Ministry of Water, Land &
Air Protection
KOOTENAY REGION

Ambient Air Quality Monitoring Report
Radium Hot Springs, British Columbia

Particulate Matter since 1998

ENVIRONMENTAL QUALITY

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Ambient Air Quality Monitoring Report
Radium Hot Springs, British Columbia

Particulate Matter Since 1998

Prepared by:

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January 2005

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BRITISH COLUMBIA

Executive Summary

There is mounting evidence that airborne particulate matter poses a significant health concern. The Ministry of Water, Land and Air Protection (MWLAP) has instituted a network for the monitoring of airborne particulate matter. This report was compiled by the MWLAP in an effort to inform the public, local government, and industry of particulate matter levels in the Village of Radium Hot Springs airshed based on monitoring conducted over the last several years. By providing such information in a readily understood format, and on an ongoing basis, it is hoped that local air quality conditions can be better understood, and that better decisions regarding air quality management can be made.

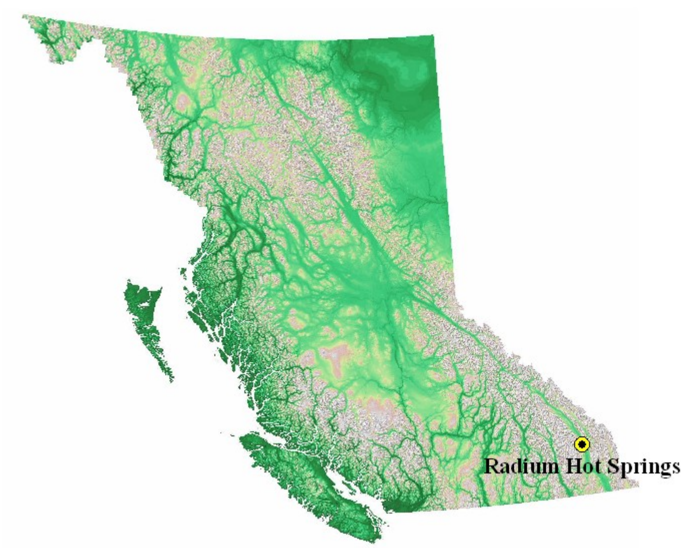
Particulate matter in Radium is currently monitored by a "Partisol" manual sampler located at the Village of Radium office building. This monitor has been in operation since 1998. For airshed management purposes, the Radium airshed roughly refers to the elongated mass of air along the Columbia River, 40 kilometres to the north and to the south, and 10 kilometres either side of the town centre, to the west and to the east. In the case of the Radium airshed, the Purcell Mountain Range and the Rocky Mountain Trench play a large role in determining the containment and/or dispersion of air pollutants.

The short monitoring history in Radium makes trend analysis of the data difficult. However, the results show that Radium's particulate matter levels and health impact indicators are well below those in other Kootenay communities. Of some concern however is a recent upward trend in health impact indicators. In 2002, there was a 196% increase of the exposure levels in Radium when compared to 2001. These levels provide a gross indication of the extent, in terms of both time and amount, that the ambient levels of particulate exceed an established health reference level. The particulate matter in Radium comes from many sources that have impacts at various times of the year. These sources include fugitive dust from traffic and natural sources, woodstove smoke, industrial emissions, slash burning activities, and forest fires.

Based on the monitoring conducted since 1998 and by the ambient standards used in British Columbia, the MWLAP does not have a major concern regarding air quality in the Radium airshed. Continued monitoring will allow the MWLAP to answer questions regarding the recent upward trend in health indicators. Even though particulate matter levels in Radium are below current ambient standards in BC, the health evidence shows that there is no safe level of exposure. This means that even at low levels of particulate matter, there is an impact on public health. Therefore, the public, government, and industry should always be working together to improve air quality for the community of Radium Hot Springs.

Preface

This report is one in a series of air quality reports that are being issued by the Kootenay Regional Office for all communities in the region where monitoring has been established. The Regional Office intends to publish air quality reports on the regional website (http://wlapwww.gov.bc.ca/kor/epd/reports.htm) to provide information to industry, local government, other stakeholders, and the public at large.



Acknowledgements

This report was prepared by Tyler Abel, Benjamin Burkholder and Paul Willis of the Ministry of Water, Land, and Air Protection. We would like to thank the following parties for their contributions to this report: Slocan Forest Products, the Village of Radium, and the MWLAP for funding the monitor in Radium; the Village of Radium for providing a site for the air monitor; Dan Flegel and Garry Bell for maintaining and servicing the monitor; Steve Sakiyama, Natalie Suzuki, Ralph Adams, Julia Beatty, and Kathy Eichenberger for their valuable contributions to this document.

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Introduction

There is mounting evidence that airborne particulate matter poses a significant health concern. The Ministry of Water, Land and Air Protection (MWLAP) has instituted a network of monitoring for airborne particulate matter (PM). This report was compiled by the MWLAP in an effort to inform the public, local government, and industry of particulate matter levels in the Village of Radium Hot Springs airshed[1]. This document will also discuss trends in air quality data and the effects of control measures undertaken in the community. By providing such information in a readily understood format, and on an ongoing basis, it is hoped that local air quality conditions can be better understood and that better decisions regarding air quality management can be made.

Particulate matter may sound like a heavy scientific expression, but it breaks down into simple concepts. Particulates are tiny solid or liquid particles that come in many shapes and sizes, and from many different sources.

The majority of particulates that have a negative effect on human health are 10 micrometres or less in diameter (PM_{10}). A micrometre is a millionth of a metre, so PM_{10} is roughly the same size as bacteria. Like bacteria, PM_{10} is invisible to the naked eye and small enough to be breathed into our lungs.

[1] A geographic area where local topography and meteorology hinder the dispersion of air pollutants away from the area.

Not all PM_{10} is created equal. It can be composed of very small particulates of about 0.1 to 0.2 micrometres in diameter, like you'd find in automobile exhaust or fireplace emissions. Particles of this size can remain suspended in the air for days and even weeks.

Fine Particulate Matter is small enough to enter our airways and lungs as we breathe.

PM_{10} can also include particulates at least 10 times this size, like you'd find as a result of agricultural tilling or road dust. Particles of this size are large enough and heavy enough that they tend to remain in the atmosphere for several hours or less.

To simplify things, we often refer to a fine and coarse fraction of PM_{10}, since they generally differ in chemical composition, source, and behaviour in the air. The fine fraction ($PM_{2.5}$) contains particulates 2.5 micrometres or smaller in diameter. This fraction is most often generated by combustion processes and by chemical reactions taking place in the air. The coarse fraction contains particulates greater than 2.5 micrometres but less than 10 micrometres in diameter.

Particulate Matter and Health Effects

Particulate matter can cause a range of effects in people from annoying symptoms such as a runny nose to increased premature mortality in the extreme case. Recent studies have associated particulate matter with longer-term effects such as lung cancer.

Particulate Matter can cause a range of effects…from annoying symptoms to premature mortality.

Fine airborne particles, called particulate matter, are the most important air pollutant in the Radium airshed and throughout the Kootenay region. Particulate matter is composed of particles small enough that they can stay suspended in the atmosphere for long periods of time. They are considered an important pollutant as they are small enough to enter our airways and lungs as we breathe.

Based on evidence from epidemiological studies, the effects of exposure to PM_{10} and $PM_{2.5}$ concentrations are reflected in:

- ❖ Increases in mortality due to cardiorespiratory diseases.
- ❖ Increases in hospitalization due to cardiorespiratory diseases.
- ❖ Decreases in lung function in children and asthmatic adults.
- ❖ Increases in respiratory stresses that can lead to absenteeism from work or school and a restriction in activities
- ❖ Chronic effects including: reduced lung function and capacity in children, increases in the development of chronic bronchitis and asthma in some adults, and reduced survival.

Those most susceptible to PM-related health impacts are children, the elderly, asthmatics, and people with pre-existing cardiorespiratory diseases.

A review of medical studies has shown that there is no apparent lower threshold for adverse health effects related to particulate matter, and has prompted governments to review and strengthen air quality criteria for PM in order to reduce the risks to Canadians[2].

[2] WGAQOG (1999) *National Ambient Air Quality Objectives for Particulate Matter. Part 1: Science Assessment Document.* A report by the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines. Minister, Public Works and Government Services.

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Air Quality Objectives/Standards

In order to evaluate air quality, standards have been introduced regarding acceptable levels of particulate matter in British Columbia.

Provincial Objectives

Recognizing the threat that PM_{10} poses to human health, the MWLAP established an air quality objective for PM_{10} of 50 µg/m^3 [3] (24-hour average) in 1995. This level is comparable to the maximum acceptable level in the National Ambient Air Quality Objective (NAAQOs) system[4] or a provincial Level B objective. More recent health evidence suggests that $PM_{2.5}$ poses a greater health risk than does the coarse fraction. However, no provincial objectives currently exist for $PM_{2.5}$.

Air Quality Index

The air quality index (AQI)[5] is the most familiar indicator of air quality to British Columbians, providing the public with a meaningful measure of outdoor air quality via daily reports available on the internet. It is determined by comparing air quality measures for contaminants such as ozone, carbon monoxide, and PM to levels established by the federal or provincial governments. In BC AQI calculations, PM_{10} levels are compared to reference levels of 25, 50 and 100 µg/m^3 (comparable to provincial Levels A, B and C, respectively).

The data analysis of this report uses the reference levels of the AQI system to count the number of days in a year that each level is exceeded (a day which exceeds level C is not counted as exceeding level A or B) and reports the percentage or number of times that each level is exceeded.

Along with these guidelines, British Columbia also references other national standards described below.

National Ambient Air Quality Objectives (NAAQOs)[6]

The National Ambient Air Quality Objectives identify benchmark levels of protection for people and the environment. NAAQOs guide federal, provincial, territorial, and regional governments in making risk-management decisions, playing an important role in air quality management. Local source permitting, air quality index calculations, and the

[3] Micrograms per cubic meter.

[4] For More Information about the NAAQO, see http://www.hcsc.gc.ca/hecssesc/air_quality/regulations.htm

[5] A numerical index of particulate matter, ozone and other common air pollutants. From the AQI, we can effectively rate air quality as "Good", "Fair", "Poor", or "Very Poor". For guidance on how to compute the AQI, see http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.info

[6] National Ambient Air Quality Standards: http://www.esemir.it/particolato/PM10.pdf , http://www.ec.gc.ca/air/qual/matter.html#science

development of provincial objectives and standards all make use of the NAAQOs.

The historical system of NAAQOs defines three objectives: a maximum desirable level, a maximum acceptable level, and a maximum tolerable level. With the exception of the maximum tolerable objective, the NAAQOs are viewed as effects-based long-term air quality goals.

Reference Levels

Although negative health effects can occur at any level of particulate matter, the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines recommended reference levels of 25 $\mu g/m^3$ (24 hour average) for PM_{10} and 15 $\mu g/m^3$ (24 hour average) for $PM_{2.5}$. These levels were intended to represent estimates above which there are demonstrated (i.e. statistically significant) effects on human health and the environment. They were not intended to be used as air quality objectives, but as the basis for establishing goals for long-term air quality management.[7]

Exposure Estimates

Exposure calculations are based on the assumption that there is a concentration below which there is no effect (or in the case of particulate matter, above which there exists a statistically significant greater health response).

In the case of PM, risk is believed to increase linearly with PM concentrations. Hence, a crude estimate of exposure (and therefore risk) can be estimated based on summing the concentration above a threshold or reference level over a specific period of time. There are many different ways of calculating exposure. The method used throughout this report is explained in Appendix G.

Canada-wide Standards (CWS) Agreement [8]

Under the Canada-wide Accord on Environmental Harmonization, the Canadian Environment Ministers (with the exception of Quebec) ratified the Canada-wide Standards (CWS) for PM and ozone in July 2000. The CWS process is expected to provide new tools for the management of environmental issues of national interest.

The standards for particulates use daily averages and are based on three calendar years of data. The 98th percentile of the daily averages is determined for the last three calendar years and then averaged. This value, referred to as the "CWS Indicator" throughout this document, can then be compared to a given standard.

The 98th percentile was chosen as the best representative of the highest daily averages in a year after examining data

[7] CEPA/FPAC Working Group on Air Quality Objectives and Guidelines (1999) *National Ambient Air Quality Objectives for Particulate Matter. Part 1: Science Assessment Document.* Minister, Public Works and Government Services.

[8] Canada-wide Standards Agreement: http://www.ccme.ca/initiatives/standards.html

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from across Canada. The proposed standard for PM_{10} was 60 μg/m^3 and a similar standard for $PM_{2.5}$ was 30 μg/m^3. Only the standard for $PM_{2.5}$ was adopted. Although there was no standard or objective set by the CWS for PM_{10}, the previously described "CWS Indicator" will be used to analyze historical trends in ambient air quality in this report.

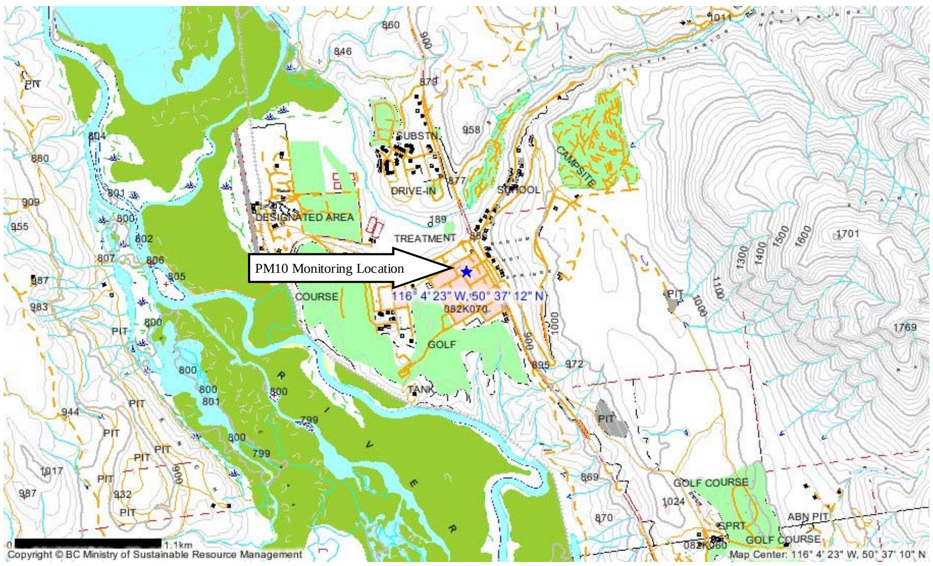


Figure 1: Map Showing the Location of PM_{10} Monitor in Radium

Monitoring Air Quality in Radium

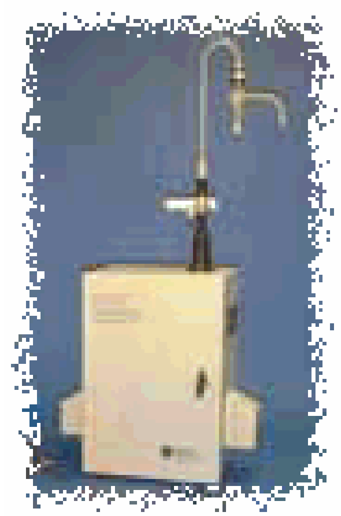
Particulate matter levels are measured to determine the concentrations which people are exposed to across British Columbia. Monitoring enables decision-makers to identify the air quality impacts of current sources, and to determine the impacts of new sources or emission control measures. It also allows comparison with standards and objectives to assess how Radium's air quality is doing in relation to other BC communities. Monitoring over long periods of time allows communities to assess trends that will show if air quality is getting better or worse. Although there are several different types of monitors used across the province, Radium is equipped with a manual, non-continuous sampler.

Manual samplers draw air through a pre-weighed filter for a specified period (usually 24 hours) at a known flow rate. The filter is then removed and sent to a laboratory to determine the gain in filter mass due to particle collection. Ambient PM concentration is calculated on the basis of the gain in filter mass, divided by the product of the sampling period and sampling flow rate. Differently sized sampling head inlets allow for the measurement of coarser PM (see Appendix A: TSP), PM_{10}, or $PM_{2.5}$. Additional analysis can also be performed on the filter to determine the chemical composition of the sample, but this is not done routinely.

Air Quality in Radium is currently monitored by a "Partisol" manual sampler located at the service garage in the Village of Radium office building (Figure 2). Since 2002, this Partisol sampler has been set to give one sample of PM_{10} every sixth day and thus does not monitor continuously. Prior to 2002, samples were taken to correspond to the operational periods of a wood waste incinerator at the Slocan Forest Products saw mill.

Figure 2:

Partisol Sampler in Radium



Airshed Description

In general, an 'airshed' is a body of air in which management strategies of any individual emission source can have an effect. For example, a backyard burning bylaw in Radium could likely positively influence the air throughout the Village of Radium and to the surrounding areas but would probably not affect air quality in Golden or Cranbrook. However, this definition is complicated by that fact that fine PM can travel thousands of kilometres.

For airshed management purposes, the Radium airshed roughly refers to the elongated mass of air along the Columbia River, 40 kilometres to the north and to the south, and 10 kilometres either side of the town centre, to the west and to the east (Figure 3).

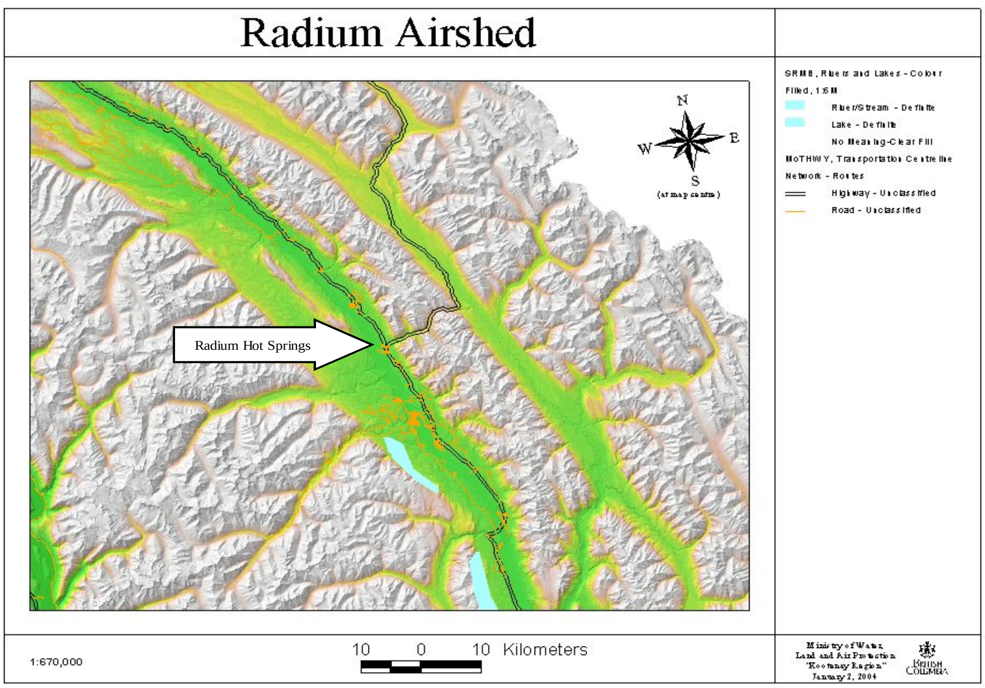


Figure 3: Village of Radium Hot Springs Airshed. Approximately 40 km along the valley in either direction, and with a width from ridgeline to ridgeline.

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Influences on Air Quality: Emissions

Provincial Overview

To characterize particulate matter levels in British Columbia, The Ministry of Water, Land, and Air Protection has been monitoring particulate matter levels throughout the province for a number of years. While the earliest monitoring dates back to 1985, the large-scale monitoring effort began in 1989.

The sources of particulate matter vary from community-to-community and from season-to-season. Based on the year 2000 provincial emissions inventory[9], an estimated 850 thousand tonnes of particulate matter (see Appendix A: Primary Pollutant) were released into the atmosphere. Note that this estimate is only for emissions that result from human activities.

Though provincial summaries may not reflect relative source contributions in individual communities such as Radium, they are useful as a benchmark for comparison.

As summarized in Figures 4a and 4b, these are the key points from the 2000 Emission Inventory with regard to particulate matter in the BC Interior:

PM_{10}

- Point sources contribute 45% of PM_{10} emissions, with 23% coming from the wood industry and 11% coming from the pulp and paper industry.
- Area sources are collectively responsible for 46% of PM_{10} emissions; 25% are from prescribed burning, 11% are from agricultural practices and 9% are from residential fuel wood combustion.

$PM_{2.5}$

- Area sources account for almost half (49%) of $PM_{2.5}$ emissions, with significant contributions from prescribed burning (33%) and residential fuel wood combustion (13%).
- Point sources contribute 40% of $PM_{2.5}$ emissions, with 20% from the wood industry and 12% the from the pulp and paper industry.

For both PM_{10} and $PM_{2.5}$, the contributions from area sources (e.g. fireplaces, wood stoves and backyard burning), mobile sources (e.g. diesel trucks), and road dust are important to local air quality. Area sources are numerous and/or widespread and are located in close proximity to where we live.

[9] MWLAP (2004) *2000 Emission Inventory Analysis Report*. Note that the estimates contained in this report include neither natural sources such as wildfires and biogenic emissions, nor fugitive road dust.

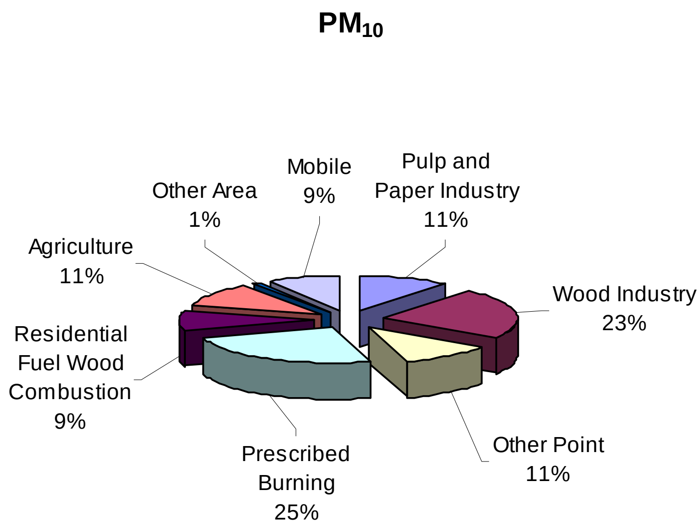

Figure 4a: Summary of PM_{10} Emissions Outside Lower Mainland

Source: *2000 Emission Inventory Analysis Repor*t, MWLAP. 2004. This estimate does not include natural sources, such as wildfires or biogenic emissions, nor fugitive road dust.

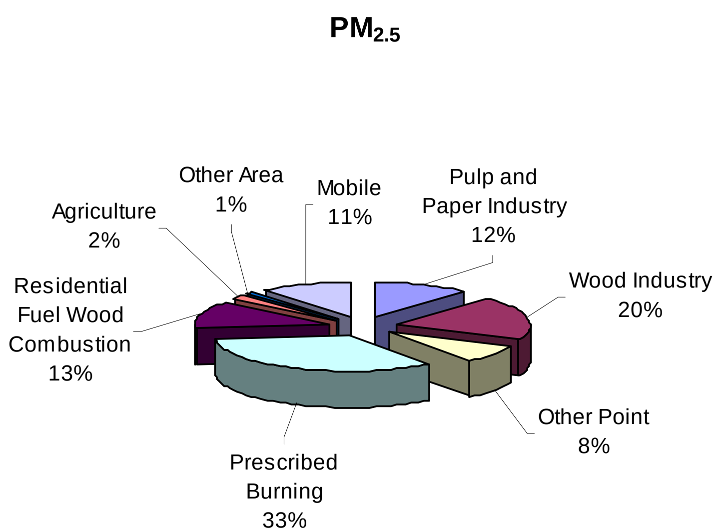

Figure 4b: Summary of $PM_{2.5}$ Emissions Outside Lower Mainland

Source: *2000 Emission Inventory Analysis Repor*t, MWLAP. 2004. This estimate does not include natural sources, such as wildfires or biogenic emissions, nor fugitive road dust.

Secondary particles[10] were not considered in the emission inventory estimates, although studies limited to the Lower Fraser Valley indicate that they comprise up to 50% of the fine particulate matter collected during the summertime. Sulphur dioxide (SO_2), nitrogen oxides (NO_x), various hydrocarbons and ammonia (NH_3) are important gases involved in the formation of secondary particles[11,12].

Major sources of SO_2 include the cement, pulp and paper, and petroleum industries, as well as motor vehicles[13]. Approximately 75% of NO_x emissions are from motor vehicles and marine vessels. Motor vehicles, solvent usage and vegetation contribute to over 70% of hydrocarbon emissions. Agriculture is the dominant source of NH_3.

The Ministry of Water, Land, and Air Protection has implemented a number of programs to reduce the amount of particulate matter emitted into the atmosphere. Regulations have been passed to reduce smoke from land-clearing fires and wood stoves[14]. A model bylaw[15] has been developed to assist local governments in restricting backyard burning. Beehive burners are being phased out, beginning in the most smoke-sensitive areas of the province.

Common sources of fine particulate matter ($PM_{2.5}$) are: smoke from burning of wood waste or garden refuse, slash burning, residential woodstoves, exhaust from car and truck engines, as well as industrial smoke stacks. In addition to sources that come from human activities, $PM_{2.5}$ is also produced by natural processes.

Depending on meteorological conditions, it is possible for particles to stay suspended in the air for long periods of time, resulting in poor air quality. For particles in the $PM_{2.5}$ size fraction, this can allow particles to travel over hundreds of kilometres over time spans of days to weeks.

The larger particles which make up the rest of the coarser particulate matter (PM_{10}) usually consist of finely ground up rock and clay. They come from both human and natural sources and are often called fugitive dust.

[10] Particles that are not directly emitted into the atmosphere, but are produced by chemical and physical processes. See Appendix A: Secondary Pollutant.

[11] Lowenthal D.H., D. Wittorff, and A.W. Gertler (1994) *CMB Source Apportionment During REVEAL - Final Report*. Air Resources Branch, British Columbia Ministry of Environment, Lands and Parks.

[12] Pryor S.C. and D. Steyn (1994) *Visibility and ambient aerosols in south-western British Columbia during REVEAL*. British Columbia Ministry of Environment, Lands and Parks.

[13] ARB (1994) *1990 British Columbia Emissions Inventory of Common Air Contaminants*, Air Resources Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, BC, December.

[14] http://www.qp.gov.bc.ca/statreg/reg/W/WasteMgmt/302_94.htm , http://wlapwww.gov.bc.ca/air/particulates/agttobsc.html

[15] http://wlapwww.gov.bc.ca/air/particulates/pdfs/bylaw.pdf

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The most common source of fugitive dust caused by human activity is dust from unpaved roads or paved roads that have had gravelled tractional material dispensed for winter travelling. When the roads are no longer frozen or wet in the springtime BC Interior, traffic grinds up the gravel into finer and finer particles. These are then either mixed into the air by passing traffic, or picked up by strong winds.

Radium Airshed Overview

A detailed emission inventory for the Radium airshed has not been completed; however, there are still known sources for particulate matter emissions.

Sources for fine particulate matter include Canadian Pacific Railway operations, heavy trucking operations, general highway vehicles, slash burning, wildfires, backyard burning, and wood stoves. A silo burner for wood waste at the local Slocan Forest Products Saw Mill was responsible for fine particulate matter emissions until late 2001 when it ceased operation.

From a Ministry sponsored phone survey[16], it was calculated that about 50% of Radium and area residents use wood for residential heating. Of these users, approximately 80% use older (less efficient) style appliances.

Airborne road traction material is a likely source of coarse particulate matter in the Radium airshed. As well, the nearby lumber mill operations produce considerable quantities of dust from both the mill and from yard traffic.

Natural sources of fugitive dust in the Radium airshed include the Columbia River and Columbia Lake banks.

[16] http://wlapwww.gov.bc.ca/air/airquality/pdfs/wood_emissions.pdf

Influences on Air Quality: Weather

Besides emission sources, both human-caused and naturally occurring, there are other factors that play an important role in the ambient air conditions. Of primary importance are the influences of complex terrain (i.e., deep valleys) and weather conditions.

Winds in the airshed generally are aligned with the valley orientation (north-northwest to south-southeast). This may be the result of either valley channelling or diurnal valley flows (see Figure 5). Thus, the Village of Radium is more susceptible to particulate matter emissions from either of these directions.

Fortunately, there are no year-round emissions sources south of the Village. However, slash-burning activities south of Radium could be of concern with this prevailing wind.

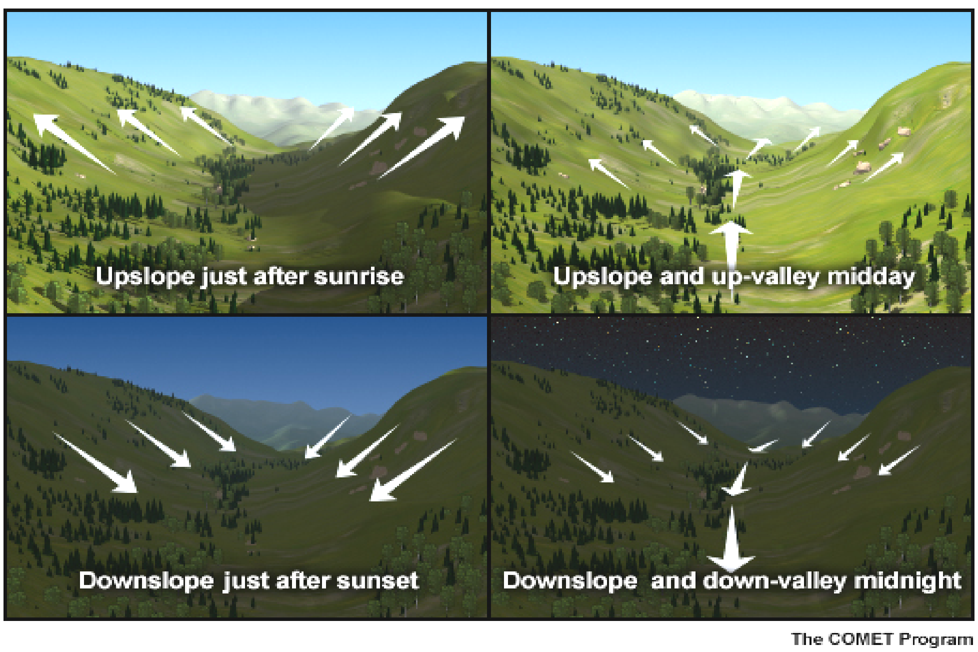

Figure 5: Diurnal Valley Flow. Airflow during the daytime tends to be towards upslope and up-valley. During the nighttime this tendency reverses and denser, cooler air pools in valley bottoms. *The source of this material is the Cooperative Program for Operational Meteorology, Education, and Training (COMET®) Web site at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR), funded by the National Weather Service. ©2002, UCAR. All Rights Reserved.*

Figure 6: Diagram of a Temperature Inversion. The warm layer of air on top of the cold layer creates an inversion layer that traps emissions close to the ground. *Graphic courtesy of Environment Waikato, Government of New Zealand.*

An airshed is often bounded by natural topographic features. In the case of the Radium airshed, the Purcell Mountain Range and the Rocky Mountain Trench play a large role in determining the containment and/or dispersion of air pollutants. The steep valley walls surrounding Radium make the airshed susceptible to a higher frequency of temperature inversions.

Steep valley walls make Radium more susceptible to temperature inversions.

Temperature inversions are common in communities located in mountain valleys or nestled up against a mountain range. Cold air sinks to the valley floor or base of the mountains; because the cold air is denser than the warmer air above, it tends to remain at the valley bottom. Hence, upward mixing of air from the surface does not occur. This is most prevalent during night time hours (see Figure 5 to see valley flow over a daily period), but can also occur during the day, especially during the winter season when daylight hours are reduced.

Unfortunately, air quality suffers in an inversion situation because pollutants like dust, smoke and vehicle emissions are trapped close to the ground by the warm layer of air above. The warm air acts like a lid and prevents pollutants from rising and dispersing (Figure 6). Prolonged periods of inversions can promote severe health effects, especially on those with respiratory problems, children, and the elderly.

Air Quality in Radium

As previously stated, there is one manual sampler located at the Village of Radium office building which is used to assess the air quality. Since 1998, Slocan Forest Products has provided funding to operate this PM_{10} sampler in Radium. More recently additional funding has come from the Village of Radium and the Ministry of Water, Land and Air Protection.

The monitoring history in Radium is short, but it is still useful to look at some of the trends and bring awareness to the state of air quality in the airshed. Table 1 shows the results of the monitoring since the operation began.

Year	Number of samplers	Mean (µg/m³)	Maximum (µg/m³)	Fair Days (%)	Poor Days (%)	Very Poor days (%)	98th Percentile (µg/m³)	NAAQOs Exposure	CWS Indicator (µg/m³)
1998	58	15.3	62	19%	2%	0%	36	535	n/a
1999	144	11.0	36	3%	0%	0%	30	63	n/a
2000	156	15.5	109	15%	0%	1%	37	521	34
2001	115	15.2	40	14%	0%	0%	33	238	33
2002	45	16.2	60	13%	2%	0%	60	706	43

Table 1: Summary of Annual PM_{10} in Radium from 1998 to 2002

The mean and maximum values for each year are for 24 hour averages. These values are measured in micrograms per cubic metre (µg/m^3). The percent of days with fair, poor, and very poor air quality are equivalent to the percent exceedances of the Level A (25 µg/m^3), Level B (50 µg/m^3), and Level C (100 µg/m^3) NAAQOs reference levels. The Canada-wide Standards Agreement (CWS) uses the three year average of the 98th percentile of daily averages as an indicator to compare communities. The NAAQOs also define an exposure to PM_{10} above a reference health level of 25 µg/m^3. Refer to Appendix G for a description of the calculation of exposure.

Trends

The results of the monitoring indicate that there has been little change in the mean PM_{10} concentration from 1998 to 2002 (Table 1). In fact, Radium's particulate matter levels and health impact indicators are well below those in most other Kootenay communities (Figure 7).

Radium's particulate matter levels are below those in other Kootenay communities.

Still, every year there are a number of days which exceed the NAAQOs health reference level. For example, in 2002, 15% of the recorded days were above the minimum long-term NAAQO health reference level. Health officials have observed more serious effects with increasing levels of PM. Children, the elderly, and those with respiratory problems are especially at risk.

Caution must be used, however, in several aspects of the analysis of this data. The last year of data (2002) shows an upward trend in all health impact indicators. Note the 8% increase of the 2002 annual mean value over the previous year, and the 13% percent increase of this same value over the average (14.3 $\mu g/m^3$) of all previous years.

Perhaps even more significant are the 196% and 108% increases shown in the 2002 NAAQOs exposure when compared, respectively, with the 2001 and 2000 data. However, the recording history is too short to make definitive conclusions regarding this trend. As well, caution should be taken when making assessment of a year when the instrument was not operating for three months[17].

It is also important to note that part of the variation in year to year concentrations of particulate matter is due to interannual climate variability, since meteorological conditions may favour dispersion in some years but not in others. For example, it was observed that ambient levels of PM across the region were relatively high during the 2002/2003 winter season[18]. Stagnant atmospheric conditions dominated much of the December and November weather patterns. The time series presented here do not take such considerations into account.

[17] Note, however, that the missing months were January, February, and March; these months typically show above average levels of PM10. Hence, the yearly average reported for 2002 may actually be underestimated. Refer to Figure 9: Exceedances By Month.

[18] Note the relative increase in PM levels from 2001 to 2002 in Nelson, Radium and Invermere shown by Figure 7. Also refer to the following for an assessment of PM levels in Prince George in 2002: http://wlapwww.gov.bc.ca/nor/pollution/environmental/air/rep02/pr_geo_rep_02.pdf

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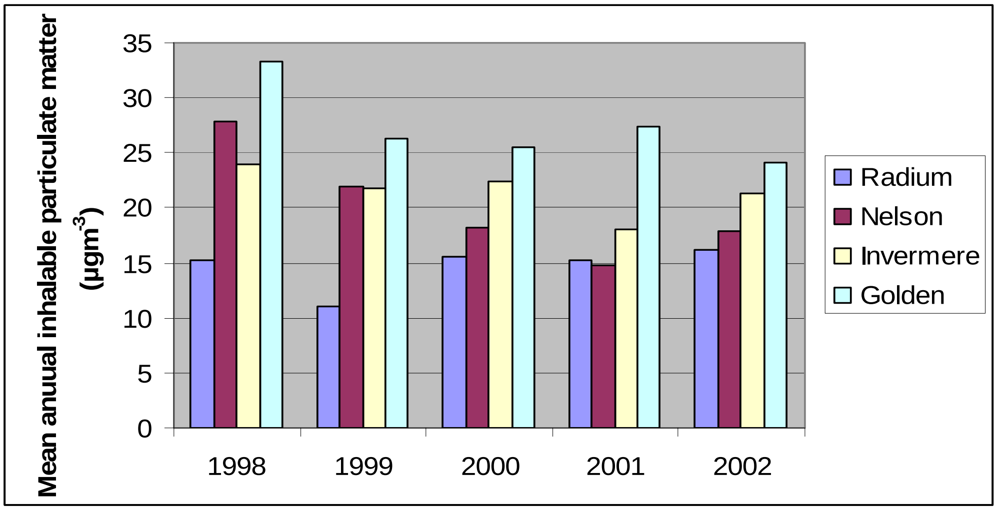

Figure 7: Comparison of mean annual PM10 concentrations with other communities in the Kootenay region from 1998 to 2002. The blue bar indicates Radium's mean which is generally below the other communities.

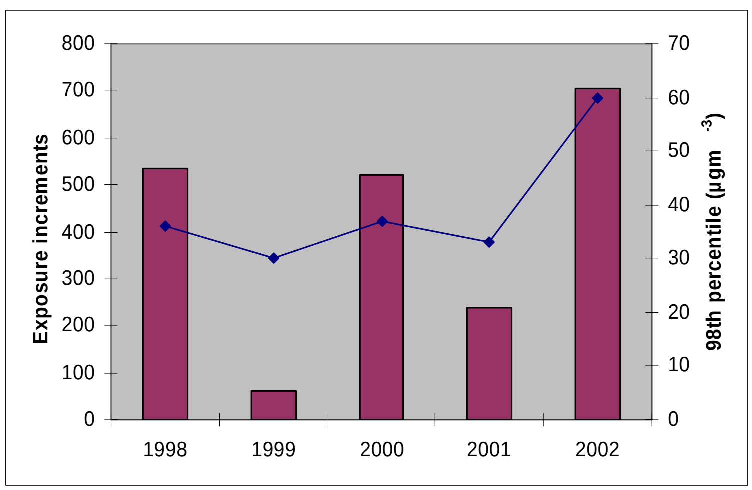

Figure 8: Exposure. Two measurements of PM_{10} are shown above. The line indicates the 98th Percentile of the daily average PM_{10} in micrograms (µg/m^3) for the year. The NAAQOs also define an exposure to PM_{10} above a reference health level of 25 µg/m^3. Refer to Appendix G for a description on the calculation of exposure.

ENVIRONMENTAL QUALITY

Radium had a 196% increase in the NAAQO exposure from 2001 to 2002.

Finally, instrument placement that will result in data that is indicative of the entire airshed is a daunting task for Ministry staff and is rarely achievable with one instrument. There exists a concern that this particular site may not be able to gauge ambient conditions with potentially higher particulate levels at some of the more northern locations in this airshed.

Particulate Matter Analysis

As previously stated, particulate matter is made up of two related but different pollutants: PM_{10} and $PM_{2.5}$. In order to further assess air quality in Radium, it is necessary to have measurements of both types. Unfortunately, $PM_{2.5}$ data is not collected in Radium. Because of this, other less precise sources of information were used to interpret particulate matter statistics.

The percentage of days with very poor, poor, and fair air quality for each month is reported in Figure 9. The graph shows three peaks in exceedance days: one winter peak in November, a spring peak in March, and a summer peak in August. These peaks are matched in Figure 10 which shows the concentration of PM_{10} by month. It should be noted that with the exception of January and May, exceedances above the health reference level were observed in all months.

The March peak corresponds with the spring thaw which usually indicates that the increased particulate matter consists of fugitive dust. In Radium this is largely due to road dust. Road traction material frozen during the winter, as well as naturally occurring dust, begins to thaw and is picked up by winds and traffic. This contributes to higher concentrations of particulate matter. Particulate matter during this time of year consists more of the coarse fraction than of the fine fraction ($PM_{2.5}$).

The August peak may be a result of fugitive road dust from dry summers or from forest fires around the region. Forest fires result in higher levels of $PM_{2.5}$ which has more severe health impacts than PM_{10}.

During November, slash burning activities are increased. This combustion source would result in higher levels of $PM_{2.5}$, and, thus, more severe health impacts. Another contributor in November could be the use of woodstoves for residential heating, or the saw-mill. The saw-mill has a greater impact in the winter as there is less dispersion in these months. The November peak is of concern to health officials as the sources contributing to this peak typically contain large amounts of $PM_{2.5}$.

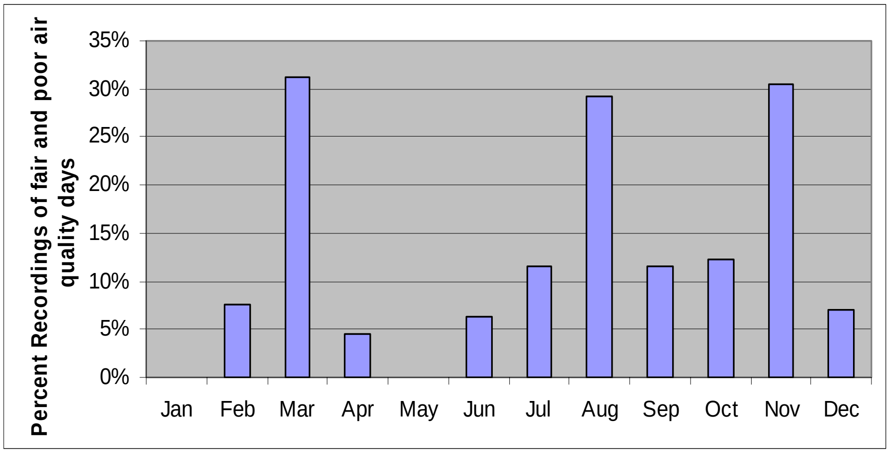

Figure 9: Exceedances by Month. The percentage of exceedances of Level A NAAQ objectives in Radium during the period 1998 to 2002. The percentage of very poor, poor, and fair days measured in each month are shown by the bars. Sample Size =518 days.

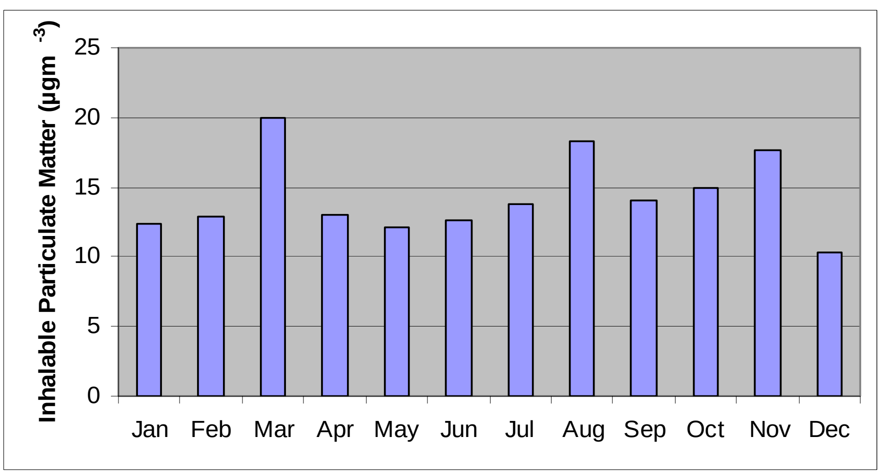

Figure 10: PM_{10} by Month. Radium's daily mean PM_{10} during the period 1998 to 2002 measured in each month are shown by the bars.

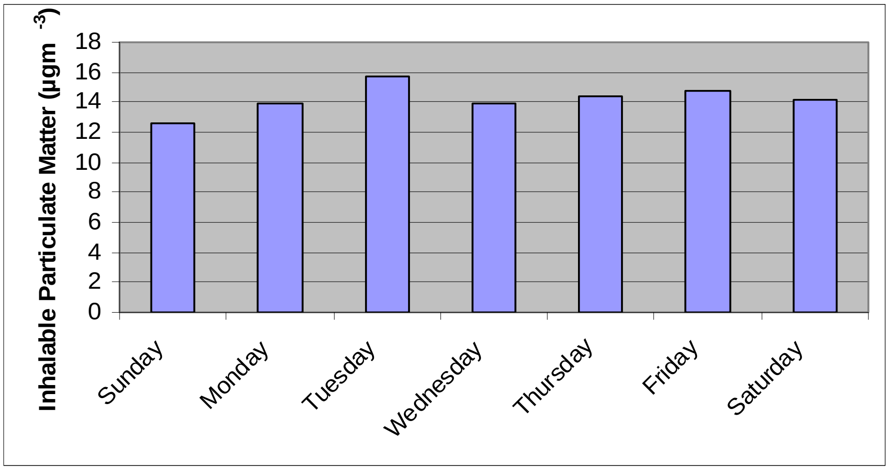

Figure 11: PM_{10} by Day of Week. PM_{10} for the period 1998 to 2002 measured on each weekday is shown by the bars.

During other times of the year, fugitive dust sources, industrial emissions, woodstove smoke, slash burning activities, and forest fires all contribute to exceedances of the standards for acceptable air quality. Emissions from combustion sources result in higher levels of $PM_{2.5}$ and more severe health impacts for residents of Radium.

PM_{10} concentrations do not show much variation throughout the days of the week (Figure 11). Slightly higher values during the Monday to Friday work week are usually attributed to fugitive dust and vehicle emissions from increased commuter traffic. In many other areas, there is a more significant drop in particulate matter on the weekend. The absence of this decline in Radium may be due to the nature of traffic in Radium. Radium's traffic is generally from the highway, which has a high weekend tourist contribution. Thus we would not expect to see the day-of-week variations due to the Monday to Friday work week.

Conclusions / Recommendations

In summary, this is what we know about the air quality in Radium:

- By the standards used in British Columbia, the Ministry does not have a major concern regarding air quality in the Radium airshed.
- However, every year there are days that exceed the NAAQOs health reference level.
- The last full year of analyzed data indicate an upward trend in all health impact indicators. Only continued monitoring to add to the existing database can answer questions regarding the current upward trend in ambient PM levels.
- Exceedances of the health reference level are concentrated in specific winter, spring, and summer months. These peaks have been linked to possible natural and human causes. Continued monitoring will aid in identifying what causes these peaks.
- With the measurements available, it is difficult to differentiate between sources and types of particulate matter. However, the November peak in PM_{10} is of concern because it corresponds to processes that emit large amounts of $PM_{2.5}$ and fine particulate matter ($PM_{2.5}$) has more serious health implications than coarse particulate matter.
- The monitoring history is very short, making trend analysis at this stage difficult.
- Although particulate matter levels in Radium are lower than in many other communities, PM_{10}, even at relatively low levels, can have an impact on community health.

The following recommendations have the potential to improve the current air quality in Radium:

- Municipal governments should consider instituting a bylaw against backyard burning, a source of $PM_{2.5}$. The MWLAP can assist with such a bylaw template.
- Residents should be encouraged to buy more efficient wood heat appliances (woodstoves). The MWLAP can partner with regional wood stove exchange programs.
- Residents should be educated in techniques regarding the proper use of woodstoves, fuel selection, as well as the storage and curing of wood. The MWLAP is currently involved with regional public awareness campaigns and can partner with

municipal governments in such programs.

- Radium and regional agencies consider identifying additional techniques that could result in more efficient winter road maintenance and a reduction in road dust. Examples of such measures are more frequent street cleaning, coarser sand for roadways, and application of magnesium chloride to keep roadways clear of ice. The MWLAP, in partnership with the Ministry of Transportation and Highways, is developing Best Management Practises for the mitigation of poor air quality due to airborne road traction material.

Who to Contact for More Information

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Public Feedback Welcomed

Appendices

Appendix A:
GLOSSARY AND ABBREVIATIONS

Air Mass:
A large body of air that has similar horizontal temperature and moisture characteristics.

Air Pollution:
Degradation of air quality resulting from unwanted chemicals or other materials occurring in the air.

Airshed:
A geographic area where local topography and meteorology hinder the dispersion of air pollutants away from the area.

Air Quality Index (AQI):
Reports levels of particulate matter, ozone and other common air pollutants. This system was developed to provide the public with a meaningful measure of outdoor quality. From the AQI, we can effectively rate air quality as “Good”, “Fair”, “Poor”, or “Very Poor”. For guidance on how to compute the AQI, see: http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.info .

Anthropogenic:
Produced by human activities.

Anthropogenic emissions:
Emissions from man-made sources as opposed to natural (biogenic) sources.

Biogenic Sources:
Biological organisms, such as plants and animals, which emit air pollutants such as volatile organic compounds. Examples of biogenic sources include animal management operations and oak or pine tree forests.

Coarse particles:
Particulate matter with diameter between 2.5 and 10 microns (PM_{10} - $PM_{2.5}$). Also referred to as “inhalable particles”.

CWS:
Canada-Wide Standards.

Diurnal:
Daily, especially with respect to actions which are completed in twenty-four hours, and which recur every twenty-four hours.

Downslope Wind:
Air that is relatively cold and thus more dense, flowing or draining to lower elevations.

Exceedance:
A measured level of an air pollutant higher than the national or provincial ambient air quality standard.

Fine particles:
Particulate matter with diameter less than 2.5 microns; $PM_{2.5.}$ Also referred to as “respirable particulate matter”.

Inhalable Particulate Matter:
Particles that are small enough to be carried into our airways.

Inversion:
An increase in temperature with height. The reverse of the normal cooling with height in the atmosphere.

Mean:
The total of all values divided by the number of samples.

Median:
The middle value in a sorted list of samples if there are an odd number of samples, or the average of the two middle values if there is an even number of samples.

MELP:
BC Ministry of Environment, Lands and Parks.

µg/m^3:
Micrograms per cubic metre (concentration).

µm:
Micrometre = 10^{-6} m (diameter).

National Ambient Air Quality Objectives (NAAQOs) :

Health-based pollutant concentration limits established by the EPA that apply to outside air.

Partisol:

A type of particulate matter sampler that collects the contaminant on a filter which is removed, typically after 24 hours of operation, and weighed to determine an average concentration.

Particulate matter (PM) :

A generic term referring to liquid or solid particles suspended in the air.

$PM_{2.5}$:

Particulate matter less than 2.5 microns in diameter. Tiny solid or liquid particles, generally soot and aerosols. The size of the particles (2.5 microns or smaller, about 0.0001 inches or less) allows them to easily enter the air sacs deep in the lungs where they may cause adverse health effects; $PM_{2.5}$ also causes visibility reduction. Also referred to as “respirable particles”.

PM_{10}:

Particulate matter less than 10 microns in diameter. Tiny solid or liquid particles of soot, dust, smoke, fumes, and aerosols. The size of the particles (10 microns or smaller, about 0.0004 inches or less) allows them to be carried into our airways. PM_{10} also causes visibility reduction and is a criteria air pollutant. Also referred to as ‘inhalable particles’.

Primary Pollutant:

A pollutant which is emitted directly into the air.

Respirable Particulate Matter:

Particles small enough to travel all the way into the deepest parts of our lungs and interact with oxygen/blood exchange.

Secondary Pollutant:

A pollutant which results from a reaction between a primary pollutant and some other substance in the air through a chemical or physical process.

Secondary Particulate Matter:

Particles ($PM_{2.5}$) that can from complicated chemical reactions of gases emitted, either through natural sources or from human activity, into the air.

TSP:

Total Suspended Particulate. Particles up to 100 microns in diameter.

Upslope Flow:
Air that is relatively warm and thus less dense, tending to rise or flow up slopes.

WLAP:
BC Ministry of Water, Land and Air Protection (formerly MELP).

Appendix B

EXPOSURE CALCULATION METHOD

Exposure calculations are based on the assumption that there is a concentration below which there is no effect (or in the case of particulate matter, above which there exists a statistically significant health response). This reference level can be exceeded either by a short period of exposure to high concentrations, or a longer period of exposure to lower concentrations.

Although there are many different ways to calculate exposure, the values cited in this report were calculated based on the NAAQO definition. This method assumes that PM_{10} has negligible health effects until the daily average exceeds a reference health level of 25 $\mu g/m^3$. For days in which this threshold is exceeded, the difference between the daily mean and the reference level is computed. After this is done for each day in a particular year, the differences are summed to provide an overall measure of exposure. Such exposure measures can be used in both inter-annual and inter-site comparisons.

Because the monitoring in Radium is done on a non-continuous basis, many days, for many years, did not have a daily average for PM_{10}. Thus, exposure values were extrapolated from the days in which daily averages were available.

For example, suppose that for a given year, 58 daily averages were available. Now, suppose that the NAAQO exposure calculation is applied to this 58 day dataset and that the resultant value is 85. An estimate for the year can then be achieved by assuming that the days sampled are representative of PM levels over the entire year and scaling the level of exposure accordingly. Thus, for our example, since the year had 365 days, we can multiply 85*(365/58) = 534.9 to get an estimate of the NAAQO exposure for this year.

Appendix C

VILLAGE OF RADIUM HOT SPRINGS
1998 PM_{10} SAMPLING RESULTS

*Monitoring began in July 1998

Month	Day	µg/m³
July	22	15
	24	12
	29	8
	30	16
	31	7
August	**5**	**26**
	6	**62**
	7	**30**
	12	**26**
	13	**28**
	14	20
	19	13
	20	17
	21	13
	26	10
	27	20
	28	**34**
September	**2**	**31**
	3	24
	4	**27**
	9	12
	10	15
	11	13
October	14	4
	15	5
	16	16
	21	10
	22	11
	23	21
	28	6
	29	13
	30	10
November	**4**	**36**
	5	**27**
	6	**31**
	11	12
	12	20
	13	4
	18	19
	19	24
	20	4
	25	10
	26	8
	27	5
December	2	4
	3	4
	5	10
	9	7
	10	4
	11	15
	16	8
	17	4
	18	11
	23	**27**
	24	4
	25	4
	30	5
	31	6

**** BOLDED TYPE INDICATES DAYS EXCEEDING NAAQ OBJECTIVES**

Appendix D

VILLAGE OF RADIUM HOT SPRINGS
1999 PM_{10} SAMPLING RESULTS

Month	Day	$\mu g/m^3$
January	1	19
	15	10
	20	7
	21	7
	22	4
	27	5
	28	11
	29	6
February	3	6
	4	4
	5	4
	10	13
	11	21
	12	20
	17	13
	18	21
	19	14
	24	8
	25	12
	26	15
March	3	0
	4	12
	5	14
	10	23
	11	11
	12	20
	31	0
April	1	16
	2	13
	7	17
	8	15
	9	7
	14	11
	15	8
	16	15
	21	4
	22	6
	23	9
	28	4
	29	8
	30	7
May	5	6
	6	17
	7	19
	12	8
	13	6
	14	4
	18	0
	19	7
	20	9
	21	15
	24	12
	26	6
	27	17
	28	16
	30	11
June	2	10
	3	11
	4	17
	9	4
	10	10
	11	4
	16	14
	17	20
	18	7
	23	15
	24	11
	25	4
	30	5
July	1	4
	2	9
	7	5
	9	11
	14	0
	15	0

	22	13
	23	8
	28	21
	29	7
	30	4

Month	Day	µg/m^3
August	4	21
	5	16
	6	16
	11	12
	12	12
	13	8
	18	15
	19	7
	20	12
	25	9
	26	17
	27	21
September	1	6
	2	10
	3	15
	8	7
	9	12
	10	0
	15	12
	16	13
	17	14
	22	24
	23	**36**
	24	6
	29	5
	30	5
October	1	7
	6	**31**
	7	0
	8	12
	13	7
	14	12
	15	16
	20	**30**
	21	**28**
	22	22
	27	20
	28	10
November	3	12
	4	14
	5	20
	10	10
	11	0
	12	0
	17	7
	18	19
	19	17
	24	0
	25	12
	26	15
December	1	10
	2	11
	3	9
	8	11
	9	10
	10	9
	15	9
	16	8
	17	0
	22	15
	23	8
	24	9
	29	10
	30	10
	31	10

**** BOLDED TYPE INDICATES DAYS EXCEEDING NAAQ OBJECTIVES**

Appendix E

VILLAGE OF RADIUM HOT SPRINGS
2000 PM_{10} SAMPLING RESULTS

Month	Day	µg/m³
January	5	23
	6	12
	7	9
	12	11
	13	11
	14	11
	19	14
	20	8
	21	14
	26	19
	27	0
	28	15
February	2	0
	3	0
	4	9
	9	5
	10	7
	11	6
	16	0
	17	12
	18	15
	23	11
	24	8
	25	**36**
March	1	14
	2	25
	3	17
	8	**45**
	9	**33**
	10	**39**
	15	**34**
	16	13
	17	**31**
	22	18
	23	8
	24	**29**
	29	17
	30	20
	31	18
April	5	14
	6	19
	7	14
	12	14
	13	6
	14	4
	19	9
	20	17
	21	12
	26	7
	27	14
	28	7
May	4	0
	5	10
	10	6
	11	7
	12	6
	17	21
	18	17
	19	13
	24	21
	25	6
	26	20
	31	10
June	1	8
	2	14
	7	9
	8	9
	9	6
	14	6
	15	8
	16	11
	21	7
	22	8
	23	9
	28	17
	29	6
	30	6
	30	**109**

Month	Day	μg/m³
July	5	6
	6	10
	7	10
	12	18
	13	21
	14	**26**
	19	14
	20	13
	21	17
	26	16
	27	23
	28	21
	2	18.7
August	3	16.7
	4	10.8
	9	22.8
	10	**31.4**
	11	**25.1**
	16	6
	17	**34**
	18	**29**
	23	13
	24	13
	25	14
	30	6
	31	6
	1	12
September	6	12
	7	17
	8	6
	13	9
	14	24
	15	15
	20	22
	22	6
	23	6
	27	21
	28	**29**
	29	23
	4	12
October	5	16
	6	18
	11	22
	12	22
	12	8
	13	**28**
	18	9
	19	11
	20	13
	25	**26**
	26	22
	27	15
	1	15
November	2	24
	3	33
	8	6
	9	6
	10	6
	15	6
	16	6
	17	6
	22	**37**
	23	**29**
	24	**26**
	29	**31**
	30	**26**
	1	**27**
December	6	13
	7	9
	13	11
	14	12
	15	13
	20	19
	21	6
	22	13

**** BOLDED TYPE INDICATES DAYS EXCEEDING NAAQ OBJECTIVES**

ENVIRONMENTAL QUALITY

Appendix F

VILLAGE OF RADIUM HOT SPRINGS
2001 PM_{10} SAMPLING RESULTS

Month	Day	µg/m³
January	1	6
	10	23
	11	10
	17	19
	18	19
	19	22
	24	8
	25	16
	26	18
	31	12
February	1	20
	2	10
	7	17
	8	17
	9	9
	14	9
	15	9
	16	24
	21	10
	22	14
	23	13
	28	23
March	**15**	**31**
	16	**33**
	21	12
	22	17
	23	16
	28	8
	29	16
	30	17
April	**4**	**31**
	5	15
	6	11
	11	6
	12	17
	13	11
	18	9
	19	10
	20	15
	25	**40**
	26	24
	27	12
May	2	6
	3	13
	4	15
	9	19
	10	14
	11	23
	16	8
	17	7
	18	14
	23	22
	24	22
	25	9
	30	10
	31	18
June	1	12
	6	8
	7	6
	8	14
	13	12
	14	8
	15	6
	20	14
	21	14
	22	15
	27	10
	28	6
	29	6
July	4	25
	5	**32**
	6	18
	25	6
	26	12
	27	11
August	1	9
	2	22
	3	25

ENVIRONMENTAL QUALITY

	8	14
	9	6
	10	24
	22	**28**
	23	9
	24	6
	29	20
	30	**28**
	31	**27**
	31	11

Month	Day	µg/m^3
September	1	10
	2	16
	5	10
	6	19
	7	9
	12	**28**
	13	17
	14	**27**
	19	7
	20	14
	21	6
	26	6
	27	7
	28	16
October	3	11
	4	11
	5	12
	12	6
	17	9
	18	13
	19	6
	24	13
	25	21
	26	18
November	**7**	**37**
	8	**30**
	9	**28**
December	**No data collected**	

**** BOLDED TYPE INDICATES DAYS EXCEEDING NAAQ OBJECTIVES**

Appendix G

VILLAGE OF RADIUM HOT SPRINGS
2002 PM_{10} SAMPLING RESULTS

Month	Day	µg/m³
January	No Data Collected	
February	No Data Collected	
March	No Data Collected	
April	8	21
	14	6
	20	19
	26	23
May	2	8
	8	13
	14	20
	20	20
	26	8
June	1	10
	7	10
	13	**34**
	19	6
	25	18
July	1	7
	7	9
	13	23
	19	16
	25	**31**
	31	4
August	6	23
	12	9
	18	5
	24	10
	30	25
September	5	9
	11	21
	17	4
	23	8
	29	8
October	5	13
	11	8
	17	11
	23	**46**
	29	20
November	**4**	**36**
	10	9
	16	12
	22	19
	28	**60**
December	4	15
	10	14
	16	4
	22	**30**
	28	4

**** BOLDED TYPE INDICATES DAYS EXCEEDING NAAQ OBJECTIVES**