

***BULKLEY VALLEY***  
***INHALABLE PARTICULATE SUMMARY***

April 1998

**Doug Johnson**  
**Head, Air Quality Unit**  
**Industrial/Special Waste/Air Assessment Section**  
**Pollution Prevention Programme**  
**Skeena Region**  
**BC Environment**





# *Executive Summary*

Combustion of wood residue and other fuels generate an air contaminant known as particulate matter. Compared with other industrial sources permitted by BC Environment, beehive burners are the largest single source of particulate emissions in the Bulkley Valley. Other sources including open burning, wood burning appliances, and motor vehicles. Combined with the topographical restraints of the Bulkley Valley, certain meteorological conditions may result in particulate emissions being trapped in the valley airshed. During such episodes, inhalable particulate concentrations may build to unhealthy levels.

Air quality monitoring data indicate both Smithers and Houston experience inhalable particulate-related air quality impacts. This has occurred, with varying severity, during every year monitored to date. Some air quality indicators, however, have shown an improvement over recent years. Others have levelled off.

Further work needs to be done to reduce particulate emissions in the airshed if we want concentrations of inhalable particulate matter to be below health impact thresholds. Of the management options presented in *Smoke Management for the '90s* (BC Environment, 1991), beehive burner phase out in smoke sensitive airsheds, such as the Bulkley Valley, remains the last significant option for particulate emission reductions and air quality management. Other management options do exist for municipal and regional governments.

# *Table of Contents*

<b>EXECUTIVE SUMMARY .....</b>	<b>i</b>
<b>TABLE OF CONTENTS .....</b>	<b>ii</b>
<b>LIST OF TABLES.....</b>	<b>iv</b>
<b>LIST OF FIGURES .....</b>	<b>v</b>
<b>INTRODUCTION .....</b>	<b>1</b>
<b>CONTROLLING FACTORS.....</b>	<b>4</b>
Meteorological Processes .....	4
Particulate Sources .....	6
<b>POTENTIAL ENVIRONMENTAL IMPACTS .....</b>	<b>12</b>
Combustion.....	12
Atmospheric Particulate Mass Balance.....	13
Potential Health Impacts of Inhalable Particulate .....	15
PM <sub>10</sub> .....	15
Other Environmental Impacts .....	16
<b>AIR QUALITY MONITORING PROGRAMME .....</b>	<b>18</b>
<b>AIR QUALITY ASSESSMENT .....</b>	<b>20</b>
Air Quality Objective Definition .....	20
British Columbia's and Canada's Air Quality Assessment Criteria.....	21
<i>Level A</i> (Maximum Desirable).....	21
<i>Level B</i> (Maximum Acceptable) .....	21

<i>Level C (Maximum Tolerable)</i> .....	21
Summary .....	21
<b>HOUSTON DATA SUMMARY .....</b>	<b>23</b>
History.....	23
Geography.....	24
Data Capture .....	24
Central Tendency .....	26
Impact Assessment.....	28
Summary .....	31
<b>SMITHERS DATA SUMMARY .....</b>	<b>32</b>
History.....	32
Geography.....	33
Data Capture .....	33
Central Tendency .....	35
Impact Assessment.....	37
Summary .....	40
<b>DISCUSSION .....</b>	<b>41</b>
<b>CONCLUSIONS .....</b>	<b>45</b>
<b>REFERENCES.....</b>	<b>46</b>
<b>GLOSSARY OF TERMS.....</b>	<b>48</b>

# *List of Tables*

Table 1. Houston Permitted Emissions.....	8
Table 2. Smithers Permitted Emissions.....	9
Table 3. Beehive Burner Proportion of Community Emissions.....	9
Table 4. Summary of Skeena Region Inhalable Particulate Monitoring Sites.....	19
Table 5. Houston Data Capture.....	25
Table 6. Measures of Houston Inhalable Particulate Impacts.....	28
Table 7. Smithers Data Capture.....	34
Table 8. Measures of Smithers Inhalable Particulate Impacts.....	38
Table 9. Population Statistics for Bulkley Valley Communities.....	43

# *List of Figures*

Figure 1. The Bulkley Valley.....	1
Figure 2. Permitted Particulate Emissions in Skeena Region. ....	7
Figure 3. A Skeena Region Beehive Burner. ....	10
Figure 4. Skeena Region 1990 Major Particulate Source Sector Emission Summary. ....	10
Figure 5. Firehall Monitoring Site .....	23
Figure 6. Houston Inhalable Particulate Monitoring Station Locations. ....	24
Figure 7. Houston Data Capture. ....	25
Figure 8. Percentile Distribution of Houston PM <sub>10</sub> Observations. ....	26
Figure 9. Houston Air Quality Trends. ....	27
Figure 10. Annual Difference in Means Compared to 1997-98 Reference Year. ....	27
Figure 11. Houston Exposure Increments. ....	29
Figure 12. Houston Air Quality Objective Exceedence Frequencies. ....	30
Figure 13. Inhalable Particulate Data Frequency Distribution. ....	31
Figure 14. St. Joseph’s School Monitoring Site.....	32
Figure 15. Smithers Inhalable Particulate Monitoring Station Location. ....	33
Figure 16. Smithers Data Capture.....	34
Figure 17. Smithers Distributions of Inhalable Particulate Observations. ....	35
Figure 18. Smithers Air Quality Trends.....	36
Figure 19. Annual Difference in Means Compared to 1997-98 Reference Year. ....	37
Figure 20. Smithers Exposure Increments. ....	38
Figure 21. Smithers Air Quality Objective Exceedence Frequencies. ....	39
Figure 22. Inhalable Particulate Data Frequency Distribution. ....	40

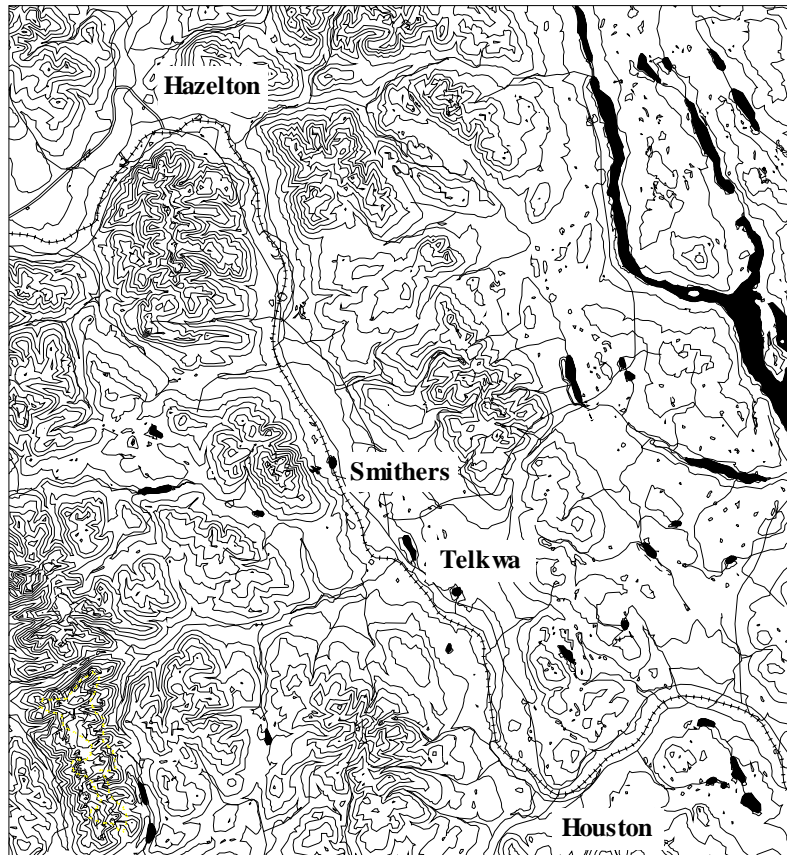


## Introduction

The Bulkley Valley is located in the western portion of British Columbia's central interior. It is approximately the same latitude as the southern end of the US state of Alaska's panhandle and approximately 200 km inland from the Pacific coast. Smithers, a central community in the valley, is located at 54° 46' 50" N latitude and 127° 10' 15" W longitude. The valley is a major transportation corridor containing the Bulkley River, the Yellowhead Highway (Highway 16), and the CN Rail railway. The primary population centres are the Hazelton, District of Houston, Town of Smithers, and the Village of Telkwa. The valley area is depicted in Figure 1.

**Figure 1. The Bulkley Valley.**

Contour interval is 200 m. Smithers is approximately 500 m above sea level. North is to the top of the map. The Bulkley drainage begins 35 km east of Houston (30 km west of Burns Lake), runs 50 km to Smithers, and continues another 60 km to the Hazelton where it joins the Skeena drainage. The valley is confined by the Babine Range of the Skeena Mountains to the east and the Hudson Bay Range of the Hazelton Mountains to the west. The headwaters of the Bulkley River are in the Nechako Plateau of the Interior Plateau.



The Bulkley Valley area was first home to the Wet'suwet'en and Gitxan First Nations whose constituent bands are generally within a 40 km radius of Hazelton. The Wet'suwet'en member bands of the Bulkley

Valley area are the Hagwilget and Moricetown. The Wet'suwet'enare part of the Carrier linguistic group. The Gitksan bands are part of the Tsimshian linguistic group. On the eastern portion of the area (past the Bulkley Valley proper) are the Broman Lake and Burns Lake bands of the Carrier Sekani Tribal Council and the Cheslatta Carrier Nation. Both nations are part of the Carrier linguistic group. (Ministry of Aboriginal Affairs, 1997).

People of European decent arrived in the Bulkley Valley area as a result of the fur trade in the early 1800's. In an attempt to connect the northern gold fields with Seattle and San Francisco, a telegraph line was constructed through the region in the mid-1800s. Construction was abandoned in Hazelton in 1866. The Bulkley Valley takes its name from the superintendent of the telegraph construction project, Charles S. Bulkley. (Bell, 1998).

Named after the hazel bushes which cover the river-carved terraces, the Hazeltons are situated at the northwestern end of the Bulkley Valley. The resource rich area has nurtured vital Northwest Coast Native cultures for over 8000 years. From 1886 to 1913 Hazelton was the upriver terminus for a fleet of sternwheelers which plied the Skeena River. People and supplies reaching Hazelton were then dispersed inland to dozens of mines, farms, and settlements making it the commercial centre of northwestern British Columbia. (Bell, 1998).

Houston lies towards the southeast end of the Bulkley Valley. Before the construction of the Grand Trunk Railway, Houston was known as Pleasant Valley. The name "Houston" most likely originated with John Houston, a popular newspaper editor from Prince Rupert. When the Grand Trunk Pacific Railway was built, cutting ties became an important local industry. In 1914, two years after the railway was built, the town was listed in the British Columbia directory with a population of 150. The 1940's brought the forest industry as we know it today to Houston; it has been a important component of the local economy since. In 1957 Houston was officially incorporated as a village. (Bell, 1998).

The town of Smithers, located in the central Bulkley Valley, was created by the Grand Trunk Pacific Railway to thwart land speculation. Realising the company needed to build a stop midway between Prince George and Prince Rupert, speculators purchased property around Telkwa and Hazelton. The railway chose to build its site in the shadow of Hudson Bay Mountain. The village, the first in British Columbia, was incorporated in 1921 and named after Sir Alfred Smithers of the Grand Trunk Pacific Railway.

The arrival of the railway facilitated exploitation of farming, ranching, and logging related resources of the valley. The area continues to attract people for its mining, tourism, and lifestyle opportunities. With such settlement and related development comes the production of waste products. Some of these wastes result

from combustion processes such as those associated with heating, transportation, and wood residue disposal.

Combustion is the burning of fuel to produce heat or light energy. Technically, this is an exothermic process whereby a hydrocarbon is oxidised. The combustion process creates a number of wastes known as air contaminants. Some of these contaminants, such as water vapour, are benign. Carbon dioxide is a critical component of the global warming debate. Other contaminants, such as particulate matter, have the potential to cause human health impacts on an episodic basis. The harmful contaminants of the combustion process are of concern to society and are, therefore, the focus of government regulatory activity.

Combined with the topographical restraints of the Bulkley Valley, certain meteorological conditions may result in particulate emissions being trapped in the valley airshed. During such episodes, inhalable particulate concentrations may build to unhealthy levels. Such levels are a form of environmental impact, *air pollution* is said to occur, and the emitted air contaminants thus become classified as *air pollutants*.

BC Environment has worked to identify specific sources of particulate emissions and develop management strategies to reduce these impacts. BC Environment regulates industrial activity, such as the operation of beehive burners, with air emissions permits that set emission limits and operating conditions. Other activities, such as the open burning of land clearing debris, are regulated by provincial regulations which set out a code of practice. Some activities, such as the use of wood burning stoves, are not regulated by any level of government.

The purpose of this document is to present information to the public, regulators, and industry regarding the inhalable particulate air quality issue in the Bulkley Valley. This presentation includes a review of potential sources of particulate matter, potential health impacts, ambient monitoring data, and regulation history.

## *Controlling Factors*

Emissions (sources) and meteorology (dispersal of emissions) are two critical variables that determine local air quality. While forces beyond human control determine meteorology, this is not the case for emissions from anthropogenic (human) sources. Thus, we are masters of our air quality. Skeena Region particulate emissions are quantified in this section and meteorological processes are explained.

### *Meteorological Processes*

In winter, northwestern North America is dominated by the polar anticyclone of the Mackenzie District which produces a continental polar air mass. Offshore, low atmospheric pressures occurs where oceanic heat sources indirectly give rise to the Aleutian low. The Pacific coast has frequent cyclonic activity in winter with the associated mix of maritime polar and maritime tropical air masses. Such unstable (windy) environments tend to have excellent dispersion characteristics: air quality problems, such as those experienced by interior communities, tend to be much less frequent or intense in such environments. In summer, the coast is dominated by the Pacific anticyclone with its maritime polar air mass. The interior is transitional between the coastal conditions and true continental conditions. It is characterised by transitional continental polar, continental tropical, and maritime polar, air masses. (Barry and Chorley, 1928).

The Bulkley Valley is located 200 kilometres inland from the west coast of North America. As such, the Coast range prevents (or modifies) maritime influences from extending inland to the valley. Stable air masses occasionally characterise valley meteorological conditions. In winter, this is in the form of continental polar air masses, typified by cold, dry, air with clear skies and low wind speeds. Clear skies, combined with long winter nights, calm winds, and bright (snow) surfaces to reflect daytime sunlight, promote an intense climatological process known as radiative cooling.

Radiative cooling is a process whereby ground surfaces lose energy (heat) by longwave radiation at a rate greater than the overlying atmosphere. Thus, over time, the ground surface is progressively colder than the overlying atmosphere. Such conditions are termed *temperature inversions*: i.e., the atmospheric temperature profile is inverted. Temperature increasing with height is opposite to the ‘normal’ atmospheric

lapse profile (temperature decreasing with height). Skiers on Hudson Bay Mountain near Smithers will recognise this phenomenon in winter whereby the mountain temperatures are much warmer than valley bottom temperatures. These processes can operate at other times of the year. However, they tend to be less intense than in winter, particularly in summer when days are long and nights are short. When these conditions coincide with high pressure subsidence, very strong temperature inversions may result.

Local topography in the Bulkley Valley can have significant influences on local meteorology and climatology. The surfaces of mountain and hillside slopes cool radiatively in the same manner as the surfaces described in the paragraphs above. The cold air overlying these surfaces is dense (heavy) and will drain down slope as a fluid (just as water does in a mountain stream). Thus, cold air accumulates and can build up in valley bottoms. This acts to intensify any radiative temperature inversion set up in the valley. In addition, any smoke at mountain slope elevation (e.g., from an open burn) can be drawn down into the valley under such conditions.

Mountainous terrain also can act to detach valley air from regional air masses. For example, cold air can collect in the valley through the processes of radiative cooling and cold air drainage. When a warm front comes in from the coast, the frontal surface can be detached from the valley bottom (forced up by mountains) resulting in stable cold air remaining trapped in the valley with unstable warm coastal air aloft. Thus, the inversion conditions can be maintained (even intensified) even though the regional air mass has changed. This is known as an *advection inversion*.

The net result of atmospheric temperature inversions from an air quality perspective is a very stable atmosphere characterised by little mixing. Such atmospheres have very limited capacity to disperse (transport) emissions such as smoke coming from a beehive burner or residential chimney. Thus, any emissions into a stable atmosphere tend to remain trapped close to their source height. Over time (hours to days), this can lead to degraded air quality as contaminants continue to be emitted into the atmosphere but are not transported away.

When the air begins to mix, (e.g.,) from thermal turbulence generated by morning solar heating (especially when the ground is snow-free) or mechanical turbulence as a regional wind picks up, the temperature inversion is broken, pollutants aloft are well-mixed through this previously-stable lower layer, and any pollutants aloft are drawn down to ground level. This is termed *fumigation* and can result in short-lived, but extremely high, concentrations of air pollutants.

These meteorological conditions are typical of any central interior community in British Columbia.

## *Particulate Sources*

Particulate emissions may be classified into three types of sources: natural, industrial, and domestic. Natural sources may include wind-blown dust, wildfires (e.g., forest fires), volcanic eruptions, sea salt spray, etc.

Industrial sources are typically ones that are regulated by government in the form of an air emissions permit or whose emissions are controlled by regulation. These would include open burning of land clearing debris, beehive burner and other sawmill emissions, and other 'smokestack-type' sources. Domestic sources tend to be smaller and emitted by individuals. Examples would include wood burning appliances and automobiles (both tailpipe and road dust). The domestic category would also include industrial transportation such as rail and trucking.

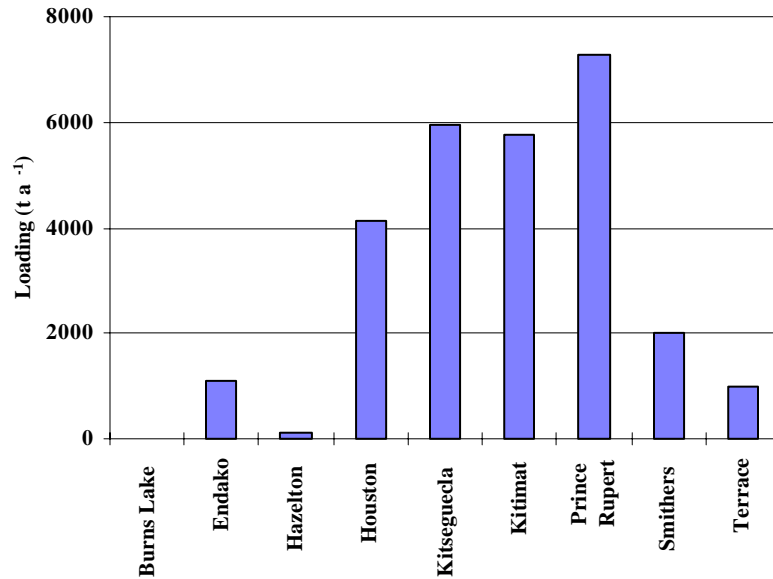
Figure 2 presents the total particulate air permit emissions for selected communities in Skeena Region. The Houston and Smithers emissions are broken down by each source with an air emissions permit in Table 1 and Table 2, respectively. The emissions depicted in these figures and tables have been extracted from the BC Environment Permit Fees Database. Permit fees are based on the *maximum* authorised discharge limit in the relevant BC Environment air emissions permit or on provincial discharge factors (usually related to production rates). While this source is consistent for the emissions data presented below, its' accuracy is, however, very dependent on how recent the air emissions permit has been updated and how much permit 'compliance insurance' an emitter wants to maintain. Comparisons between industrial sectors (e.g., smelting versus sawmilling) are less accurate than comparisons between operations in the same sector (e.g., two sawmills). In summary it should be remembered that the emission estimates presented below do not reflect actual emissions and the community-total emissions data do not include unpermitted sources such as natural emissions, road dust, wood burning stoves, automobile exhaust, etc.

**Figure 2. Permitted Particulate Emissions in Skeena Region.**

Annual emissions, expressed in tonnes per year, have been extracted from the BC Environment Permit Fees Database. Emission totals are based on the maximum authorised discharge limit in the relevant BC Environment air emissions permit, or on provincial discharge factors (usually related to production rates). As such, natural or domestic sources are not included.

***Skeena Region Permitted Particulate Loading***

(Current as of 22 February 1998)



**Table 1. Houston Permitted Emissions.**

CO denotes carbon monoxide, NO\* oxides of nitrogen, PM particulate matter, SO\* oxides of sulphur, VOC volatile organic compounds. Emissions are expressed as tonnes per year for all sources associated with an air emissions permit.

**Houston Permitted Emissions (t a<sup>-1</sup>)**

<i>Source</i>	<i>CO</i>	<i>NO*</i>	<i>PM</i>	<i>SO*</i>	<i>VOC</i>
Northwood Pulp & Timber	11110	113	2088	16	974
Houston Forest Products	11281	99	2061	12	986
Houston Forest Products	10	0	3	0	1
<b>Total</b>	<b>22402</b>	<b>213</b>	<b>4151</b>	<b>28</b>	<b>1962</b>

Current: 24 2 1998

**Houston Permitted Emissions (relative frequency)**

<i>Source</i>	<i>CO</i>	<i>NO*</i>	<i>PM</i>	<i>SO*</i>	<i>VOC</i>
Northwood Pulp & Timber	50%	53%	50%	57%	50%
Houston Forest Products	50%	47%	50%	43%	50%
Houston Forest Products	0%	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

Current: 24 2 1998

**Table 2. Smithers Permitted Emissions.**

CO denotes carbon monoxide, NO\* oxides of nitrogen, PM particulate matter, SO\* oxides of sulphur, VOC volatile organic compounds. Emissions are expressed as tonnes per year for all sources associated with an air emissions permit. PIR (Pacific Inland Resources) and Repap are the two Smithers-area sawmills, however, only PIR operates a beehive burner.

<b>Smithers Permitted Emissions (t a<sup>-1</sup>)</b>					
<i>Source</i>	<i>CO</i>	<i>NO*</i>	<i>PM</i>	<i>SO*</i>	<i>VOC</i>
West Fraser Mills (PIR)	7750	109	1595	6	681
Repap Smithers	3	15	91	0	11
L.B. Paving	1	1	37	3	1
NewPro	545	16	252	3	38
Reako Exploration Ltd.	0	0	0	0	0
Petrocan	0	0	0	0	0
<b>Total</b>	<b>8298</b>	<b>140</b>	<b>1975</b>	<b>12</b>	<b>732</b>

Current: 10 3 1998

<b>Smithers Permitted Emissions (relative frequency)</b>					
<i>Source</i>	<i>CO</i>	<i>NO*</i>	<i>PM</i>	<i>SO*</i>	<i>VOC</i>
West Fraser Mills (PIR)	93%	78%	81%	51%	93%
Repap Smithers	0%	10%	5%	1%	2%
L.B. Paving	0%	1%	2%	21%	0%
NewPro	7%	11%	13%	28%	5%
Reako Exploration Ltd.	0%	0%	0%	0%	0%
Petrocan	0%	0%	0%	0%	0%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

Current: 10 3 1998

As can be seen by comparing Figure 2 with Table 1 and Table 2, sawmill emissions are significant compared to communities such as Kitimat, where particulate emissions are dominated by the paper mill and aluminium smelter, and Prince Rupert (pulp mill). As can be seen from Table 3, which depicts the proportion of permitted particulate emissions from beehive burners, the burners themselves dominate the local permitted emissions environment. Not surprisingly, beehive burner emissions are therefore one of concern to BC Environment with respect to managing inhalable particulate emissions in airsheds plagued by inhalable particulate air quality issues.

**Table 3. Beehive Burner Proportion of Community Emissions.**

Ratio represents the proportion of permitted particulate emissions generated by beehive burners.

	<b>Total PM (t a<sup>-1</sup>)</b>	<b>Beehive Burners (t a<sup>-1</sup>)</b>	<b>Ratio</b>
Houston	4151	3146	76%
Kitsegucla	5971	4560	76%
Smithers	2018	1191	59%
<b>Total</b>	<b>12141</b>	<b>8897</b>	<b>73%</b>

Current: 24 2 1998

As depicted in Figure 3, a beehive burner is a conical-shaped single chamber incinerator used for the disposal of wood residue (BC Environment, 1995a). In the Bulkley Valley airshed, three beehive burners continue to operate: two in Houston and one in Smithers. The Carnaby burner further down-valley near Kitsegucla (on the Skeena River) receives some of the Smithers sawmilling industry wood residue.

**Figure 3. A Skeena Region Beehive Burner.**

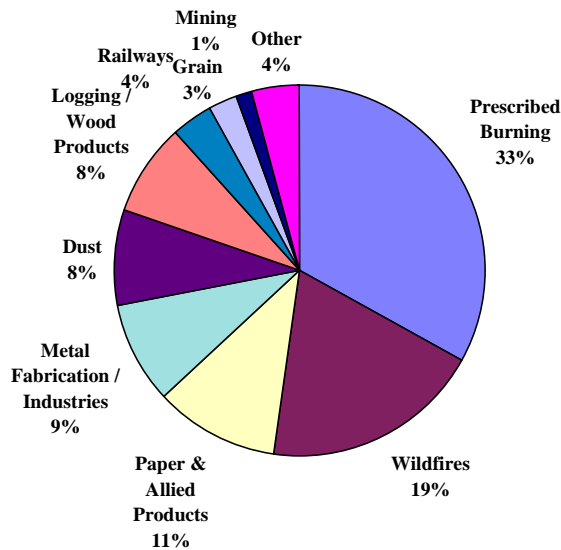


Figure 4 is presented to put the permitted emissions into regional perspective. Note that sawmills (and beehive burners) play a comparable role to other permitted sources (as previously depicted in Figure 2). However, there are other significant sources at play such as prescribed burning and wildfires which do not have BC Environment air emissions permits. Also note how insignificant domestic sources, such as those included in the “Other” category (e.g., vehicles and space heating), appear in the regional perspective on a total annual loading basis.

One important qualifier regarding Figure 4 should be noted: the geographical distribution of these sources is not equal across the region. Permitted and domestic sources are concentrated in the valleys

**Figure 4. Skeena Region 1990 Major Particulate Source Sector Emission Summary..**

Includes permitted, regulated, and unpermitted (domestic) sources. “Other” category includes: Agricultural, Motor Vehicles, non-metallic Mining, Marine Vessels, Coal, Space Heating, Miscellaneous, Burning (area), Landfills, Miscellaneous, Asphalt, Food Products, Off-Road Engines, Aircraft, Chemical Manufacturing, Oil/Gas Related, Concrete, Gypsum/Limestone (BC Environment, 1994).

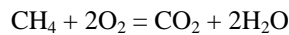


containing much of the region's population. Natural and regulated sources such as wildfires and prescribed burning tend to occur well removed from population centres. Therefore, the relative breakdown of regional emission sources is in no way directly correlated with impacts: sources closest to receptors (people) have the greatest potential for impacts. For example, on the finest scale, one person operating a wood burning stove poorly can create an extreme air pollution problem for their neighbours. Note that if the prescribed burning and wildfire categories are removed from Figure 4, then industrial sources comprise 32% of the total, dust 17%, railways 8%, agricultural and motor vehicles 2% each, and other 4%.

## *Potential Environmental Impacts*

### *Combustion*

Freshly cut wood contains between 45% and 55% water by weight. The remainder consists of a wide variety of hydrocarbons and other organic compounds. Combustion is the exothermic process whereby the hydrocarbon is oxidised. E.g.,



or

Methane + Oxygen = Carbon Dioxide + Water

As impurities are added and/or the hydrocarbon becomes more complex, the chance of more complex by-products may result. Some of these by-products are atmospheric contaminants. For example, adding sulphur to the hydrocarbon results in the formation of sulphur oxides (SO<sub>2</sub>, SO<sub>4</sub>). If combustion is inefficient due to impurities or an inadequate oxygen supply, potentially harmful by-products result. These are generally known as products of incomplete combustion (PIC). If these potentially harmful by-products impact the environment, they are termed air pollutants.

The efficiency of wood combustion depends on moisture content, temperature, and oxygen supply. Wet wood burns poorly because the pre-ignition phase is prolonged, lowering the combustion temperature. A fire which is starved of air also burns poorly, increasing the production of PIC. Many of the pollutants contained in wood smoke are strongly associated with chronic respiratory impacts such as increased airway resistance and decreased vital capacity. Most researchers believe that these impacts far outweigh all other possible human health impacts. Common PIC and their potential human health impacts are summarised below.

- **Acrolein** - irritation of the eyes and respiratory tract.
- **Carbon Monoxide (CO)** - angina in people with heart disease, lethal at very high concentrations.
- **Formaldehyde (HCHO)** - headaches, respiratory tract irritation, probably carcinogenic.
- **Nitrogen Oxides (NO<sub>x</sub>)** - bronchial congestion, lung edema (fluid congestion), fibrotic changes in the lungs.
- **Particulate** - fine particulate, i.e., particulate matter with an aerodynamic diameter less than or equal to a nominal 10 micrometres (PM<sub>10</sub>), penetrates to the lung's alveolar region and may affect lung function. It can also interact with visible light causing a haze which limits visual range. As humans are acutely most sensitive to fine particulate compared to other contaminants, the inhalable particulate portion of the PIC is an appropriate one on which to focus combustion-related air quality management strategies. As such, a more detailed discussion regarding the characteristics and impacts of fine particulate is presented below.
- **Polynuclear Aromatic Hydrocarbons (PAHs)** - PAHs are among the most harmful of the products of incomplete combustion. Certain PAHs (e.g., Benzo(a)Pyrene) are probable human carcinogens and are classified as air toxics. Exposure to such PAHs is associated with a small, but not insignificant, cancer risk.
- **Volatile Organic Compounds (VOCs)** - respiratory irritation and illness, some (e.g., benzene) are carcinogenic.

### *Atmospheric Particulate Mass Balance*

Atmospheric particulate is transitory. Although timescales and processes vary with particulate size, all atmospheric particulate will eventually be deposited back where much of it originates: on earth. While in the atmosphere, it can interact with other air contaminants and various lifeforms, including humans.

It is useful to define three size ranges with respect to the mass balance and health aspects of particulate matter. The entire domain of particulate matter in the atmosphere is known as total suspended particulate. Within this domain is a sub-category 10 µm in diameter and less (also known as PM<sub>10</sub>: particulate matter < 10 µm). Within this sub-category is another domain, 2.5 µm in diameter and less (PM<sub>2.5</sub>).

Total suspended particulate (TSP) is a general term for airborne particles such as smoke, fume, dust, flyash, and pollen. Suspended particles may be solid or liquid, organic or inorganic. Because of their weight, particles larger than 10 micrometres settle to the earth's surface quickly. This process is known as sedimentation (settling out of the air under the force of gravity). If such particles happen to be inhaled, they tend to collect in the throat and nose, and are eliminated from the body by sneezing, coughing, nose blowing (collectively known as the upper respiratory system), or through the digestive system. Generally, these particles are not associated with human health impacts. One obvious exception is pollen, which triggers allergic reactions among many people.

Particles greater than 2.5 µm in diameter are formed primarily by mechanical processes such as construction, demolition, unpaved road dust, wind erosion, etc. (Wolff, 1996). They contain materials common to the earth's crust and the ocean, reflecting the fact that natural sources are contributors to the coarse fraction. Industrial activities that involve grinding or pulverising, such as mining, quarrying and cement manufacturing, are also important. These particles don't stay in the air long, settling to the ground within a matter of a few hours to a few days (BC Environment, 1995).

Particles less than 2.5 µm in diameter are formed primarily by combustion or secondary chemical reactions in the atmosphere (Brook *et al.*, 1997; Wolff, 1996). Fine particles contain a higher proportion of potentially harmful chemical species, such as acids, heavy metals, and PAHs, compared to particles greater than 2.5 µm in diameter (Brook *et al.*, 1997). Fine particulate matter (PM<sub>2.5</sub>) can remain suspended in the atmosphere for days to weeks.

PM<sub>10</sub> will generally remain entrained in the atmosphere until some process acts to change the regional air mass as a whole at which point they are either moved from an area or removed from the atmosphere. Such processes include the passage of a frontal or pressure systems. Fronts define the boundaries between air masses. Therefore, when they pass through an area they bring with them a new airmass. In Skeena Region this typically means a clean air mass; however there are instances where the new airmass contains air contaminants, such as smoke from open burning or forest fires.

Like low pressure systems, fronts are often associated with precipitation. When in the form of rain, such precipitation can act as a very efficient scrubber, thereby removing aerosol pollutants, such as particulates, from the atmosphere. The particles may simply be washed out of the atmosphere or may be part of the condensation process itself.

Particle size plays another important role other than associated residence time in the atmosphere. 10 µm is also a threshold for entering human pulmonary system (the lungs) and is therefore also known as the inhalable particulate size fraction. Such particles are known to cause human health impacts. In addition, particles 10 µm in diameter and smaller have increasing potential to scatter light and therefore generate atmospheric haze. Therefore, environmental scientists and regulators are concerned with the PM<sub>10</sub> subset of total suspended particulate.

---

---

## *Potential Health Impacts of Inhalable Particulate*

### **PM<sub>10</sub>**

In 1993 the Provincial Health Officer, John Millar, noted that particulate matter health impacts appeared to be greater than those associated with any other outdoor air pollutant. In that year Dr. Millar's office released a report summarising the health risks associated with airborne particulate (Vedal, 1993). The British Columbia Ministry of Health subsequently characterised airborne small particulate from combustion sources as being the single greatest air pollution problem in British Columbia (Ministry of Health, 1994). Exposure to inhalable particulate matter can have the following effects (Vedal, 1993; Vedal, 1995):

- decrease in levels of pulmonary lung function in children and adults with obstructive airways disease;
- increase in daily prevalence of respiratory symptoms in children and adults;
- increase in functional limitations as reflected by school absenteeism and restricted activity days;
- increase in physician and emergency room visits for asthma and other respiratory conditions;
- increase in hospitalisations for respiratory and probably cardiac conditions;
- increase in cardiac and respiratory mortality on days after those with high particulate levels.

Senior citizens and people who already have lung or heart problems are most at risk of dying prematurely, but normal healthy adults and children can also be affected (BC Environment, 1995; Ministry of Health, 1994).

Vedal (1995) notes that exposure to each  $10 \mu\text{g m}^{-3}$  increment of inhalable particulate above a base level of  $20 \mu\text{g m}^{-3}$  results in a linear increase in health impacts. The greater the exposure increments, the greater the risk of impacts. This is known as a 'dose accumulation' form of air pollution impact assessment.

Specifically, each  $10 \mu\text{g m}^{-3}$  increment of PM<sub>10</sub> over  $20 \mu\text{g m}^{-3}$  has the following impacts:

- 1.0% increase in total mortality;
- 3.4% increase in respiratory mortality;
- 1.4% increase in cardiac mortality;
- 0.8% increase in respiratory hospitalisation;
- 0.6% increase in cardiac hospitalisation;
- 0.7% increase in asthma hospitalisations;
- 3.4% increase in asthma emergency visits;

- 2.3% increase in chronic obstructive pulmonary disease emergency visits;
- 9.5% increase in respiratory reduced activity days;
- 4.9% increase in minimal reduced activity days;
- 4.1% increase in school absenteeism;
- 3.0% increase in lower respiratory illness;
- 0.7% increase in upper respiratory illness;
- 1.2% increase in cough.

When inhaled, fine particles can penetrate deep into the lung's alveolar region. Here fine particles can affect pulmonary lung function as this is where oxygen enters the bloodstream. Lung function may be impaired temporarily or permanently. Fine particulate matter may contribute to the development of chronic bronchitis and may be a predisposing factor to acute bacterial and viral bronchitis, especially in sensitive individuals. It also may aggravate bronchial asthma, the late stages of chronic bronchitis, pulmonary emphysema, and existing cardiovascular disease. Exposure also can have effects on mucociliary clearance and other host defence mechanisms and can promote morphological alteration of lung tissue. Recent studies such as Schwartz *et al*, (1996) have suggested that it is exposure to very fine particles (PM<sub>2.5</sub>) that is specifically responsible for observed associations of particulate matter with daily mortality. The US EPA has indicated that it is the very smallest particles (PM<sub>2.5</sub>) that have the worst effects on health (Walsh, 1995, in Acid News, 1996). Note that PM<sub>2.5</sub> is the combustion-source size fraction of total suspended particulate.

### ***Other Environmental Impacts***

Another environmental impact of fine particulate matter includes visibility degradation. As particulate matter (especially fine particulate matter) accumulate in the atmosphere, the particles act to scatter and absorb light. The net effect is that these particulates can obscure the view, making it difficult for residents and tourists alike to "enjoy the scenery". Professional photographers do not always appreciate a 'washed out' landscape. An entire region may experience such a reduction in visibility due to large sources of particulate such as forest fires or open burning. Thus, visibility is degraded obscuring vistas resulting in a highly visible form of air pollution.

Visibility degradation can take on a much more serious nature when it interferes with the navigation of vehicular traffic on highways and around airports. This occurs when nearby smoke sources obscure pilots' and drivers' vision. Aircraft navigation can be impacted by open burning of land clearing debris when large volumes of smoke obscure the landscape from pilots using visual navigation. These environmental impacts are serious from a road and air safety perspective.

The soiling effect of particulate matter is another environmental impact. When particulates fall out of the atmosphere they can accumulate on people's cars, laundry drying outside, and in their homes. Thus, elevated levels of atmospheric particulate can have a 'nuisance impact' on the environment.

## *Air Quality Monitoring Programme*

At the beginning of the decade, BC Environment Skeena Region identified inhalable particulate as an emerging air quality issue. Consequently, an inhalable particulate sampling programme was initiated in Smithers. A sampling network was developed and upgraded as resources became available. Meanwhile, BC Environment Air Resources Branch initiated emissions inventory work. These efforts formed the precursor to BC Environment policy initiatives related to managing the inhalable particulate air quality issue.

When, in 1993 the Provincial Health Officer noted that particulate matter health impacts appeared to be greater than for any other outdoor air pollutant, he further identified a need for increased monitoring of airborne particulate in the province's population centres. As authorised by Section 10 (Permits) of the *Waste Management Act*, the Regional Waste Manager may require permittees to monitor the environment that will be affected by waste discharges and require permittees to conduct related studies. With the establishment of an air quality objective for PM<sub>10</sub>, this has included having inhalable particulate monitoring and assessment programmes undertaken by Skeena Region air emission permittees.

The current status and history of inhalable particulate monitoring in Skeena Region is identified in Table 4.

**Table 4. Summary of Skeena Region Inhalable Particulate Monitoring Sites.**

Notes: TEOM denotes Tapered Element Oscillating Microbalance, *continuous real-time* technology; HiVol and Partisol samplers collect samples according to the *National Air Pollution System* (one daily bulk sample every six days (NAPS schedule)). The Kitseguecla and Telkwa (Manalta Office) programmes are expected to commence in the spring of 1998. The Partisols deployed in Kitimat will be upgraded to TEOMs in mid-1998.

Location	Site No.	Sampler	Start Date	End Date
Burns Lake	E219592	HiVol	4-Oct-93	7-Aug-96
Burns Lake	E225267	TEOM	21-Feb-97	➔
Hazelton-DFO	E218578	HiVol	8-Mar-93	7-Aug-96
Hazelton-Spooner	E216334	HiVol	2-Nov-91	24-May-92
Houston-Firehall	M107004	TEOM	20-Sep-94	➔
Houston-Siverthorne	E218548	HiVol	12-Feb-93	23-Sep-94
Kitimat-Minette	E207182	Partisol	22-Mar-95	20-Jul-96
Kitimat-Rail	E223827	Partisol	23-Nov-96	➔
Kitimat-Riverlodge	E216670	Partisol	22-Mar-95	➔
Kitimat-Service Centre	E216669	Partisol	22-Mar-95	17-Nov-96
Kitimat-Whitesail	E223615	Partisol	26-Jul-96	➔
Kitseguecla		HiVol		➔
New Aiyansh	E225285	HiVol	5-Mar-97	➔
Prince Rupert-Galloway Rapids		TEOM	Apr-98	
Prince Rupert-Ocean Centre	E226868	HiVol	1-May-97	➔
Port Edward		TEOM	Apr-98	
Queen Charlotte City		TEOM	25-Nov-96	16-Apr-97
Quick	E226268	TEOM	9-May-97	➔
Smithers-Railway	E226589	HiVol	16-Jul-90	16-Aug-91
Smithers-St. Joseph's School	E226589	HiVol	16-Jul-90	21-Mar-94
Smithers-St. Joseph's School	M107005	TEOM	15-May-92	➔
Telkwa		TEOM	4-Feb-98	➔
Telkwa - Manalta Office		Partisol		➔
Terrace-Access Centre	E226869	TEOM	17-Apr-96	➔
Terrace-BC Hydro	E222636	HiVol	18-Oct-95	➔
Terrace-Bench		HiVol	6-Aug-96	5-Nov-96
Terrace-Clarence Michael	E222818	HiVol	18-Oct-95	4-Mar-96
Terrace-Firehall	435079	HiVol	16-Oct-93	22-Mar-96

## *Air Quality Assessment*

The first aspect in any air quality assessment is to determine the representativeness of data both in terms of physical siting and data collected. It must be recognised the atmosphere is a dynamic fluid; air quality therefore varies over space and time. There will be locations in any community that experience poorer air quality than recorded at a monitoring station. Likewise other sites will have better air quality. Most communities have only a single monitoring site. Therefore, air quality monitors are sited to provide a representative estimate of community exposure to air contaminants.

Monitoring programmes should strive for at least 85% data capture. When data capture is less than 75%, such data may be considered not representative of the environment sampled for purposes of trend or statistical summary assessments.

There are three types of assessment that may be conducted using data derived from a programme that samples the concentrations of atmospheric contaminants. Comparing the relevant air quality objective to a given air quality monitoring data set can yield statistics representative of the *frequency* of objective exceedence (how often the objective is not met). However, this method does not characterise exceedence magnitudes (total exposure to contaminants at polluted levels) . This ‘dose accumulation’ (exposure increment) approach is a measure of the *intensity* of impacts occurring in a community (noted previously in the Potential Health Impacts of Inhalable Particulate section on page 15). However, it must be emphasised that, while an excellent tool for air quality assessment, the exposure increment is not a formal provincial “standard” like an air quality objective. The third type of assessment includes descriptive statistics such as mean concentrations and tests of significant differences.

### *Air Quality Objective Definition*

British Columbia’s ambient air quality ‘standards’ are in the form of objectives and guidelines and are comprised of two or three levels (A, B, and C). Canadian objectives are also defined for two or three levels (Desirable, Acceptable, Tolerable). Air quality objectives are designed to prevent air pollution, as defined as the presence in the environment of substances or contaminants that substantially alter or impair the

usefulness of the environment (*Waste Management Act*, 1996). Objective levels are defined in more detail in the following sub-sections.

### ***British Columbia's and Canada's Air Quality Assessment Criteria***

#### ***Level A (Maximum Desirable)***

Designed to provide **long term protection for all environments**. This level is reasonable for polluted areas to aim for and to achieve. This level represents a conservative approach of *protecting the most sensitive receptor*, thereby providing a wide margin of safety to protect other less sensitive receptors.

#### ***Level B (Maximum Acceptable)***

Intended to be the **acceptable interim objective**. This level provides adequate protection against adverse effects on human health and comfort, vegetation, animals, soil, water, materials, and visibility.

#### ***Level C (Maximum Tolerable)***

Defines the **"immediate" ambient objective**. Due to a diminishing margin of safety, appropriate action is immediately required to protect the health of the general population when concentrations of air contaminants exceed this level.

With respect to air quality assessment work, new sources, in general, should be designed such that their emissions would not result in any Level A air quality objective exceedences. For existing situations, BC Environment in general would work to progressively improve (reduce) emissions in an airshed with the goal of meeting the Level A air quality objective.

Note that many of British Columbia's air quality impact criteria were developed in the 1970s. In 1995 British Columbia proclaimed an Interim Air Quality Objective for fine particulate:  $50 \mu\text{g m}^{-3}$  (24 hour average concentration). This is intended to be equivalent to a Maximum Acceptable level in the national air quality objective system. A Maximum Desirable equivalent level has not been proclaimed. In Skeena Region, BC Environment has identified an annual air quality objective of  $20 \mu\text{g m}^{-3}$  (Johnson, 1992, 1994) to complement a  $50 \mu\text{g m}^{-3}$  daily objective.

### ***Summary***

In summary, air quality can be characterised by measure of central tendency (average and range of concentrations and how they change over time) or in terms of their impacts. Air quality impacts can be

measured in terms of frequency or magnitude. Frequency statistics for inhalable particulate may be expressed as the number of daily exceedences of the  $50 \mu\text{g m}^{-3}$  air quality objective. Such measures should be expressed as percent of days sampled if comparisons are to be made between stations or years, as the number of samples will change for any given period and between sampling sites.

Exposure increments represent the intensity of air pollution impacts. For inhalable particulate they are calculated by counting the number of daily  $10 \mu\text{g m}^{-3}$  increments above  $20 \mu\text{g m}^{-3}$ . These must be normalised to account for differences in the number of samples collected between sampling periods and between stations. BC Environment Skeena Region normalise this statistic to a 365 day-year equivalents.

An assessment for the communities of Smithers and Houston using these measures is presented in the following sections. Please note that time periods for which data collection is below 75% of the number of possible samples may not be representative of that location or time period. Summaries are grouped in one year sample periods which run from July to June. 1997-98 summaries are current to mid-April 1998.

## *Houston Data Summary*

### *History*

In February 1993 a high volume sampler was deployed at Silverthorne School. It was operated by BC Environment and subsequently taken over by Northwood Pulp and Timber and Houston Forest Products as part of their air emissions permits. Houston Forest Products appealed this requirement to the Environmental Appeal Board Panel. The Board agreed that there exists sufficient legislated authority for BC Environment to require industry to share the costs of monitoring environmental impacts of their waste emissions. Furthermore, such monitoring should be continuous. As a result, each of the two Houston permittees were required to contribute one-third of the costs to install a new continuous, real-time, inhalable particulate and meteorological monitoring station; BC Environment covered the other one-third which is considered to represent non-permitted sources such as mobile (e.g., vehicles), woodstoves, and open burning. This cost sharing formula will continue as long as the mill is emitting waste into the common airshed (Environmental Appeal Board, 1994). The new monitoring station is located a few hundred metres from the Silverthorne school site in the Houston Firehall (Figure 5). It began operation in October 1994. While it may appear obvious, the Board's decision firmly links the concept that beehive burner emissions may impact nearby communities and, as such, burner operators are responsible for the fate of their emissions.

**Figure 5. Firehall Monitoring Site**



## Geography

Houston, population 3,934 (1996), is located in the Bulkley Valley along the south side of the Bulkley River. It is bisected by Buck Creek with the town core located to the east. Highway 16 parallels, and is adjacent to, the railway tracks bisecting the community along a northeast-southwest axis. The Houston Forest Products and Northwood Pulp and Timber sawmills are located less than 5 km to the west of town. Local relief is not as extreme as points further down valley such as Telkwa and Smithers. Figure 6 depicts the monitoring site locations.

**Figure 6. Houston Inhalable Particulate Monitoring Station Locations.**



Silverthorne School and the Firehall are both located near the commercial area of town. Silverthorne School is in a residential area on the south east corner of town. The Firehall site is a few hundred metres away in the transitional land use area between the Silverthorne residential area, the pure commercial land use of downtown, and the transportation corridor. Both sites may see some local through-traffic; surrounding roads are paved.

## Data Capture

Table 5 and Figure 7 depicts the data capture rates associated with the Houston monitoring programme, in both tabular and graphical formats. Note the poor data capture rates in the early years of the programme.

**Table 5. Houston Data Capture.**

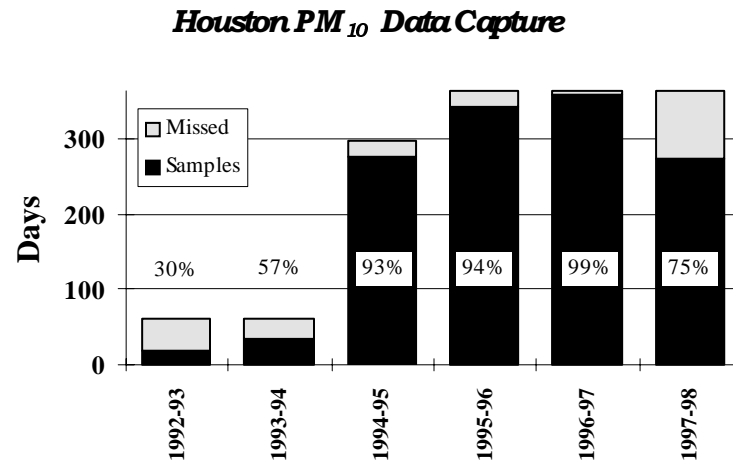
The most recent year is current to mid-April 1998. The less than 365 days per year sample days between 1992 and 1994 reflect the operation of the high volume sampler on a NAPS schedule (one 24 hour period every six days) prior to the installation of the continuous analyser in September 1994.

**Houston PM<sub>10</sub> Data Capture**

Period	Samples	Missed	Sample Days	%
1990-91	0	N/A	N/A	N/A
1991-92	0	N/A	N/A	N/A
1992-93	18	42	60	30%
1993-94	34	26	60	57%
1994-95	278	20	298	93%
1995-96	344	22	366	94%
1996-97	360	5	365	99%
1997-98	275	90	365	75%

1994-95 represents an integrated assessment of the NAPS and TEOM schedules.

**Figure 7. Houston Data Capture.**

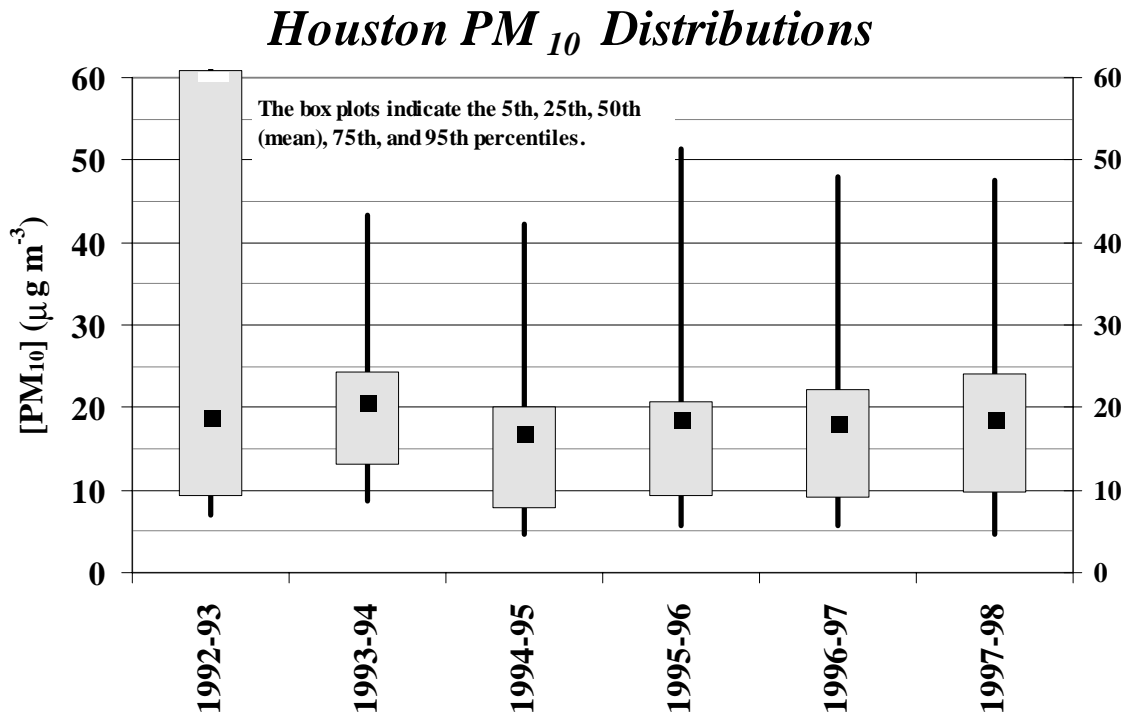


## Central Tendency

Figure 8 depicts the percentile distributions of the Houston PM<sub>10</sub> data by monitoring year. Excluding the extremes of the first year (which is considered unrepresentative with respect to its very poor data capture), the 25<sup>th</sup> and 75<sup>th</sup> percentile concentrations have increased over the past four years. The others do not show any trend. The running annual mean, depicted in Figure 9, also depicts the variable pattern associated with the 50<sup>th</sup> percentile concentration. Figure 10 demonstrates that the 1997-98 mean does not differ significantly from any previous year.

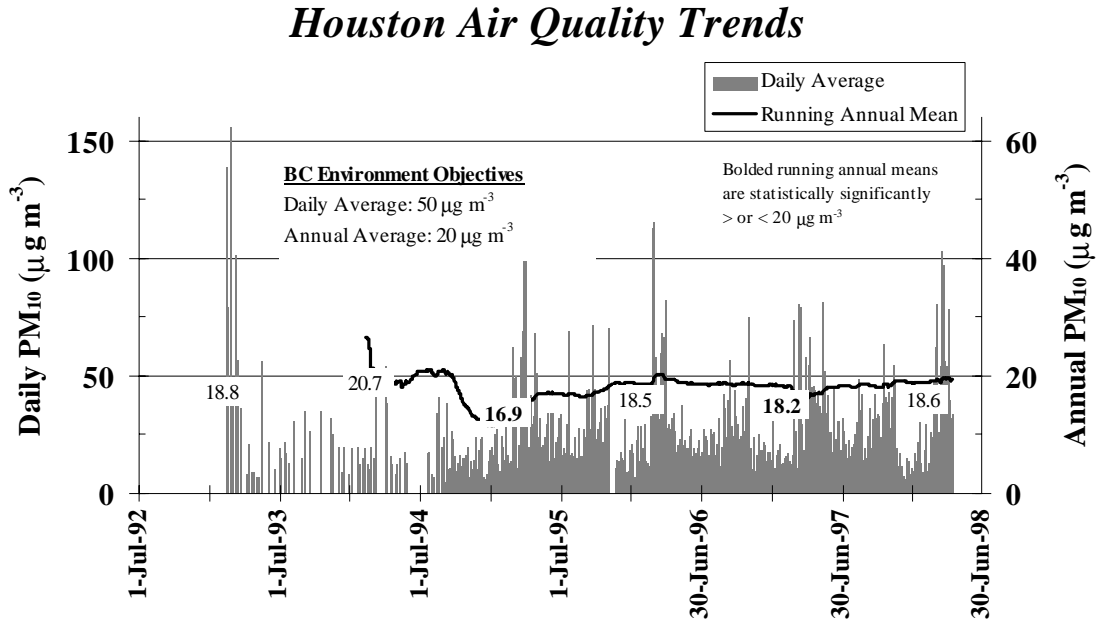
**Figure 8. Percentile Distribution of Houston PM<sub>10</sub> Observations.**

The most recent year is current to mid-April 1998. The top of the top bar depicts the 95<sup>th</sup>, top of the box the 75<sup>th</sup>, black square the 50<sup>th</sup>, box bottom the 25<sup>th</sup>, and line bottom the 5<sup>th</sup> percent highest reading of the mean daily inhalable particulate concentrations for each particular year. 1992-93 should be considered grossly unrepresentative of the year and should not be used for comparative purposes.



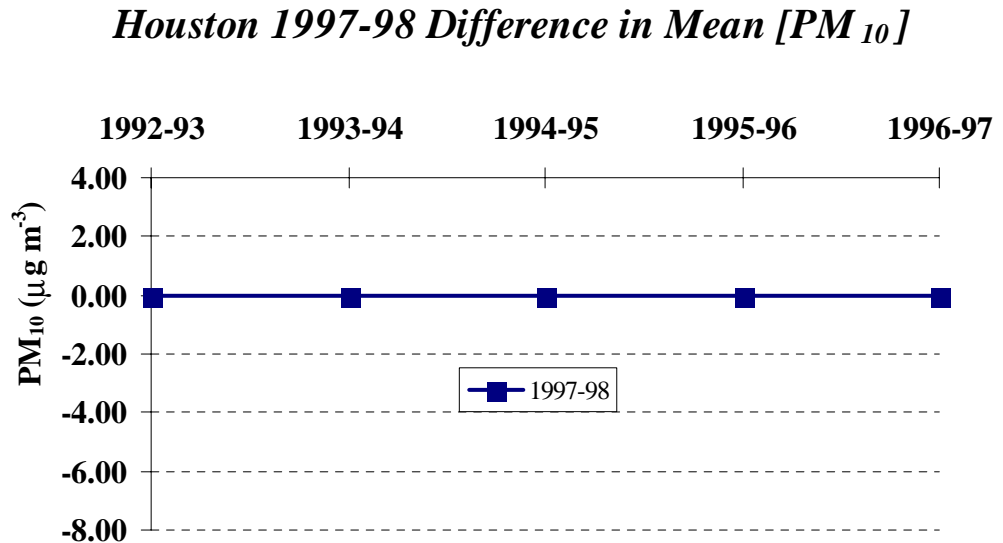
**Figure 9. Houston Air Quality Trends.**

The most recent year is current to mid-April 1998. High volume samples are midnight -to-midnight (February 1993-September 1994) from the NAPS schedule; TEOM readings are maximum daily averages. Running annual mean is based on midnight-to-midnight daily averages. Numbers on the chart are annual means; they were significantly less than  $20 \mu\text{g m}^{-3}$  in the 1994-95 and 1996-97 monitoring periods.



**Figure 10. Annual Difference in Means Compared to 1997-98 Reference Year.**

The most recent year is current to mid-April 1998. This chart presents significant difference between this year's (1997-98) mean inhalable particulate concentration compared with other years. Zero denotes no significant difference. A negative number indicates the current year is that many micrograms per cubic metre lower, on average, than the year in comparison. A positive number indicates the current year is that many micrograms per cubic metre higher, on average, than the year in comparison. Non-zeros are statistically significant at the 0.05 significance level using a two-tailed t-test.



## Impact Assessment

Table 6 presents various impact-related summary statistics. Figure 11 and Figure 12 are plots of these two statistics.

### Table 6. Measures of Houston Inhalable Particulate Impacts.

The most recent year is current to mid-April 1998. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective ( $50 \mu\text{g m}^{-3}$  averaged over 24 hours) recorded at midnight. Use of continuous monitoring technology (since September 1994) allows for assessment of daily air quality objective exceedences that occur at hours other than midnight. The Daily Peak (DP) statistic denotes additional days per year in which the running 24 hour mean concentration exceeded the air quality objective at some point in the day, but did not at (exclusive of) midnight. 1992-93 should be considered grossly unrepresentative of the year and should not be used for comparative purposes. It is presented merely to illustrate that exceedences and increments did occur that year.

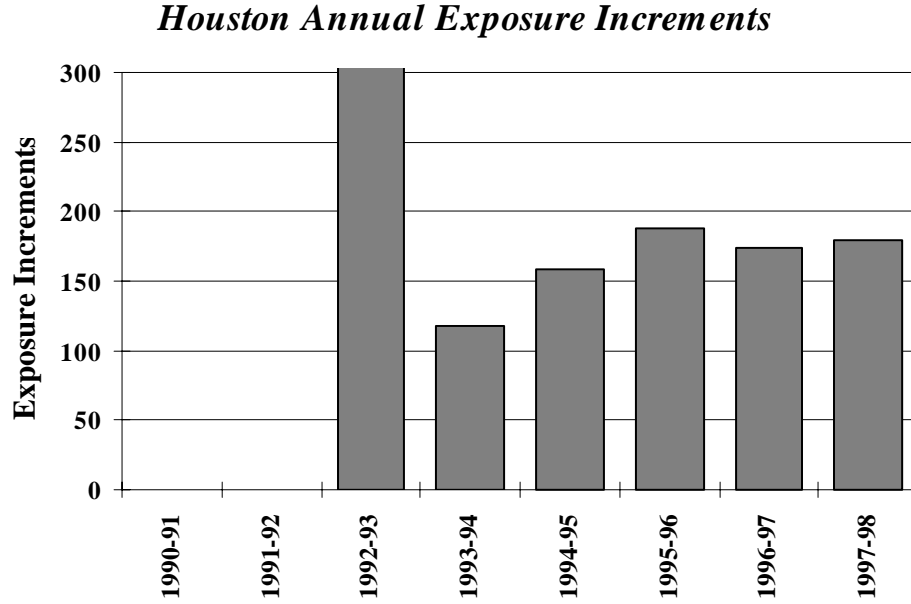
### Measures of Houston $\text{PM}_{10}$ Impacts

	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
MDA $> 50 \mu\text{g m}^{-3}$ *	38.9%	5.9%	2.5%	5.5%	4.4%	3.5%
DP $> 50 \mu\text{g m}^{-3}$ *	0.0%	0.0%	2.5%	2.0%	2.8%	1.9%
Total Exceedences	38.9%	5.9%	5.1%	7.6%	7.2%	5.4%
Exposure Increments	1014	118	159	188	174	180
Sample Days	18	34	278	344	360	360
Total Days	365	365	365	366	365	365
Data Capture	30%	57%	93%	94%	99%	76%

\*MDA denotes midnight daily averages; DP denotes daily peak (exclusive of MDA)

**Figure 11. Houston Exposure Increments.**

The most recent year is current to mid-April 1998. Increments are normalised to a 365-day year to account for differences in the number of samples collected between sampling periods and to ensure representative comparisons between stations. 1992-93 should be considered grossly unrepresentative of the year and should not be used for comparative purposes. It is presented merely to illustrate that increments did occur that year.



**Figure 12. Houston Air Quality Objective Exceedence Frequencies.**

The most recent year is current to mid-April 1998. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective ( $50 \mu\text{g m}^{-3}$  averaged over 24 hours) recorded at midnight. Use of continuous monitoring technology (since September 1994) allows for assessment of daily air quality objective exceedences that occur at hours other than midnight. The Daily Peak (DP) statistic denotes additional days per year in which the running 24 hour mean concentration exceeded the air quality objective at some point in the day, but did not at midnight. 1992-93 should be considered grossly unrepresentative of the year and should not be used for comparative purposes. It is presented merely to illustrate that exceedences did occur that year.

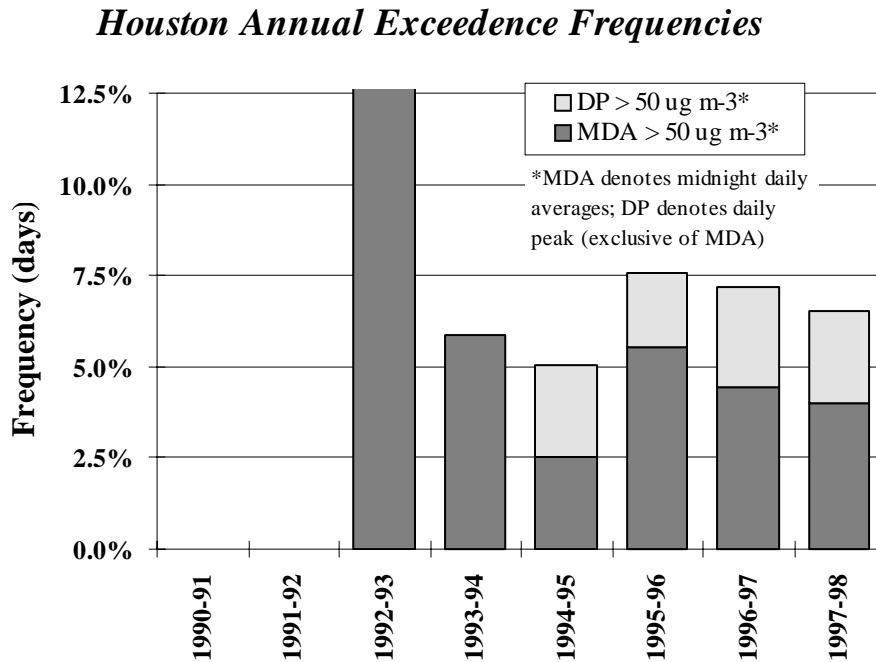
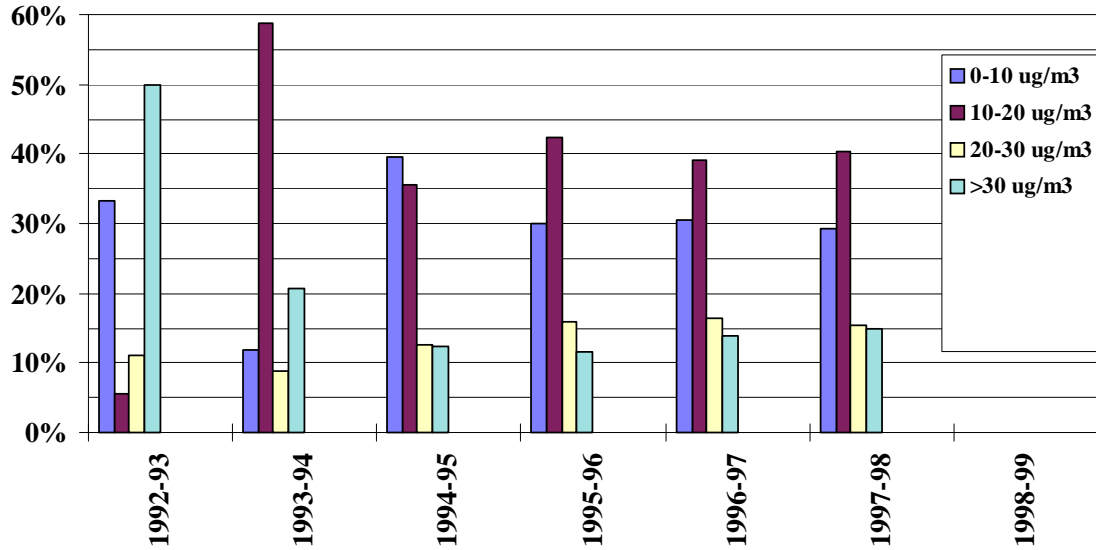


Figure 11, which depicts the number of exposure increments (normalised to a 365-day year), shows increments appear to have levelled off over the past few years at  $175 \pm 15$  increments per year. This contrasts with Figure 12 which shows a decline in frequency of Interim Air Quality Objective exceedences. This apparent contradiction is explained in Figure 13, a depiction of the data frequency distribution. Figure 13 shows the frequency of concentrations greater than  $30 \mu\text{g m}^{-3}$  (exposure increment threshold) have increased over the previous three years. Other concentration classes have no clear trend. Therefore, the decrease in high concentrations of inhalable particulate (greater than  $50 \mu\text{g m}^{-3}$ ; the Interim Air Quality Objective and threshold for 3 exposure increments) have somewhat been offset by an increase in inhalable particulate concentrations greater than  $30 \mu\text{g m}^{-3}$ . Remember that Figure 8 shows over the last three years an increase in the 75<sup>th</sup> percentile concentration (the one closest to  $30 \mu\text{g m}^{-3}$ ) while the 95<sup>th</sup> percentile concentration has declined or remained steady.

**Figure 13. Inhalable Particulate Data Frequency Distribution.**  
 The most recent year is current to mid-April 1998. The chart depicts the distribution of all 24 hour average observations over a range of concentrations. Based on midnight daily averages.

*Houston PM<sub>10</sub> Data Frequency Distribution*



**Summary**

When assessed in terms of the Interim Air Quality Objective exceedences, inhalable particulate air quality in Houston has shown some improvement over the last three years. However, ‘particulate doses’ (concentrations greater than 30 µg m<sup>-3</sup>, the exposure increment threshold) do not show a similar decrease in magnitude or frequency. Expressed as an annual sum, they have remained steady at approximately 175 increments. The 75<sup>th</sup> percentile concentrations have been increasing over the past four years. The mean concentration has been variable; generally, there has been no significant changes in mean annual inhalable particulate concentrations over the years.

## *Smithers Data Summary*

### *History*

In July 1990 Skeena Region's first inhalable particulate sampling programme was initiated with a high volume sampler at St. Joseph's school. This programme was subsequently upgraded with the support of Environment Canada and the British Columbia Lung Association to a continuous, real-time, sampler. A number of additional parameters are also monitoring at this site (Figure 14). The inhalable particulate PM<sub>10</sub> programme is currently operated with the support of local industry, with the exception of Skeena Cellulose (cf. Table 2 on page 9).

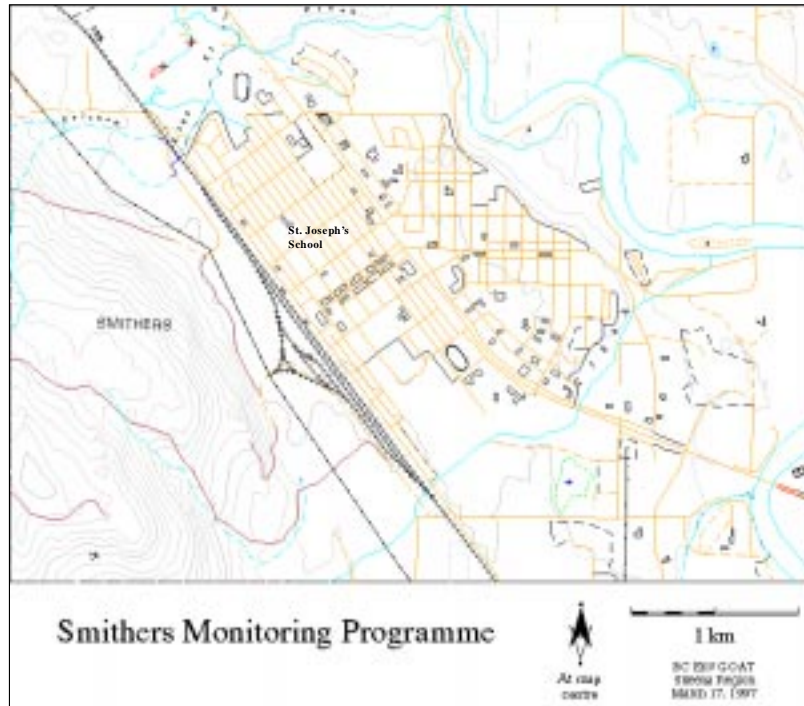
**Figure 14. St. Joseph's School Monitoring Site.**



## Geography

Smithers, population 5,624 (1996), is located in the (long axis) centre of the Bulkley Valley approximately 60 km north west and down river of Houston. The Smithers sawmills are 2-3 km Southeast of the town centre. While the valley is fairly wide at this point, it is confined by significant topographical obstructions. The town itself is located

**Figure 15. Smithers Inhalable Particulate Monitoring Station Location.**



between the base of Hudson Bay Mountain (2575 m) and the Bulkley River. The Bulkley River drains into the Skeena River at Hazelton 80 km to the northwest. 20 kilometres across valley from Smithers is the Babine mountain range (elevations in excess of 2000 m). Figure 15 depicts the monitoring station location, St. Joseph's School, in the town of Smithers.

## Data Capture

As depicted in Table 7 and Figure 16, the data capture record for the Smithers programme has been exceptional: all years have enough data to be considered representative. Unfortunately, the Smithers TEOM was not functional during October 1996 when the station underwent a significant upgrade. It therefore missed a serious open burning smoke event: the 1996-97 summary will therefore be biased low in this context.

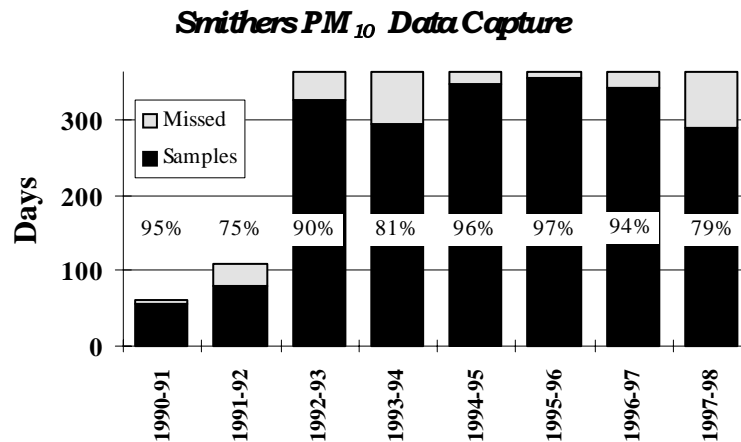
**Table 7. Smithers Data Capture.**

The most recent year is current to mid-April 1998. The less than 365 days per year sample days between 1990 and 1992 reflect the operation of the high volume sampler on a NAPS schedule (one 24 hour period every six days) prior to the installation of the continuous analyser in May 1992.

### Smithers PM<sub>10</sub> Data Capture

Period	Samples	Missed	Sample Days	%
1990-91	57	3	60	95%
1991-92	81	27	108	75%
1992-93	328	37	365	90%
1993-94	297	68	365	81%
1994-95	350	15	365	96%
1995-96	356	10	366	97%
1996-97	343	22	365	94%
1997-98	290	75	365	79%

1991-92 represents an integrated assessment of the NAPS and TEOM schedules.

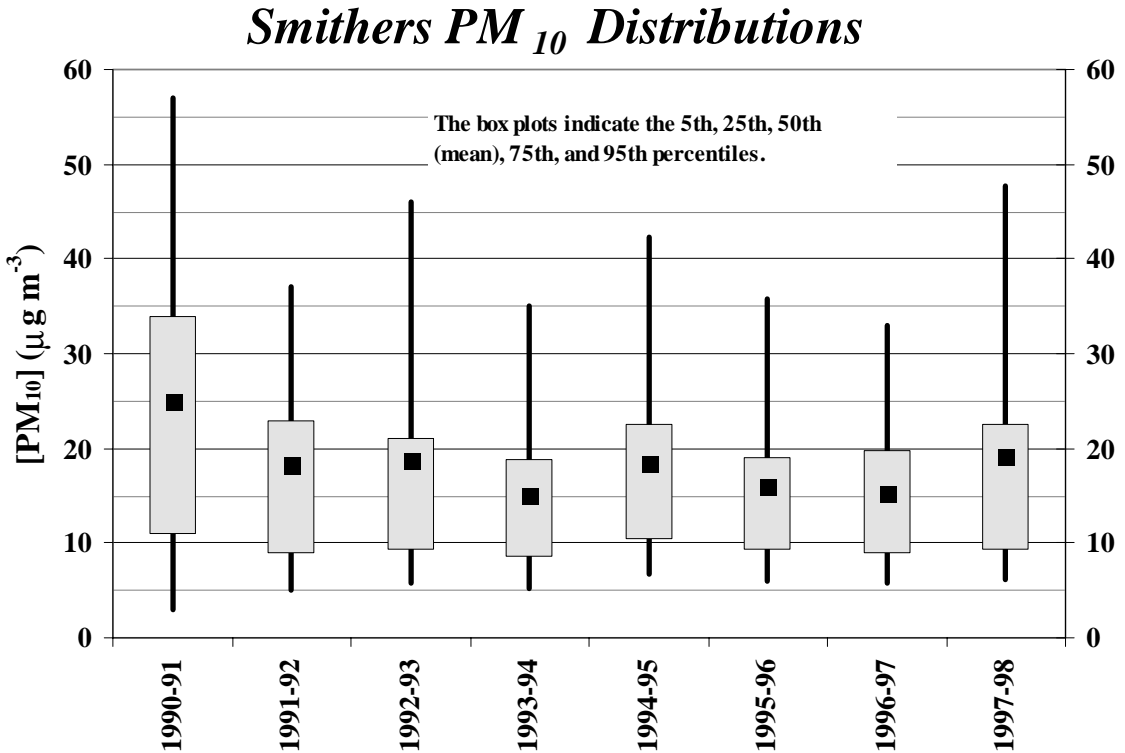
**Figure 16. Smithers Data Capture.**

**Central Tendency**

Figure 17 depicts the percentile distribution of the Smithers PM<sub>10</sub> data by monitoring year. Note the turn around this year of the gradual reduction in the percentile concentration magnitudes (except for the 75<sup>th</sup> percentile) over the last four years, reversing a general reduction in the magnitude of exposures to inhalable particulate. The trend for entire period is characterised by a variable sinusoidal wave pattern. Figure 18 depicts a similar trend of initially variable mean concentrations followed by a declining trend, until the turn around in 1997-98. Figure 19 shows air quality this year, while significantly better than the first year monitored (1990-91), is significantly worse than three out of the four pervious years.

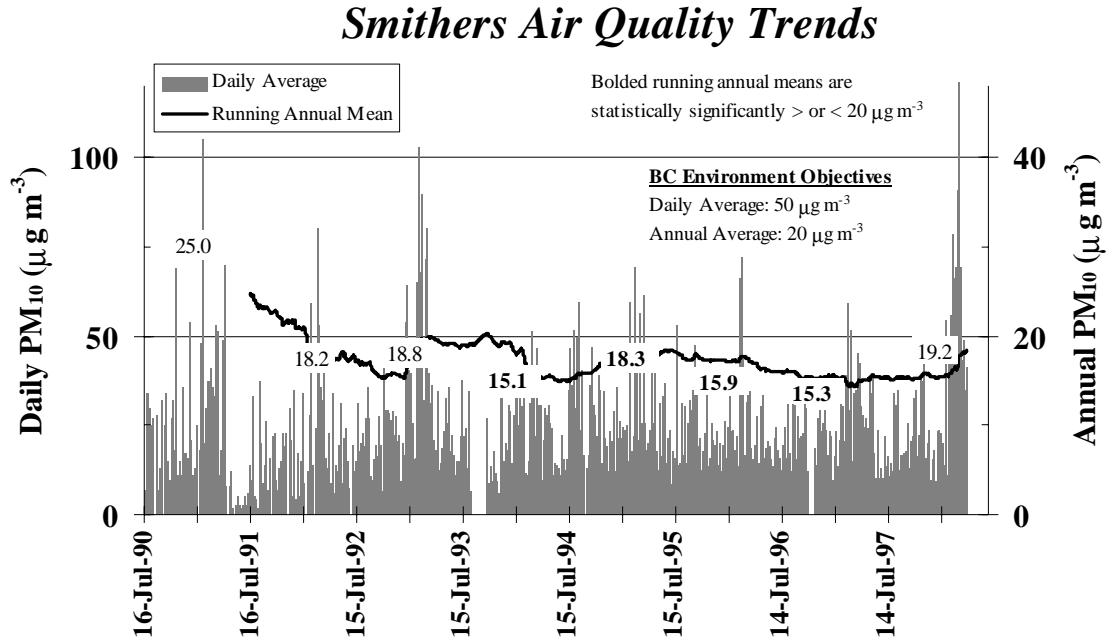
**Figure 17. Smithers Distributions of Inhalable Particulate Observations.**

The most recent year is current to mid-April 1998. The top of the top bar depicts the 95<sup>th</sup>, top of the box the 75<sup>th</sup>, black square the 50<sup>th</sup>, box bottom the 25<sup>th</sup>, and line bottom the 5<sup>th</sup> percent highest reading of the mean daily inhalable particulate concentrations for each particular year.



**Figure 18. Smithers Air Quality Trends.**

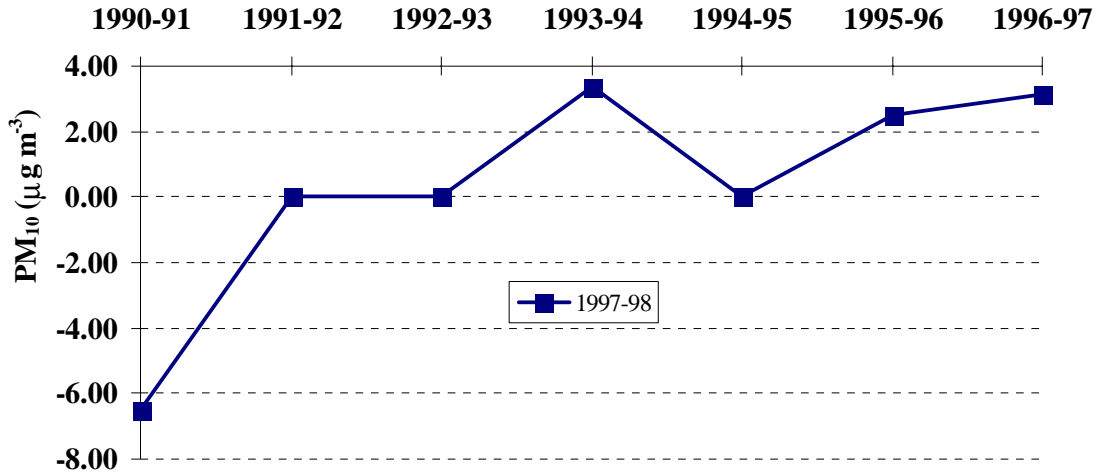
The most recent year is current to mid-April 1998. High volume samples are midnight -to-midnight (July 1990-May 1992) from the NAPS schedule; TEOM readings are maximum daily averages. Running annual mean is based on midnight-to-midnight daily averages. Numbers on the chart are annual means; between 1993-94 and 1996-97 than annual means were significantly less than  $20 \mu\text{g m}^{-3}$ .



**Figure 19. Annual Difference in Means Compared to 1997-98 Reference Year.**

The most recent year is current to mid-April 1998. This chart presents significant difference between this year's (1997-98 to date) mean inhalable particulate concentration compared with other years. Zero means no significant difference. A negative number indicates the current year is that many micrograms per cubic metre lower, on average, than the year in comparison. A positive number indicates the current year is that many micrograms per cubic metre higher, on average, than the year in comparison. Non-zeros are statistically significant at the 0.05 significance level using a two-tailed t-test.

*Smithers 1997-98 Difference in Mean [PM<sub>10</sub>]*



**Impact Assessment**

Table 8 presents various impact-related summary statistics. Figure 20 and Figure 21 are plots of these two statistics.

**Table 8. Measures of Smithers Inhalable Particulate Impacts.**

The most recent year is current to mid-April 1998. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective ( $50 \mu\text{g m}^{-3}$  averaged over 24 hours) recorded at midnight. Use of continuous monitoring technology (since May 1992) allows for assessment of daily air quality objective exceedences that occur at hours other than midnight. The Daily Peak (DP) statistic denotes additional days per year in which the running 24 hour mean concentration exceeded the air quality objective at some point in the day, but did not at (exclusive of) midnight.

#### Measures of Smithers $\text{PM}_{10}$ Impacts

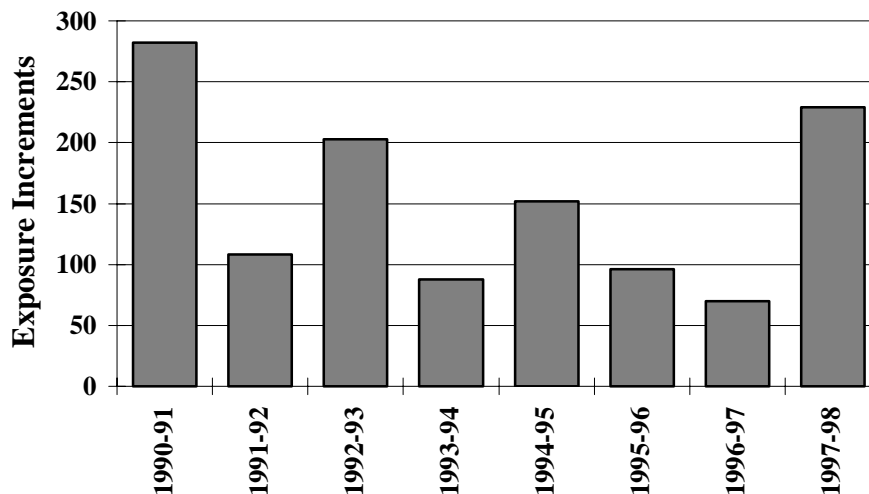
	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
MDA $> 50 \mu\text{g m}^{-3}$ *	10.5%	3.7%	4.3%	0.3%	3.1%	2.2%	0.6%	4.7%
DP $> 50 \mu\text{g m}^{-3}$ *	0.0%	0.0%	2.5%	0.3%	3.2%	0.9%	0.9%	2.6%
Total Exceedences	10.5%	3.7%	6.8%	0.7%	6.4%	3.1%	1.5%	7.3%
Exposure Increments	282	108	203	88	152	96	70	229
Sample Days	57	81	328	297	350	356	343	343
Total Days	365	366	365	365	365	366	365	365
Data Capture	95%	75%	90%	81%	96%	97%	94%	79%

\*MDA denotes midnight daily averages; DP denotes daily peak (exclusive of MDA)

**Figure 20. Smithers Exposure Increments.**

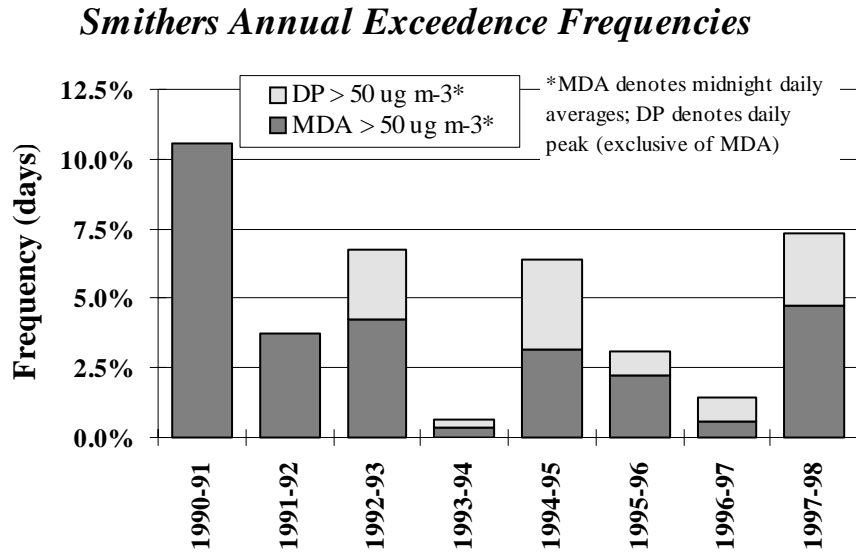
The most recent year is current to mid-April 1998. Increments are normalised to a 365-day year to account for differences in the number of samples collected between sampling periods and to ensure representative comparisons between stations.

#### Smithers Annual Exposure Increments



**Figure 21. Smithers Air Quality Objective Exceedence Frequencies.**

The most recent year is current to mid-April 1998. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective ( $50 \mu\text{g m}^{-3}$  averaged over 24 hours) recorded at midnight. Use of continuous monitoring technology (since May 1992) allows for assessment of daily air quality objective exceedences that occur at hours other than midnight. The Daily Peak (DP) statistic denotes additional days per year in which the running 24 hour mean concentration exceeded the air quality objective at some point in the day, but did not at midnight.

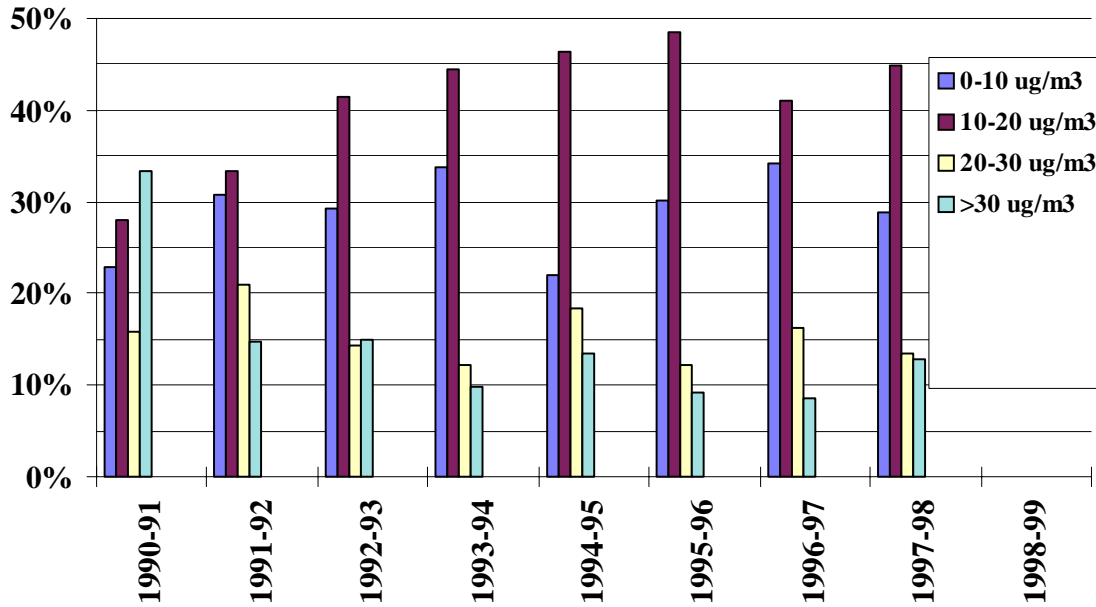


The patterns in the measures of central tendency are mirrored by measures of impact assessment. Figure 20, the number of annual exposure increments, depicts the variability in the Smithers exposure (does accumulation) pattern over the period of the entire monitoring record. Similarly, Figure 21 depicts a variable frequency of exceedences over the monitoring record.

An examination of the frequency distribution of  $\text{PM}_{10}$  data from Smithers yields some interesting observations. Generally, all classes, including the one which includes concentrations detrimental to human health ( $30 \mu\text{g m}^{-3}$  and greater), have fluctuated over the years. One noteworthy trend is that characterising intermediate concentrations ( $10\text{-}20 \mu\text{g m}^{-3}$ ), which have generally increased in their proportion such that they now represent almost 45% of the daily means (up from 28% in 1990-91).

**Figure 22. Inhalable Particulate Data Frequency Distribution.**  
 The most recent year is current to mid-April 1998. The chart depicts the distribution of all 24 hour average observations over a range of concentrations. Based on midnight daily averages.

*Smithers PM<sub>10</sub> Data Frequency Distribution*



**Summary**

All measures of assessment show 1997-98 to be a year reversing an improving air quality trend of the three years previous.

---

---

## *Discussion*

We have the ability to improve air quality in our communities by changing the quantity of particulate matter emitted into the atmosphere. While this is very hard to do with respect to natural sources; domestic and industrial sources may be improved by a combination of education, regulation, and technology. These strategies have been applied in the Bulkley Valley in an effort to improve air quality. They are summarised below chronologically.

BC Environment has undertaken a number of educational initiatives, as have local and provincial interest groups. These groups include the British Columbia Lung Association, the Physician's Environmental Concerns Committee (PECC), Environmental Action for Our Children's Heritage (E.A.C.H.), Ministry of Forests, and the Town of Smithers Environmental Services Committee (Air Quality). Initiatives have included public presentations, production of educational videos (BC Environment, no date; E.A.C.H., no date), leaflet drops, newspaper advertisements, etc. Smithers was the focus of much of the education initiatives.

In 1992 with the deployment of continuous real-time monitoring technology, BC Environment Skeena Region implemented the *Smithers Air Quality Management Plan* for particulate matter (Johnson, 1992). The plan included an incremental response to deteriorating air quality conditions, including voluntary wood stove and fireplace use restrictions and health-related air quality advisories.

In 1993, the British Columbia government enacted the *Open Burning Smoke Control Regulation*, which had the effect of imposing a code of practice (enacted in 1994) on much of the open burning conducted in the province. The code is designed to ensure that smoke emissions are minimised and impacts on human populations are prevented.

In 1994, the British Columbia government enacted the *Solid Fuel Burning Domestic Appliance Regulation* which regulates wood burning stove and fireplace emissions from new appliances. In effect, this requires

new wood burning appliances to use state of the art emissions control technology. Particulate emissions are much lower compared to old airtight wood burning stoves. Also in 1994, the *Low Sulphur Diesel Regulation* was passed by the provincial government to reduce emissions of particulates and their precursor gases from on-road diesel vehicles.

In 1995, the *Smithers Air Quality Management Plan* was expanded to include the Bulkley Valley (Johnson, 1994), to incorporate the new continuous, real-time, inhalable particulate monitor in Houston. Health advisories were revised in consultation with the Skeena Health Unit of the Ministry of Health. The plan now includes guidelines for when BC Environment would implement the provisions of the *Open Burning Smoke Control Regulation* to effectively ban open burning of land clearing debris during air pollution episodes. The first ban was implemented in March 1995. Current to mid-April 1998, there have been 14 such bans, covering 86 days in total.

Also in 1995, the province enacted the *Wood Residue Burner and Incinerator Regulation* (BC Environment, 1995). This, effectively, gave notice to the sawmill industry of the government's intention to follow-up on its proposed management strategy to phase out beehive burners (BC Environment, 1991), particularly in smoke sensitive airsheds (SSAs). As of January 1998, approximately one half of the province's Tier I (SSA) beehive burners have shut down, including a silo burner in New Hazelton.

In 1997, the town of Smithers effectively banned backyard burning.

It may be hypothesised that monitoring programmes themselves act to reduce emissions. The early days of the Smithers sampling programme saw a very public debate in the news media regarding assessments of the initial data. The debate focused on particulate sources and what could be done to improve emissions. There may be increased vigilance by industry with respect to the performance of permitted or regulated particulate sources knowing that air quality conditions can be quantified. The continuous, real-time, monitoring technology gives people information they need to act locally to improve emissions during periods of poor air quality, whether it be a voluntary curtailment of wood stove use, walking or biking instead of driving, or refraining from outdoor burning. BC Environment itself places higher priority on enforcement and compliance initiatives during periods of poor air quality.

Given the regulatory and education initiatives over the years, perhaps one would expect a stronger or more consistent indication of improved air quality than has been presented in previous sections. It should be remembered, however, that air quality is also strongly dependent on meteorological conditions. Such conditions vary from year to year thereby masking the significance of emission reductions, particularly in the short term.

Also, regulatory and education initiatives are superimposed on a backdrop of continued growth in the valley. People are not just ‘particulate sinks’ (absorbing particulate from the atmosphere in their lungs), but act as particulate sources (e.g., clearing land for housing, home heating emissions, emissions from vehicles and roads). Thus, the more people, the more particulate emissions. The 1991-96 growth rate for valley communities is depicted in Table 9. Note the double-digit growth rates for Telkwa and Smithers (the Indian reserves are spread out throughout the regional district and are not necessarily concentrated in the Bulkley Valley).

**Table 9. Population Statistics for Bulkley Valley Communities.**

DM denotes District Municipality, R Indian Reserve, SRD Subdivision of Regional District, T Town, and VL Village. Bulkley-Nechako Subdivision B includes the Smithers-Houston area (to just east of Topley; includes Granisle); Subdivision C includes from east of Topley to just west of Endako (includes Burns Lakes, Francois Lake, Ootsa Lake). Kitimat-Stikine Subdivision B includes the Hazelton area through to just east of Moricetown. From BC Stats (1998).

Area Type	Area Type	1996 Census Population	1991-96 Growth Rate (%)	1996 Private Dwellings	1996 Land Area (km <sup>2</sup> )	Pop/km <sup>2</sup> (1996)
<b>Bulkley-Nechako</b>	<b>RD</b>	<b>41642</b>	<b>8.6</b>	<b>14292</b>	<b>72101</b>	<b>0.6</b>
Burns Lake	VL	1793	6.3	677	8	239.1
Houston	DM	3934	8.4	1420	74	53.0
Smithers	T	5624	11.8	2044	14	413.5
Telkwa	VL	1194	24.2	375	5	221.1
Subdivision B	SRD	6505	8.5	2134	17844	0.4
Subdivision C	SRD	4015	8.2	1385	19334	0.2
Indian Reserves	R	3449	23.0	901	86	40.1
<b>Kitimat-Stikine</b>	<b>RD</b>	<b>43618</b>	<b>5.0</b>	<b>14687</b>	<b>91909</b>	<b>0.5</b>
Hazelton	VL	347	2.4	139	3	119.7
New Hazelton	DM	822	4.6	296	25	33.3
Subdivision B	SRD	2098	-6.5	746	7757	0.3
Indian Reserves	R	7209	17.4	1934	108	67.0

In assessing the air quality data collected in the Bulkley Valley over the past 3-4 years it is evident that there is qualified improvement. The frequency of Interim Air Quality Objective exceedences in Houston is slowly declining. Other indicators remain constant in spite of growth in the area. Houston mean and median inhalable particulate concentrations show little change. Similarly Houston exposure increments, though significant in terms of magnitude, have levelled out. Smithers data generally show an improvement in all assessment statistics occurring in recent years, with the current year being an exception to this trend.

While not a measure of impacts, the *Bulkley Valley Air Quality Management Plan's* annual air quality objective of 20 µg m<sup>-3</sup> may be considered as a relative benchmark to assess long term trends in central tendency (average concentrations of PM<sub>10</sub>). In Smithers, annual means have been significantly less than the

Plan's objective of  $20 \mu\text{g m}^{-3}$  for four of the eight years monitored, all occurring in the last five years. In Houston, only two of the six years monitored (1994-95 and 1997-98) have been significantly less than the annual objective. With respect to an impact assessment objective, the Bulkley Valley airshed has never met the daily air quality objective (equivalent to the Interim Air Quality Objective) of no exceedences of  $50 \mu\text{g m}^{-3}$  in any given monitoring year.

## *Conclusions*

It would appear that recent regulatory initiatives, such as those in place for new woodstoves and open burning, combined with public information campaigns, have had qualified success. Some air quality indicators show an improvement. Others have levelled off. However, interim air quality objective exceedences and high magnitude exposure increments are occurring in both Houston and Smithers, every year, regardless of meteorological conditions and emission reduction and management strategies. Meanwhile, valley population continues to increase.

Of the management options presented in *Smoke Management for the '90s* (BC Environment, 1991), beehive burner phase out in smoke sensitive airsheds remains the last significant policy option to be implemented for particulate emission reductions and air quality management. Currently, this question is before the residents of the Bulkley Valley.

With respect to other aspects of air quality management, municipalities and regional districts have the authority to regulate emissions such as those from wood burning appliances, backyard burning, and seasonal activities such as street sweeping. It is recommended they examine such options through their environmental services committees and/or official community plans to reduce their particulate loading into the atmosphere, especially during meteorological conditions associated with high air pollution potential. In addition, there is opportunity for BC Environment to eliminate some or all of the exemptions that exist with respect to its regulation of open burning of land clearing debris.

Co-location of continuous PM<sub>2.5</sub> monitors with the TEOM PM<sub>10</sub> monitors would help apportion the combustion component of PM<sub>10</sub>. This would allow regulatory agencies to better focus their emission management strategies.

## References

- Acid News. 1996. *Scientists Now More Sure*. 1: 9. February.
- Barry, R.G. and R.J. Chorley. 1982. *Atmosphere, Weather and Climate*. Methuen & Co. 407 pp.
- BC Environment. 1996. *Waste Management Act*. Queen's Printer. Victoria.
- BC Environment. 1995a. *Wood Residue Burner and Incinerator Regulation*. Waste Management Act. B.C. Reg. 519/95. Deposited December 7, 1995. O.C. 1488/95. Effective January 1, 1996.
- BC Environment. 1995b. *Clean Vehicles and Fuels for British Columbia*. A policy paper.  
<http://www.elp.gov.bc.ca/sppl/cvf/>
- BC Environment. 1994. *1990 British Columbia Emissions Inventory of Common Air Contaminants*. Air Resources Branch, Victoria.
- BC Environment. 1991. *Smoke Management for the '90s*. Clean Air Policy Steering Committee. Victoria.
- BC Environment. No date. *Wood Stoves - Burn Hot, Burn Clean*. Ministry of Environment, Lands and Parks, Ministry of Health, British Columbia Lung Association, British Columbia Wood Stove Manufactures. Video. 10 minutes.
- BC Stats. 1998. *British Columbia Municipal and Regional District 1996 Census Results*.  
[http://www.bcstats.gov.bc.ca/data/cen96/mun\\_rd.htm](http://www.bcstats.gov.bc.ca/data/cen96/mun_rd.htm). 20 April 1998.
- Bell. 1998. *Bell's Mile by Mile Travel Guide for Alaska, Yukon & British Columbia!*  
<http://alaskan.com/bells/>.
- Brook, J.R., T.F. Dann, and R.T. Burnett. 1997. The Relationship Among Total Suspended Particulate, PM<sub>10</sub>, PM<sub>2.5</sub>, and Inorganic Constituents of Atmospheric Particulate Matter at Multiple Canadian Locations. *Journal of the Air and Waste Management Association*. 47: 2-19.
- (British Columbia) Environmental Appeal Board (1994). Appeal No. 94/14 Waste Management.  
<http://www.eab.gov.bc.ca/waste/94-14.htm>
- E.A.C.H. No Date. *Breathing Easier*. Peak Productions. Video. 21:48 minutes.
- Johnson, D.D. 1994. *Bulkley Valley Air Quality Management Plan*. Air Quality Management Plan AQMP-95-01. Air Quality Unit. Environmental Protection Programme, BC Environment, Skeena Region. 38 pp.
- Johnson, D.D. 1992. *Smithers Air Quality Management Plan: Particulates*. Air Quality Management Plan AQMP-92-01. Environmental Protection Programme, BC Environment, Skeena Region.
- Ministry of Aboriginal Affairs. 1997. <http://www.aaf.gov.bc.ca/aaf/nations/nations.htm>.
- Ministry of Health. 1994. *"Particulate Matter" Air Pollution: What you can't see may be very dangerous to your health!* British Columbia Ministry of Health, Health File #35 - Spring 1994.  
<http://www.hlth.gov.bc.ca/hlthfile/hfile35.html>
- Schwartz, J., D.W. Dockery, and L.M. Neas. 1996. Is Daily Mortality Associated Specifically with Fine Particles? *Journal of the Air and Waste Management Association*. 46: 927-939.

Vedal, S. 1995. *Health Effects of Inhalable Particles: Implications for British Columbia*. Air Resources Branch, Ministry of Environment, Lands and Parks.

Vedal, S. 1993. *Health Effects of Wood Smoke: A Report to the Provincial Health Officer of British Columbia*. 34 pp.

Walsh, M.P. 1995. *Car Lines*. November.

Wolff, G.T. 1996. The Scientific Basis for a Particulate Matter Standard. *Environmental Management*. October: 26-31.

## *Glossary of Terms*

**Acceptable Air Quality**

Intended to be the acceptable interim objective (Level B). This provides adequate protection against adverse effects on human health and comfort, vegetation, animals, soil, water, materials, and visibility.

**Aerosol**

Solid or liquid material suspended in the atmosphere.

**Air Emissions**

Solid, liquid, or gaseous material emitted to the atmosphere.

**Air Pollution**

The presence in the environment of substances or contaminants at concentrations that substantially alter or impair the usefulness of the atmosphere.

**Air Quality Index**

Relative scale of ambient air quality for a particular emission.

**Air Quality Management Plan**

A plan integrating air quality monitoring, assessment, and control, designed with the objective of eliminating air pollution.

**Ambient Air Quality**

The quality of the surrounding atmosphere. As opposed to “emission” that refers to ‘end of the pipe’ air quality.

**Anthropogenic**

Human-related.

**BC Environment**

British Columbia Ministry of Environment, Lands and Parks.

**Biomass**

Any organic material; includes firewood and wood ‘waste’.

**Canadian Emission Standard**

Performance Testing of Solid-Fuel-Burning Stoves, Inserts, and Low-Burn-Rate Factory-Built Fireplaces  
CAN/CSA-B415.1 standard published by the Canadian Standards Association from time to time.

**Contaminant**

A solid, gas, or liquid that is emitted into the atmosphere that has the potential of causing an environmental impact (pollution of the air, water, or ground).

**Daily Average**

Midnight to midnight average (as opposed to the maximum daily average).

**Desirable Air Quality**

Designed to provide long term protection for all environments; protects the most sensitive receptor (Level A).

**Dustfall (DF)**

Relatively large/heavy particulate matter that, after being emitted into the atmosphere, falls out very quickly (i.e., does not remain in suspension).

**HiVol**

High volume sampler. Used to collect particulate matter (PM<sub>10</sub> and TSP) over a 24 hour period. They, unlike the TEOM, are not real time nor are they typically run continuously.

**Inhalable Particulate (PM<sub>10</sub>)**

The size fraction of particulate matter suspended in the atmosphere that is inhalable; i.e., that can enter the human respiratory system. Commonly defined as those particles less than 10 µm in diameter.

**Maximum Daily Average**

Highest value of running daily means during a midnight-to-midnight period. Usually represents the maximum of 24 daily means recorded each hour during a 1 am-to-midnight period.

**Meteorology**

The physics of weather processes.

**mg dm<sup>-2</sup> day<sup>-1</sup>**

mass (of particulate) per square decimetre (one tenth of a metre square or 10 centimetres square) per day. A rate of particulate accumulation or deposition. Commonly associated with *dustfall*.

**Micrometre**

10<sup>-6</sup> metres (one millionth of a metre; there are 1 000 micrometres in a millimetre).

**µg m<sup>-3</sup>**

Micrograms per cubic metre. A microgram is 10<sup>-6</sup> grams (one millionth of a gram). A measurement of the mass of particulate in one cubic metre of air.

**µm**

Micrometre. A micrometre is 10<sup>-6</sup> metres (one millionth of a metre; there are 1 000 micrometres in a millimetre).

**NAPS**

National Air Pollution Surveillance. A protocol which specifies one midnight-to-midnight sample collected once every six days.

**PAH**

Polynuclear Aromatic Hydrocarbons.

**PM<sub>10</sub>**

Inhalable Particulate.

**Pollution**

The presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment (*Waste Management Act*, 1996).

**Pollution Abatement Order**

Order issued under the *Waste Management Act* by the Regional Waste (Environmental Protection) Manager. The intent of the order is to stop pollution.

**Polynuclear Aromatic Hydrocarbons**

Semi-volatile organic compounds consisting of three or more condensed aromatic rings, where certain carbon atoms are common in two or three rings. PAHs are produced as a result of the incomplete combustion of high-molecular-weight hydrocarbon species and pyrolytic decomposition of fossil fuels and other organic (containing carbon and hydrogen) materials. PAHs are considered carcinogenic when exposure to elevated levels occurs over long periods of time. Production is favoured by an oxygen-deficient flame.

**Radiative Cooling**

Radiative process where the earth loses heat faster than the overlaying atmosphere. The process results in an atmospheric temperature inversion.

**Recreational Wood Burning**

Residential wood burning not primarily associated with heating the home. Examples include fireplaces and stoves used to warm a room, campfires, bonfires, etc.

**Temperature Inversions**

Atmospheric conditions characterised by the ground surface being colder than overlaying layers. Such conditions are very stable and thus inhibit dispersion of emissions throughout the atmosphere.

**TEOM**

Tapered Element Oscillating Microbalance; a continuous, real-time, PM<sub>10</sub> ambient air quality monitor.

**Tolerable Air Quality**

Defines the "immediate" ambient objective (Level C). Concentrations of air contaminants beyond which action is required without delay to protect the health of the general population.

**Topography**

The physical relief of an area (mountains and valleys).

**Total Suspended Particulate (TSP)**

Total mass of suspended particulate matter in the atmosphere.

**TSP**

Total Suspended Particulate.

**µg m<sup>-3</sup> and µm**

µ is the Greek letter mu. See references under "micro".

**US Emission Standard**

New Source Performance Standards, Title 40, Part 60, Sub-part AAA of the Code of Federal Regulations (USA) (7-1-92 Edition), published by the United States Environmental Protection Agency.

**Waste Management Act**

An Act of provincial legislation that governs much of BC Environment's environmental protection work in the area of air quality.