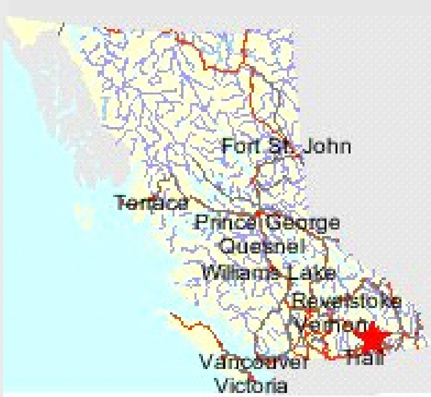
Ministry of Environment
KOOTENAY REGION

Ambient Air Quality Monitoring Report
Nelson, British Columbia



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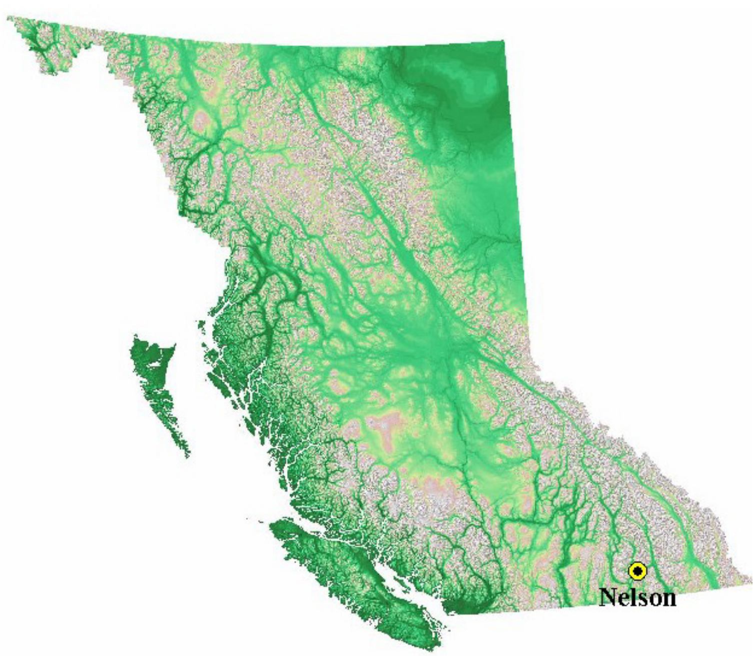
Preface

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 air quality is monitored. It is the intention of the Regional Office of the Ministry of Environment to publish air quality reports on our website (http://wlapwww.gov.bc.ca/kor/epd/reports.htm) in order to provide the information to industry and local government, other stakeholders and the public at large. By providing such information in a readily understood format, it is hoped that local environmental quality conditions can be better understood, and better decisions regarding air quality management can be made.



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Ambient Air Quality Monitoring Report
Nelson, British Columbia

Particulate Matter - 1991 to 2005

Prepared by:

Ministry of Environment
Environmental Quality Section
205 Industrial Road G
Cranbrook B.C.
V1C 6H3

August, 2006

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Executive Summary

There is mounting evidence that airborne particulate matter (PM) poses a significant health concern, especially to the young, the elderly, and those with cardiorespiratory diseases. To measure airborne particulate matter in the Kootenay Region, the Ministry of Environment (MoE) has instituted a network of sampling stations that has monitored PM over the last several years. This report summarizes the data from monitoring in Nelson, with the ultimate goal of improving the decision-making process for air quality management in the Nelson airshed.

The Nelson airshed is generally defined by the Kootenay River valley from Balfour to Castlegar. The extent is approximately 50 km long and is 20 km wide.

Long-term monitoring of particulate matter in Nelson has been done by a "Hi-Vol" manual sampler located at the government building at 310 Ward Street. This monitor has been in operation since 1985 with measurement of inhalable particulate matter (PM_{10}) beginning in 1991. In 2005, three continuous samplers were installed at 333 Victoria Street to measure inhalable and respirable (fine) PM, and ozone.

The results of the monitoring indicate that there was a decreasing trend in the average inhalable particulate matter concentration in the early 1990s, followed by an increase in the mid to late 1990s, with high measurements recorded between 1997-1999. Since then, air quality has improved, with a decline in all health indicators in 2001, returning to levels found in the mid-1990s. The particulate matter in Nelson comes from many sources, which have different impacts at various parts of the year. These sources include fugitive dust from traffic and natural sources, vehicle emissions, smoke from woodstoves, slash burning, and forest fires.

Particulate matter levels in Nelson are comparable to levels found in most Kootenay communities and are typically within Provincial guidelines. Nevertheless, in relation to the air quality objectives and standards used in British Columbia, the MoE has some concern regarding air quality in the Nelson airshed because of the risk of high concentrations during thermal inversions. A state of complacency should not prevail in Nelson, because even low levels of particulate matter have an impact on public health. Therefore, the public, government agencies, and industry should always be working together to improve air quality for the community of Nelson.

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Figures and Tables

1.0 Introduction

There is mounting evidence that airborne **particulate matter** poses a significant health concern and thus the Ministry of Environment (MoE) has instituted a network of monitoring for airborne particulate matter (PM). The data resulting from the monitoring has been compiled and analysed by the MoE for this report to inform the public, local government, and industry about particulate matter levels in the Nelson **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, it is hoped that local air quality conditions can be better understood and that better-informed decisions regarding air quality management can be made.

Many pollutants are known to have detrimental effects on human and environmental health. The common ones monitored in B.C. are: nitrogen dioxide, sulphur dioxide, total reduced sulphur, carbon monoxide, ozone, formaldehyde, and particulate matter. However, in most Kootenay Region communities, including Nelson, particulate matter is the most serious health concern, and as such this report will deal only with particulate matter.

"Particulate matter" may sound like a scientific expression, but it breaks down into simple concepts. Particulates are tiny solid or liquid particles that come in many shapes and sizes, and are 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 (µm) 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.

Fine particulate matter is small enough to enter our airways and lungs as we breathe.

Figure 1 demonstrates that particulate matter comes in a wide range of sizes and differs in chemical composition, source, and behaviour in the air. Collectively, PM_{10} includes the **coarse fraction** ($PM_{10-2..5}$), the **fine fraction** ($PM_{2.5-0.1}$), and the **ultrafine** fraction ($PM_{<0.1}$)

The fine fraction are particles smaller than 2.5 µm in diameter and as small as 0.1 to 0.2 µm in diameter. Particles of this size are usually formed by chemical reactions. Many of these particles are produced directly during combustion or burning but are also indirectly created from reactions in the atmosphere (also known as 'secondary PM'). Common sources of $PM_{2.5}$ are: smoke from burning of woodwaste or garden refuse; slash burning;

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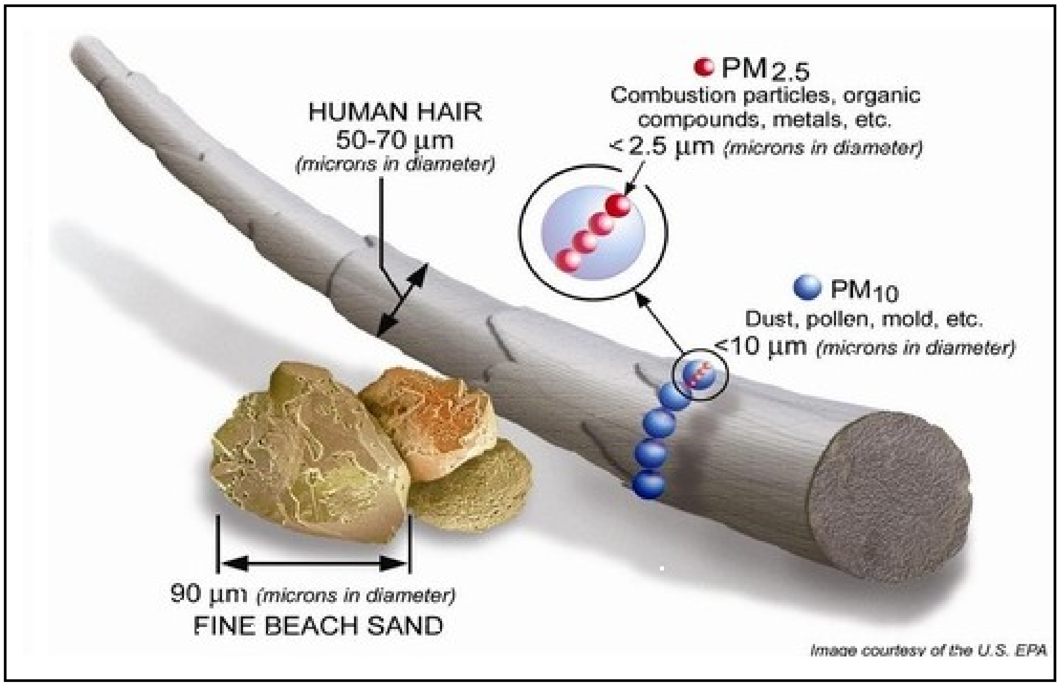
[1] A geographic area that, because of topography, meteorology, and/or climate, is frequently affected by the same air mass.

British Columbia The Best Place on Earth | Ministry of Environment residential woodstoves; exhaust from car and truck engines; and industrial smoke stacks. As well as sources related to human activities, respirable particulate matter is also produced by natural processes (e.g. forest fires). Complicated secondary reactions involving sunlight, ozone, and compounds normally emitted into the air from such processes as decomposition in the soil, compounds emitted by trees, and forest fires can produce blue **hazes**. These types of hazes, either human-caused or naturally produced, can be of concern to a tourist-based community like Nelson, as they contribute to visibility impairment of the scenic landscape. Depending on meteorological conditions, it is possible for particles from the $PM_{2.5}$ size fraction to stay suspended in the air for long periods of time, resulting in poor air quality.

Figure 1 – Relative Sizes of Particulate Matter



The coarse fraction are particles between 2.5 µm and 10 µm in diameter. Particles of this size usually consist of finely ground rock and clay, comes from both human and natural sources, and is often called **fugitive dust**. The most common source of fugitive dust caused by human activity is from unpaved roads or paved roads that have had gravelled traction material applied for winter travelling. In spring, when the roads are no longer frozen or wet, traffic grinds up the gravel into finer and finer particles. These are then either thrown into the air by passing traffic, or picked up by strong winds. Other sources of coarse fraction particulate matter include industrial emissions (e.g., flyash) and sea salt. Depending on meteorological conditions it is possible for the particles to stay suspended for hours or days, resulting in poor air quality. Natural sources of fugitive dust are river and lake banks and dust storms, a problem that affects Nelson when water levels are low.

1.1 Particulate Matter and Health Effects

Small airborne particles or particulate matter are the air pollutants of greatest concern in the Nelson airshed and throughout the Kootenay Region. There are two main reasons for the concern over this pollutant: 1) these particles are small enough to enter our airways and lungs as we breathe, and 2) the emission sources typically found in interior B.C. tend to produce significant amounts of PM.

Human health is affected by the two kinds of particulate matter (PM), designated by both the size of the particle and by their consistency. ***Inhalable*** **particulate matte**r, also known as PM_{10}, consist of particles small enough to be carried into our airways. However, some of these particles are large enough to get trapped in the larger airways and do not reach the smallest airways and cavities in our lungs. The fine and ultrafine fractions, also known as $PM_{2.5}$, are those particles that can travel into the deepest parts of our lungs, hence, the term ***respirable*** **particulate matter**.

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

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 increased development of chronic bronchitis and asthma in some adults, and reduced survival.

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

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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 safe lower threshold for adverse health effects related to particulate matter, which 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.

2.0 Air Quality Objectives/Standards

In order to evaluate air quality, objectives and standards have been introduced regarding acceptable levels of PM_{10} in British Columbia.

2.1 *Provincial Objectives*

Recognizing the threat that PM_{10} poses to human health, the former Ministry of Environment, Land, and Parks (MELP) established an air quality objective for PM_{10} of 50 $\mu g/m^3$ (24-hour average) in 1995. This level is comparable to the maximum acceptable level in the National Ambient Air Quality Objective (NAAQOs) system[3] 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[4]) 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 provincial AQI calculations, PM_{10} levels are compared to reference levels of 25, 50, and 100 $\mu g/m^3$ (comparable to provincial reference 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 and reports the percentage of days that each level is exceeded.

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

[3] For more information about NAAQO, see: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/air/naaqo-onqaa/particulate_matter_matieres_particulaires/summary-sommaire/98ehd220.pdf

[4] 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 calculate the AQI, see http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.info.

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2.2 National Ambient Air Quality Objectives (NAAQOs)[5]

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 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 (i.e., goals determined by the epidemiological effects established by statistical analysis).

Reference Levels

Although negative health effects can occur at any level of particulate matter, the CEPA/FPAC[6] 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 enforceable air quality objectives, but as the basis for establishing goals for long-term air quality management.[7]

Exposure Estimates

Risk to human health is believed to increase linearly with PM concentrations. Hence, a simple estimate of exposure, and therefore risk, can be estimated by summing the concentration above a threshold or reference level over a specific period of time. The method used in this report to calculate exposure is explained in Appendix E.

2.3 Canada-wide Standards (CWS) Agreement

Under the Canada-wide Accord on Environmental Harmonization, the Canadian Environment Ministers (with the exception of Quebec) ratified the Canada-wide

[5] National Ambient Air Quality Objectives: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/naaqo-onqaa/particulate_matter_matieres_particulaires/science_evaluation_scientifique/index_e.html
[6] Canadian Environmental Protection Act Federal-Provincial Advisory Committee
[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.

Standards (CWS) for PM and ozone in July 2000[8]. The CWS process is expected to provide new tools for the management of environmental issues of national interest.

The standards for particulates is based on daily average $PM_{2.5}$ measurements over three consecutive calendar years. The 98^{th} percentile is often used in analyses and comparisons because it reduces the bias caused by a single extremely high reading. For each year, the 98th percentile of the daily averages is determined, then averaged for the last three calendar years. This value, referred to in this report as the **CWS Indicator**, can then be compared to the standard and to other communities.

The adopted standard for $PM_{2.5}$ is 30 $\mu g/m^3$. Although there was no standard or objective set by the CWS for PM_{10}, the previously described "CWS Indicator" is used to analyze historical trends in ambient air quality in this report.[9]

2.4 Comparison of Federal and Provincial Air Quality Criteria

British Columbia has defined three levels (A, B, C) as reference levels, based on the National Ambient Air Quality Objective (NAAQOs) system of the federal government. Level A (less than 25 $\mu g/m^3$) provides good air quality, and will provide long-term protection for the health of people, plants, and animals. Level B provides adequate protection, but may affect personal comfort in sensitive individuals. The range of PM_{10} for Level B is 25 to 50 $\mu g/m^3$. At Level C, above 50 $\mu g/m^3$, appropriate action is required to protect human health.

Table 1 summarizes the provincial and federal air quality criteria.

Level	**Description**	**AQI Rating** (PM_{10} concentration in $\mu g/m^3$)	**Equivalent federal objective**
A	Provide long term protection	Good - up to 25	Maximum desirable
B	Provide adequate protection, but may affect personal comfort. For PM_{10}, the concentration is 50 $\mu g/m^3$.	Fair – 25 to 50	Maximum acceptable
C	Appropriate action required to protect human health	Poor – 50 to 100	Maximum tolerable

Table 1 – Comparison of provincial and federal air quality criteria.

[8] Canada-wide Standards Agreement: http://www.ccme.ca/ourwork/air.html?category_id=99
[9] The B.C provincial government has an objective for PM_{10}, and the federal government has a standard for $PM_{2.5}$. but there is no common objective or standard for both pollutants.

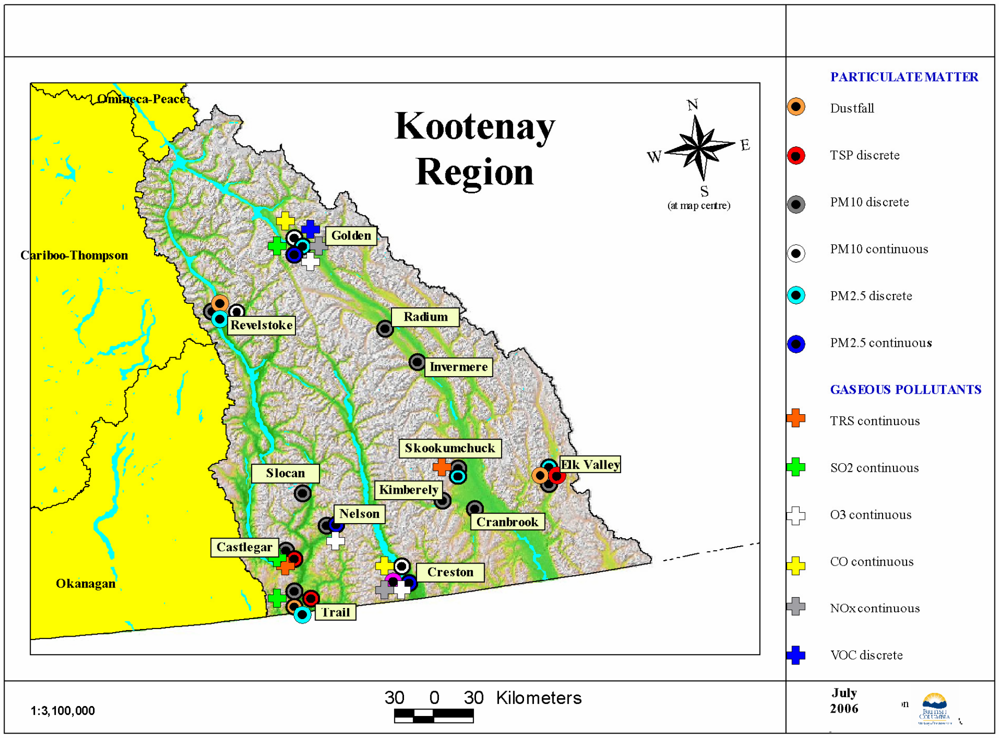
3.0 Air Quality Monitoring in Nelson

Particulate matter levels are measured to determine the concentrations to which people in B.C. communities are exposed. Monitoring enables regulators and policymakers to identify the air quality impacts of current sources and to determine the impacts of new sources or emission control measures. Monitoring over long periods of time allow communities to assess trends that will show if air quality is getting better or worse. It also allows comparison with standards and objectives to assess how Nelson's air quality is doing in relation to health standards. Comparisons can also be done between the air quality in Nelson and in other B.C. communities for which air quality is monitored.

To characterize particulate matter levels in British Columbia, the Ministry of Environment and its predecessors have been monitoring particulate matter levels throughout the province for a number of years. While the earliest monitoring dates back to the early-70s, the large-scale monitoring effort began in 1989.

Several different types of air quality monitors are used across the province. Nelson is equipped with a manual, non-continuous sampler and automatic continuous samplers for PM_{10}, $PM_{2.5}$, and ozone (O_3).

Figure 2 – Air Quality Monitoring Sites in Kootenay Region



Air quality in Nelson is currently monitored by a high air volume (“**Hi-Vol**”) manual sampler located at the government building on 310 Ward Street (Figure 3 and Figure 5). This monitor has been in operation since 1985, with measurement of inhalable particulate matter (PM_{10}) beginning in 1991[10].

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 sampling period and sampling flow rate. Different size sampling head inlets allow for the measurement of very coarse, coarse, or fine PM. Additional analysis can also be performed on the filter to determine the chemical composition of the sample, but is not

[10] PM data collected at this site prior to 1991 includes measurement of very coarse particles (total suspended particulates). While these data represent valid and useful information, the calibration needed to compare to PM_{10} or $PM_{2.5}$ sampling technology is often inaccurate; hence they are not included in this report.

done routinely. This Hi-Vol sampler is set to take one sample of PM_{10} every sixth day (60 or 61 samples per year) and thus is considered a non-continuous sampler.

Environment Canada's National Air Pollution Surveillance (NAPS) program selected Nelson as an airshed of concern and, in 2005, supplied three continuous samplers to help better understand the nature of any air quality problems (Figure 4). These instruments, installed on the roof of the government building on 333 Victoria Street are a TEOM[11] ($PM_{2.5}$), TEOM (PM_{10}), and an ozone sampler. Appendix F1 lists the sampling regime that has been used in Nelson since the start of air quality monitoring.

Because of the continuous data collection and reporting in near real-time, data is available to the public and ministry and health professionals within hours of the sampling. The air quality index is now available, and if needed, health advisories can be issued based on current conditions.

[11] Tapered element oscillating microbalance - an instrument capable of continuously measuring the mass of pollutants in air.

Figure 3 -- High-volume (Hi-Vol) manual sampler on the roof of the government building collects a sample over a 24-hour period every sixth day

Figure 4 – TEOM continuous samplers for PM_{10}, $PM_{2.5}$, and ozone atop the current government building. These were installed in 2005.

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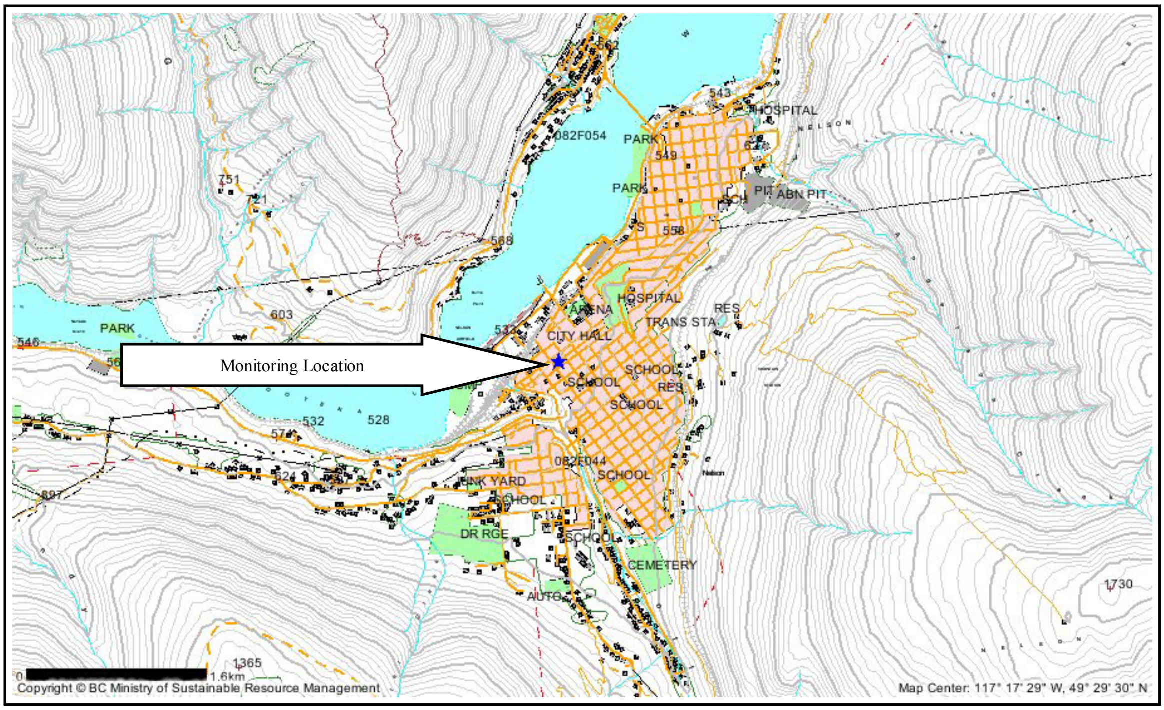
Figure 5 - Location of air quality (PM) sampling instruments in Nelson



4.0 Airshed Description

In general, an **airshed** is that body of air in which management strategies of any individual emission source can have an effect. For example, the backyard burning bylaw in Nelson likely has a positive influence to the air throughout Nelson and surrounding areas, but will likely not affect air quality in Trail or Castlegar. For airshed management purposes, the Nelson airshed is defined by the Kootenay River valley from Balfour to Castlegar. The extent is approximately 30 km from Nelson northeast to Balfour and 20 km west to the Crescent Valley. The ridge to ridge distance is approximately 20 km. The airshed also includes a side valley to the south towards Salmo, approximately 10 km long. (Figure 6).

The steep valley walls that define the airshed make Nelson susceptible to temperature **inversions**, which 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 and because it is denser than the warmer air, it remains trapped by the warm air above. These stagnant conditions prevent upward mixing of the air, allowing pollutants levels to increase near the surface (Figure 7). This is most prevalent during the night but can also occur during the day, especially during the winter season when daylight hours are reduced.

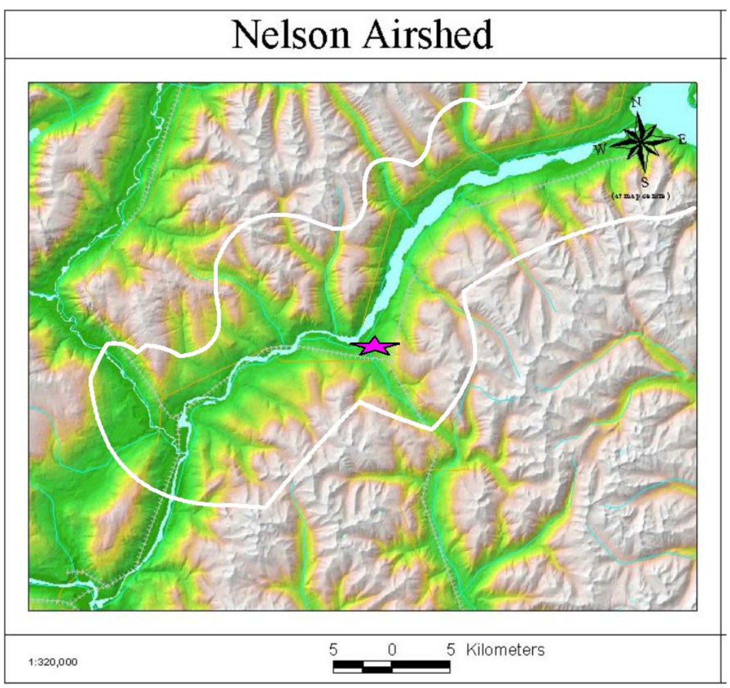


Figure 6 - The steep mountains around Nelson confine the flow of air masses, influencing air quality from Balfour to Castlegar.

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In Nelson, thermal effects[12] from Kootenay Lake can cause cloud cover lasting for several days, and which act to inhibit the "break-up" of the inversions, hence confining the pollutants to the airshed. These prolonged periods of inversions can have severe health effects, especially for those with respiratory problems, as well as children and the elderly. Thus, even though Nelson lacks any major industrial source of pollutants, air quality in the community remains a concern for the Ministry because of the inversions.

Temperature Inversion Conditions

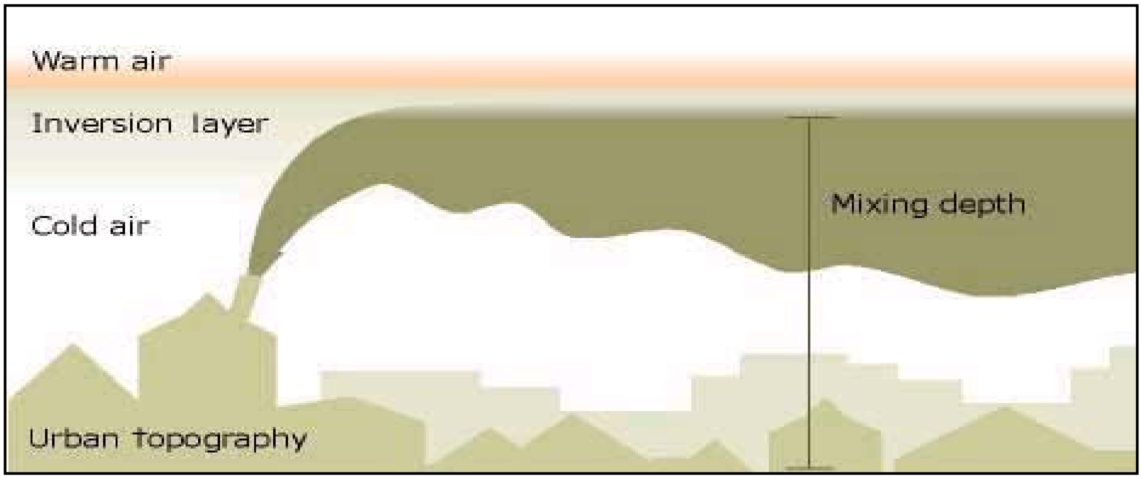


Figure 7 - The warm layer of air on top of the cold layer creates an inversion layer that traps emissions close to the ground.

Graphic courtesy of Environment Waikato, Government of New Zealand.

[12] Differences in temperatures and ability to retain heat between land surfaces and water bodies.

4.1 Influences on Air Quality: Emissions

Provincial Overview

The sources of particulate matter vary from community-to-community and from season-to-season. Based on the year 2000 provincial **emissions inventory**[13], an estimated 850 thousand tonnes of particulate matter were released into the atmosphere as **primary pollutants**[14]. Note that this estimate is only for emissions that result from human activities (i.e., **anthropogenic** emissions).

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

For both PM_{10} and $PM_{2.5}$, the contributions from **area sources**[15] (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.

Point sources[16] of PM in the region include industrial operations, such as wood and pulp mills.

As summarized in Figures 8 and 9, these are the key points from the 2000 Emissions Inventory with regard to particulate matter in the B.C. 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.

[13] MWLAP (2004) *2000 Emissions 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.
[14] Primary pollutants are the chemicals that are emitted directly into the atmosphere. Secondary pollutants are the result of primary pollutants reacting chemically or physically to form different compounds.
[15] An emission source of pollutants that covers a large, and sometimes poorly defined, area.
[16] An emission source of pollutants that remains in a small identifiable area.

$PM_{2.5}$

- 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.

Secondary particles[17] were not considered in the emissions 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 summer. Sulphur dioxide (SO_2), nitrogen oxides (NO_x), various hydrocarbons, and ammonia (NH_3) are important gases involved in the formation of secondary particles[18,19]. Major sources of SO_2 include the cement, pulp and paper, and petroleum industries, as well as motor vehicles[20]. Approximately 75% of NO_x emissions are from motor vehicles and marine vessels. Motor vehicles, solvent usage and vegetation[21] contribute to over 70% of hydrocarbon emissions. Agricultural use of fertilizers is the dominant source of NH_3.

[17] Particles that are not directly emitted into the atmosphere, but are produced by chemical and physical processes. See Appendix A: Secondary Pollutant.
[18] 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.
[19] 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.
[20] ARB (1994) *1990 British Columbia Emissions Inventory of Common Air Contaminants,* Air Resources Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C., December.
[21] "Biogenic" sources are a subset of natural sources and include only those sources that result from biological activity. Biogenic emissions represent a significant portion of the natural source emissions. VOC, NOx, and the greenhouse gases can all be emitted from biogenic sources.

Sources of Inhalable Particulate Matter (PM_{10})

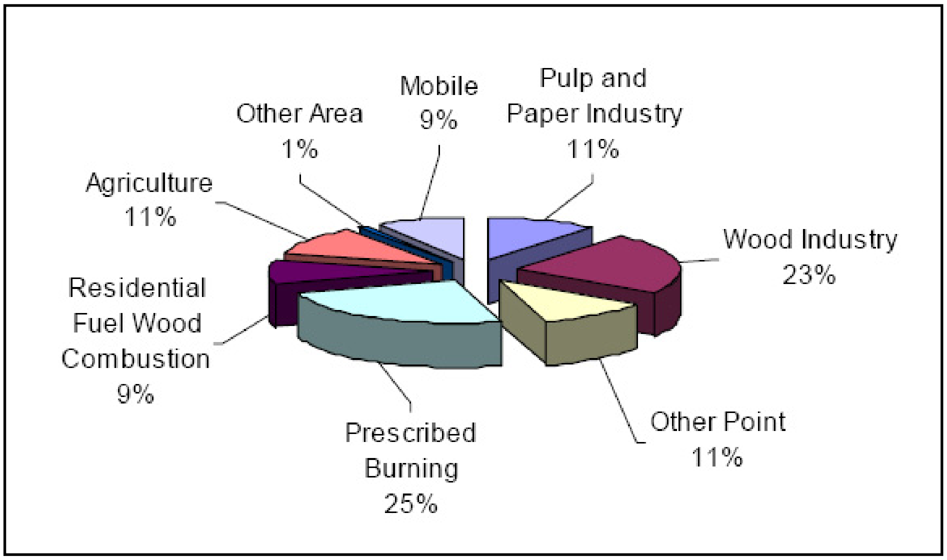
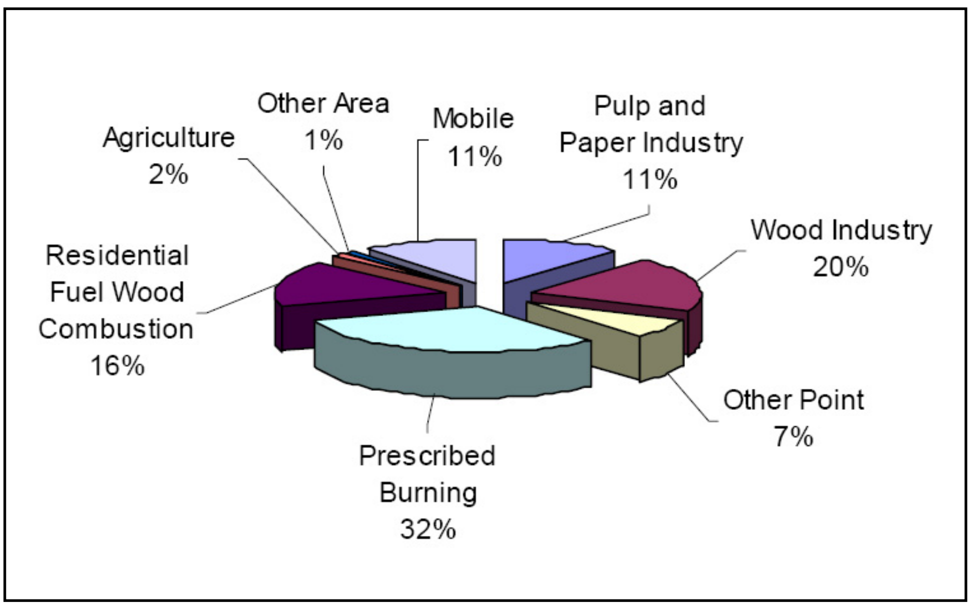


Figure 8 (above) - Human-caused sources of PM_{10}
Figure 9 (below) - Human-caused sources of $PM_{2.5}$
Both figures are for areas outside the Lower Mainland, and exclude natural sources, such as wildfires or **biogenic** emissions, and fugitive road dust. Source: 2000 Emissions Inventory Analysis Report, MWLAP. 2004.

Sources of Respirable (Fine) Particulate Matter ($PM_{2.5}$)



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Of course, each airshed will have a unique mix of emissions and sources. While a rigorous emission inventory has not been produced for the Nelson airshed it is clear that the sources will be somewhat different than those indicated by the graphics in Figures 8 and 9. The main difference relates to the relatively minor influence in Nelson from sources such as the pulp and paper industry and wood products industry. The primary emission sources in Nelson are residential heating, mobile (including resultant road dust), prescribed (including 'slash') burning, lake/river beds, and wild fires.

The provincial government 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[22.] A model bylaw[23] has been developed to assist local governments in restricting backyard burning. Beehive burners (large domed incinerators used by lumber mills to burn wood waste) are being phased out, beginning in the most smoke-sensitive areas of the province.

[22] *Environmental Management Act* http://www.env.gov.bc.ca/epdiv/env_mgt_act/.
A Guide to the Open Burning and Smoke Control Regulation
http://www.env.gov.bc.ca/air/particulates/agttobsc.html
[23] Model burning bylaw http://www.env.gov.bc.ca/air/particulates/pdfs/bylaw.pdf

4.2 Influences on Air Quality: Weather and Terrain

Besides emission sources, both human-caused and naturally occurring, there are other factors that play an important role in 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-northeast to south-southwest), which may be the result of either valley channelling or diurnal valley flows (Figure 10). In either case, the town of Nelson is more susceptible to particulate matter emissions from these directions.

Daily Cycle of Air Flows in Valleys

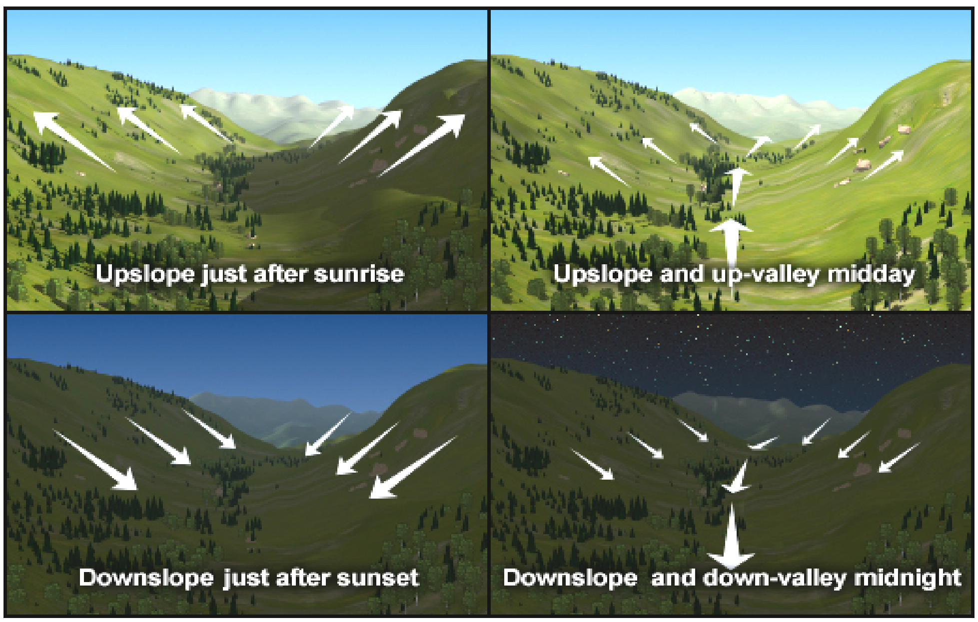


Figure 10 - Airflow during the daytime tends to be upslope and up-valley. During the nighttime this tendency reverses and denser, cooler air pools in valley bottoms.

Source: 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.

Wind speed and direction are important drivers of ambient air pollutant levels. Generally, low wind speeds, like those often encountered during stagnant winter time conditions, impede the ability of the atmosphere to disperse pollutants. Of course, wind direction dictates whether pollutants from any one source are being carried towards or away from an air quality sampler.

An airshed is often bounded by natural topographic features. In the case of the Nelson airshed, the Selkirk and Monashee Mountains play a large role in determining the containment and/or dispersion of air pollutants. The steep valley walls make Nelson more susceptible to temperature inversions.

5.0 Air Quality in Nelson

As explained above, there are several air quality samplers located in Nelson. Since 1991, the Ministry of Environment has operated an inhalable particulate matter (PM_{10}) high volume (Hi-Vol) sampler at the government building on 310 Ward Street, and it has provided a substantial amount of data to assess air quality trends in Nelson. Table 1 summarizes the results of the PM_{10} monitoring since the operation of the Hi-Vol began.

The continuous samplers have been in operation only since 2005 so the data from them is very limited. Because of this, most of this report is based on the long-term Hi-Vol data.

5.1 Results and Trends

Each Hi-Vol filter sample is reported as an average of the PM_{10} concentration for a 24-hour period. The results of these samples (a maximum of 60 or 61 per year – one sample every six days) are analyzed to calculate the **mean** (arithmetic average), **median** (value closest to the centre of the range of readings), 98^{th} percentile and maximum. Because of equipment failures or problems with laboratory analysis, data are not obtained for every sampling day. The data capture rate reflects the annual availability of data and therefore a measure of the representativeness of the data for a particular year.

Comparison among Communities

To put air quality in Nelson in perspective, it was compared to other B.C. communities as shown in Figure 11. Abbotsford, Golden, and Radium were chosen to compare to Nelson, to demonstrate a range of geographic locations and air quality differences. Although Abbotsford has the lowest PM_{10} concentrations, it suffers with higher ozone levels, especially in summer, whereas Kootenay communities have low ozone concentrations, but PM_{10} is a concern. These disparities demonstrate the difference in regional air quality issues. Over the period from 2000 to 2005, Nelson's air quality was usually within an acceptable range. Golden had air quality readings higher than Nelson, well above acceptable concentrations.

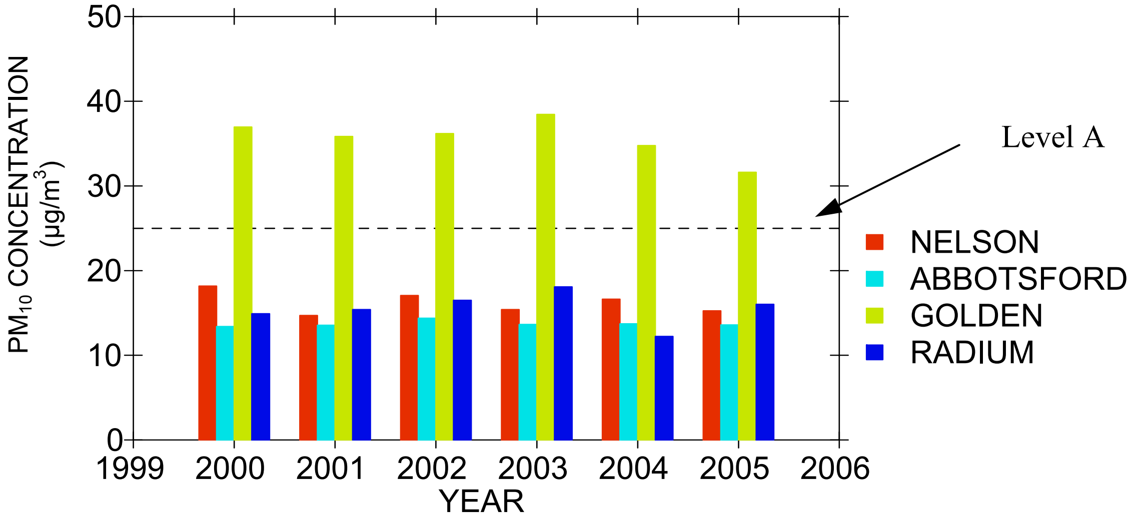
Year	Data Capture (%)	Mean (ug/m^3)	Median (ug/m^3)	98th Percentile (ug/m^3)	Fair Days (%)	Poor Days (%)	Very Poor Days (%)	Exposure Indicator (ug/m^3 per day per year)	CWS Indicator (ug/m^3)
1991*	21.7	22	18	57	25.0	6.3	0	148	n/a
1992	82.0	19	16	51	16.0	4.0	0	117	n/a
1993	63.9	18	15	43	14.8	1.6	0	66	110
1994	59.0	15	13	31	12.2	0	0	36	73
1995	95.1	16	15	37	13.8	0	0	44	49
1996	98.4	19	14	52	16.7	3.3	0	110	63
1997	93.4	22	19	88	19.0	5.2	0	176	110
1998	88.5	28	23	65	35.2	7.4	1.9	338	208
1999	93.3	22	18	57	17.9	7.1	0	143	219
2000	95.1	18	17	51	8.6	3.4	0	63	181
2001	91.8	15	12	41	10.5	0	0	45	84
2002	54.1	17	14	31	17.5	2.5	0	55	54
2003	75.4	15	14	38	8.7	2.2	0	56	52
2004	91.8	17	14	55	8.9	5.4	0	78	63
2005	86.9	15	12	40	14.8	1.9	0	61	65

Table 2 - Summary of annual inhalable particulate matter (PM_{10}) measured in Nelson from 1991 to 2005. Data capture is the percentage of samples collected in a year, compared to the maximum possible number of samples (60 or 61 per year). Concentrations (Mean, Median, and 98th Percentile) are measured in micrograms per cubic metre (µg/m^3). The Mean is the calculated arithmetic average of readings for each day sampled. The Median is the middle reading of the range of readings[24]. The 98th Percentile is the near-maximum reading in each year (the absolute maximum reading is not used for analysis because an unusually high reading can distort the analysis unduly).

The percent of days with Fair, Poor, and Very Poor air quality are measures of **exceedances** of NAAQO levels, showing the percentage of days where PM_{10} exceeded Level A (25 µg/m^3), Level B (50 µg/m^3), and Level C (100 µg/m^3). The **Exposure Indicator** is a cumulative factor of the time exposed to PM_{10} above a reference health level of 25 µg/m^3 (see Appendix E for the method of calculation). The CWS indicator is the three-year running average of the 98th percentile of daily averages - an indicator used to compare communities.

24 The arithmetic mean (or arithmetic average), geometric mean, and median are statistical terms describing methods of determining the **central tendency** of a set of data. Though they are considered to be "averages" they are often not the same. The use of the term "average" without a descriptive qualifier (such "arithmetic") in this report is more qualitative and suggests what a "typical" air quality reading would be for that weekday/month/year. More on this topic can be found in Appendix C.

* 1991 has low data capture rate – it is presented here, but were not used in further analysis of annual trends of Nelson's air quality.



Comparison of PM_{10} in Nelson, Abbotsford, Golden, and Radium

Figure 11 - Average PM_{10} concentrations for Nelson and three other B.C. communities from 2000 to 2005. Nelson's average air quality has been fairly consistent over this period, and closely comparable to Radium. Abbotsford has had slightly lower concentrations of PM_{10}, but has different air quality problems (primarily ozone). Golden has had higher levels of PM_{10}, averaging about double the concentrations measured in Nelson. The dotted line at 25 µg/m^3 is the lower reference level, equivalent to provincial Level A.

Annual Comparisons

The results of the monitoring indicate that there was a decreasing trend in the mean inhalable particulate matter (PM_{10}) concentration in the early 1990s. The year 1999 also had high readings. These levels of PM_{10} are similar to levels recorded in other Kootenay communities, as shown in Figure 11.

The CWS Indicator and the Exposure Indicator also have decreased in recent years, after being quite high from 1996 to 1999 (Figure 13).

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Annual PM_{10} Variation in Nelson between 1992 and 2005

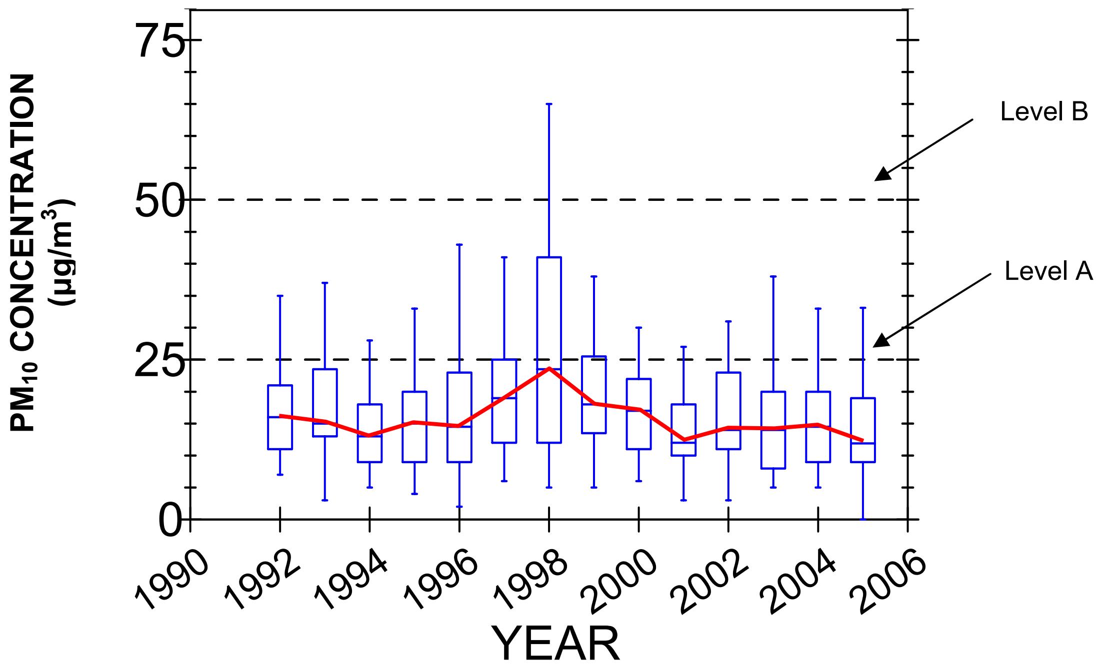

Figure 12 – For each year, the rectangle (box) and lines provide information about the average and extreme PM_{10} concentrations. The median value (the line in the middle of each box) is an average value for each year. It has been fairly consistent, except for a rise in 1997, 1998, and 1999, which were bad years for forest fires. The boxes show the range of the middle 50% of the readings. The lines extending from the ends of the boxes show most of the extreme range of readings for each year. For example, in 1992, the median concentration was about 16 $\mu g/m^3$, 50% of the readings were between 12 and 21 $\mu g/m^3$, the minimum reading was 3 $\mu g/m^3$, and the maximum was 35 $\mu g/m^3$. The dotted lines at 25 and 50 $\mu g/m^3$ represent B.C. Level A and Level B reference levels. For further explanation about reading this type of graph, see Appendix B. For further information on statistical significance of these years see Appendix C.

However, based on the NAAQO standards, there are still a number of days each year that exceed standards for fair (Level B) and poor (Level C) air quality. (Figure 13) The year with the most exceedances was 1998 (the severe fire year), and 2002 and 2005 were higher than other recent years. However, the overall average since 1999 has been lower than pre-1997 levels. Exceedance days are of particular concern to health officials, especially the effects on children, the elderly, and those with respiratory problems. The exposure increments also reflected the spike in PM concentration in 1998, but have otherwise been fairly consistent.

Ideally, there should be no exceedance days, so even 10 to 15% exceeding Level A and 3 to 5% exceeding Level B are cause for concern about air quality.

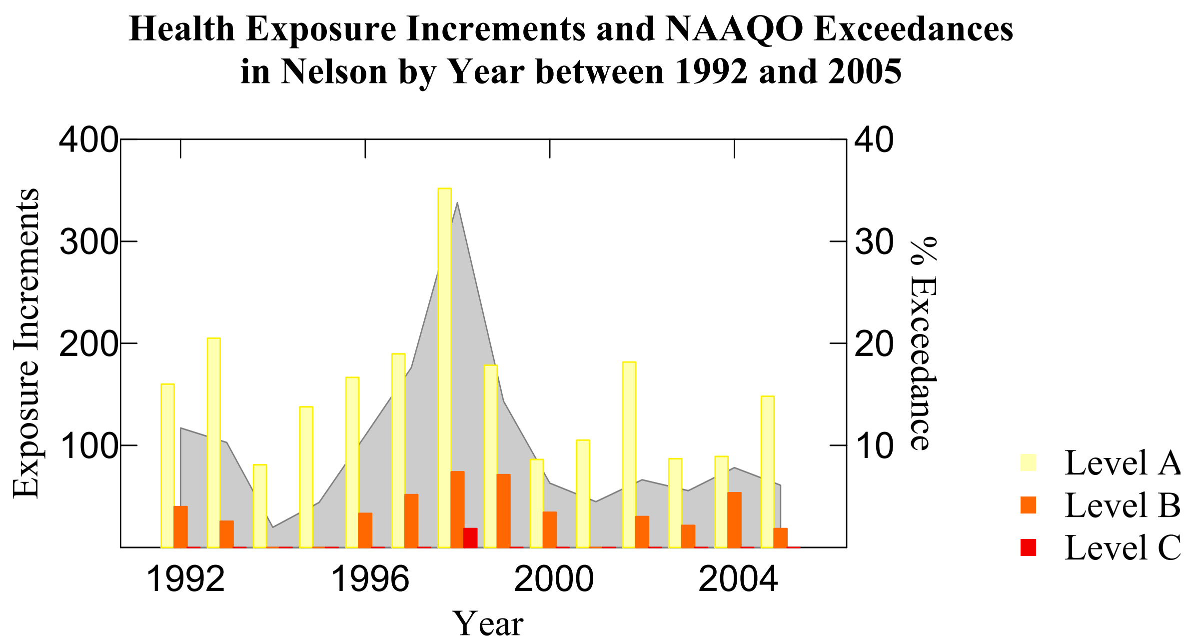

Figure 13 – The grey profile describes the annual variation in the Exposure Indicator – a measurement of cumulative exposure to PM_{10} (using the scale of the left axis). In 1998, severe forest fires caused higher exposure estimates. The bars represent the percentage of days when PM_{10} exceeded Levels A, B, and C NAAQO health levels (right axis). Again, 1998 showed the most exceedances, and was the only year to have a Level C exceedance. Since then, exceedances have returned to levels slightly below pre-1997 levels.

It is also important to note that part of the variation in year to year concentrations of PM_{10} is due to between-year climate variability, since meteorological conditions will favour dispersion in some years and not others. The time series presented here have not been de-climatized to adjust for this factor.

Seasonal, Monthly, and Day of Week Patterns

The PM_{10} data for Nelson were examined for trends based on seasonal, monthly, and day of week patterns. The analysis by seasons (Figure 14) shows no clear trends, as there is considerable variability among seasons and years. Averaged over the range of years analyzed in Table 2, winter has the highest PM_{10} concentrations, and autumn has the lowest. However, one can discern considerable inter-annual variability. For example, summer has the highest levels in some years, typically caused by forest fires, especially 1998.

Seasonal Variation of PM_{10} in Nelson from 1992 to 2005

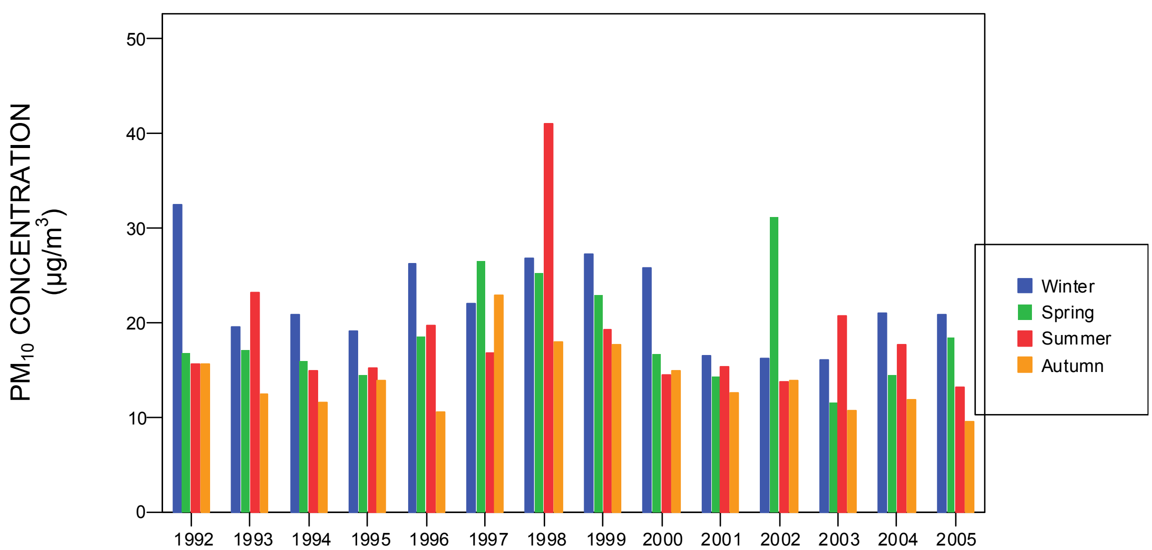

Figure 14 – Four coloured bars show the seasonal PM10 concentrations for each year. Only one pattern is noticeable in the graph. Autumn PM_{10} is often lower than other seasons. Some high readings in summer and fall, such as in 1998, are often related to forest fires. Within a given year, seasons can vary widely, such as in 2002, where spring was considerably higher than the other seasons.

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Monthly variation in PM_{10} concentration for each month is shown in Figure 15.

The graph shows two peaks in PM_{10} concentration. The February-March peak is likely from road traction material being ground into finer dust that can become airborne when roads dry in spring. The slight peak in August reflects the impact of forest fire smoke.

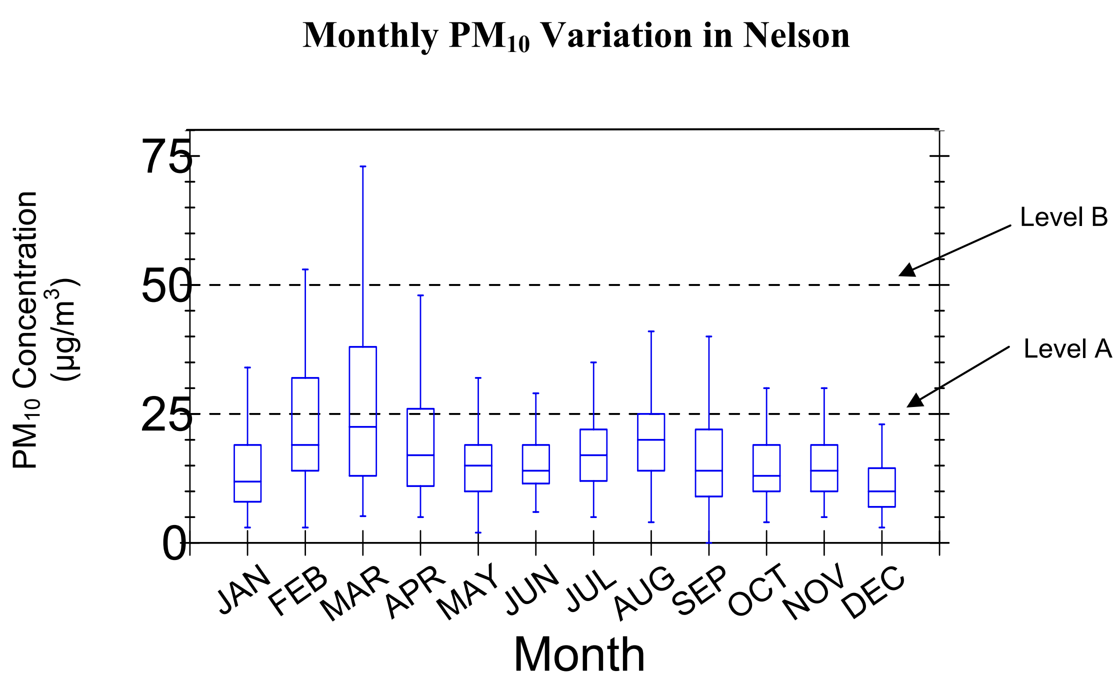

Figure 15 – Monthly particulate matter concentrations for the period 1991 to 2005. The worst month has been March, followed by February and August. The median value (the line in the middle of each box) is an average value for each month. The boxes show the range of the middle 50% of the readings. The lines extending from the ends of the boxes show most of the extreme range of readings for each year. For example, in March the average (median) has been 23 µg/m^3, half of the readings are between 17 and 37 µg/m^3, and the range of readings is from 7 to 73 µg/m^3. See Appendix B for further explanation of this type of graph.

In Figure 16, PM_{10} exceedances by month indicate that many days have substandard air quality; approximately 40% of the days are Level A or Level B health reference levels.

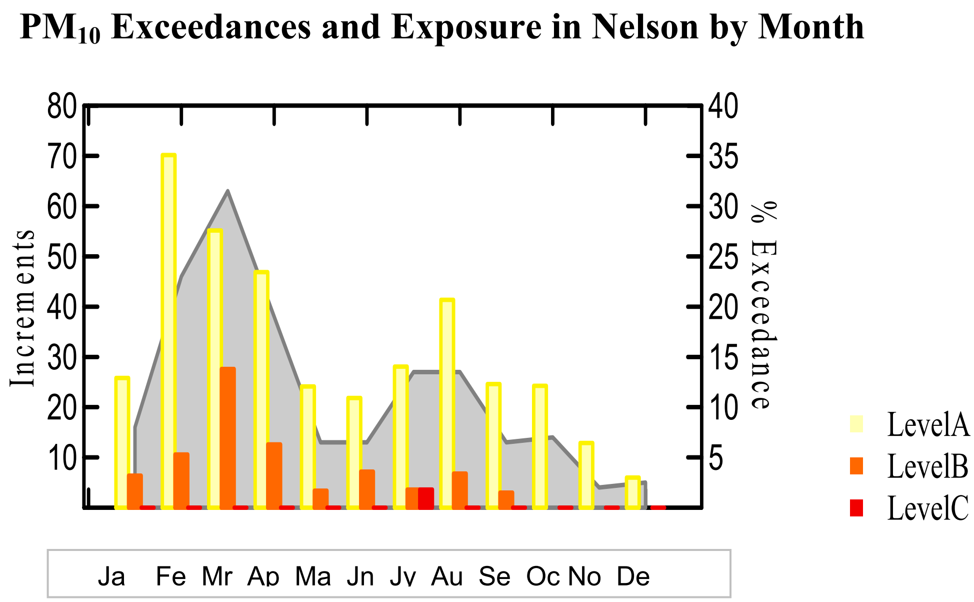

Figure 16 - The grey profile describes the monthly variation in the Exposure Indicator – a measurement of cumulative exposure to PM_{10} (using the scale of the left axis). The bars represent the percentage of days when PM_{10} exceeded Levels A, B, and C NAAQO health levels (right axis). These health indicators show that in February and March, over 40% of the days exceed the minimum air quality (25 µg/m^3) for human health, when Level A and Level B exceedances are combined. August also shows an elevated health risk.

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Figure 17 shows the variation in PM_{10} for the days of the week. Increased activities during weekdays result in higher concentrations, and reduced activities on Sunday cause lower concentrations.

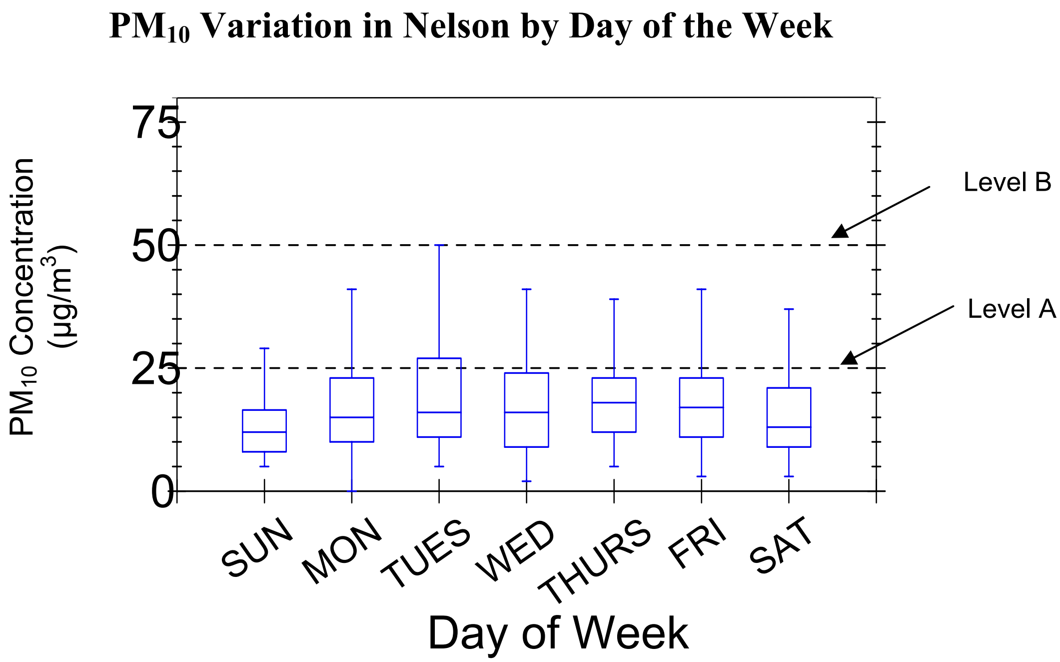

Figure 17 – Particulate matter concentrations for each weekday for the period 1991 to 2005. Weekday readings (Monday to Friday) are higher, which can probably be attributed to increased industrial and vehicular activity. Sunday concentrations are lower, when activities are at a minimum. See Appendix B for further explanation of this type of graph.

Patterns from Continuous Sampling

The installation of TEOM samplers for PM_{10} and $PM_{2.5}$ in March 2005 expanded the air quality monitoring capabilities for Nelson, although not enough data has been collected to identify long-term trends. Because $PM_{2.5}$ is a portion of PM_{10}, it should always be less, as shown in Figure 18. Generally, the concentrations of these two forms of particulate matter are related, although the exact relationship can vary depending on the season, source of emissions, and type of chemicals that make up the emissions.

In the data collected so far, the two particulate matter types seemed consistent in some months, but varied in others. Concentration of PM_{10} varied widely, being high in late winter, and slightly lower in the autumn. The level of $PM_{2.5}$ has remained consistent, except for an increase in August, followed by a drop in September. This indicates that there may be a steady background level, with smoke from forest fires as a clearly identifiable source.

The inconsistent relationship between PM_{10} and $PM_{2.5}$ is clearly shown by the high PM_{10} levels in late winter while $PM_{2.5}$ was unchanged, and in August, where $PM_{2.5}$ increased while PM_{10} actually dropped.

Comparison of PM_{10} and $PM_{2.5}$ by Month

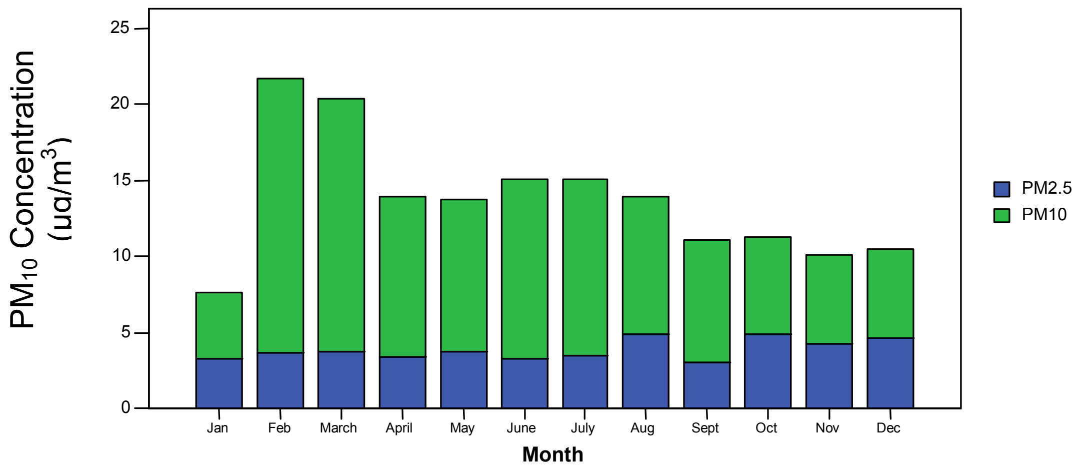

Figure 18 – Two continuous (TEOM) samplers monitored PM_{10} and $PM_{2.5}$ simultaneously from March 2005 until June 2006. Both sets of data are summarized for each month. $PM_{2.5}$ was fairly consistent over this period of time. The level of PM_{10} was much higher in late winter, rose slightly in the summer, and was lower in the autumn. From September to January, the two readings follow parallel trends, but diverge in February-March and in August. Data are very limited; therefore long-term trends cannot be assessed. See Appendix D for a regression analysis of the comparison of PM_{10} and $PM_{2.5}$ data.

Ongoing monitoring with continuous samplers (TEOMs) will increase the knowledge about air quality in Nelson, allowing us to understand the variations in concentrations of PM, its sources, and its effects. Further, officials can react better to episodes of diminished air quality by determining the causes, and by issuing timely air quality warnings.

6.0 Conclusions / Recommendations

In summary:

- With the exception of 1997, 1998, and 1999 (bad fire years), the air quality in Nelson has remained in a fairly stable state.
- Every year there are days that exceed national guidelines for acceptable air quality that are a concern to public health officials.
- Exceedances of these standards are concentrated in specific late winter and summer months. These peaks have been linked to natural and human causes. Continued and increased monitoring will aid in identifying what causes these peaks.
- The steep valley walls surrounding Nelson makes it more susceptible during the winter to temperature inversions that trap particulate matter. These periods of inversions during times of higher emissions from road dust and wood burning appliances can result in adverse health effects, making Nelson an airshed of concern for the MoE.
- With only discrete PM_{10} measurements, it is difficult to differentiate between sources and types of particulate matter in Nelson. A more comprehensive monitoring program began in 2005 involving continuous $PM_{2.5}$ and PM_{10} measurements.

Because of the high potential for inversions in the Nelson airshed, the community should be concerned about particulate matter levels. Even low or moderate amounts of particulate matter emissions can be magnified by the effects of an inversion, resulting in negative health effects. In addition, the community should be attempting to reduce levels of particulate matter as there is no minimum health impact level or 'safe' level for PM_{10} or $PM_{2.5}$[25]. This means that even at low levels of particulate matter there is an impact on community health.

Figure A4 in Appendix C identifies yearly trends of ambient levels in Nelson. Those involved with developing airshed management planning (typically municipal levels of government, industrial stakeholders, MoE, and advocacy groups) should examine more closely those years outside the expected range (as determined by statistical analysis) for possible reasons for a particular year's elevated/depressed level. In particular, departures from the norm may be a result of favourable/unfavourable weather conditions. Others may be a result of changes in airshed emission levels/sources. Such knowledge will help guide the identification of strategies to improve air quality.

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[25] http://www.healthservices.gov.bc.ca/pho/pdf/phoannual2003.pdf

The following are some recommendations to improve current air quality in Nelson:

- Residents should be encouraged to buy more efficient wood heat appliances (woodstoves).
- Residents should be educated in techniques of efficient woodstove operation, selection of fuel, and proper storage and curing of wood.
- Local municipalities should continue to identify different/additional techniques that could result in more efficient winter road maintenance and reduction of road dust. Examples of such measures are more frequent street cleaning, coarser sand for roadways, and possibly the use of magnesium chloride to keep roadways clear of ice. A recent collaboration between MoE and the Ministry of Transportation and Highways has resulted in the development of a 'best management practises' document. This can be found at:
  http://www.env.gov.bc.ca/air/airquality/pdfs/roaddustbmp_june05.pdf
- Local municipalities are encouraged to engage in air quality management planning. A tool to assess the need for planning and the options to consider has been developed and can be accessed at:
  http://www.airqualityplanning.ca/
- Bylaw enactment and enforcement is another tool often used to improve local air quality. The following sites offer examples to help guide local levels of government in bylaw development:
  Backyard burning bylaw template:
  http://www.env.gov.bc.ca/air/particulates/pdfs/bylaw.pdf
  Wood stove bylaw template:
  http://www.ec.gc.ca/cleanair-airpur/default.asp?lang=En&n=975A1778-1

For More Information

The Environmental Quality Branch of the Ministry of Environment has several reports on air quality at http://www.env.gov.bc.ca/air/airquality/index.html

A report on Air Quality in the Kootenays 1993-1999 is available at http://wlapwww.gov.bc.ca/kor/epd/pdf/kootenay_air_quality_report.pdf

The Environmental Protection Division of the Ministry of Environment in the Kootenay Region has information at http://wlapwww.gov.bc.ca/kor/

B.C. provincial legislation related to air quality is described at http://www.env.gov.bc.ca/air/airregs.html

The 2003 Provincial Health Officer annual report about air quality in British Columbia can be found at http://www.healthservices.gov.bc.ca/pho/pdf/phoannual2003.pdf

Ministry of Environment
Contact: Paul Willis

205 Industrial Rd. G,
Cranbrook, B.C. V1C 6H3
Phone: (250) 489-8540
Fax: (250) 489-8506
Email: Paul.Willis@gov.bc.ca

Public feedback is welcomed

Appendices

Appendix A - Glossary and Abbreviations

98th percentile In a sequential list of data values, the 98th percentile is the data value that is 98 percent of the way through the list from the smallest reading (or 2 percent below the highest reading). The absolute maximum reading is not used for analysis because an unusually high reading may be the result of outlier (or suspect) data and can distort the analysis unduly.

Aerosol A particle of solid or liquid matter that can remain suspended in the air because of its small size (generally under one micron).

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

Airshed A geographic area that, because of topography, meteorology, and/or climate, is frequently affected by the same air mass. In general, it is that body of air in which management strategies of any individual emission source can have a discernible effect.

Air Quality Index (AQI) Reports levels of ozone, particulate matter, and other common air pollutants. Higher AQI ratings for a pollutant indicate higher levels of contaminants in an airshed. For guidance on how to compute the AQI, see http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.info.

Anthropogenic Produced by human activities.

ARB Air Resources Branch, Ministry of Environment

Area source An emission source of pollutants that covers a large, and sometimes poorly defined, area – sometimes call non-point source (e.g., prescribed burning and residential fuel wood combustion). Note: A single residential wood burning appliance is considered a small source of emissions, but many appliances together can emit a significant amount of emissions, and are collectively thought of as an area source, instead of many small point sources.

Biogenic Having to do with living organisms as sources. For example, major sources of biogenic emissions in the Kootenay Region are trees.

Carbon monoxide (CO) A colourless, odourless, poisonous gas, produced by incomplete burning of carbon-based fuels.

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Central tendency In statistics, a measure of the middle or center of a set of data. The arithmetic mean is the most commonly used, but median, mode, and geometric mean are also used. See Appendix C for a detailed description.

CEPA/FPAC The Canadian Environmental Protection Act Federal-Provincial Advisory Committee directs the development and assessment of National Ambient Air Quality Objectives (NAAQOs) for airborne pollutants.

Coarse fraction Particulate matter with diameter between 2.5 and 10 microns ($PM_{10-2.5}$). Also referred to as "inhalable particulate matter."

CWS Indicator A measure of the severity of maximum levels of $PM_{2.5}$ concentration. The 98th percentile of the daily averages is determined for each year, then averaged for the last three calendar years (which reduced the influence of a particularly bad year). This value can then be compared to a given standard and to other communities. Though the CWS standard for particulate matter is limited to $PM_{2.5}$ concentrations, this report adopts this algorithm for PM_{10} analysis and comparison purposes.

Emissions Inventory (EI) A list of air pollutants emitted into a community's atmosphere in amounts (commonly tonnes) per day or year, by type of source.

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

Exposure Indicator A measure of the accumulated exposure to PM_{10} over a specified time (typically one year), taking into account both the concentration of PM_{10} and the length of time of exposure. Larger exposures indicate an increased risk to human health.

Fine fraction Particulate matter with diameter less than 2.5 microns; $PM_{2.5}$. Also referred to as "respirable particulate matter".

Fugitive dust PM_{10} from finely ground rock and clay, origination from human sources such as sand and gravel traction material applied to roads in winter, or from natural sources such as exposed lake beds and river banks.

Haze Atmospheric aerosol of sufficient concentration to be visible. The particles are so small that they cannot be seen individually but are still effective at attenuating light and reducing visual range.

Hi-Vol High volume sampler – an instrument that draws large volumes of air through a filter that traps pollutants.

Inversion An increase in temperature with height, which is the reverse of the normal cooling with height in the atmosphere. Warm air at ground level tends to rise, but because warmer air is already above it, vertical air movement is minimized, trapping atmospheric pollutants in the lower troposphere, and resulting in higher concentrations of pollutants at ground levels than would usually be experienced.

Mean In statistics, an "average" (arithmetic mean) calculated by dividing the total of all values of a set of data by the number of values. (In special circumstances, the geometric mean is used instead – see Appendix C.)

Median In statistics, the value closest to the middle in a ordered list of data values.

MoE B.C. Ministry of Environment. (formerly Ministry of Water, Land, and Air Protection - MWLAP).

MELP B.C. Ministry of Environment, Lands and Parks. (predecessor to MWLAP).

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

µm Micrometres (10^{-6} m) (diameter)

Mobile sources Motor vehicles and other moving objects that release pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles, and gasoline-powered lawn mowers. Mobile sources are divided into two groups: road vehicles, which include cars, trucks, and buses, and non-road vehicles, which includes trains, planes, and lawn mowers.

MWLAP B.C. Ministry of Water, Land and Air Protection (formerly Ministry of Environment, Lands and Parks and now the Ministry of Environment).

NAPS National Air Pollution Surveillance Network. NAPS was established by Environment Canada to monitor and assess the air quality in Canadian urban regions.

National Ambient Air Quality Objectives (NAAQO) Health-based pollutant concentration objectives, developed by Environment Canada and used as objectives and standards in B.C.

National Ambient Air Quality Standards (NAAQS) Health-based pollutant concentration limits established by the United States Environmental Protection Agency that apply to outside air.

Nitrates (NO^{3-}) Those gases and aerosols that have origins in the gas-to-aerosol conversion of nitrogen oxides, e.g., NO_2; of primary interest are nitric acid and ammonium nitrate.

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Nitrogen oxides (NO_x) Gases formed mainly from atmospheric nitrogen and oxygen when combustion takes place under conditions of high temperature and high pressure; considered a major air pollutant and precursor of ozone.

NO_x NO + NO_2 + poorly defined fraction of other NO_x species (given conventional analyzers).

Ozone (O_3) A major component of smog. Ozone is not emitted directly into the air but is formed by the reaction of volatile organic compounds (VOCs) and NO_x in the presence of heat and sunlight.

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: the fine fraction of PM, also called respirable particulate matter. 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.

PM_{10} Particulate matter less than 10 microns in diameter, including both coarse and fine fractions, also called inhalable particulate matter. 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 easily enter the respiratory system where they may be deposited, resulting in adverse health effects. PM_{10} also causes visibility reduction and is a criteria air pollutant.

$PM_{10-2.5}$/PM_{coarse} Particulate matter between 2.5 and 10 microns in diameter; the coarse fraction of PM. Particles that are typically generated by mechanical grinding or crushing (e.g. road dust) but can include soot, ash and pollen (biogenic) particles. These particles are less likely to enter the air sacs of the lungs but instead are trapped by the mucous membranes and other lung defenses. Coarse particles are not deemed as dangerous to human health as $PM_{2.5}$ but are, nevertheless, associated with inflammatory symptoms such as asthma and other respiratory ailments.

Point source An emission source of pollutants that remains in a small identifiable area (e.g., an industrial plant)

Primary particle The fraction of $PM_{2.5}$ or PM_{10} that is directly emitted from combustion and fugitive dust sources.

Primary pollutant The emissions discharged from a source that either retain their form or are transformed into secondary pollutants.

Secondary particle The fraction of PM_{10} and $PM_{2.5}$ that is formed in the atmosphere. Secondary particles are products of the chemical reactions between primary pollutant gases, such as nitrates, sulphur oxides, ammonia, and organic products.

SO_2 See Sulphur dioxide

Sulphur dioxide (SO_2) A pungent, colourless gas formed as a byproduct of the combustion of fossil fuels.

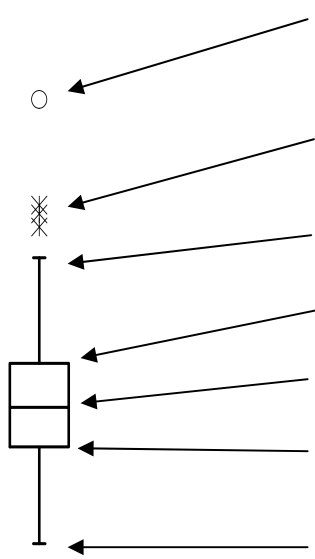
TEOM Tapered element oscillating microbalance. An instrument for the continuous measurement of PM.

Ultrafine fraction Particulate matter with diameter less than 0.1 microns.

Appendix B - Reading a Boxplot Graph

A boxplot describes the distribution of a set of data. When data are listed in numerical order, a boxplot indicates how many of the data values are contained within a certain range, and how widely the data are spread out.

The median value (the line in the middle of each box) represents the middle value of a sequential list of data. It is the midpoint, where 50% of the data readings are lower and 50% are higher. The ends of the box show the range of the middle 50% of the data – from 25% to 75% through the range of data. The lines extending from the ends of the boxes (called whiskers) show most of the extreme range of readings for each year. The whiskers extend to existing data points, but only to a maximum of 1.5 times longer than the length of the box. If the data are fairly evenly distributed, most of it should fall within the whiskers. Points beyond the whiskers are extreme values, and indicate problems with air quality or with the data. These outliers and outside values were not plotted in figures for this report.



Outlier	Extreme values. (Confidence in the data is low.)
Outside values	Extreme values
Upper inner fence	Most data is below this
Upper hinge (75th percentile)	
Median	Midpoint of the data
Lower hinge (25th percentile)	
Lower inner fence	Typically the lowest value

Figure A1. A typical boxplot with the names and descriptions of key features.

Appendix C – Central Tendency and Statistical Significance[26]

In statistics, **central tendency** is a measure of the location of the middle or the centre of a distribution of data. The definition of "middle" or "centre" is purposely left somewhat vague so that the term "central tendency" can refer to a wide variety of measures.

The arithmetic mean (also known as the arithmetic average) is the most commonly used measure of central tendency (refer to Table 2 and Figures 11, 14, 18). It takes every score into account, is the most efficient measure of central tendency for normal distributions[27] and is mathematically tractable making it possible for statisticians to develop statistical procedures for drawing inferences about means.

On the other hand, the mean is not appropriate for highly skewed distributions[28] and is less efficient than other measures of central tendency when extreme scores are possible. Environmental data can often be highly skewed and means tend to be unduly influenced by extreme events, rendering it less appropriate to indicate "typical" or "average" or "central" tendencies. The geometric mean is a viable alternative if all the scores are positive and the distribution has a positive skew.

The Nelson PM_{10} data appears to be a typical example of environmental time series data. Figure A2 shows that this data distribution is skewed to the right bringing into question whether the mean will be the best descriptor of this data.

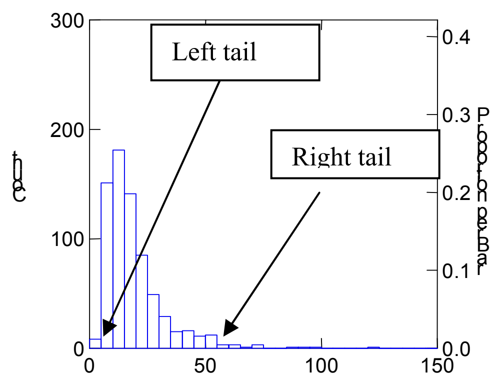


Figure A2. Histogram of Nelson PM_{10} data distribution, showing a highly skewed distribution.

[26] Although this report explains the concepts of statistics needed to understand Nelson's air quality, other reference material should be consulted to understand all the details of the report. Some statistical results have been included for those conversant with advanced statistical concepts.
[27] The normal distribution (the "bell-shaped curve" which is symmetrical about the mean) is a theoretical function commonly used in inferential statistics as an approximation to sampling distributions. Normal distributions are symmetric with scores more concentrated in the middle than in the tails.
[28] A distribution is skewed if one of its tails is longer than the other. A positive skew means that it has a long tail in the positive direction (sometimes called "skewed to the right") and a negative skew has a long tail in the negative direction (sometimes called "skewed to the left").

A common statistical approach to find the best central tendency measure is to transform the data in some manner so they approximate a normal distribution. In the case of the Nelson data, the natural logarithm of the original data results in a more normally distributed curve, as shown in Figure A3.

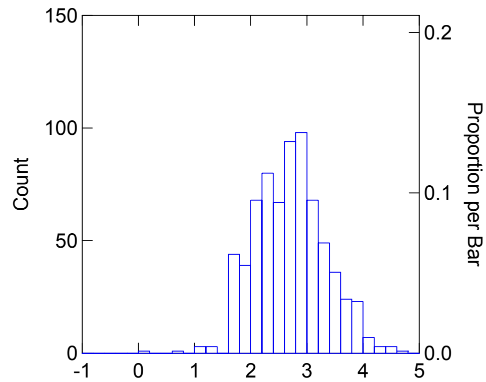


Figure A3. Histogram of the natural logarithm of Nelson PM_{10} data, showing a normal distribution.

It is from this form of the data that we then compute the measures of central tendency. The mean for each year is calculated and is referred to as the geometric mean. Confidence intervals at the 95% level[29] are calculated as well.[30]

Figure A4 shows these geometric means (red circles) and the confidence intervals (range in blue vertical lines) for each year. Once these means have been determined, a mean (arithmetic) of the yearly means (geometric) with its corresponding confidence intervals is calculated. These are overlaid in Figure A4 as a black horizontal line and dashed horizontal lines, respectively. Note that while the general trends of this data, as represented in Figure A3, compare well with Figure 11 and Figure 12, the values of the geometric means (Figure A4) are consistently less than the arithmetic means (Figures 11, 12). This is a feature of the geometric mean calculation and caution is required when comparing graphs derived from different distributions of the same data.

[29] In other words, the mean is considered statistically significant within these upper and lower limits with 95% confidence, or nineteen times out of twenty. Means outside of this range cannot be considered similar and represent statistical departures from typical values.

[30] A test for autocorrelation (estimated to be less than .2) suggests that there is little autocorrelation; hence, the ambient levels between years can be considered independent of each other.

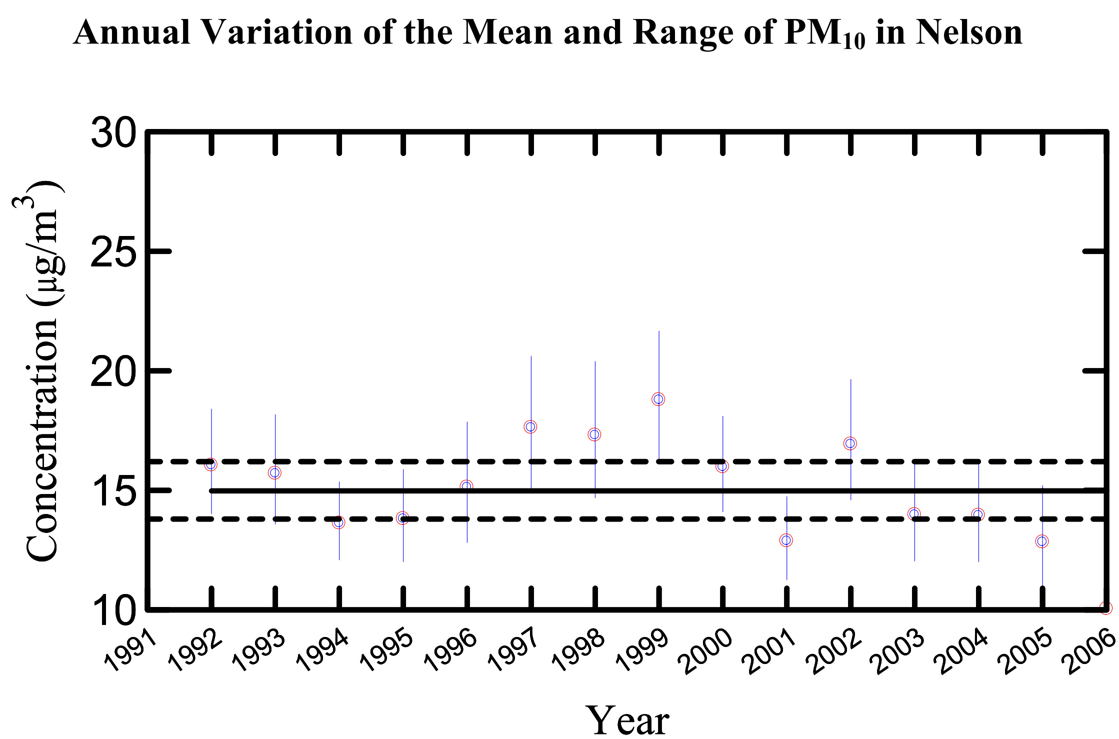


Figure A4. Statistical significance of yearly levels of PM_{10}. The red circles represent the annual geometric mean of PM_{10} data, and show that several years were significantly different than the overall mean of all data. To reduce bias, data from the extreme wildfire event of 1998 has been removed

The strength of this plot lies in its ability to statistically demonstrate which years of the data range represent 'significant' departures from average. Such departures are those where yearly means lie outside of the confidence intervals of the entire data set: the years 1997, 1998, 1999, 2002 (unusually high), and 2001, 2005 (unusually low). Investigation into the possible reasons for these departures is beyond the scope of this report but could provide useful information for those involved with airshed management planning.

Appendix D - Regression Analysis

Comparison of PM_{10} and $PM_{2.5}$ Data from Continuous Samplers

An emission source can produce particulate matter of one size, or different sizes (PM_{10} and $PM_{2.5}$). An analysis of the relationship comparing the concentrations of the fractions can help to understand the sources of PM, and the health consequences of poor air quality.

The relationship, or lack of relationship, can be used to identify emission sources and patterns in fluctuations in air quality. For example, high concentrations of $PM_{2.5}$ in winter might be attributed to smoke from wood burning appliances, and high concentrations of PM_{10} in spring may come from dust created by traction materials (sand) applied to roads.

In Nelson, continuous samplers measured the two fractions simultaneously between March 2005 and June 2006. Linear regression analyses were run on the data to determine the strength of the relationship, using SPSS statistical software.

A linear regression equation is a slope-intercept form of an equation, where the slope indicates the amount the dependent variable changes for each unit change of the independent variable, and the constant indicates how much the whole line shifts vertically.

dependent variable = slope x (independent variable) + constant

In terms of comparing $PM_{2.5}$ to PM_{10}:

concentration of $PM_{2.5}$ = (coefficient x (concentration of PM_{10})) + constant

Figure A5 is the same as Figure 18, reproduced here for convenience.

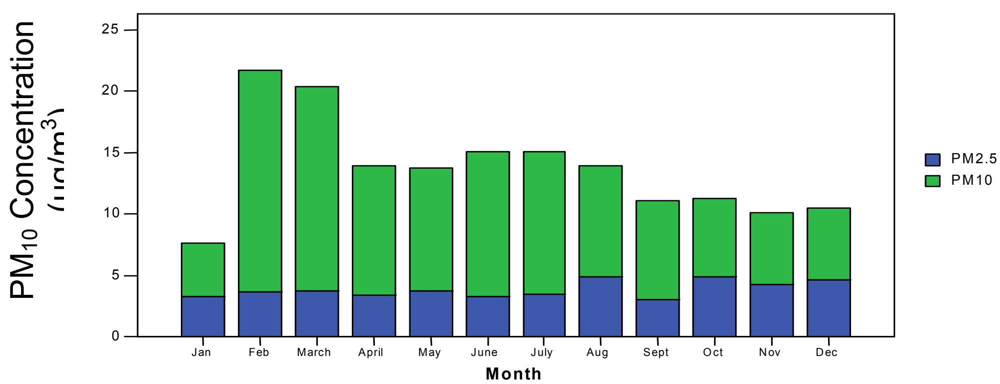


Figure A5. Comparison of Nelson PM_{10} and $PM_{2.5}$ data by month.

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Regression for All Data

The regression equation is:

$$(\text{Concentration of PM}_{2.5}) = 0.121\ (\text{Concentration of PM}_{10}) + 2.098$$

Model Summary(b)

Model	R	R^2	Std. Error of the Estimate
1	.482(a)	.232	1.79340

a Predictors: (Constant), Mean_PM10
b Dependent Variable: Mean_PM25

Table A1. Model summary of regression of PM_{10} and $PM_{2.5}$ for all data.

Coefficients(a)

Model		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
	(Constant)	2.098	.165	12.686	.000
	Mean_PM10	.121	.010	11.731	.000

a Dependent Variable: Mean_PM25

Table A2. Coefficients of regression of PM_{10} and $PM_{2.5}$ for all data.

The low value of R^2 (.232) indicates that the regression equation does not match actual conditions very well. (An R^2 of 1.0 indicates a perfect relationship.) An inspection of Figure 18 shows why the equation does not model the relationship well: the two fractions often vary independently. For example, in the period from January to March, PM_{10} varies considerably, but $PM_{2.5}$ was almost constant.

To investigate the relationship between PM_{10} and $PM_{2.5}$ further, analyses were done on each month individually.

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Regressions by Month

In these analyses, R^2 varies considerably. January shows a good relationship (.723) but February shows a poor relationship (.293). As examples, regression equations for these months are:

January: **(Concentration of $PM_{2.5}$) = 0.662 (Concentration of PM_{10}) – 1.751**
February: **(Concentration of $PM_{2.5}$) = 0.046 (Concentration of PM_{10}) + 2.626**

Model Summary(b)

Month	R	R^2	Adjusted R^2	Std. Error of the Estimate
Jan	.850(a)	**.723**	.713	.68732
Feb	.542(a)	**.293**	.266	1.14113
March	.712(a)	**.507**	.491	.96506
April	.768(a)	**.590**	.583	1.02824
May	.866(a)	**.750**	.746	.98791
June	.607(a)	**.368**	.357	1.31614
July	.785(a)	**.616**	.603	.94877
Aug	.889(a)	**.790**	.783	1.58016
Sept	.854(a)	**.729**	.719	1.18718
Oct	.953(a)	**.907**	.904	.77248
Nov	.872(a)	**.760**	.751	.85590
Dec	.534(a)	**.286**	.261	2.31581

a Predictors: (Constant), Mean_PM10
b Dependent Variable: Mean_PM25

Table A3. Model summary for regression of PM_{10} and $PM_{2.5}$ by month.

However, based on the data accumulated, there is no clear and usable relationship between PM_{10} and $PM_{2.5}$. Further data collection and analysis, and an understanding of the sources of PM emissions, would be required to determine if a useful relationship exists.

The coefficients and constants for each month are shown below.
Blue – the constant in the equation
Red – the coefficient in the equation

Coefficients(a)

Month	Model		Unstandardized Coefficients		t	Sig.
			B	Std. Error		
Jan	1	(Constant)	-1.751	.590	-2.967	.006
		Mean_PM10	.662	.076	8.697	.000
Feb	1	(Constant)	2.626	.370	7.091	.000
		Mean_PM10	.046	.014	3.286	.003
March	1	(Constant)	2.237	.318	7.037	.000
		Mean_PM10	.075	.013	5.647	.000
April	1	(Constant)	.889	.300	2.959	.004
		Mean_PM10	.177	.019	9.132	.000
May	1	(Constant)	.213	.292	.729	.469
		Mean_PM10	.258	.019	13.433	.000
June	1	(Constant)	1.249	.389	3.212	.002
		Mean_PM10	.133	.023	5.760	.000
July	1	(Constant)	.738	.432	1.709	.098
		Mean_PM10	.180	.026	6.819	.000
Aug	1	(Constant)	-3.806	.874	-4.355	.000
		Mean_PM10	.623	.060	10.457	.000
Sept	1	(Constant)	-2.534	.672	-3.770	.001
		Mean_PM10	.498	.057	8.671	.000
Oct	1	(Constant)	-2.590	.465	-5.566	.000
		Mean_PM10	.666	.040	16.857	.000
Nov	1	(Constant)	-1.217	.606	-2.007	.055
		Mean_PM10	.546	.058	9.411	.000
Dec	1	(Constant)	.972	1.144	.850	.402
		Mean_PM10	.345	.101	3.405	.002

a Dependent Variable: Mean_PM25

Table A4. Coefficients of regression of PM_{10} and $PM_{2.5}$ by month.

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Comparison of PM_{10} Data from Manual and Continuous Samplers

The operation of the TEOM continuous sampler starting in March 2005 also allows the comparison of one air quality parameter (PM_{10}) as measured by two types of instruments: Hi-Vol manual sampler and TEOM continuous sampler. During the period from March 2005 to February 2006, the TEOM sampled every day (336 days of valid data) and the Hi-Vol sampled every 6th day (49 days of valid data), so comparisons can be done for the 49 days of coincident sampling.

The scatter diagram below shows that there seems to be a good relationship between theses two sets of data.

Scatter Diagram of Hi-Vol and TEOM Data Sets

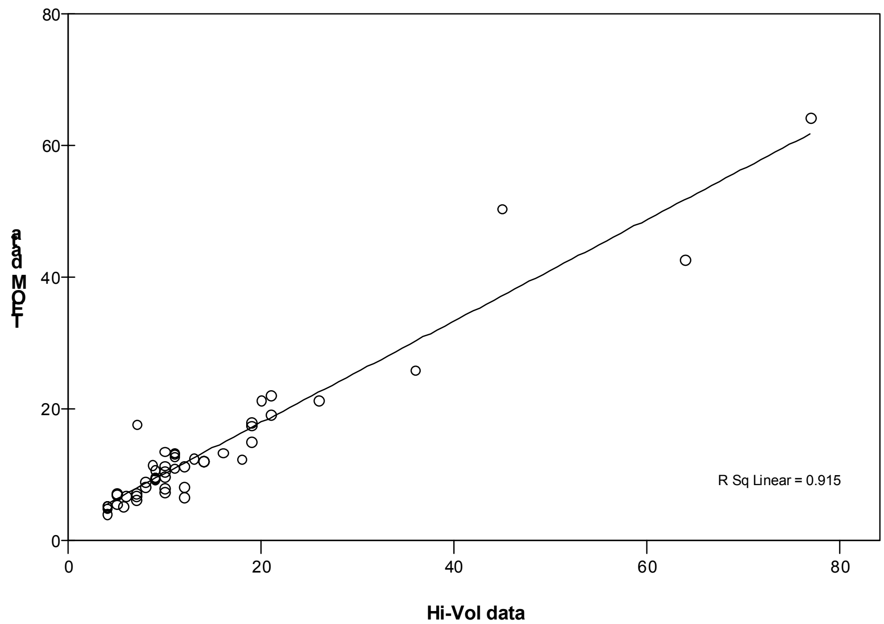

Figure A6. PM_{10} data from two sampling instruments on days when both were in operation.

Regression with a Constant

The regression equation is:

TEOM reading = 0.770 (Hi-Vol reading) +2.544

This shows a very good relationship (R^2 = .915), indicating that Hi-Vol data are good predictors of TEOM data.

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Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.957(a)	.915	.913	3.35115

a Predictors: (Constant), HiVol_PM10
b Dependent Variable: Mean_PM10

Table A5. Model summary of regression for PM_{10} data from Hi-Vol and TEOM samplers.

Coefficients(a)

Model		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
1	(Constant)	2.544	.691	3.682	.001
	HiVol_PM 10	.770	.034	22.488	.000

a Dependent Variable: Mean_PM10

Table A6. Coefficients of regression for PM_{10} data from Hi-Vol and TEOM samplers.

Regression through the Origin (without a Constant)

The regression can also be done with the relationship being forced through the origin of the graph (i.e., when the Hi-Vol reads zero concentration, the TEOM should also read zero concentration).

The regression equation is:

TEOM reading = 0.861 (HiVol reading)

This shows a very good relationship (R^2 = .956), further indicating that Hi-Vol data are good predictors of TEOM data. (Note: this value of R^2 is calculated differently than the earlier R^2 for regression with a constant, and cannot be directly compared.)

Model Summary(c,d)

Model	R	R Square(a)	Adjusted R Square	Std. Error of the Estimate
1	.978(b)	.956	.955	3.76397

a For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
b Predictors: HiVol_PM10
c Dependent Variable: Mean_PM10
d Linear Regression through the Origin

Table A7. Model summary for regression through the origin for PM_{10} data from Hi-Vol and TEOM samplers.

Coefficients(a,b)

Model		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
1	HiVol_PM10	.861	.027	32.313	.000

a Dependent Variable: Mean_PM10
b Linear Regression through the Origin

Table A8. Coefficient of regression through the origin for PM_{10} data from Hi-Vol and TEOM samplers.

Appendix E - Calculation of Exposure

An exposure calculation is a technique to combine the AMOUNT of a pollutant to which we are exposed, and the TIME that we are exposed to the pollutant. At the two extremes, a low concentration of a pollutant could be in the air for several months, yielding an exposure, but the same exposure would result if there was a high concentration of the pollutant for a few days and clean air for the rest of the time. (One of the assumptions is that these two types of exposures will have similar effects on human health.)

Exposure calculations are based on the assumption that there is a concentration (25 $\mu g/m^3$) below which there is minimal risk to health, and above which there exists a statistically significant greater 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, divided by 10, and rounded up to the nearest whole number. After this is done for each day in a particular year, the numbers 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 Nelson 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 for which daily averages were available.

For example, suppose that for a given year, 58 daily averages were available and the NAAQO exposure calculation is applied to this 58 day dataset, with a resultant value of 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 F1 – Air Quality Sampling Parameters and Sites in Nelson

Legend
TSP – Total suspended particulates
Met – Meteorological (weather) data
PM_{10} – Particulate matter (up to 10 µm diameter)
$PM_{2.5}$ - Particulate matter (up to 2.5 µm diameter)
O_3 - Ozone

Manual – Hi-Vol sampler, one sample every six days

Start – End Date	Parameter	Sampling Type and Frequency	MoE Site Identification
March 1985 – May 1985	TSP	Manual (1 in 6)	0260101
June 1985 – November 1992	TSP	Manual (1 in 6)	E206375
October 1985 – September 1987	Met	Continuous	M114216
September 1991 – present	PM_{10}	Manual (1 in 6)	E206375
March 2005 – July 2006	PM_{10}	Continuous	E258315
March 2005 – present	$PM_{2.5}$	Continuous	E258315
March 2005 - present	O_3	Continuous	E258315

Table A9. Dates and frequencies of sampling air quality parameters at Nelson MoE sites.

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Appendix F2 – Air Quality Sampling Sites and Parameters in Kootenay Region Communities

Some communities have had samplers located in several sites within their boundaries. If there was more than one site, the quantity is listed in parentheses after the community name. The Dates of Operation list the first and last dates of any sampling for each airshed, but are not specific for each parameter. The Parameters Measured lists all parameters that have been measured at each site. Not all parameters have been measured at all times. Golden is undergoing a Source Apportionment Study, hence has some specialized sampling equipment.

Legend
TSP – Total suspended particulates
PM_{10} – Particulate matter (up to 10 µm diameter)
$PM_{2.5}$ - Particulate matter (up to 2.5 µm diameter)
PM coarse ($PM_{10-2.5}$)
Dustfall
Metals – Heavy metals – arsenic, cadmium, zinc
TRS – Total reduced sulphur
O_3 - Ozone
NO_2 - Nitrogen dioxide
NO – Nitric oxide
SO_2 – Sulphur dioxide
CO – Carbon monoxide
Aethalometer – an instrument for measuring elemental (black) carbon
PM speciation – instruments that measure specific chemicals found in emissions
VOC – Volatile organic compounds
Met – Meteorological (weather) data

Table A10 Dates and air quality parameters measured at West Kootenay sites

Airshed	Dates of Operation	Parameters Measured
Canal Flats	February 1974 – January 1985	Dustfall
Castlegar (9 sites)	March 1985 - present	TSP PM_{10} Dustfall Metals TRS NO_2 SO_2 CO Met

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Airshed	Dates of Operation	Parameters Measured
Cranbrook	September 1990 – November 1998 August 2000 – September 2000 March 2001 - present	PM_{10} $PM_{2.5}$ Met
Creston	September 1990 – present	PM_{10} $PM_{2.5}$ CO NO_2 O_3 SO_2 Met
Elk Valley (4)	April 1978 – present	TSP PM_{10} Dustfall
Elkford	October 1982 – March 1993	TSP PM_{10} Dustfall
Golden (4 sites)	January 1992 – present	PM_{10} $PM_{2.5}$ PM coarse Aethalometer PM speciation VOC NO_2 NO CO O_3 SO_2 Met
Grand Forks	August 1973 – present	TSP PM_{10} $PM_{2.5}$ Dustfall Met
Invermere	July 1993 - present	PM_{10}
Kimberley	May 1988 – present	TSP PM_{10} SO_2
Kokanee Park	July 2001 – August 2002	PM_{10}

Airshed	Dates of Operation	Parameters Measured
Nelson	March 1985 – present	TSP PM_{10} $PM_{2.5}$ O_3 Met
Radium	July 1998 - present	PM_{10}
Revelstoke	May 1989 – present	PM_{10} $PM_{2.5}$ Dustfall Met
Skookumchuck	August 1987 – July 2005	TRS Met
Slocan	April 1985 – May 1986 November 1991 - present	TSP PM_{10} Dustfall
Sparwood	January 1982 – present	TSP PM_{10} $PM_{2.5}$ Dustfall
Trail (14 sites)	February 1970 - present	TSP PM_{10} $PM_{2.5}$ Dustfall Metals SO_2 Met
Ymir	May, 1984 – February 1988	TSP Dustfall

Appendix G1 – Graph of Nelson Hi-Vol PM_{10} Data 1991 to 2005

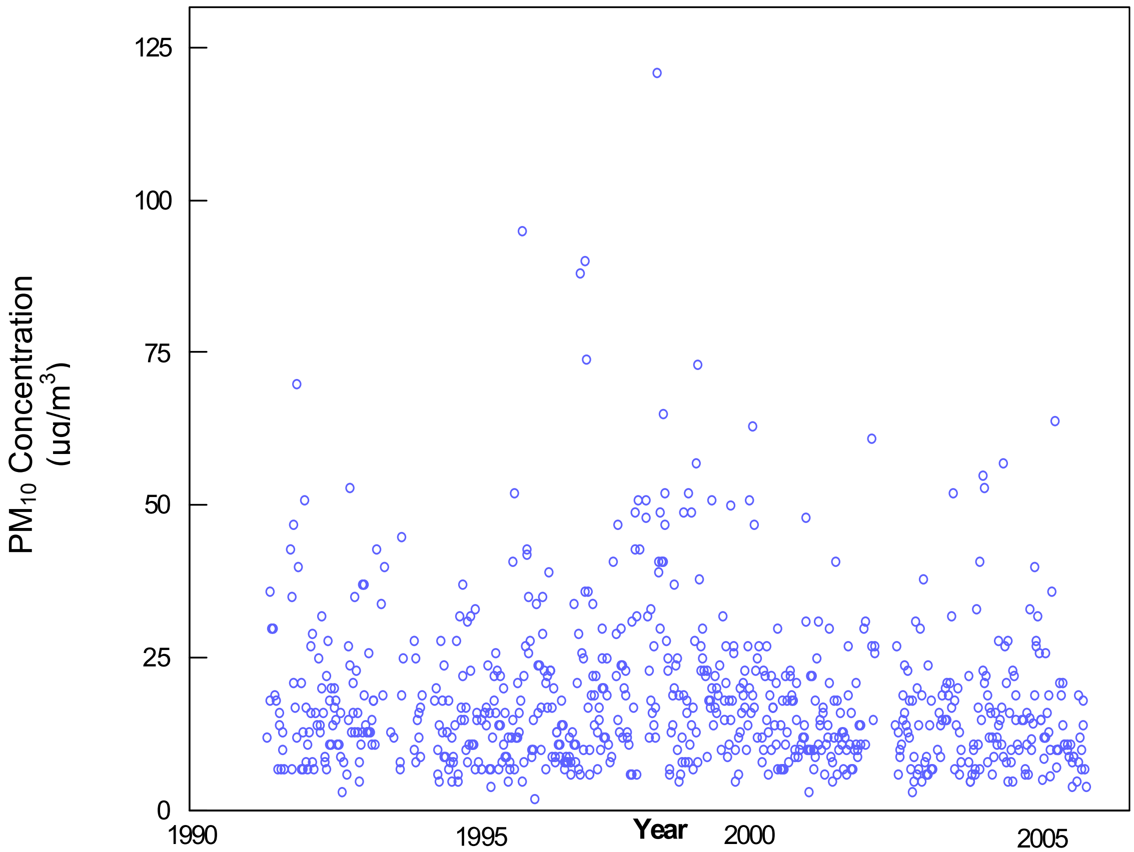

Figure A7. Raw PM_{10} data. n=729.

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Appendix G2 - Nelson Hi-Vol PM_{10} Data for 1991

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	01	24
	07	10
	13	9
	19	35
	25	6
	31	7
February	No data	
March	No data	
April	No data	
May	No data	
June	No data	
July	No data	
August	No data	
September	10	12
	27	36
October	03	18
	09	30
	15	30
November	02	19
	08	18
	20	7
	26	16
December	02	14
	08	7
	14	10
	20	13
	26	7

Appendix G3 - Nelson Hi-Vol PM_{10} Data for 1992

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	No data	
February	06	43
	12	35
	18	7
	24	21
March	01	47
	07	17
	13	70
	19	12
	25	40
April	12	21
	18	7
	24	13
	30	7
May	06	51
	12	8
	18	17
	24	11
	30	7
June	05	13
	11	27
	17	16
	23	29
	29	8
July	05	7
	11	16
	29	14
August	04	25
	10	13
	16	14
	22	32
	28	20
September	03	16
	09	8
	15	9
	21	22
	27	7
October	03	28
	09	18
	15	11
	21	11
	27	20
November	02	14
	08	17
	14	20
	20	15
	26	18
December	02	11
	14	11
	20	16
	26	9

Appendix G4 - Nelson Hi-Vol PM_{10} Data for 1993

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	01	3
	13	8
	31	6
February	06	15
	12	27
	18	53
	24	24
March	02	13
	08	21
	14	16
	20	13
	26	35
April	01	23
	07	13
	13	16
	19	8
	25	5
May	01	11
	07	13
	13	37
	19	37
	25	19
	31	14
June	06	13
	12	13
	18	26
	24	13
	30	13
July	06	15
	12	11
	18	18
	24	18
	30	11
August	05	43
September	10	34
	22	19
	28	40
October	No data	
November	03	13
	27	12
December	No data	

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Appendix G5 - Nelson Hi-Vol PM_{10} Data for 1994

PM_{10} in µg/m³

Month	Day	PM_{10}
January	02	7
	08	8
	14	19
	20	45
	26	25
February	No data	
March	No data	
April	02	28
	08	10
	14	8
	20	25
	26	15
May	02	12
	08	16
	14	17
	20	9
	26	19
June	No data	
July	No data	
August	18	18
	24	20
	31	10
September	05	6
	11	5
	17	14
	23	28
	29	18
October	05	13
	11	9
	17	24
	23	9
	29	13
November	04	13
	10	18
	16	7
	22	8
	28	12
December	04	5
	10	8
	16	9
	22	14

Appendix G6 - Nelson Hi-Vol PM_{10} Data for 1995

PM_{10} in µg/m³

Month	Day	PM_{10}
January	03	28
	09	6
	15	5
	21	32
	27	17
February	02	15
	08	37
	14	22
	20	15
	26	17
March	04	10
	10	8
	16	31
	22	11
	28	32
April	03	23
	09	11
	15	11
	21	11
	27	33
May	03	7
	09	16
	15	15
	21	8
June	08	15
	14	7
	26	16
July	02	16
	08	14
	14	17
	20	24
	26	7
August	01	16
	07	4
	13	7
	19	12
	25	22
	31	18
September	06	16
	12	26
	18	23
	24	14
	30	7
October	06	22
	12	14
	18	8

Month	Day	PM_{10}
	24	20
	30	11
November	05	16
	11	9
	17	9
	23	12
	29	5
December	05	7
	11	8
	17	12
	23	41
	29	15

Appendix G7 - Nelson Hi-Vol PM_{10} Data for 1996

PM_{10} in $\mu g/m^3$

Month	Day	PM_{10}
January	04	52
	10	7
	16	12
	22	12
	28	21
February	03	13
	09	16
	15	18
	21	5
	27	95
March	04	22
	10	8
	16	27
	22	42
	28	43
April	03	26
	09	35
	15	28
	21	10
	27	9
May	03	10
	09	15
	15	2
	27	34
June	02	16
	08	24
	14	24
	20	10
	26	17
July	02	29
	08	35
	14	23
	20	7
	26	21
August	01	22
	07	17
	13	39
	19	23
	25	23
	31	17
September	06	9
	12	20
	18	8

Month	Day	PM_{10}
	24	9
	30	13
October	06	13
	12	11
	18	11
	24	9
	30	18
November	05	14
	11	14
	17	7
	23	8
	29	9
December	05	8
	11	8
	17	9
	23	12
	29	8

Appendix G8 - Nelson Hi-Vol PM_{10} Data for 1997

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	04	6
	10	13
	16	34
	22	11
	28	11
February	03	8
	09	21
	15	7
	21	29
	27	6
March	05	88
	11	26
	17	10
	23	25
	29	36
April	04	90
	10	74
	16	17
	22	36
	28	10
May	04	6
	10	19
	16	34
	22	22
	28	19
June	03	14
	09	22
	15	13
	21	7
	27	15
July	03	17
	09	10
	15	20
	21	25
	22	30
	27	12
August	02	20
	08	12
	14	19
	20	25
	26	11
September	07	8
	13	9

Month	Day	PM_{10}
October	01	41
	13	22
	19	29
	25	47
	31	15
November	06	13
	12	30
	18	24
	24	12
	30	24
December	06	20
	12	23
	18	19
	24	13
	30	12

Appendix G9 - Nelson Hi-Vol PM_{10} Data for 1998

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	05	11
	17	6
	23	6
	29	31
February	04	17
	10	49
	16	43
	22	6
	28	32
March	06	51
	12	43
April	23	48
	29	51
May	05	32
	11	23
	17	12
	23	18
	29	33
June	04	16
	10	27
	16	14
	22	17
	28	12
July	04	121
	10	41
	16	39
	22	30
	28	49
August	03	41
	09	41
	15	65
	21	52
	27	47
September	02	28
	08	23
	14	25
	20	6
	26	7
October	02	13
	08	19
	14	14
	20	20
	26	37

Month	Day	PM_{10}
November	01	24
	07	25
	13	10
	19	19
	25	5
December	01	6
	07	12
	13	8
	19	49
	25	19
	31	8

Appendix G10 - Nelson Hi-Vol PM_{10} Data for 1999

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	06	16
	12	18
	18	8
	24	52
	30	11
February	05	14
	11	49
	17	7
	23	17
March	01	28
	07	57
	13	13
	19	73
	25	8
	31	38
April	06	27
	12	23
	18	30
	24	25
	30	23
May	06	22
	18	9
	24	23
	30	18
June	05	18
	11	17
	17	51
	23	20
	29	14
July	05	17
	11	22
	17	16
	23	20
	29	19
August	04	24
	22	10
	28	32
September	03	18
	09	15
	15	21
	21	27
	27	9

Month	Day	PM_{10}
October	03	18
	09	11
	15	15
	21	50
	27	18
November	02	27
	08	26
	14	10
	20	5
December	02	6
	08	12
	14	13
	20	20
	26	16

ENVIRONMENTAL QUALITY

Appendix G11 - Nelson Hi-Vol PM_{10} Data for 2000

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	01	19
	07	21
	13	17
	19	23
	25	10
	31	27
February	06	14
	12	20
	18	51
	24	16
March	01	19
	07	63
	13	47
	19	17
	25	23
	31	25
April	06	12
	12	27
	30	12
May	06	8
	12	10
	18	23
	24	22
	30	15
June	05	27
	11	6
	17	13
	23	19
	29	22
July	05	10
	11	17
	17	17
	23	14
	29	11
August	04	21
	10	30
	16	7
	28	14
September	03	7
	09	7
	15	18
	21	7
	27	22

Month	Day	PM_{10}
October	03	11
	09	18
	15	13
	21	8
	27	22
November	02	23
	08	18
	14	19
	20	18
	26	10
December	02	9
	08	15
	14	21
	20	9
	26	10

Appendix G12 - Nelson Hi-Vol PM_{10} Data for 2001

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	13	11
	19	12
	25	12
	31	14
February	06	48
	12	31
	18	10
	24	3
March	02	10
	08	10
	14	22
	20	22
	26	10
April	01	7
	07	9
	13	18
	19	25
	25	31
May	01	11
	07	15
	13	14
	19	10
	25	17
	31	16
June	06	6
	18	11
	24	12
	30	14
July	06	21
	12	30
	18	9
	24	8
	30	5
August	05	12
	11	18
	17	41
	23	6
	29	18
September	04	10
	10	12
	16	16
	22	13
	28	11

Month	Day	PM_{10}
October	04	13
	10	7
	16	12
	22	6
	28	10
November	02	19
	09	27
	15	11
	21	7
	27	16
December	03	7
	15	10
	21	11
	27	21

ENVIRONMENTAL QUALITY

Appendix G13 - Nelson Hi-Vol PM_{10} Data for 2002

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	02	10
	08	9
	14	14
	20	14
	26	11
February	13	30
	19	11
	25	31
March	No data	
April	02	61
	08	27
	14	15
	20	26
	26	27
May	No data	
June	No data	
July	No data	
August	No data	
September	05	14
	11	27
	17	6
	23	13
	29	9
October	05	10
	11	11
	17	19
	23	15
	29	16
November	04	24
	10	14
	16	23
	22	13
	28	18
December	04	12
	10	7
	16	3
	22	18
	28	5

Appendix G14 - Nelson Hi-Vol PM_{10} Data for 2003

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	03	9
	09	31
	15	6
	21	20
	27	7
February	02	14
	08	30
	14	19
	20	5
March	04	38
	10	8
	16	6
	22	9
	28	24
April	03	6
	09	14
	15	7
	21	18
	27	7
May	No data	
June	02	10
	08	16
	14	9
	20	14
	26	15
July	02	19
	14	20
	20	15
	26	15
August	01	21
	07	19
	13	21
	25	17
	31	32
September	06	52
	12	7
	18	18
	30	14
October	06	20
	12	6
	18	13
	24	10
	30	8
November	No data	

Month	Day	PM_{10}
December	11	22
	17	8
	23	5
	29	5

Appendix G15 - Nelson Hi-Vol PM_{10} Data for 2004

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	04	6
	10	10
	16	11
	22	6
	28	7
February	03	33
	09	17
	15	11
	21	41
	27	7
March	04	15
	10	55
	16	23
	22	53
	28	21
April	03	22
	09	19
	15	8
	21	12
	27	17
May	03	16
	09	6
	15	12
	21	9
June	02	16
	08	12
	14	11
	20	14
	26	28
July	02	15
	08	11
	14	17
	20	9
	26	57
August	01	27
	07	8
	13	21
	19	28
	25	5
	31	16
September	06	8
	12	10

Month	Day	PM_{10}
	18	5
	24	23
	30	22
October	06	19
	12	15
	24	11
	30	10
November	23	15
	29	15
December	05	6
	11	7
	17	11
	23	16
	29	6

E N V I R O N M E N T A L   Q U A L I T Y

Appendix G16 - Nelson Hi-Vol PM_{10} Data for 2005

PM_{10} in µg/m^3

Month	Day	PM_{10}
January	04	33.1
	10	15.3
	16	11.8
	22	10
	28	14.4
February	03	19
	09	40
	15	28
	21	27
	27	32
March	11	26
	17	15
	23	15
	29	5.2
April	04	8.7
	10	12
	16	12
	22	26
	28	16
May	04	13
	10	19
	16	10
	22	5.7
	28	36
June	21	64
	26	7.1
	27	10
July	03	10
	09	10
	21	21
	27	19
August	02	14
	08	21
	14	11
	20	11
September	01	10
	07	11
	13	9
	19	0
	25	11
October	01	4
	07	8
	13	9
	19	9
November	06	5
	12	8
	18	19
	24	12
	30	10
December	06	7
	12	14
	18	18
	24	7
	30	4