Air Quality in Merritt, British Columbia

British Columbia Ministry of Environment

Thompson Region

Environmental Quality Section
Kamloops, British Columbia

March 2006

Air Quality in Merritt, British Columbia

Summary

Air pollution can have a number of adverse impacts on a community. Poor air quality can be a significant health risk, degrade visibility and negatively affect tourism[1]. The cumulative impacts of air emissions can prohibit or limit opportunities for local or regional economic expansion. Based on the current information that is currently available, we conclude the following:

1. **Smoke and dust are at concentrations that can negatively affect health and degrade visibility**. While the concentration of smoke in some areas of Merritt is similar to that in many other communities in British Columbia, certain residential areas, particularly near the industrial park, are probably experiencing higher concentrations. Dust concentrations are significantly higher throughout Merritt than in other B.C. community.
2. Sources of smoke include the industrial park (including Tolko Industries' beehive burner), forestry burning, vehicles and domestic heating. Sources of dust are the log-sort yards and similar unpaved areas in the industrial park, as well as road-traction material on local roads and highways.
3. The City of Merritt should create an air quality stakeholder committee that would draft an airshed plan to improve air quality.
4. An air quality monitoring program should be reinstated in Merritt to locate pollutant sources and to monitor the effects of a Merritt airshed plan.

Airborne particles discussed in this report are less than 10 microns (millionths of a metre) in diameter and are labelled ***PM_{10}****. These particles are commonly subdivided into a fine fraction and coarse fraction.*

The fine fraction consists of particles of 2.5 microns in diameter (or less), labelled ***$PM_{2.5}$****. Such particles are mostly associated with smoke and haze, so this document refers to them simply as "****smoke****."*

*The coarse fraction includes particles of 2.5 to 10 microns in diameter. These are mostly microscopic dust particles, so are referred to simply as "****dust****."*

Purpose of this Report

The purpose of this report is to characterize air quality in Merritt and to recommend courses of action to improve air quality. It does this by:

- Describing the historical air quality monitoring programs in Merritt.
- Explaining the characteristics and health effects of the main types of pollutants found in Merritt.
- Comparing air quality in Merritt to other locations in British Columbia.
- Identifying sources of air pollution.
- Outlining airshed management options.
- Recommending ways to protect and improve air quality over the long term.

[1] *Guide to Airshed Planning in British Columbia*, Ministry of Environment, Victoria B.C. March 2004. http://www.env.gov.bc.ca/air/airquality/pdfs/airshedplan.pdf

Air Quality Monitoring in Merritt

In 1990, the British Columbia Ministry of Environment began making measurements of airborne particles in Merritt. An air-quality monitoring instrument was installed on the roof of the South Central Health Unit, at the corner of Granite and Garcia Streets. Measurements were taken every six days for 14 years, until 2003. Through most of this period, the measured levels of inhalable particulate matter (PM_{10}) were among the highest recorded in the province.

In order to get more information about the nature and origin of the air pollution in Merritt, a partnership was formed to do a detailed set of air quality and weather measurements over a period of a full year. The partners were the City of Merritt, several of the industrial companies operating in the city, and the Ministry of Environment. Co-funded by the city and industry, a mobile air-monitoring station capable of detailed measurements of many types of pollutants was operated from May 1999 to June 2000. The station was placed in a vacant lot at the corner of Granite and Garcia streets, directly across the street from the South Central Health Unit, where the long-term measurements had been made.

Using all these measurements, an analysis of the air quality in Merritt was undertaken by the ministry. Only particulate matter (smoke and dust) and ozone occurred at concentrations high enough to be of any concern. The following discusses the specific characteristics, health effects and sources of these pollutants.

Airborne Particulates

PM_{10} refers to microscopic particles that are 10 microns (millionths of a metre) or smaller in diameter. PM_{10} is generally comprised of two types of particles.

The largest particles are composed primarily of rock and soil. For the purpose of this report, these particles of referred to as “dust.” When inhaled, most of these particles are deposited in the upper portion of the respiratory tract airways (nose, mouth, and throat). Dust has been shown to aggravate cough, phlegm, rhinitis and asthma and to produce other upper airway symptoms[2]. Dust particles are between 2.5 and 10 microns in diameter. In Merritt, these airborne particles originate primarily from the crushing of sand, silt and gravel by motor vehicles and industrial equipment, as well as natural sources. Dust is often repeatedly stirred up by traffic and by industrial equipment.

---

[2] *Human Health Effects of the Coarse Fraction of Particulate Matter: Update in Support of the Canada-Wide Standards for Particulate Matter and Ozone*. Prepared for the Canadian Council of Ministers of the Environment March 2003

The smallest types of airborne particles are associated with smoke and haze. These extremely small solid and liquid particles (less than 2.5 microns in diameter) are composed of various chemicals, including sulphates, nitrates, organic carbon and elemental carbon. These particles are designated as $PM_{2.5}$. Smoke and haze particles are a byproduct of burning wood and fossil fuels. They are also produced by atmospheric chemical reactions involving volatile organic compounds (VOCs), sulphur dioxide (mostly from industry), nitrogen oxides (from vehicles and burning) and ammonia (from agriculture). VOCs are hydrocarbons and related gases. They are emitted both by humans and natural sources

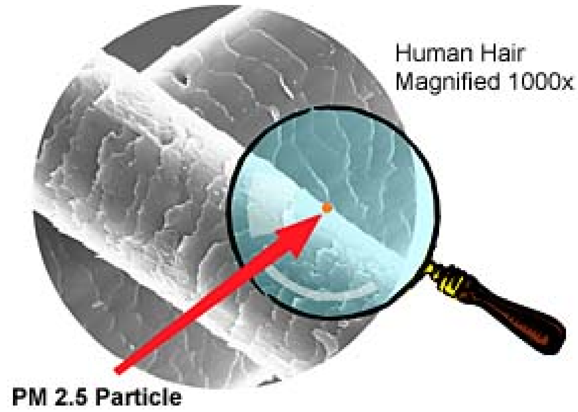

Figure 1 PM2.5 particles are less than 2.5 microns in diameter. They are so small that 30 of them side-by-side would barely equal the width of a human hair. Coarse particles (primarily dust, between 2.5-10 microns in diameter) are larger, but they are still much smaller than the width of a human hair.

In Merritt, the main sources of smoke and haze are industry, open burning, wood-burning appliances and motor vehicles.

The Provincial Health Officer, in his 2003 annual report[3], noted that smoke and haze particles are more hazardous to health than dust particles, since they are inhaled more deeply, and tend to deposit in the airways and tissues of the lungs. They can even enter the blood stream. They contribute to chronic lung conditions and have specifically been shown to aggravate asthma, bronchitis, respiratory infections, and cardiac conditions. Smoke and haze have also been shown to increase the risk of lung cancer and depressed lung function. Research has shown that there is no threshold below which smoke has no health effects. Therefore reducing smoke concentrations by any amount improves health[3] and is the most effective way of reducing adverse health effects in Merritt due to adverse air quality.

Ozone

Ozone is a gas composed of three atoms of oxygen. It is a strong oxidant that can increase the severity of acute respiratory disease, reduce lung function, and aggravate asthma and bronchitis. Ozone is produced in the atmosphere when nitrogen oxide gases (emitted by natural sources, burning and motor vehicles) and volatile organic compounds (from both human and natural sources) react in the presence of sunlight, particularly during hot weather.

---

[3] *Every Breath You Take…. Provincial Health Officer's Annual Report 2003, Air Quality in British Columbia, A Public Health Perspective*. B.C. Ministry of Health Services, Office of the Provincial Health Officer. Page 13. and *A Citizen's Guide to Air Pollution*, David Bates, Robert Caton, 2002.

Other Air Pollutants in Merritt

Additional pollutants that were monitored in Merritt in 1999 and 2000 included carbon monoxide, nitrogen oxide, nitrogen dioxide and sulphur dioxide. Maximum concentrations of carbon monoxide, a product of incomplete combustion largely from vehicle emissions, were higher in Merritt than Kamloops or Kelowna. Maximum concentrations of nitrogen oxides and sulphur dioxide were similar to those in Kamloops, Kelowna and Vernon. The maximum concentrations of all these pollutants in Merritt are well below the B.C. Level A objectives, which represent the most stringent provincial criteria. Table 1 lists the concentrations at Merritt and at other southern Interior locations.

Table 1. Maximum pollutant concentrations (other than ozone and particulate matter) at the Granite-Garcia site in Merritt, with comparisons to other dry southern Interior locations. Merritt data is for the period May 1999 to May 2000, while data for other cities is for 2004. Units are micrograms per cubic metre.

	Carbon Monoxide		**Nitrogen Dioxide**		**Nitrogen Oxide**		**Sulphur Dioxide**	
Units: *micrograms per cubic metre*	Maximum 1 hour	Maximum 8 hour average	Maximum 1 hour	Maximum 24 hour average	Maximum 1 hour	Maximum 24 hour average	Maximum 1 hour	Maximum 24 hour average
Merritt Granite-Garcia	3400	2063	94	63	223	99	16	4
Kamloops Brocklehurst	2200	1471	78	61	206	112	48	8
Kelowna	2900	1729	86	59	246	63	8	3
Vernon			84	58	336	142		
B.C. Level A Objective	14300	5500	400	200	NA	NA	450	160

Comparison to Other Communities

Concentrations of dust are high in Merritt compared to other British Columbia communities[4]. Figure 2 shows that concentrations of PM_{10} (combination of dust and, to a lesser extent, smoke) at Merritt are considerably higher than those in Kamloops and Chilliwack, while $PM_{2.5}$ concentrations are similar. Kamloops was chosen for this comparison because it has a similar dry Interior climate to that of Merritt. Chilliwack was chosen because it is downwind of Greater Vancouver, a significant source of pollutants.

[4] *Particulate Matter in British Columbia – A Report on PM_{10} and $PM_{2.5}$ Mass Concentrations up to 2000*. May 2003. B.C. Ministry of Water, Land and Air Protection (now the Ministry of Environment) and Environment Canada. Page 41.
http://www.env.gov.bc.ca/air/particulates/pdfs/pmreport_final/pmreportfinal_feb04.pdf

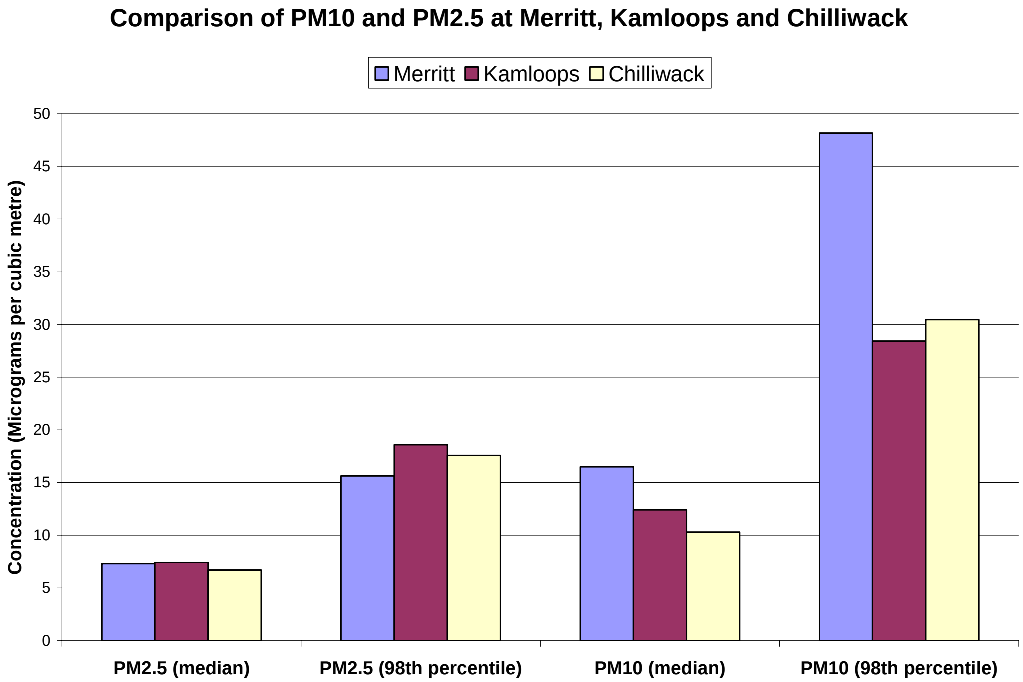

Figure 2. Comparison of the concentration of PM_{10} (smoke and dust) and $PM_{2.5}$ (smoke) at three communities in southwestern British Columbia. The median and 98th percentiles of these concentrations suggest that the concentration of dust is considerably higher in Merritt, while the concentration of smoke is about the same in each community. The 98th percentile is a measure of extremely high concentrations. Data is from May 1999 to June 2000.

Although smoke concentrations measured in downtown Merritt are very similar to Kamloops and Chilliwack, certain residential areas, particularly near the industrial park, are likely experiencing higher smoke concentrations, based on a preliminary analysis of existing air quality and wind data. This will be dealt with in detail in Appendix A.

Ozone concentrations in the dry, sunny areas of the southern Interior are relatively uniform, as shown by a comparison of Merritt to other communities using a measure called the Canada-wide Standard (Table 2). The Canada-wide Standard (CWS) for ozone is 65 parts per billion (8-hour average). The CWS yardstick for an individual community is based on the fourth-highest daily-maximum ozone concentration during each year. Where enough data exists, this value is averaged over three years. The vast majority of ozone is assumed to be generated outside Merritt and it is unlikely that concentrations are strongly influenced by activity within the city. As a result, this report will focus on smoke, haze and dust — the pollutants that the City of Merritt can influence most directly.

Table 2. Comparison of ozone concentrations in Merritt to those in Kamloops and Chilliwack, using the Canada-wide Standard yardstick. Ozone concentrations are slightly lower in Merritt. See text for an explanation of the Canada-wide Standard.

Units: parts per billion	**Canada-wide Standard Metric for Ozone**
Merritt	54 [5]
Kamloops	60
Kelowna	58

Air Pollution Sources in Merritt

A detailed assessment of the sources of pollutants in Merritt has not been done yet. This section is a preliminary, qualitative source apportionment to help identify leading sources of smoke and dust. This will be done by analyzing smoke and dust measurements in downtown Merritt, and relating these to simultaneous wind measurements. This allows the identification of the wind directions from which the highest smoke and dust concentrations are observed. Therefore, the probable sources of emissions can be inferred. More data is necessary to confirm the findings in this section. A possible monitoring program to obtain these new data is outlined in the appendix.

Sources of Smoke and Haze ($PM_{2.5}$)

As noted in a previous section, the main sources of smoke and haze in Merritt are industry, open burning, wood-burning appliances and motor vehicles. Although smoke concentrations in downtown Merritt are similar to other B.C. communities, an analysis of pollutant concentrations and wind information in downtown suggests that smoke concentrations near the industrial park are likely higher. If so, this smoke would pose an increased health risk to neighbourhoods adjacent to the industrial park. Increased smoke concentrations near the industrial park also would suggest that the park likely contributes to the general degradation of air quality throughout Merritt. This is the conclusion of an analysis of air quality data from the monitor at the corner of Granite and Garcia streets, 1.35 kilometres north-northeast of the beehive burner (location shown in Figure 3).

This analysis showed that, under brisk wind speeds only, smoke concentrations at ground level were significantly higher when winds blew from the direction of the industrial park (200 degrees, or south-southwest) compared to when similarly brisk winds blew from most other directions from the southeast through west-southwest. This is shown in Figure 4 and Figure 9. Appendix A contains more information on this analysis, including the rationale for focusing on specific wind conditions and on the estimated amounts of smoke that can be attributed to the beehive burner and other sources in the industrial park. Additional monitoring is required to increase our understanding of the smoke emissions from the industrial park and their relative contribution to air quality degradation in Merritt.

---

[5] Merritt measurement based on only one year of data. Other measurements are based on three years of data.

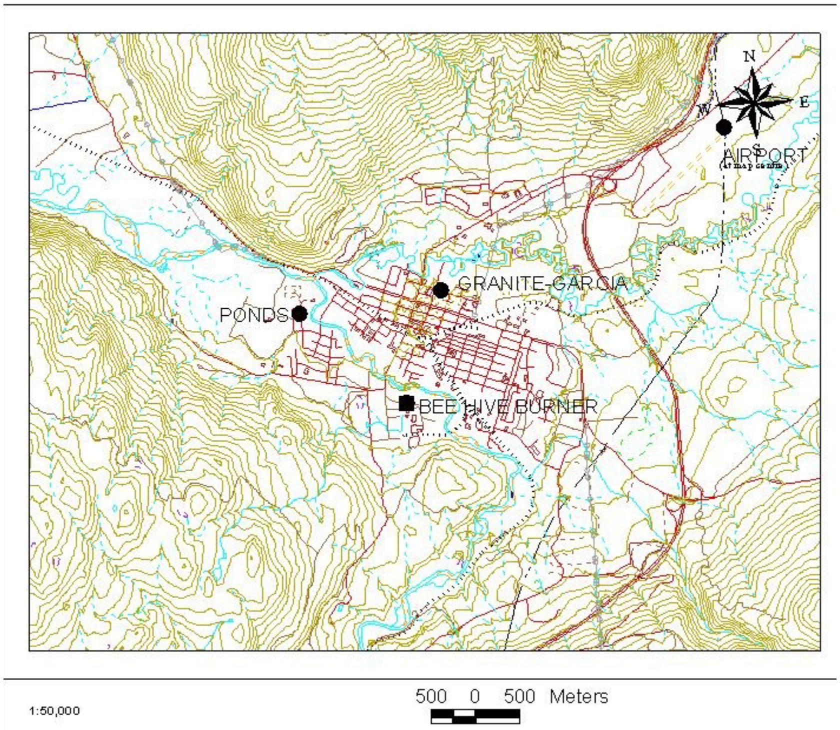

Figure 3. City of Merritt, with the location of the beehive burner and the air quality monitoring sites at Granite-Garcia, sewage treatment ponds, and the Merritt Airport in the 1990s and early 2000.

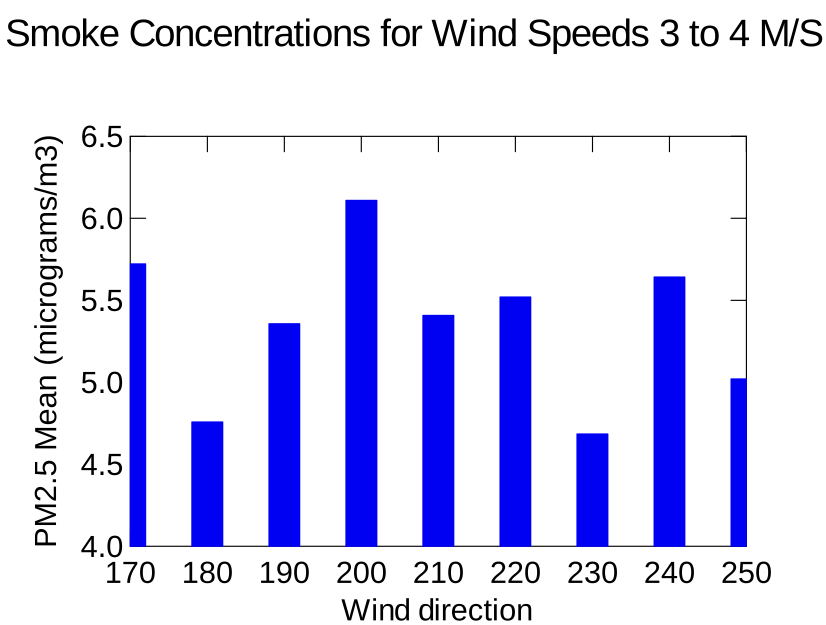

Figure 4. Average $PM_{2.5}$ concentrations in downtown Merritt during brisk wind speeds of 3 to 4 metres per second (m/s) from May 1999 to May 2000 for winds from the 170 degrees (south-southeast) through 250 degrees (west-southwest). The beehive burner is in the direction of 200 degrees from the monitor.

Information from air quality and weather monitoring in Merritt also showed that, when all wind speeds were considered, smoke concentrations are usually highest when winds are light. This would suggest that sources of smoke in Merritt are within, or very close to, the city. In addition to the industrial park, these sources probably include wood-stove space heating, backyard burning, automobiles and local agricultural and forestry burning. Most of the periods of high concentrations occurred in the fall and early winter, when a persistent temperature inversion in the lower atmosphere is most common. This atmospheric condition reduces dispersion of pollutants and leads to a build-up of pollutants over time.

Sources of Dust

As noted earlier, dust concentrations are generally higher in Merritt than in other cities in British Columbia[6]. Table 3 also shows that the concentration of PM_{10} (dust plus smoke) is higher inside the city (Granite-Garcia Streets, and the nearby sewage treatment ponds) than outside at sites such as the airport (3.5 km northeast of downtown). Since the majority of PM_{10} is generally dust, this table suggests that the main source of dust is *within* the city, rather than outside.

Table 3. Concentrations of PM_{10} (dust, plus smoke) at three sites in Merritt: Granite-Garcia, near downtown; the sewage treatment ponds on the western edge of downtown; and the Merritt Airport, about 3.5 kilometres northeast of the downtown (see Figure 2 in Appendix A). Median concentrations are the middle value of all concentrations. The 98th percentile is a standard measure of an extremely high concentration. Concentrations of PM_{10}, which is mostly dust, are generally the highest in or near the downtown core. Data is from May 1999 to June 2000.

Units: Micrograms per cubic metre	**Granite-Garcia** near downtown	**Merritt Airport** 4 km northeast of downtown	**Sewage Treatment Ponds** Western edge of downtown
maximum	53	42	45
median	17	11	17
98 percentile	49	32	43

The log-sort yards at Aspen Planers are a major source of dust when they are operating. This is illustrated in Figure 5, which shows a sharp decrease in PM_{10} concentrations when the log-sort yards closed in late 1998 and then an abrupt rise in concentrations when they were reopened in 2002.

[6] *Particulate Matter in British Columbia, A Report on PM_{10} and $PM_{2.5}$* B.C. Ministry of Water, Land and Air Protection (now the Ministry of Environment) and Environment Canada. Page 41 http://www.env.gov.bc.ca/air/particulates/pdfs/pmreport_final/pmreportfinal_feb04.pdf

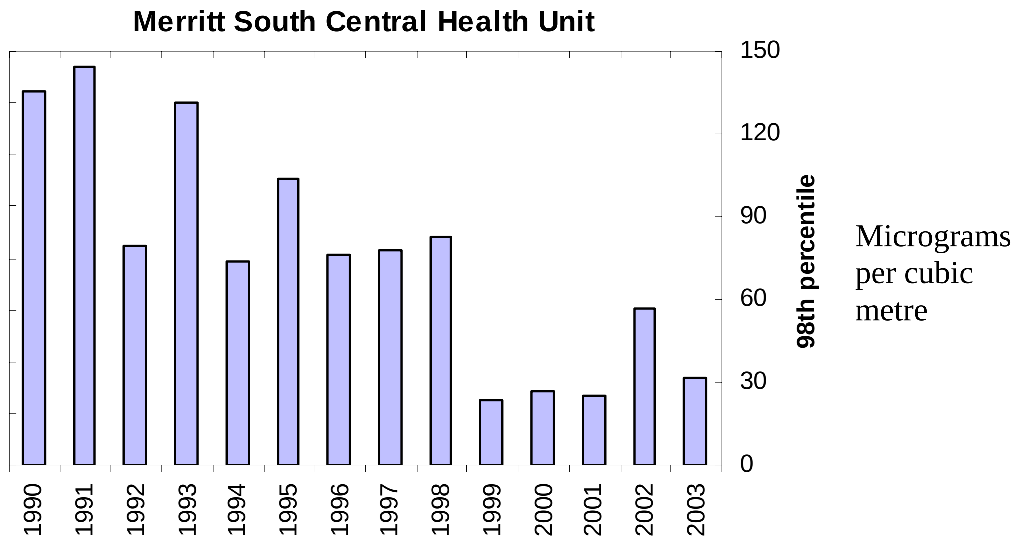

Figure 5. Annual concentrations of PM_{10} (mostly dust) in the City of Merritt from 1990 to 2003 in micrograms per cubic metre. Concentrations were higher prior to 1999 when the works yard at Aspen Planers was operating. Concentrations rose again in 2002 when the works yard resumed operations. The graph is a measure of one of the highest annual concentrations. Specifically, the values shown are the "98^{th} percentile," which is a measure of the 8^{th} highest daily PM_{10} concentrations each year.

Air quality monitoring in 1999 and 2000 also showed that dust was more likely to occur in Merritt when the wind direction at the Granite-Garcia monitoring site was from the general area of the industrial park (190 to 230 degrees inclusive, or SSW through SW). This again suggests that large quantities of dust are contributed by the industrial park and other sources in those directions.

Further analysis of air quality data in downtown Merritt (Figures 6 and 7) reveals that concentrations of dust vary with differing wind and weather conditions, the day of the week and the season:

- The graphs in Figure 6 show that dust concentrations are higher on weekdays, during both light and strong winds. This suggests that traffic and industry are major sources of dust, since both of these are more active producers of dust during weekdays.
- These graphs also show that concentrations of dust in downtown Merritt are higher with strong winds, suggesting that significant sources of dust are originating outside of the downtown area.
- The graphs in Figure 7 show that concentrations have two seasonal peaks:
    1. During February and March, likely related to the drying out of road-traction material spread on areas roads during winter.
    2. During August, with highest concentrations during brisk winds. These winds are common in Merritt during summer afternoons. The source of this dust is likely the intense drying of exposed soil in forested and agricultural areas to the southwest of the city, as well as the log-sort yards in the industrial area.

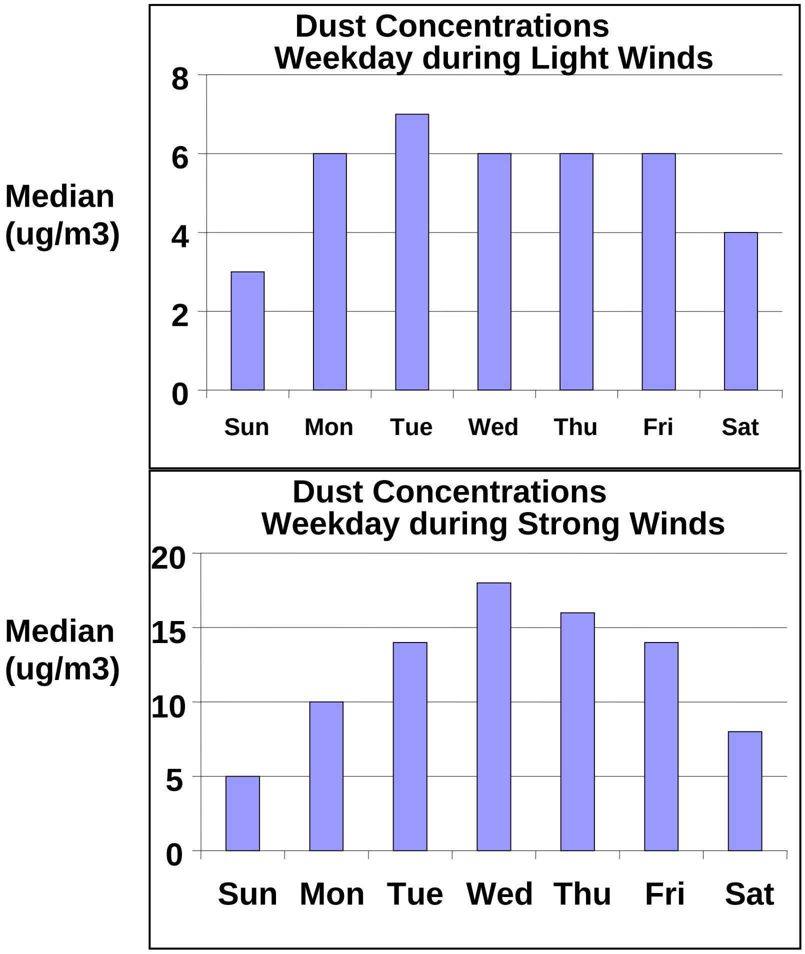

Figure 6. Median concentrations of dust in downtown Merritt for each weekday during light winds (0-4 m/s) and strong winds (above 4 m/s).

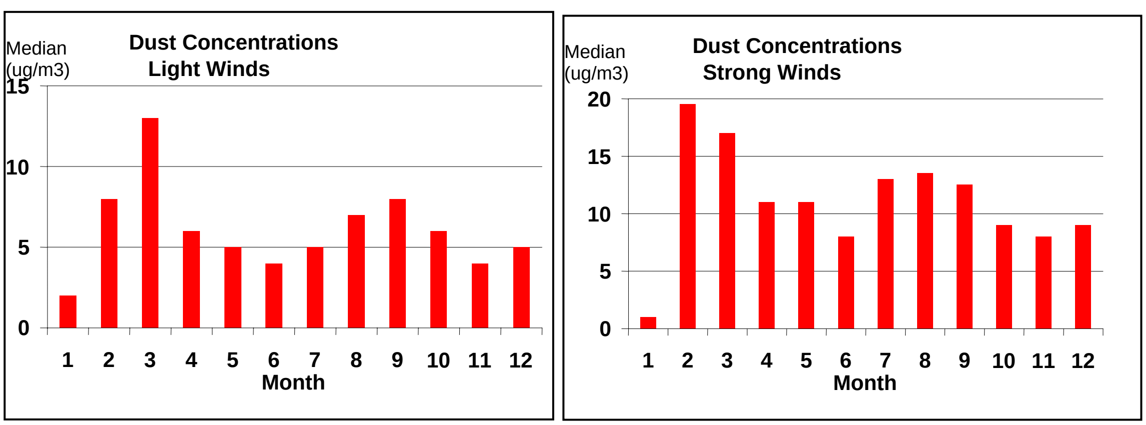

Figure 7. Median concentrations of dust in downtown Merritt for each month of the year during light winds (0-4 m/s) and strong winds (above 4 m/s)

Air Quality, Growth and Economic Development

The cumulative impacts of air emission sources can prohibit or limit opportunities for local or regional economic expansion[7]. Reducing the emission of smoke and dust will improve the aesthetics of Merritt and the health of its citizens. This should enhance economic growth and development of the city. Also, disposing of wood waste (or residue) using clean-burning technology could increase economic development by providing a readily available fuel.

Reductions in pollutant emissions in Merritt will also help British Columbia meet the Canada-wide Standard and its provisions for "Continuous Improvement" and "Keeping Clean Areas Clean," recognizing that polluting up to a limit is not acceptable and that the best strategy is to keep clean areas clean This standard was adopted by the Canadian Council of Ministers of the Environment (CCME) in June, 2000.

Possible Approaches to Managing Air Quality in Merritt

Specific steps can be taken to reduce the discharge of both dust and smoke in and around Merritt.

- The City of Merritt could review its burning bylaws to address air quality problems related to industrial emissions, the misuse of wood stoves and the use of backyard boilers.
- Zoning in Merritt could be reviewed to determine if sufficient buffering is being allowed between the industrial park and new development.
- The city could review the spreading of road-traction material in winter and its removal in spring in order to identify ways to reduce this material as a dust source. Best management practices (BMPs) have recently been developed in British Columbia to address this issue[8].
- Industry could continuously wet down and remove dust in the log-sort yards and other sites in high traffic areas of the industrial park. Yards could also be paved.
- Industry could install wind breaks at the log-sort yards to reduce the dust problem.
- Industry could divert wood waste to cogeneration facilities or other operations that efficiently burn wood waste so that the beehive burner can be phased out of operation.
- These and other suggestions could best be provided to the city by an air quality stakeholder committee, which would draw on the expertise of industry, ENGOs, governments, the public, the Interior Health Authority and other interested parties.

Conclusions

1. There are two distinct air pollutants of concern in Merritt that are controllable: smoke (and haze) particles, and dust particles. These microscopic particles contain different ingredients, have different sources and result in different health and visibility impacts.

---

[7] *Guide to Airshed Planning in British Columbia*, Ministry of Environment, Victoria B.C. March 2004.
[8] *Best Management Practices to Mitigate Road Dust from Winter Traction Materials*, Ministry of Environment, 2005. http://www.env.gov.bc.ca/air/airquality/pdfs/roaddustbmp_june05.pdf

2. Smoke concentrations in Merritt can negatively impact health and reduce visibility. While the concentration of smoke and haze in some areas of the city is similar to that in many other communities in British Columbia, some residential areas, particularly near the industrial park, are probably experiencing high concentrations. Sources of smoke and haze particles include industry, agricultural and forestry burning, vehicles and domestic heating. Smoke particles have been shown to increase the risk of premature death and to harm the very young and those with existing cardiac or respiratory conditions. Smoke particles at all concentrations degrade health, so current smoke concentrations are contributing to chronic illness[9]. Therefore, any reduction in smoke concentrations will have a beneficial effect.
3. Dust concentrations are significantly higher in Merritt than in other British Columbia communities. High concentrations of dust have been shown to aggravate existing respiratory conditions and increase illness in susceptible individuals. The main sources of dust are the log-sort yards and other unpaved areas in the industrial park, as well as road-traction material on local roads and highways.
4. The beehive burner is perceived by residents to be a large source of smoke and haze in Merritt and is a cause of numerous complaints about air quality. The beehive burner also degrades the views of the city and the surrounding mountains, and contributes to reduced visibility. Future plans for this burner need to be identified.

Recommendations

It is important to protect and improve the air quality in the Merritt area for the health of its population now and in the future. The Ministry of Environment recommends two further steps:

1. **The City of Merritt should create an air quality stakeholder committee.** This committee would recommend a plan to improve and protect air quality in the city. It would be chaired by a municipal official and include representation from industry, First Nations, governments, the agricultural community, the health sector, non-government organizations and the public. It would have a terms of reference that would include a feasible set of goals that would be achieved in a specific time period. The Ministry of Environment will contribute $3500 to facilitate discussion at a public forum on air quality in support of the work of this committee. This forum would have to be held this fall or winter. Appendix D briefly lists some possible goals of an air quality stakeholder committee.
2. **Air quality monitoring should be resumed in Merritt.** The Ministry of Environment will contribute equipment and expertise to reinstall air quality monitoring equipment to better identify the sources of dust, smoke and haze. This would support the work of the air quality stakeholder committee. Some in-kind and financial assistance will be required from stakeholder partners to renew the monitoring program, which is described in Appendix C.

[9] *Every Breath You Take: Air Quality in British Columbia, A Public Health Perspective. The Provincial Health Officer's Annual Report 2003*. Pp 13, 19, 30 and 54. British Columbia Ministry of Health Services

For more information, contact:

Eric Taylor,
Air Quality Meteorologist, Environmental Quality Section
Thompson Region
British Columbia Ministry of Environment
1259 Dalhousie Drive
Kamloops, British Columbia
V2C 5Z5

E-mail: Eric.Taylor@gov.bc.ca.
Phone: (250) 371-6296.
Fax: (250) 828-4000

Ralph Adams
Head, Environmental Quality Section
Thompson Region
British Columbia Ministry of Environment
1259 Dalhousie Drive
Kamloops, British Columbia
V2C 5Z5

E-mail: Ralph.Adams@gov.bc.ca
Phone: (250) 371-6279
Fax: (250) 828-4000

Appendix A: The Merritt Beehive Burner

Detection of Smoke from the Beehive Burner

One large and visible source of $PM_{2.5}$ in Merritt is the beehive burner, operated by Tolko Industries, but used by other forest product companies. Even when the burner is operating at high temperatures, a plume is highly visible at some distance from the burner. This section will show that elevated smoke concentrations were detected at the Granite-Garcia monitoring site when brisk winds were blowing from the direction of the Merritt beehive burner during the period May 1999 to May 2000.

The detection of burner smoke was carried out as follows.

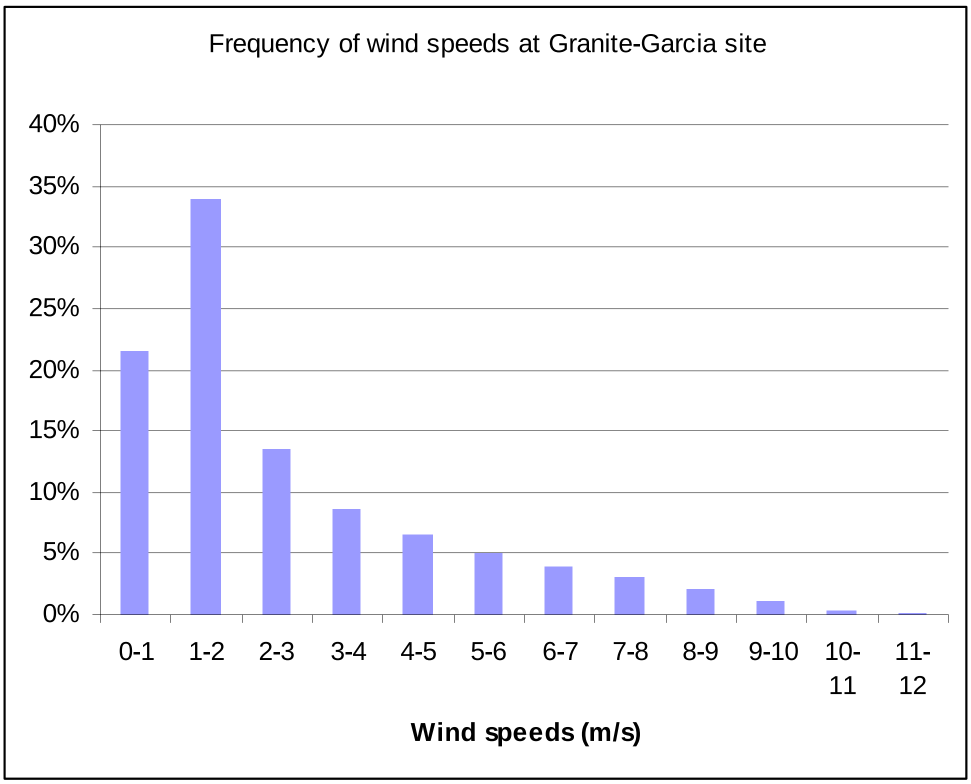

Figure 8. Frequency of hourly wind speeds at Granite-Garcia site for all wind speed categories from May 1999 to June 2000. 55% of all hourly winds were less than 2 metres per second (m/s).

Figure 8 shows that winds are usually light (less than two metres per second) in Merritt. Light winds generally have highly variable directions. Smoke emitted by the beehive burner or any other source under light wind conditions would gradually disperse throughout the airshed, but this smoke may arrive at distant monitors from many directions because of the light and variable nature of the winds. This makes the remote detection of smoke from any source difficult during light and variable winds.

Therefore, to see if the Granite-Garcia monitor had detected increased concentrations of smoke when winds blew from the direction of the burner, an analysis of $PM_{2.5}$ concentrations was made *only during brisk wind conditions* when smoke would have travelled quickly in a relatively straight line from the burner, a direction of 200 degrees. Wind speeds of three or four metres per second were chosen for this analysis. Specifically, we tested whether the $PM_{2.5}$ concentrations were higher from the direction of the burner compared to concentrations when the wind was blowing from nearby directions. Using box plots of concentrations from all directions, coupled with a statistical analysis, Figure 9 shows that there are significant peaks of concentration at 200 (the burner direction), 80 and 260 degrees from Granite-Garcia.

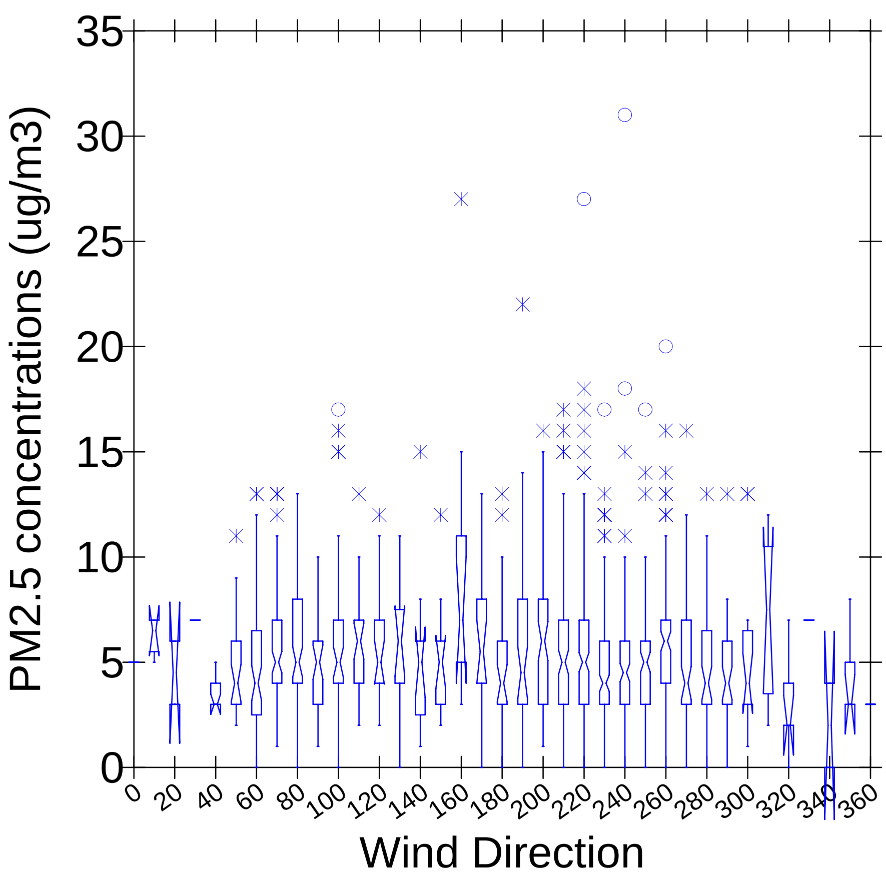

Figure 9. Box plots of the 1619 hourly concentrations of $PM_{2.5}$ at the Granite-Garcia site from all directions when wind speeds were 3 or 4 metres per second during the entire year of monitoring. The narrowest part in the middle of each box is the median concentration. Each box returns to full width when the 95% confidence level for the median value has been reached. Smoke concentrations reach local maximums at 200, 160, 80, 260 and 310 degrees. The 95% confidence limits are too wide for several of these directions to be able to confidently make conclusions, but there is confidence that there are local maximums of $PM_{2.5}$ concentrations when winds blew from directions 200, 80 and 260 degrees.

To specifically test the concentrations at the 200 degree direction, we compared the group of smoke concentrations from 200 degrees with those from 230 degrees. As in the box plot graph, winds below three m/s (9 km/hr) were ignored because these wind speeds were considered too light, with highly variable directions. Winds above four m/s (16.2 km/hr) were also ignored because there were not enough instances of hourly winds blowing from the 230 degree direction at those speeds. Table 4 shows the mean and standard deviation of the $PM_{2.5}$ hourly concentrations from both wind directions 200 and 230 degrees. Table 5 shows that these two sets of hourly concentrations are significantly different from each other, and that different source strengths are likely present.

This analysis suggests that there is a significant increase in smoke at the Granite-Garcia site when winds blow from the direction of the burner. Two other directions (80 and 260 degrees) also had significant increases, so other point sources could be significant contributors of smoke to the airshed.

Table 4. Mean and standard deviation of hourly $PM_{2.5}$ concentrations at the Granite-Garcia monitoring site when brisk winds were blowing from either 200 or 230 degrees (SSW or WSW). The beehive burner is in a direction of 200 degrees from the monitor. Observations were only analyzed when the wind speed at the monitor was 3 or 4 metres per second.

Wind Direction	Number of Hours of Brisk Winds	Mean $PM_{2.5}$ Concentration	Standard Deviation of $PM_{2.5}$ Concentration
From 200 degrees (Burner direction)	73	6.110 $\mu g/m^3$	3.588
From 230 degrees	148	4.676 $\mu g/m^3$	2.691

Table 5. The difference in the average concentration of smoke ($PM_{2.5}$) at the Granite-Garcia site when winds were blowing either from direction 200 or direction 230.
This table shows that the difference in these average concentrations is significant, implying that we are more than 99% confident that smoke concentrations are higher when brisk winds are blowing directly from the beehive burner (direction 200) than when they are blowing from direction 230. The difference in means (1.43 $\mu g/m^3$) is assumed to be the contribution of the emissions from the beehive burner.

Separate Variance	Pooled Variance
Difference in means = 1.434 $\mu g/m^3$	Difference in means = 1.434 $\mu g/m^3$
95.00% CI = 0.478 to 2.389 $\mu g/m^3$	95.00% CI = 0.550 to 2.318 $\mu g/m^3$
t = 2.972	t = 3.196
df = 119.5	df = 219
p-value = 0.004	p-value = 0.002

Estimation of $PM_{2.5}$ Closer to the Beehive Burner

During the brisk wind conditions that were analyzed in this part of the study, $PM_{2.5}$ concentrations downwind from the burner are roughly estimated in Table 6. This estimate assumes that the burner is contributing an average of 1.43 $\mu g/m^3$ to the ambient concentrations at the Granite-Garcia site, since this was the average difference in concentrations between the two wind directions. The estimate in column 2 assumes that this contribution varies by the inverse of the square of the distance from the burner. This latter assumption would not be valid near the ground very close to the burner, as the plume will be concentrated well above the ground.

To confirm that the estimates in column three in Table 6 are not unreasonable, SCREEN3, a Gaussian plume air-quality-dispersion model was used to estimate concentrations downwind from the burner. Only wind speeds of three metres per second were used, and five atmospheric stability classes were used. Columns four to eight in Table 6 provide the SCREEN3-estimated $PM_{2.5}$ concentration downwind from the burner when the wind is blowing towards the Granite-Garcia site and the concentration at this site is fixed at 6.11µg/m^3. This table shows that the simple inverse-square estimates are within the range of estimates provided by SCREEN3 over the set of five stability classes and are therefore not unreasonable.

Table 6. Estimates of the average concentrations of $PM_{2.5}$ at selected distances downwind from the beehive burner when the wind speed is set at 3 m/s. An inverse square technique as well as a dispersion model called SCREEN3 was used to estimate these concentrations. Five atmospheric stability classes were used with SCREEN3, with A being very unstable, C and D being neutral stability and E being very stable. The concentration at 1.35 km from the burner was fixed as the measured average concentration at Granite-Garcia (6.11 µg/m^3) when wind was blowing directly from the burner.

Distance from the Burner (km)		**Inverse Square Estimate** (µg/m^3)	**SCREEN3 Estimate** (µg/m^3) Stability Class A	**SCREEN3 Estimate** (µg/m^3) Stability Class B	**SCREEN3 Estimate** (µg/m^3) Stability Class C	**SCREEN3 Estimate** (µg/m^3) Stability Class D	**SCREEN3 Estimate** (µg/m^3) Stability Class E
1.35	Measured at Granite-Garcia site	**6.11**	**6.11**	**6.11**	**6.11**	**6.11**	**6.11**
1	*Estimated concen-trations*	*7*	*7*	*7*	*7*	*7*	*6*
0.5		*10*	*15*	*15*	*12*	*9*	*6*
0.3		*13*	*29*	*29*	*19*	*11*	*5*
0.2		*18*	*50*	*50*	*27*	*8*	*6*

The analysis using SCREEN3 indicates the potential for higher concentrations occurring closer to the beehive burner than what occurs at Granite-Garcia under certain meteorological conditions. The SCREEN3 analysis also indicates that it would be reasonable to conduct a more detailed modeling study to consider all meteorological conditions and to consider monitoring at locations near the beehive burner to confirm these results.

From this analysis, we conclude that:

1. During brisk wind conditions, air blowing from the direction of the beehive burner (200 degrees) had significantly higher concentrations of $PM_{2.5}$ than air blowing from

other nearby directions. This suggests that the burner may be contributing to elevated surface concentrations of $PM_{2.5}$ (smoke) in Merritt

2. Within a few hundred metres of the burner, $PM_{2.5}$ concentrations are likely higher and almost certainly pose an increased health risk. Further monitoring of smoke is necessary in residential areas close to the burner to improve our understanding of smoke concentrations there. Future monitoring is addressed in Appendix C.

Summary

- Smoke concentrations at the Granite-Garcia site were about 1.4 $\mu g/m^3$ higher when brisk winds blew from the direction of the beehive burner, compared to concentrations when brisk winds blew from most other directions. The Granite-Garcia site is 1.35 km to the north-northeast of the burner. One assumption is that the burner was responsible for the average 1.4$\mu g/m^3$ increase. If this assumption is correct, one rough estimate is that the median concentration of smoke (during brisk winds) between 200 and 300 metres of the burner is between 13 and 18 $\mu g/m^3$ as shown in Table 6. This is a high median concentration and suggests that the Reference Health Level for $PM_{2.5}$ of 15 $\mu g/m^3$ would be frequently exceeded within 300 metres of the burner.

- The beehive burner is likely affecting ground-level air quality in Merritt and the local effects in the neighbourhoods surrounding the burner are probably the most critical.

- Additional monitoring is required to increase our understanding of the smoke emissions from the industrial park and their contribution to air quality degradation in Merritt.

Appendix B: A Proposal to Revive an Air Quality Monitoring Program in Merritt

Objective of Monitoring Air Quality in Merritt

Continuous monitoring of gases and particulate occurred in 1999 and 2000 at the corner of Granite and Garcia Streets. At that time, less expensive noncontinuous monitoring was also operating at the Merritt Airport and near the sewage treatment ponds.

Some further monitoring of air quality is necessary to:

- Determine how much of the smoke and dust originates in the industrial park
- Estimate the concentration of smoke and dust in residential areas near the industrial park
- Determine if air quality in Merritt has changed since monitoring was in place in 2000, and assess the effectiveness of any future program to curb emissions.

Estimated Monitoring Program

A cost-effective monitoring program to meet these objectives would include the noncontinuous monitoring of smoke and dust at the Granite-Garcia site and at locations north and south of the industrial park. This would require five noncontinuous monitors to measure pollutants at the locations in Table 7.

Table 7. Possible future locations of particulate monitors to assess particulate concentrations and to better identify mission sources.

Location	Pollutants to Be Measured
Granite and Garcia Street intersection	$PM_{2.5}$ and PM_{10} (two monitors)
North of the industrial park	PM_{10}
South of the industrial park	PM_{10}
Near the industrial park	$PM_{2.5}$

Equipment

The Ministry of Environment is willing to contribute most of the equipment for this program, including the two monitors at the Granite and Garcia site, and the two monitors north and south of the industrial park.

Partners in this project could contribute by purchasing an additional Partisol monitor to measure $PM_{2.5}$ near the industrial park. This monitor will remain in the Merritt airshed at the end of this monitoring program for use by the community. The cost of a Partisol monitor is $9,000.

Operational Requirements

Operational costs associated with these noncontinuous particulate monitors include maintenance, the analysis of the filters and a dedicated person to change the filters once every six days. The Ministry of Environment is willing to provide much of the maintenance costs and will be able to provide funds for the analysis of filters from two of the five monitors.

Partners could contribute to the operation of the monitoring equipment for one year by providing $1000 towards maintenance, and funds to analyze filters from three of the five monitors. Additionally, partners could contribute by providing a person to change the filters regularly every 6th day.

Estimates of Possible Costs

Possible capital and operational costs for this revived monitoring program are in the following tables:

Table 8. Capital Cost Estimate

Organization		Capital Cost Item	Capital Cost
Ministry of Environment		One Partisol Monitor and three Hi-Vol Monitors	$36,000
Ministry of Environment		One meteorological monitoring station	$10,000
	TOTAL MoE Capital		**$46,000**
Partner		One Partisol Monitor	$9,000
	TOTAL Partner Capital		**$9,000**

Table 9. Operational Cost Estimate (annual)

Organization		Annual Operational Activity	Annual Cost
Ministry of Environment		Laboratory analysis of filters for two monitors	$2,600
Ministry of Environment		0.25 equivalent of a full-time employee[10]	$20,000
	TOTAL MoE Operational		**$22,600**
Partner		Laboratory analysis of filters for three monitors	$3,900
Partner		Financial assistance towards maintenance	$1,000
Partner		0.1 equivalent of a full-time employee[11]	$8,000
	TOTAL Partner Operational		**$12,900**

[10] The ministry will provide expertise to install, operate and maintain the equipment, to train staff to change the filters, to record and analyze the data, and to report the results.

[11] A partner is needed to provide a person to change the filters for all five monitors every six days. A filter change for all monitors will take approximately two hours.

Appendix C: Goals of a Possible Merritt Airshed Management Plan

A stakeholder air quality committee would oversee the development of a City of Merritt airshed management plan. Some suggestions for possible goals of such a plan are:

1. Improve our understanding of air quality problems in the city and the sources of air pollutants.
2. Develop a plan to reduce the discharge, or the impacts of, dust and smoke in the most appropriate way. This will require a joint effort by all the partners of the committee. This plan should specifically identify ways to reduce the emissions from the beehive burner that is negatively affecting air quality. It could also include a process to ensure that future residential areas are sufficiently distant from current and future industrial sites in order to protect the health of all citizens now and in the future.
3. Implement emission-control measures and zoning changes through cooperation with industry, the public, and municipal, provincial and federal partners.
4. Evaluate and report on the effectiveness of these emission controls through ongoing monitoring of the air quality and emission controls.

The Ministry of Environment has developed a detailed *Guide to Airshed Planning in British Columbia*[12] that provides important information for communities about setting up an airshed management plan.

[12] Published in 2004 by the British Columbia Ministry of Environment. http://www.env.gov.bc.ca/air/airquality/pdfs/airshedplan.pdf