation used at the Aberdeen site. We have no information on whether the instrumentation at the two locations have been calibrated in a consistent fashion and no information from the sources on what the expected

errors are in the measurements at the two locations. Our assumption in this discussion is that the hourly or 15 minute data as provided might have errors of the order of +/- 5 to 10%.

Table 1 illustrates the month average pattern of PM_{10} and $PM_{2.5}$ for the three stations. All three sites show the impacts in the measured concentrations of July and August forest fires as well as the November slash burning. It is noteworthy that the average concentrations of both PM_{10} and $PM_{2.5}$ in November are similar at the Aberdeen and upwind sites, supporting the regional nature of particulate emissions from slash burning at this time of the year (Tsigaris and Schemenauer, 2015). The downtown Federal building averaged a higher value of 12.6 μg/m3. This may have resulted from winter inversions trapping air contaminants inside the valley.

Table 1. A comparison of the average monthly values of PM_{10} and $PM_{2.5}$ at the KGHM Ajax upwind site, the BC MOE Aberdeen site, and the downtown Federal Building monitoring station. The units are micrograms per cubic meter (μg/m3).

	Upwind Ajax Station		Aberdeen Station		Federal Building	Difference Federal Building and Upwind Station
	PM10	PM2.5	PM10	PM2.5	PM2.5	$PM_{2.5}$
Feb-15	4.7	0.7			7.5	6.8
Mar-15	5.3	0.9			7.7	6.8
Apr-15	5.3	0.6			5.9	5.3
May-15	8.5	1.5			6.6	5.1
Jun-15	8.6	2.1			6.0	3.9
Jul-15	13.3	5.6			8.7	3.1
Aug-15	11.2	5.4			13.2	7.8
Sep-15	5.4	1.9			7.0	5.1
Oct-15	6.2	3.2	7.9	5.5	8.8	5.6
Nov-15	9.7	5.9	9.2	6.8	12.6	6.7
Dec-15	3.4	0.7	4.1	3.2	7.9	7.2
Jan-16	2.8	0.2	5.0	4.2	8.5	8.3
Feb-16	3.1	0.3	7.1	2.0	8.6	8.3

Note: Particulate matter measured in μg/m3. Upwind Station series starts on 2/3/2015 10:00 a.m. and ends on 2/25/2016 6:00 a.m.

The upwind station can be considered as potentially providing the regional/background levels. Over a full 12 month period (3 February 2015 to 2 February 2016) it averaged 2.5 μg/m3 (Table 2). Spring background from March to May averages 1 ug/m3; summer from June to August averages, 4.4 ug/m3 much higher, due to forest fires in July and August; fall from September to November averages, 3.7 ug/m3, higher due to slash burning activity; and winter background from December to February averages only 0.4 ug/m3. This is consistent with the literature. McKendry (2006) finds the average background level at 2 μg /m3 in B.C. He also finds seasonal variation in background levels as is found in this report. Background ranges from 1 - 4 μg/m3

with closer to 4 μg/m3 in summer due to forest fires. Drier regions like Kamloops have slightly higher levels. Suzuki and Taylor (2003), also for B.C., found that natural sources of $PM_{2.5}$ in non-urbanized regions are 25 percent of the ambient $PM_{2.5}$ concentration. Since the historical average in Kamloops is 8.7 μg/m3 (Tsigaris and Schemenauer, 2016b) and if background represents 25% of this value, then background $PM_{2.5}$ should be approximately 2.2 μg/m3, which is consistent with the upwind monitoring station being a relatively remote site.

Table 2. Average values of PM 10 and PM 2.5 are given for the KGHM Ajax upwind station for the period 3 February 2015 to 2 February 2016, and for the period 16 October 2015 to 31 December 2015 when data are also available for the Aberdeen station. The units are micrograms per cubic meter (μg/m3). The value for the Federal Building is the 2015 annual average.

	Upwind Ajax Station		Aberdeen Station		Federal Building
Period	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	$PM_{2.5}$
2/3/2015 - 2/2/2016	7.1	2.5			8.5
10/16/2015 – 12/31/2015	6.4	3.4	6.8	5.1	

Note: Upwind Ajax station from 2/3/2015 – 2/2/2016 represents one full year.

During a comparable measurement period from mid-October 2015 to December 2015, when data are available from both sites, the Aberdeen site averaged 5.1 μg/m3 while the upwind site recorded a lower average value of 3.4 μg/m3. It appears that Aberdeen has higher than background levels as it is impacted by emissions from the industrial, transportation and residential activities of the city of Kamloops.

Comparing the Federal Building with the Upwind Ajax station provides information on the contribution to the ambient $PM_{2.5}$ concentration from other sources such as transportation, industry and heating. To detect the contribution of road and industrial sources it is best to compare the spring and early summer period since there are no forest fires, no slash burning, minimal heating by industrial and residential sources, and few of the typical winter inversions occurring. During the period from March to June 2015, transportation and industry contribute (Table 1 last column) on average 5 μg/m3, with a variation from 3.9 – 6.8 μg/m3. This is determined by looking at the differences between the average PM 2.5 concentrations in downtown Kamloops and the upwind station for the period mentioned. Transportation and industry operate year round and hence are present in the winter time too when inversions are frequent. Heating does play a role in the winter but is not the major contributor to the deterioration of the air quality in Kamloops as measured by the annual average.

3. Wind Directions at the KGHM Ajax MET and Aberdeen Sites

Figure 1 shows the frequency of the wind directions at the KGHM Ajax MET site and the Aberdeen site from October 16th 2015 to December 31st 2015 when there are concurrent data. Both sites show the highest frequency of winds as being from the south and a preponderance of the winds from the southern half of the terrain. The KGHM Ajax MET site shows a greater alignment of winds to the south and north than the Aberdeen site, which reflects a blockage of the winds by the Sugarloaf Mountain terrain feature to the southwest of the KGHM Ajax MET

site. Winds from directly south are observed 31.8 percent of the time at the KGHM Ajax MET site while at the Aberdeen site they are observed 21.5% of the time. Northwest winds at the KGHM Ajax MET site are observed 14.3% of the time while at Aberdeen they occur 6.6% of the time.

Figure 1. The frequencies of winds from eight directions are presented for the KGHM Ajax Met site (in blue) and for the Aberdeen site (in red). Wind directions are shown on the eight-sided contours for the period from October 16th 2015 to December 31st 2015 with concurrent data.

The wind rose shown in Figure 1 for the KGHM Ajax MET provides little information about the undisturbed wind flow over the plant boundary of the proposed mine site and as we saw above the upwind monitoring site does not have meteorological data. This raises some doubts as to whether the air quality measurements at the upwind site are in fact representative of air entering the area of the proposed mine. It is a reasonable assumption that the upwind monitoring site provides a first approximation of the regional background concentrations of fine particulates in the air but the exact movement of air around the terrain features on the proposed mine site are not known.

The wind rose at the KGHM Ajax MET site shows the importance of the local topography in defining the movement of air in complex terrain. Without a model resolution that allows for small and medium scale terrain features to be adequately represented, the model will be unable to resolve movements of air on the scales up hundreds of meters or a kilometer. This is directly

relevant to understanding the movement of pollutant laden air from the proposed mine site into upper Aberdeen and southern Kamloops.

4. Wind Speeds and Gusts at the KGHM Ajax MET and Aberdeen Sites

It is very important to understand the wind gusts present on the proposed mine site. Wind gusts raise surface dust and also distribute dust from all sources in the vertical. Unfortunately, there are no measurements of wind gust magnitudes or frequency from within the plant boundary of the proposed mine. There are some data from the KGHM Ajax MET site and they are examined in this section. It is important to bear in mind, however, that the meteorological data from this site are not characteristic of the area within the plant boundary (see the discussion above).

In Figure 2 we see a strong peak in the distribution of maximum wind speeds measured in 15 minute intervals at the KGHM Ajax MET site. The peak is at about 2.5 m/s, which is fairly low but we see that the tail of the distribution (fat tail) extends out to greater than 20 m/s. In 2015 approximately 24 percent of the time, i.e., 8,276 out of 35,034 15 minute max wind speed intervals, gusts were greater than or equal to 7 m/s (25.2 kilometers per hour). The maximum value recorded was 25.5 m/s (92 kilometers per hour). It is not known what the values would be for locations within the plant boundary where the main roads would be located, or where the blasting would be done for the pit, or where the exposed tailings beaches would be. In addition, it is important to note that wind gusts are not part of the modeling effort undertaken in the application for the mine. So there are not even modeled wind gust calculations to examine.

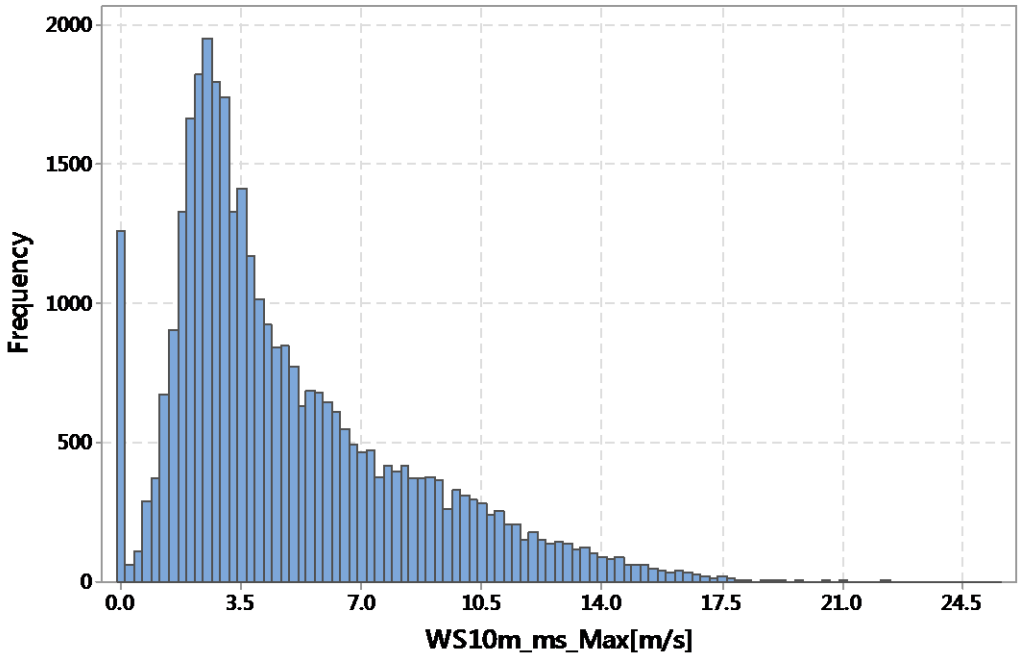

Figure 2: A histogram showing the frequency of occurrence of the maximum wind speeds in 15 minute intervals at the upwind site for the calendar year 2015. These represent the peak wind gusts.

Table 3. A summary is given of the wind data from the KGHM Ajax MET site for a period of one year. Wind speeds are in meters per second (m/s). The table provides the average wind speeds and the peak wind speeds (gusts) at the 10 meter height on the tower at the site.

Variable	Observations	Mean	StDev	Minimum	Q1	Median	Q3	Maximum
WS10m_ms	35034	2.8	2.2	0.0	1.24	2.3	3.9	14.9
WS10m_Max	35034	4.9	3.5	0.0	2.41	3.8	6.7	25.5

Table 3 shows the mean average wind speed and the mean of the maximum wind speeds in the 15 minute data blocks. The mean maximum speed is 4.9 m/s (17.6 kilometers per hour). The maximum gust is 92 kilometers an hour (25.5 m/s) and occurred with south winds on 13 August 2015 at 3:45 AM. Half of the maximum wind data show values that are greater than or equal to 13.7 kilometers an hour. Twenty five percent of the data show values greater than 24 kilometers an hour. Figure 3 shows the maximum wind speeds are highest from the southwest with an average speed of 6.4 m/s (23 kilometers per hour). This is followed by northwest, south and southeast with average maximum speeds of 5.4, 5.3 and 5.2 m/s respectively. East with 4.5, northeast with 3.8 and north with 2.4 m/s have the lowest average maximum speeds.

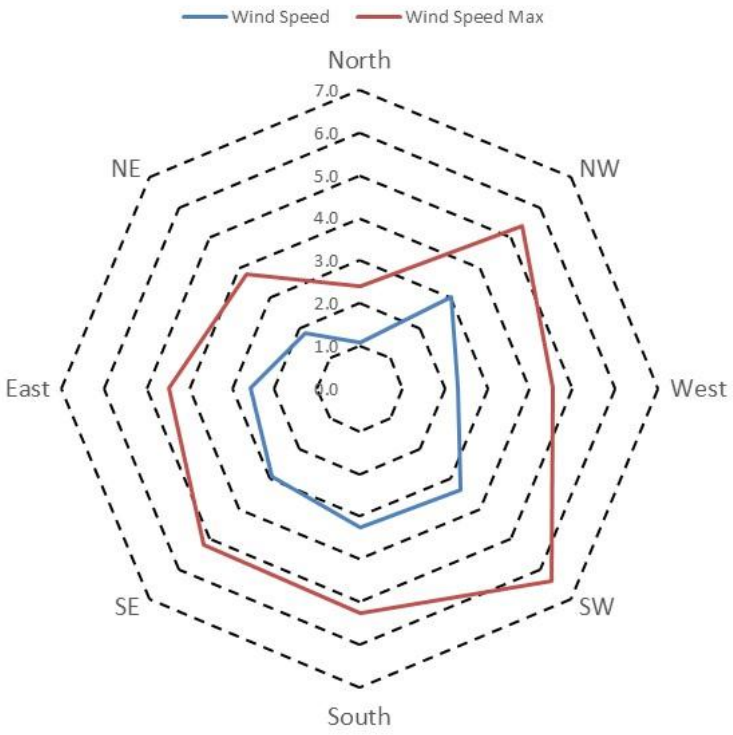

Figure 3. The distribution of average values of the maximum wind speeds by direction at the KGHM Ajax met site. The contour values are in meters per second.

A quick literature search reveals a large number of papers relating wind speeds and wind gusts to the production of airborne dust and its mixing in the vertical and transport downwind (e.g. Countess Environmental, 2006; Kok et al. (2012), Lu et al. (2013), Wang et al. (2015)).

5. Conclusions

This brief report serves several purposes. It updates the air quality and meteorological data from the monitoring station in upper Aberdeen. Summaries of these data now extend from the initiation in mid-October 2015 to the end of February 2016. This report also calculates average values of $PM_{2.5}$ and PM_{10} from the KGHM Ajax upwind site and compares them to the Aberdeen site. It should be noted that though the upwind site is to the southwest of the proposed mine site there are no meteorological data that have been made available and so it is not been demonstrated that winds passing over the upwind site subsequently passed over the site of the proposed mine. Finally, this report summarizes the wind directions, wind speeds, and wind gusts at the KGHM Ajax Met site, which is located on the north side of Sugarloaf Mountain and thus has a poor exposure to winds from southwesterly directions.

In the KGHM Ajax Application for the proposed mine on the southern edge of Kamloops, they use an estimated value of 3.8 μg /m³ for the background concentration of fine particulates ($PM_{2.5}$). This is estimated from looking at a partitioning of emission sources in the urban area. This examination of average concentrations of $PM_{2.5}$ at the rural upwind site shows the background concentration for a 12 month period to be 2.5 μg /m³. This is a significant difference from what is in the Application and more in agreement with the expected value based on the literature and to the Steyn (2016) review of the air quality section of the Application.

An examination of the wind data from the KGHM Ajax met site shows a strong tendency for the winds to come from either the northwest or the south, with much lower frequencies from the southwest or northeast. This would be in agreement with terrain induced changes in prevailing wind directions as a result of the proximity of Sugarloaf Mountain to the southwest of the monitoring station. It also is a clear indication that terrain features in and around the proposed mine site do influence wind directions and thus the lack of any meteorological data from within the plant boundary of the proposed mine is a serious deficiency and could lead to a lack of understanding of the movement of particulate and gaseous pollutants from the mine site into the city of Kamloops.

Wind gusts are short-term high wind speed events that are very location dependent. They are important because the literature demonstrates that wind gusts distribute particulates from the surface in the vertical through the turbulent nature of the gusts. This then increases transport downwind by the prevailing winds. Wind gusts are not measured within the proposed plant boundary and are not modeled in the application for the proposed mine. Despite the poor location of the KGHM Ajax Met site it does provide some information on the maximum wind speeds in 15 minute time blocks. For the calendar year 2015 these values are typically low but the distribution extends out to a maximum value of 25.5 m/s, with half of the values greater than 3.8 m/s (13.7 km/h). Incorporating this distribution of wind gusts into the air quality modeling is important to both make it more realistic and to determine how wind gusts may impact calculated concentrations of downwind particulates.

Sources for the Data

The hourly measurements at the Aberdeen and downtown Federal Building monitoring stations in Kamloops 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. The meteorological data from the Ajax Met station on the north side of Sugarloaf Mountain and the upwind air quality station on the east side of the Lac Le Jeune Road were provided by the KGHM Ajax mine through the British Columbia Environmental Assessment Office.

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