BULKLEY VALLEY

INHALABLE PARTICULATE SUMMARY

February 2000

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Executive Summary

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

Air quality monitoring data indicate both Smithers and Houston experience inhalable particulate concentrations at levels associated with health 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.

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 point source option for particulate emission reductions and air quality management. Other management options exist for municipal and regional governments.

This version of the *Bulkley Valley Inhalable Particulate Summary* is an update, completed in February 2000, of the original document published in the spring of 1998. PM_{10} data have been updated and a new section containing Smithers $PM_{2.5}$ monitoring results has been included.

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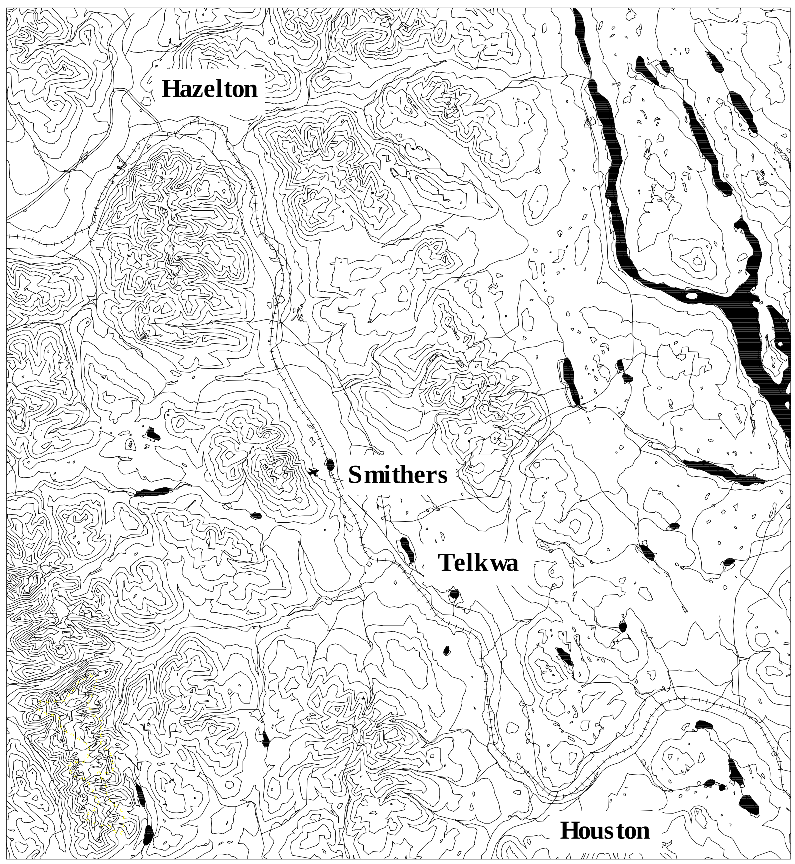
Introduction

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 Hazeltons, District of Houston, Town of Smithers, and the Village of Telkwa. The valley area is depicted in Figure 2.

Figure 2. 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 Hazeltons 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 Gitxsan 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'en are part of the Carrier linguistic group. The Gitxsan 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 associated air quality impacts. BC Environment regulates industrial activity, such as the operation of beehive burners, with air emissions permits that set emission limits and operating conditions. Recently, West Fraser and BC Environment have implemented a beehive burner episode management plan. The plan allows for the burner to be shut down when directed by BC Environment in response to periods of poor air quality and/or dispersion meteorology. 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 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 overlaying atmosphere. Thus, over time, the ground surface is progressively colder than the overlaying 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 3 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 necessarily reflect actual emissions (or environmental impacts) and the community-total emissions data do not include unpermitted sources such as natural emissions, road dust, wood burning stoves, automobile exhaust, etc.

Figure 3. **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.

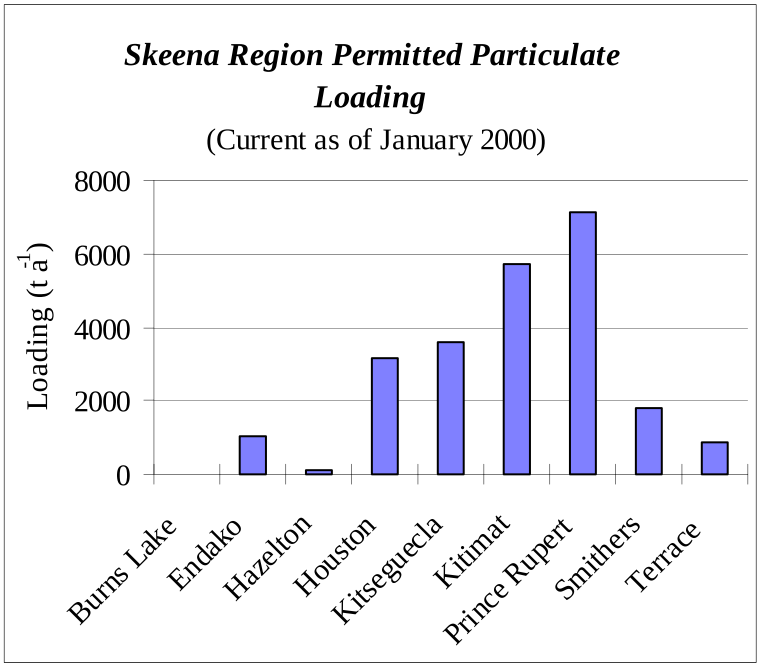


Table 1. **Houston Permitted Emissions.**
CO denotes carbon monoxide, NO* oxides of nitrogen, PM particulate matter, SO* oxides of sulphur, VOC volatile organic compounds. Emissions are expressed as tonnes per year (percent total) for all sources associated with an air emissions permit.

Source	*CO*	*NO**	*PM*	*SO**	*VOC*
Canfor	9514 (63)	101 (65)	1985 (63)	15 (66)	847 (63)
Houston Forest Products	5542 (37)	55 (35)	1170 (37)	8 (34)	501 (37)
Total	**15056 (100)**	**156 (100)**	**3155 (100)**	**22 (100)**	**1348 (100)**
Current: 6 2 2000					

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 (percent total) 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.

Source	***CO***	***NO****	***PM***	***SO****	***VOC***
West Fraser Mills (PIR)	6302 (100)	98 (39)	1380 (76)	5 (77)	561 (97)
Repap Smithers	3 (0)	15 (6)	91 (5)	0 (1)	11 (2)
L.B. Paving	0 (0)	0 (0)	16 (1)	1 (9)	0 (0)
NewPro	28 (0)	142 (56)	323 (18)	1 (13)	7 (1)
Reako Exploration Ltd.	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Petrocan	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	**6333 (100)**	**254 (100)**	**1810 (100)**	**7 (100)**	**581 (100)**
Current: 6 2 2000					

As can be seen by comparing Figure 3 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.

	Total PM ($t\ a^{-1}$)	**Beehive Burners ($t\ a^{-1}$)**	**Ratio**
Houston	3155	2018	64%
Kitseguecla	3612	2200	61%
Hazelton	102	0	0%
Smithers	1810	968	53%
Total	**8679**	**5186**	**60%**

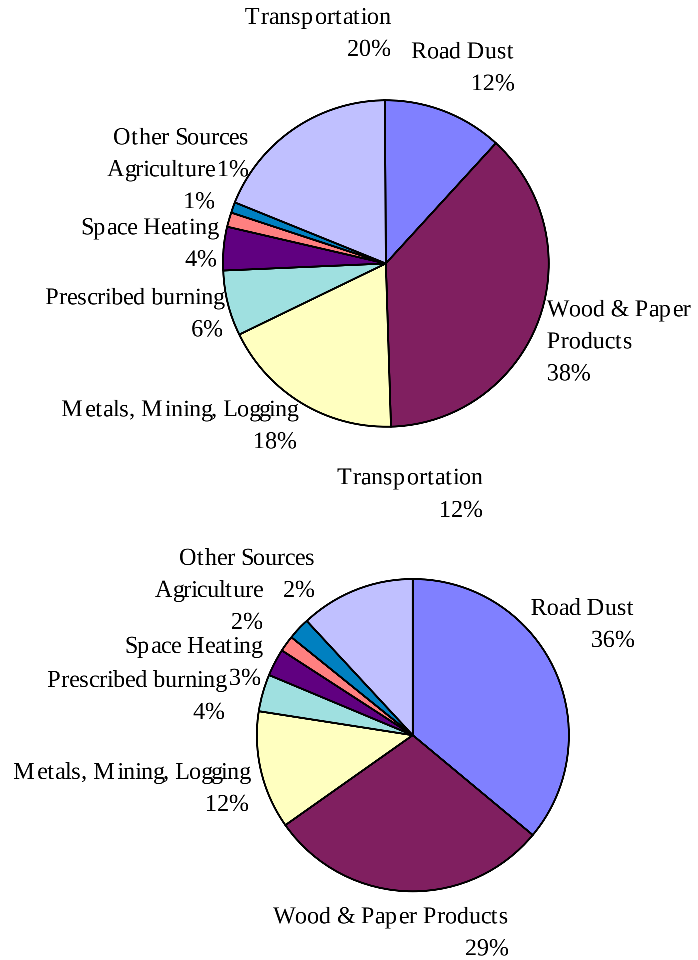
Current: 6 2 2000

As depicted in Figure 4, 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 Kitseguecla (on the Skeena River) receives some of the Smithers sawmilling industry wood residue.

Figure 4. A Skeena Region Beehive Burner.

Figure 5 is presented to put the permitted emissions into regional perspective. It represents the 1995 British Columbia Emissions Inventory, includes permitted, regulated, and unpermitted (domestic) sources. PM_{10} (bottom) emissions total 26,099 t. $PM_{2.5}$ emissions (top) total 15,262 t. Natural sources contribute a similar amount of PM_{10} ($PM_{2.5}$): wildfires emitted 20,496 t (18,918 t) and marine aerosols 6,237 t (1,075 t) (not plotted). Note that wood and paper products (including beehive burners) play a significant role compared to other permitted sources. Also note the relative insignificance of space heating in the regional perspective on a total annual loading basis.

Figure 5. Skeena Region 1995 Major Particulate Source Sector Emission Summary.
Includes permitted, regulated, and unpermitted (domestic) sources. "Other" category includes: Municipal and Woodwaste Landfills, Bakeries, Commercial/ Light Industrial General Particulate, Fugitive Emissions Construction/Demolition, Household Barbecues, Cut Back Asphalt Application, Gravel Pits, Welding, Restaurants, Tobacco, Breweries (Tony Wakelin, pers. comm.). The top image is for $PM_{2.5}$; the bottom PM_{10}.



One important qualifier regarding Figure 5 should be noted: the geographical distribution of these sources is not equal across the region. Permitted and domestic sources are concentrated in the valleys 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.

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.,

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

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_2, SO_4). 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_x) - 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_{10}), 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. Five PAHs (including Benzo(a)Pyrene) are classified as "probably carcinogenic to humans" and are considered "toxic" under the Canadian Environmental Protection Act (Germain, 1995). The Government of Canada has concluded (Government of Canada et al., 1994, p. vi and p. 42): "Polycyclic aromatic hydrocarbons are entering the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment. The PAHs benzo[a]pyrene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene may constitute a danger in Canada to human life or health." Exposure to elevated concentrations of carcinogenic 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 will 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_{10}: particulate matter < 10 μm). Within this sub-category is another domain, 2.5 μm in diameter and less ($PM_{2.5}$).

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 upper respiratory system processes), 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 ($PM_{2.5}$) can remain suspended in the atmosphere for days to weeks.

PM_{10} 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_{10} subset of total suspended particulate.

Potential Health Impacts of Inhalable Particulate

PM_{10}

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 may also be affected (BC Environment, 1995; Ministry of Health, 1994).

Vedal (1995) notes that exposure to each 10 $\mu g\ m^{-3}$ increment of inhalable particulate above a base level of 20 $\mu g\ m^{-3}$ 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 $\mu g\ m^{-3}$ increment of PM_{10} over 20 $\mu g\ m^{-3}$ 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 ($PM_{2.5}$) 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 ($PM_{2.5}$) that have the worst effects on health (Walsh, 1995, in Acid News, 1996). Note that $PM_{2.5}$ 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_{10}, 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)).

Location	Site No.	Sampler	Start Date	End Date
Burns Lake	E219592	HiVol	04-Oct-93	07-Aug-96
Burns Lake	E225267	TEOM	21-Feb-97	
Hazelton-DFO	E218578	HiVol	08-Mar-93	07-Aug-96
Hazelton-Spooner	E216334	HiVol	02-Nov-91	24-May-92
Houston-Firehall	M107004	TEOM	20-Sep-94	
Houston-Siverthorne	E218548	HiVol	12-Feb-93	23-Sep-94
Kitimat-Rail	E223827	TEOM	Aug-98	
Kitimat-Riverlodge	E216670	TEOM	Aug-98	
Kitimat-Service Centre	E216669	TEOM	Aug-98	
Kitseguecla		HiVol		
New Aiyansh	E225285	HiVol	05-Mar-97	
Prince Rupert-Galloway Rapids	E231838	TEOM	Apr-98	
Prince Rupert-Ocean Centre	E226868	HiVol	01-May-97	
Port Edward	E225184	TEOM	Apr-98	
Queen Charlotte City		TEOM	25-Nov-96	16-Apr-97
Quick	E226268	TEOM	09-May-97	31-May-98
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	
Smithers-St. Joseph's School	E226589	Partisol PM2.5	21-Apr-96	24-Mar-98
Stewart		HiVol	Jan-00	
Telkwa	E230557	TEOM	04-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	06-Aug-96	05-Nov-96
Terrace-Clarence Michael	E222818	HiVol	18-Oct-95	04-Mar-96
Terrace-Firehall	435079	HiVol	16-Oct-93	22-Mar-96

More details regarding the Houston and Smithers monitoring programmes are presented in subsequent sections.

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 dose (total exposure to contaminants at polluted levels). A ‘dose accumulation’ approach is a measure of the *intensity* of impacts occurring in a community (noted previously with respect to the ”exposure increments” of Vedal (1994) in the Potential Health Impacts of Inhalable Particulate section on page 14). 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). They represent a level of an air contaminant’s absolute concentration. 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. Previously in some airsheds, application of different levels depended on land use: Level A was applied to residential areas, Level B to industrial areas.

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 $\mu g\ m^{-3}$ (24 hour average concentration). This is intended to be equivalent to a Maximum Acceptable level in the national air quality objective system (and is, therefore, a *de facto* Level B objective). A Maximum Desirable equivalent level has not been proclaimed. In Skeena Region, BC Environment has identified an annual air quality objective of 20 $\mu g\ m^{-3}$ (Johnson, 1992, 1995) to complement a 50 $\mu g\ m^{-3}$ daily objective. No Maximum Desirable level (Level A) has been formally defined in British Columbia or Canada.

Clearly, the lack of a Level A air quality objective for inhalable particulate makes air quality assessments using traditional absolute concentrations somewhat limited. Level B exceedences (daily concentrations greater than 50 μg m^{-3}) characterise very serious air quality episodes. BC Environment impact assessment staff have denoted the Good/Fair air quality index breakpoint for PM_{10} at 25 μg m^{-3}. Thus, 25 μg m^{-3} is effectively defined as a reference level below which no statistically significant human health impacts can be observed. Similarly Vedal (1995) notes measurable impacts occur at concentrations greater than 20 μg m^{-3}. Based on North American studies examining hospitalisation and mortality relationships with air pollution, the Federal Provincial Working Group on Air Quality Objectives and Guidelines (1997) have recommended a 24 hour Reference Level for PM10 of 25 μg m^{-3} and 15 μg m^{-3} for PM[1]. (A Reference Level represents a concentration above which human health effects can be demonstrated). Furthermore, Federal Provincial Working Group on Air Quality Objectives and Guidelines (1999) note there is no clear evidence of a threshold level for the positive associations between particulate matter and both daily mortality and hospitalisation rates; therefore, a safe level of exposure to particulate matter cannot be identified. The Federal Provincial Working Group on Air Quality Objectives and Guidelines work defines the latest in particulate matter air quality assessment criteria in Canada.

The issue of visibility protection is one that has not been assessed in Canada. For example, the definition of pollution under the *Waste Management Act* includes "the presence in the environment of... contaminants that substantially alter or impair the usefulness of the environment". Included in the definition of contaminant in the Act is: a "substance that is emitted into the air and that... interferes or is capable of interfering with visibility." Submicrometre particles are optically active. You can, therefore, have a situation where moderate concentrations of particles in the submicrometre size range can interfere with visibility for an hour or two. Thus the definition of pollution could easily be satisfied without necessarily resulting in a 24 hour PM_{10} average exceeding 50 μg m^{-3} or even 20 μg m^{-3}. It is not uncommon for BC Environment to receive comments from the public about optically poor air quality when running daily means are in the 20s of μg m^{-3}.

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 exceedence frequency of a reference level (magnitude), or absolute exposure (dose). Frequency statistics for inhalable particulate may be expressed as the number of daily exceedences of the 50 μg m^{-3} air quality objective or the 25 μg m^{-3} Recommended Reference Level. Such measures should be

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[1] Sometimes referenced as the CEPA Objective on air quality charts.

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 exposure intensity to air pollution impacts. For inhalable particulate they are calculated by counting the number of daily 10 $\mu g\ m^{-3}$ increments above 20 $\mu g\ m^{-3}$. 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 normally run from July to June. 1999-00 summaries are current through to January 2000 (and are, therefore, an incomplete representation of the 1999-00 sampling period).

Houston Data Summary

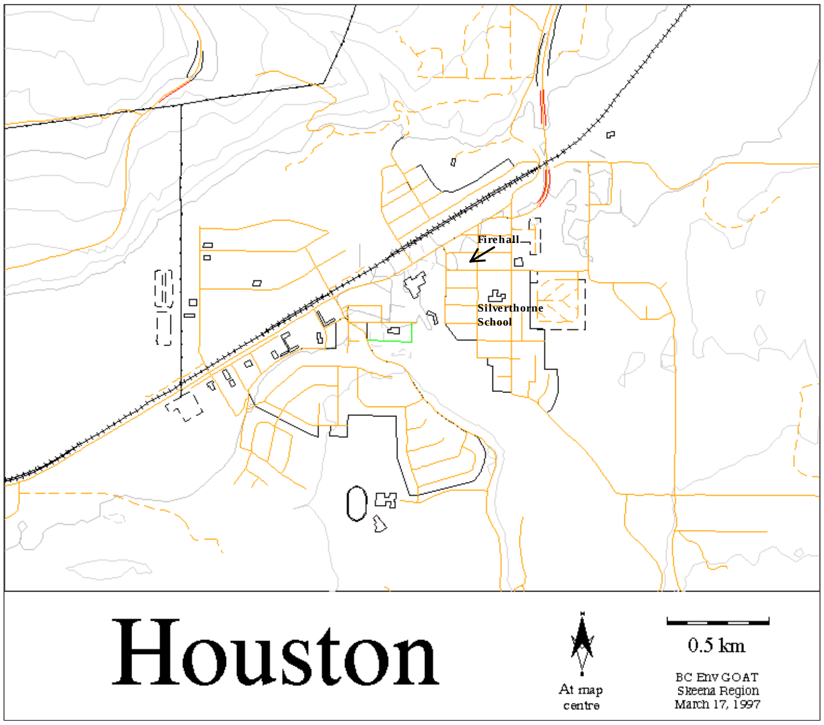
History

Figure 6. Firehall Monitoring Site

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. 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 6). 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.

Geography

Figure 7. Houston Inhalable Particulate Monitoring Station Locations.



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 7 depicts the monitoring site 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 8 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.

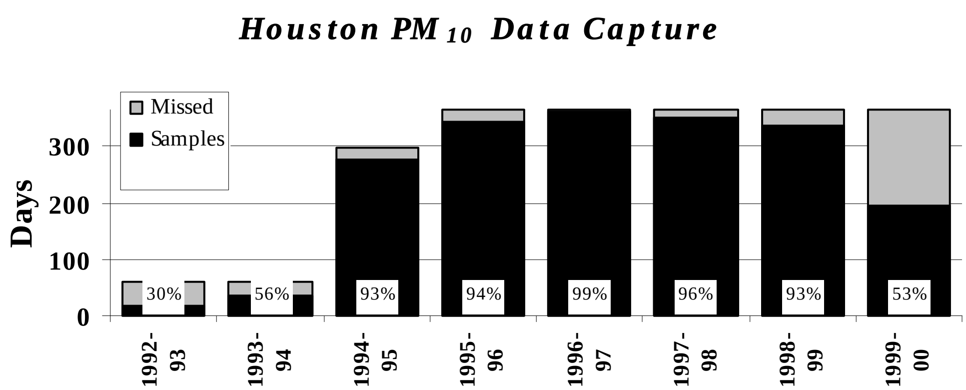
The most recent year is current to January 2000. The less than 365 days per year sample days between 1992 and 1994 reflect the operation of the high volume sampler on a NAPS schedule (one 24 hour period every six days) prior to the installation of the continuous analyser in September 1994.

Houston PM_{10} Data Capture

Period	Samples	Missed	Sample Days	%
1992-93	18	43	61	30%
1993-94	34	27	61	56%
1994-95	278	21	299	93%
1995-96	344	22	366	94%
1996-97	361	4	365	99%
1997-98	351	14	365	96%
1998-99	338	27	365	93%
1999-00	194	172	366	53%

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

Figure 8. Houston Data Capture.



Central Tendency

Figure 9 depicts the percentile distributions of the Houston PM_{10} data by monitoring year. While not consistent for all percentiles, one trend to note is the constant decline of the 98th percentile concentrations over the past five years. The running annual mean, depicted in Figure 10, also depicts the variable pattern associated with the 50th percentile concentration. Figure 11 demonstrates that the 1999-00 mean generally does not differ significantly from any previous year (except 1997-98).

Figure 9. Percentile Distribution of Houston PM_{10} Observations.
The most recent year is current to January 2000. The top of the top bar depicts the 98th, top of the box the 75th, black square the 50th, box bottom the 25th, and line bottom the 5th percent highest reading of the midnight 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 comparison purposes.

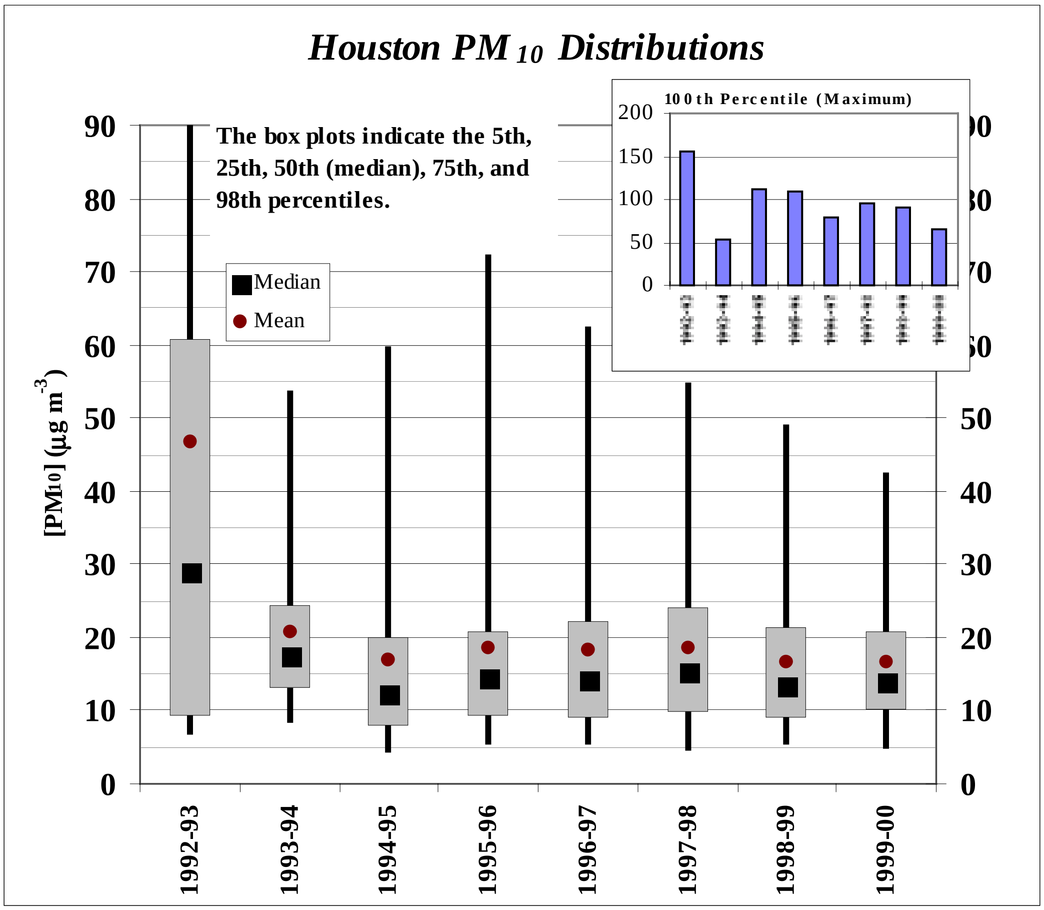


Figure 10. Houston Air Quality Trends.
The most recent year is current to January 2000. High volume samples are midnight-to-midnight (February 1993-September 1994) from the NAPS schedule; TEOM readings are maximum daily averages. Running annual mean is based on midnight-to-midnight daily averages. Numbers on the chart are annual means; they are significantly less than 20 μg m^{-3} over the past four years.

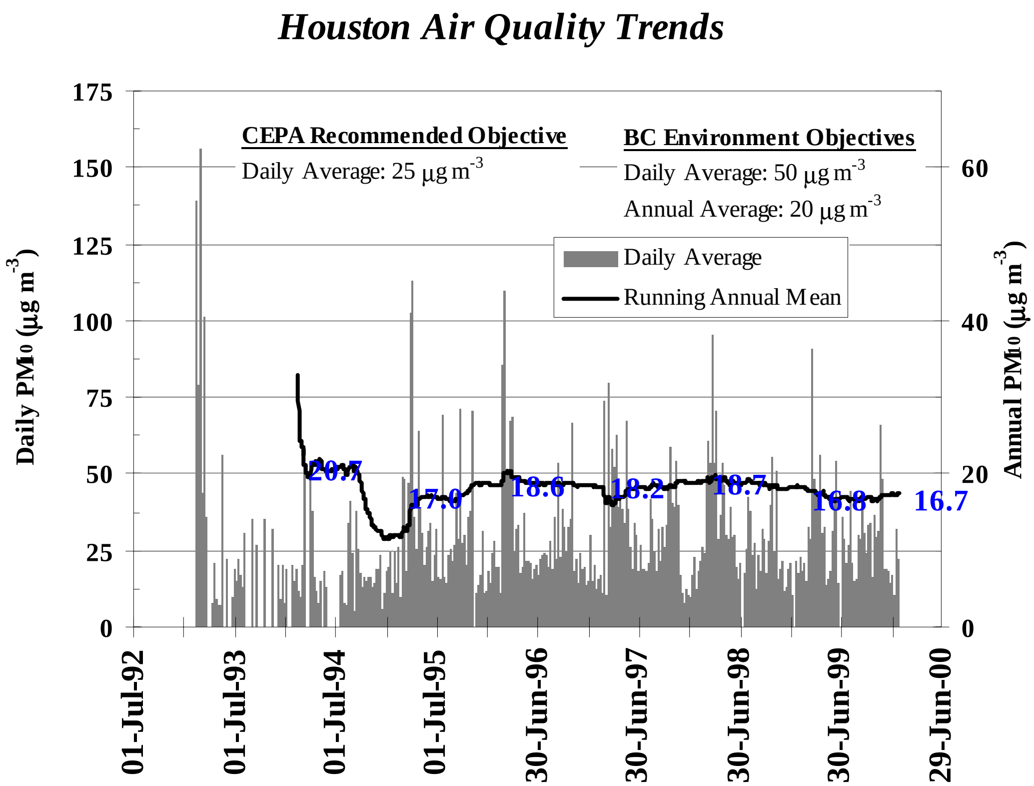
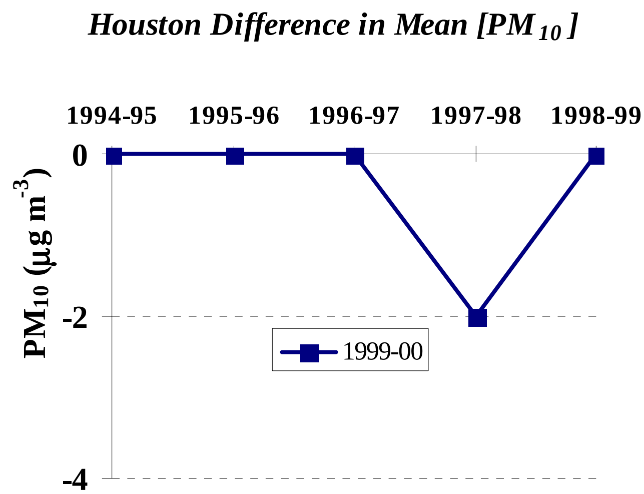


Figure 11. Annual Difference in Means Compared to 1999-00 Reference Year.
The most recent year is current to January 2000. This chart presents significant difference between this year's (1999-00) mean inhalable particulate concentration compared with other years. Zero denotes no significant difference. 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 12 through Figure 14 are plots of these statistics.

Table 6. Measures of Houston Inhalable Particulate Impacts.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the air quality objective or reference level 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 or reference level at some point in the day, but did not at (exclusive of) midnight. 1992-94 and 1999-00 are considered unrepresentative of the year and are not presented for comparative purposes. However, exceedences and increments do occur these years.

	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
MDA > 25 µg m-3*	#N/A	#N/A	17.3%	17.4%	19.4%	27.7%	17.6%	#N/A
DP > 25 µg m-3*	#N/A	#N/A	6.1%	8.4%	10.0%	13.0%	9.4%	#N/A
Total Exceedences	#N/A	#N/A	23.4%	25.9%	29.4%	40.6%	27.0%	#N/A
MDA > 50 µg m^{-3}*	#N/A	#N/A	2.5%	5.5%	4.4%	6.4%	2.1%	#N/A
DP > 50 µg m^{-3}*	#N/A	#N/A	2.5%	2.0%	2.8%	3.7%	2.7%	#N/A
Total Exceedences	#N/A	#N/A	5.0%	7.6%	7.2%	10.1%	4.8%	#N/A
Exposure Increments	#N/A	#N/A	161	189	174	172	122	#N/A
Samples	18	34	278	344	361	351	338	194
Sample Days	61	61	299	366	365	365	365	366
Data Capture	30%	56%	93%	94%	99%	96%	93%	53%

*MDA denotes midnight daily averages; DP denotes daily peak (exclusive of MDA)
Only years with representative data capture are depicted

Figure 12. Houston Exposure Increments.
The most recent year is current to January 2000. 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. 1992-94 and 1999-00 are considered unrepresentative of the year and are not presented for comparative purposes. However increments do occur these years (early indications from 1999-00 indicate increments are holding steady compared to 1998-99).

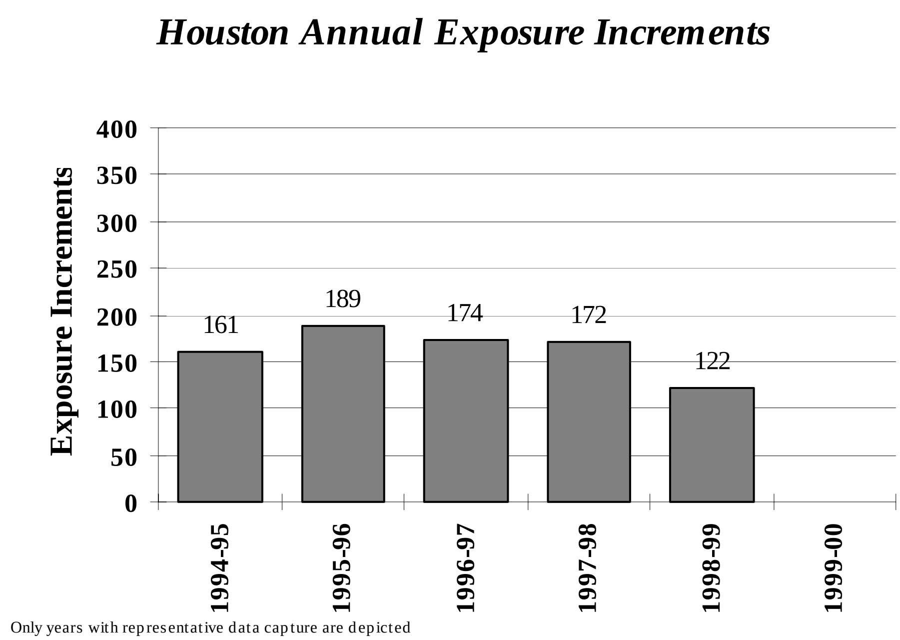


Figure 13. Houston Recommended Reference Level Exceedence Frequencies.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the Federal-Provincial Working Group on Air Quality Objectives and Guidelines recommended daily Reference Level (25 µg m^{-3} averaged over 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 Reference Level at some point in the day, but did not at midnight. 1992-94 and 1999-00 are considered unrepresentative of the year and are not presented for comparative purposes. However, exceedences do occur these years (early indications from 1999-00 indicate exceedences are steady compared to 1998-99).

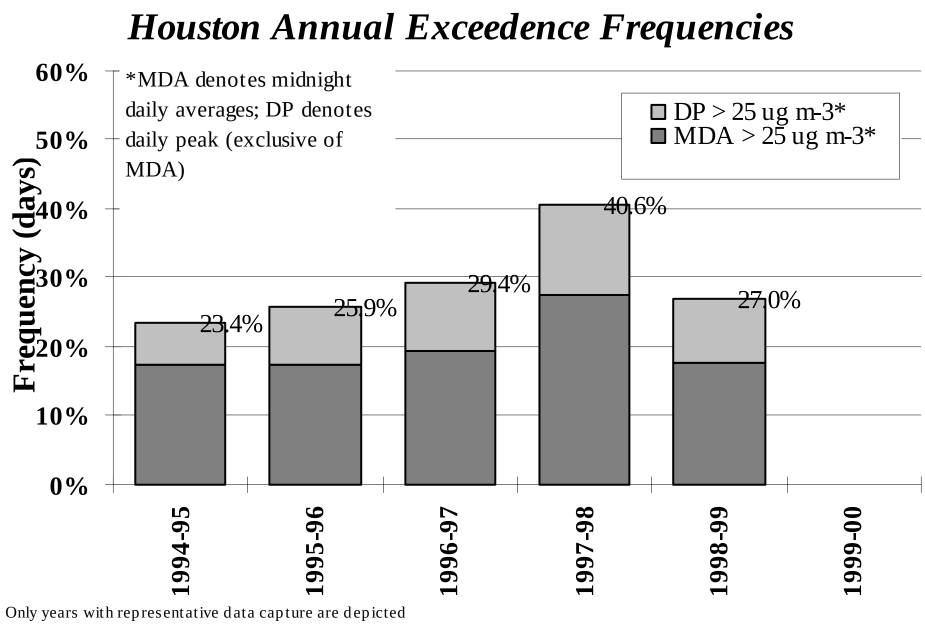


Figure 14. Houston Interim Air Quality Objective Exceedence Frequencies.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective (50 µg m^{-3} averaged over 24 hours) recorded at midnight. Use of continuous monitoring 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. 1992-94 and 1999-00 are considered unrepresentative of the year and are not presented for comparative purposes. However, exceedences do occur these years (early indications from 1999-00 indicate exceedences are down compared to 1998-99).

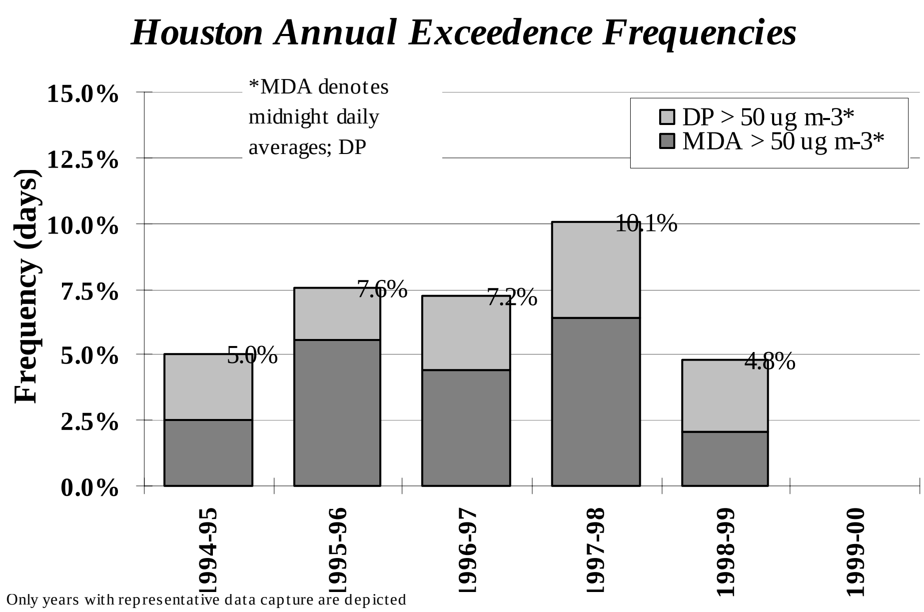
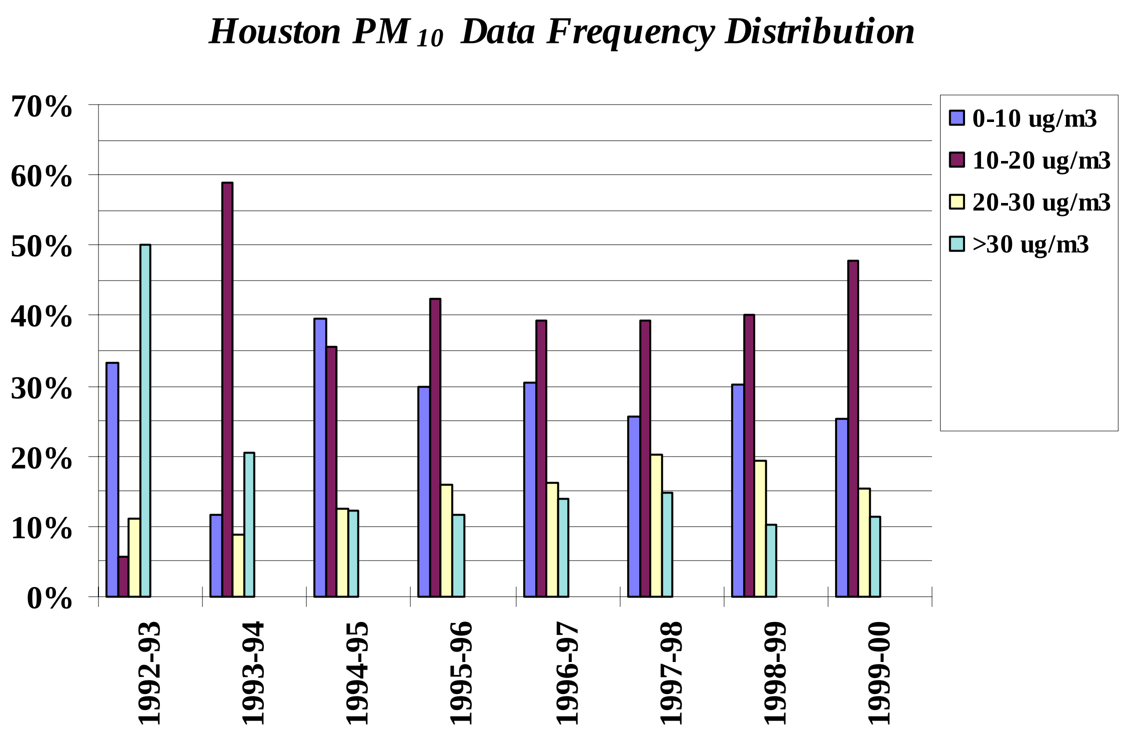


Figure 12, which depicts the number of exposure increments (normalised to a 365-day year), shows increments over past few years of 175 ±15 increments per year, with the exception of 1998-99 which was 122. This pattern is also seen in Figure 13 and Figure 14. Figure 9 shows the 98th percentile concentration has declined over the last several years. Figure 15 depicts the frequency distribution of Houston inhalable particulate data.

Figure 15. Inhalable Particulate Data Frequency Distribution.
The most recent year is current to January 2000. The chart depicts the distribution of all 24 hour average observations over a range of concentrations. Based on midnight daily averages.



Summary

When assessed in terms of the Interim Air Quality Objective and Recommended Reference Level exceedences, inhalable particulate air quality in Houston has shown deterioration up to 1997-98 and subsequent recent improvement. Expressed as an annual sum, exposure increments have remained steady at approximately 175 ±15 increments but declined in the last year to 122. The mean concentration has been variable and creeping down recently, however, there has been no significant changes in mean annual inhalable particulate concentrations over the years (excepting 1997-98).

Smithers Data Summary

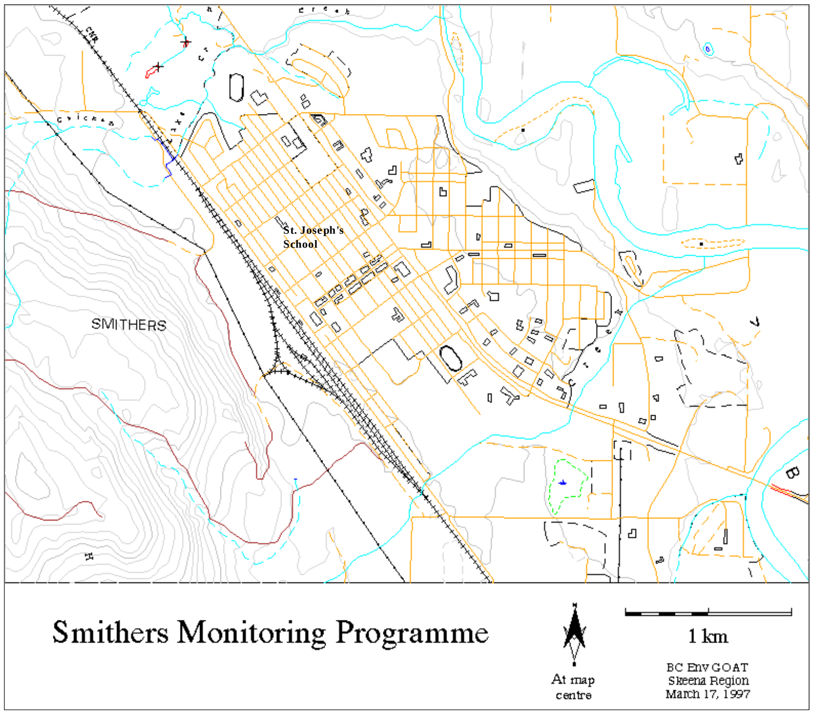
History

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 16). The inhalable particulate PM_{10} programme is currently operated with the support of local industry (cf. Table 2 on page 8). $PM_{2.5}$ was monitored for a two year period from April 1996 to March 1998.

Figure 16. St. Joseph's School Monitoring Site.

Geography

Figure 17. **Smithers Inhalable Particulate Monitoring Station Location.**



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 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 17 depicts the monitoring station location, St. Joseph's School, in the town of Smithers.

PM_{10} (Inhalable Particulate)

Data Capture

As depicted in Table 7 and Figure 18, 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.

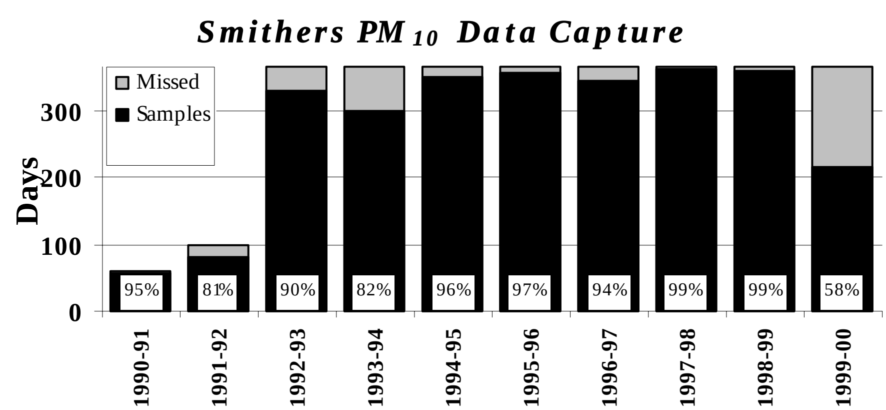
The most recent year is current to January 2000. The less than 365 days per year sample days between 1990 and 1992 reflect the operation of the high volume sampler on a NAPS schedule (one 24 hour period every six days) prior to the installation of the continuous analyser in May 1992.

Smithers PM_{10} Data Capture

Period	Samples	Missed	Sample Days	%
1990-91	57	3	60	95%
1991-92	81	19	100	81%
1992-93	328	37	365	90%
1993-94	300	65	365	82%
1994-95	350	15	365	96%
1995-96	356	10	366	97%
1996-97	343	22	365	94%
1997-98	363	2	365	99%
1998-99	360	5	365	99%
1999-00	214	152	366	58%

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

Figure 18. Smithers Data Capture.



Central Tendency

Figure 19 depicts the percentile distribution of the Smithers PM_{10} data by monitoring year. The trend for entire period is characterised by a variable sinusoidal wave pattern with various peaks and troughs occurring in synchronicity. Figure 20 depicts a similar trend of initially variable mean concentrations followed by a declining trend in 1995-96, until the turn around in 1997-98, then improving again in the period since. Figure 21 shows air quality this year is significantly better than six of the previous years.

Figure 19. Smithers Distributions of Inhalable Particulate Observations.
The most recent year is current to January 2000. The top of the top bar depicts the 98th, top of the box the 75th, black square the 50th, box bottom the 25th, and line bottom the 5th percent highest reading of the midnight mean daily inhalable particulate concentrations for each particular year.

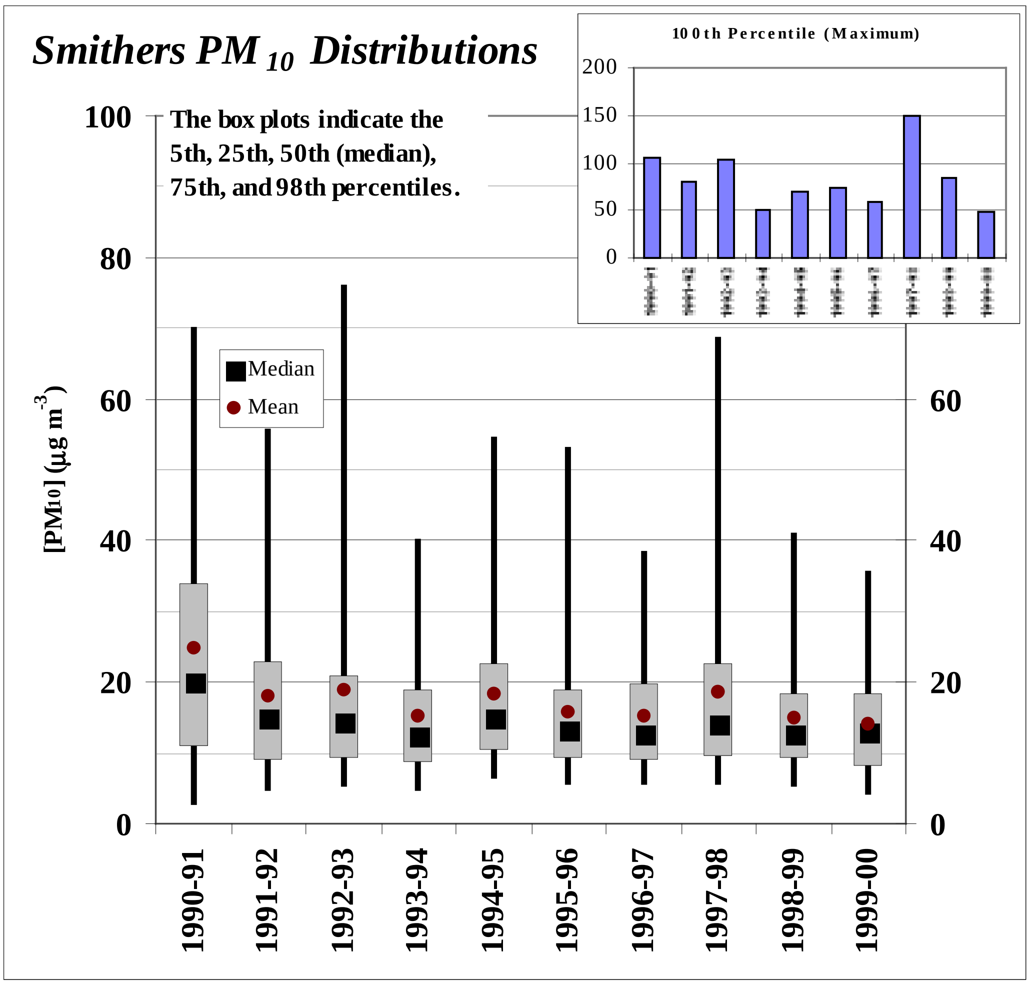


Figure 20. Smithers Air Quality Trends.
The most recent year is current to January 2000. High volume samples are midnight-to-midnight (July 1990-May 1992) from the NAPS schedule; TEOM readings are maximum daily averages. Running annual mean is based on midnight-to-midnight daily averages. Numbers on the chart are annual means; since 1993-94 all annual means (excepting 1997-98) were significantly less than 20 μg m^{-3}.

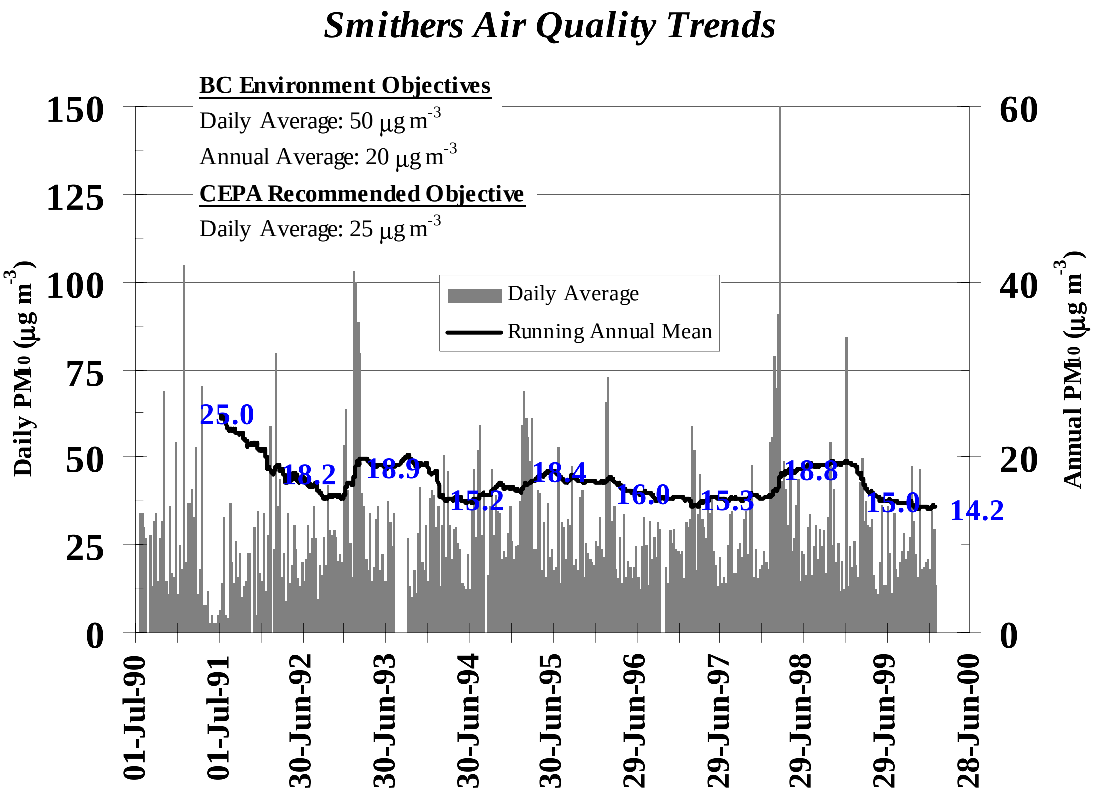
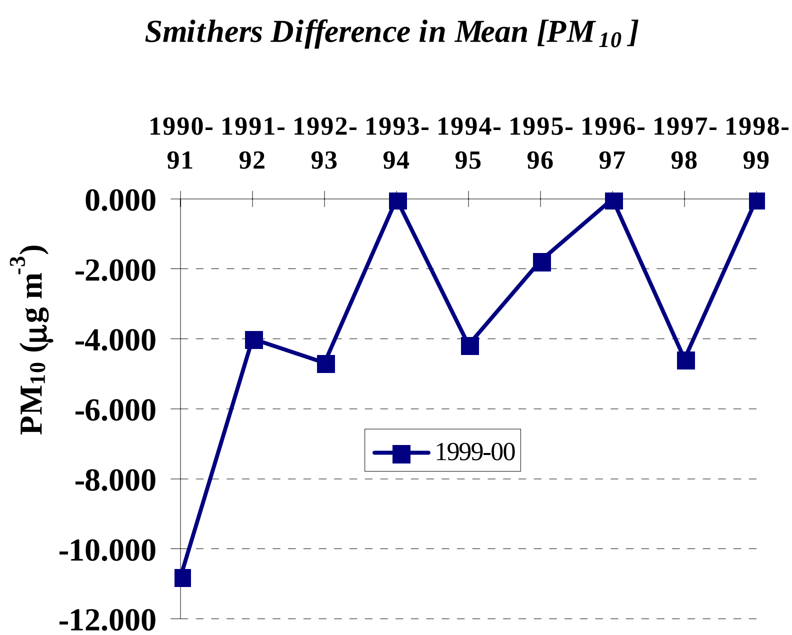


Figure 21. Annual Difference in Means Compared to 1999-00 Reference Year.
The most recent year is current to January 2000. This chart presents significant difference between this year's (1999-00 to date) mean inhalable particulate concentration compared with other years. Zero means no significant difference. 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.



Impact Assessment

Table 8 presents various impact-related summary statistics. Figure 22 through Figure 24 are plots of these statistics.

Table 8. Measures of Smithers Inhalable Particulate Impacts.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the air quality objective or reference level 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 or reference level at some point in the day, but did not at (exclusive of) midnight.

Measures of Smithers PM_{10} Impacts

	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
MDA > 25 mg m-3*	42.1%	19.8%	20.4%	15.3%	20.6%	12.6%	13.7%	18.7%	11.7%	#N/A
DP > 25 mg m-3*	0.0%	4.9%	10.8%	6.9%	12.2%	5.8%	10.0%	10.3%	8.6%	#N/A
Total Exceedences	42.1%	24.7%	31.2%	22.2%	32.8%	18.4%	23.7%	29.0%	20.3%	#N/A
MDA > 50 µg m^{-3*}	10.5%	3.7%	4.3%	0.3%	3.1%	2.2%	0.6%	3.6%	0.6%	#N/A
DP > 50 µg m^{-3*}	0.0%	0.0%	2.5%	0.3%	3.2%	0.9%	0.9%	2.2%	0.6%	#N/A
Total Exceedences	10.5%	3.7%	6.7%	0.7%	6.4%	3.1%	1.5%	5.8%	1.1%	#N/A
Exposure Increments	282	108	182	84	154	97	70	204	61	#N/A
Samples	57	81	328	300	350	356	343	363	360	214
Sample Days	60	100	365	365	365	366	365	365	365	366
Data Capture	95%	81%	90%	82%	96%	97%	94%	99%	99%	58%

*MDA denotes midnight daily averages; DP denotes daily peak (exclusive of MDA)
Only years with representative data capture are depicted

Figure 22. Smithers Exposure Increments.
The most recent year is current to January 2000. 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 (early indications from 1999-00 indicate increments are less than 1998-99).

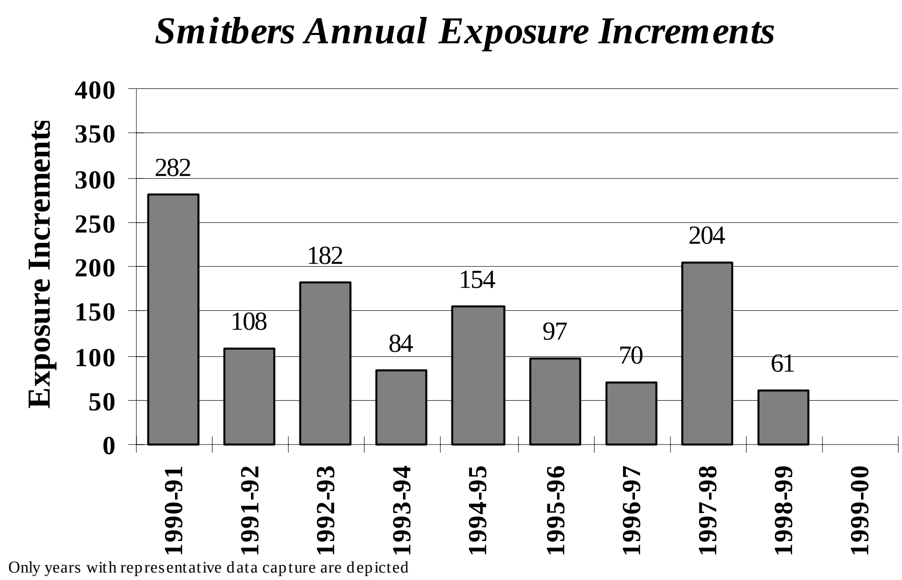


Figure 23. Smithers Recommended Reference Level Exceedence Frequencies.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the Federal-Provincial Working Group on Air Quality Objectives and Guidelines recommended daily Reference Level (25 µg m^{-3} averaged over 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 Reference Level at some point in the day, but did not at midnight. 1999-00 is considered unrepresentative of the year and are not presented for comparative purposes. However, exceedences do occur this year (early indications from 1999-00 indicate exceedences are as frequent as those occurring 1998-99).

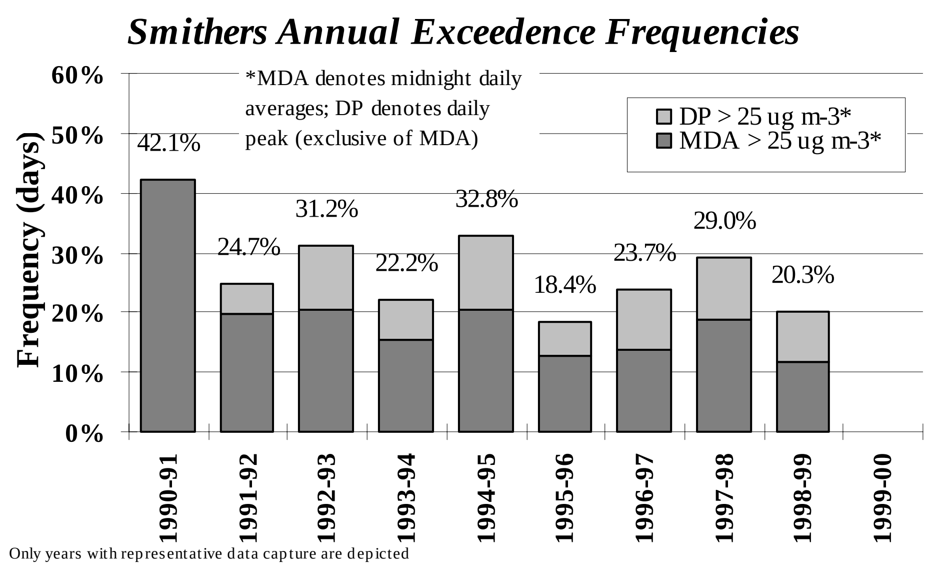
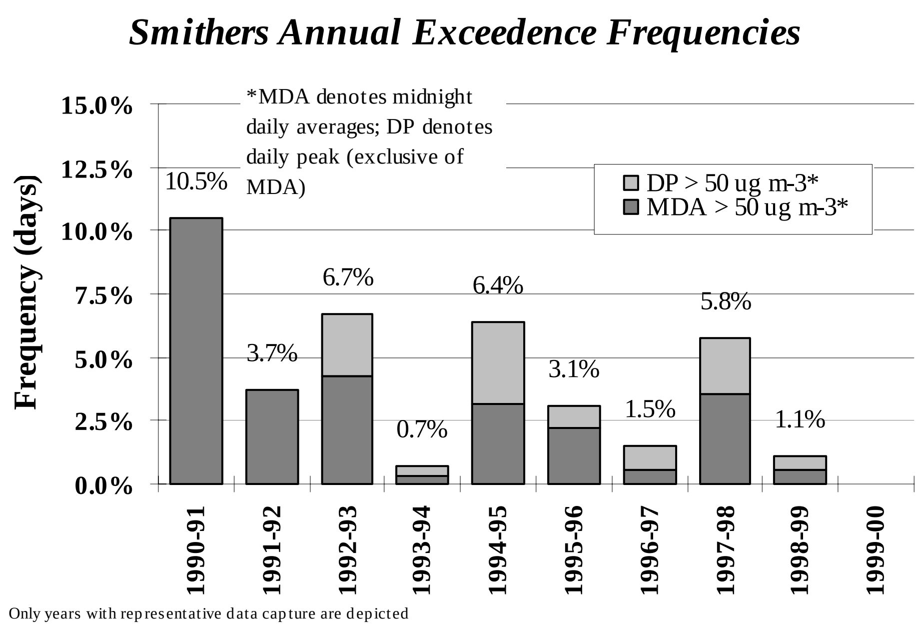


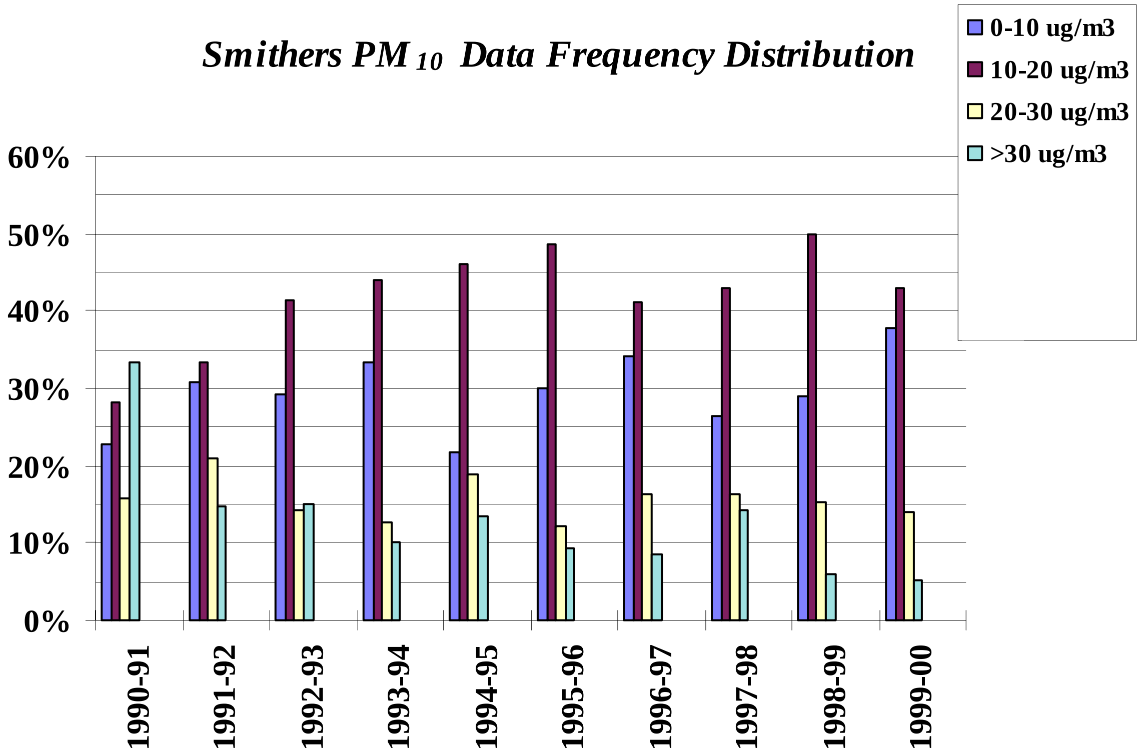
Figure 24. Smithers Interim Air Quality Objective Exceedence Frequencies.
The most recent year is current to January 2000. MDA refers to the number of exceedences of the BC Environment Interim Air Quality Objective (50 µg m^{-3} averaged over 24 hours) recorded at midnight. Use of continuous monitoring 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. 1999-00 is considered unrepresentative of the year and are not presented for comparative purposes. However, exceedences do occur this year (early indications from 1999-00 indicate exceedences are down compared to 1998-99)



The patterns in the measures of central tendency (e.g., Figure 19) are mirrored by measures of impact assessment. Figure 22, 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 23 and Figure 24 depict a variable frequency of exceedences over the monitoring record.

An examination of the frequency distribution of PM_{10} data from Smithers (Figure 25) yields similar patterns. Generally, all classes, including the one which includes concentrations detrimental to human health (30 µg m^{-3} and greater), have fluctuated over the years.

Figure 25. Inhalable Particulate Data Frequency Distribution.
The most recent year is current to January 2000. The chart depicts the distribution of all 24 hour average observations over a range of concentrations. Based on midnight daily averages.



$PM_{2.5}$ (Fine Particulate)

Data Capture

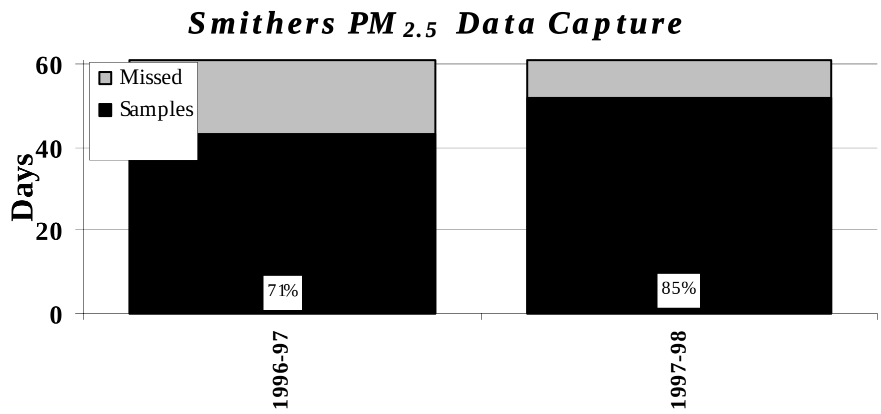
Table 9 and Figure 26 depict the data capture record for the Smithers $PM_{2.5}$ monitoring programme. Given the less than 75% data capture in 1996-97, interpretations drawn from these data should be viewed with caution: that sample year may not be representative of the period (but these data do match the general PM_{10} trends observed over these two years). Monitoring 'years' go from April through March.

Table 9. Smithers $PM_{2.5}$ Data Capture.
The operation of the partisol $PM_{2.5}$ sampler was on a NAPS schedule (one 24 hour period every six days) .

Smithers $PM_{2.5}$ Data Capture

Period	Samples	Missed	Sample Days	%
1996-97	43	18	61	71%
1997-98	52	9	61	85%

Figure 26. Smithers $PM_{2.5}$ Data Capture.



Central Tendency

Figure 27 depicts the percentile distribution of the Smithers $PM_{2.5}$ data by monitoring year. Figure 28 depicts daily and running annual means.

Figure 27. Smithers $PM_{2.5}$ Distributions of Inhalable Particulate Observations.
The top of the top bar depicts the 98^{th}, top of the box the 75^{th}, black square the 50^{th}, box bottom the 25^{th}, and line bottom the 5^{th} percent highest reading of the mean daily inhalable particulate concentrations for each particular year.

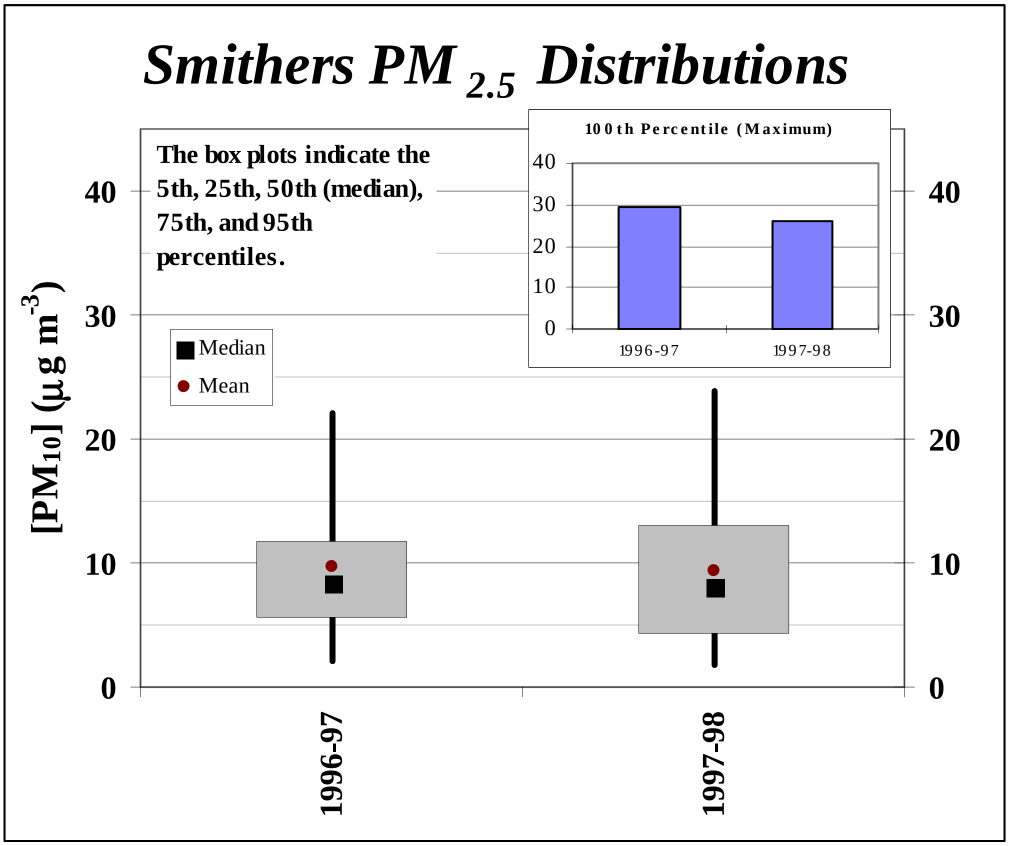
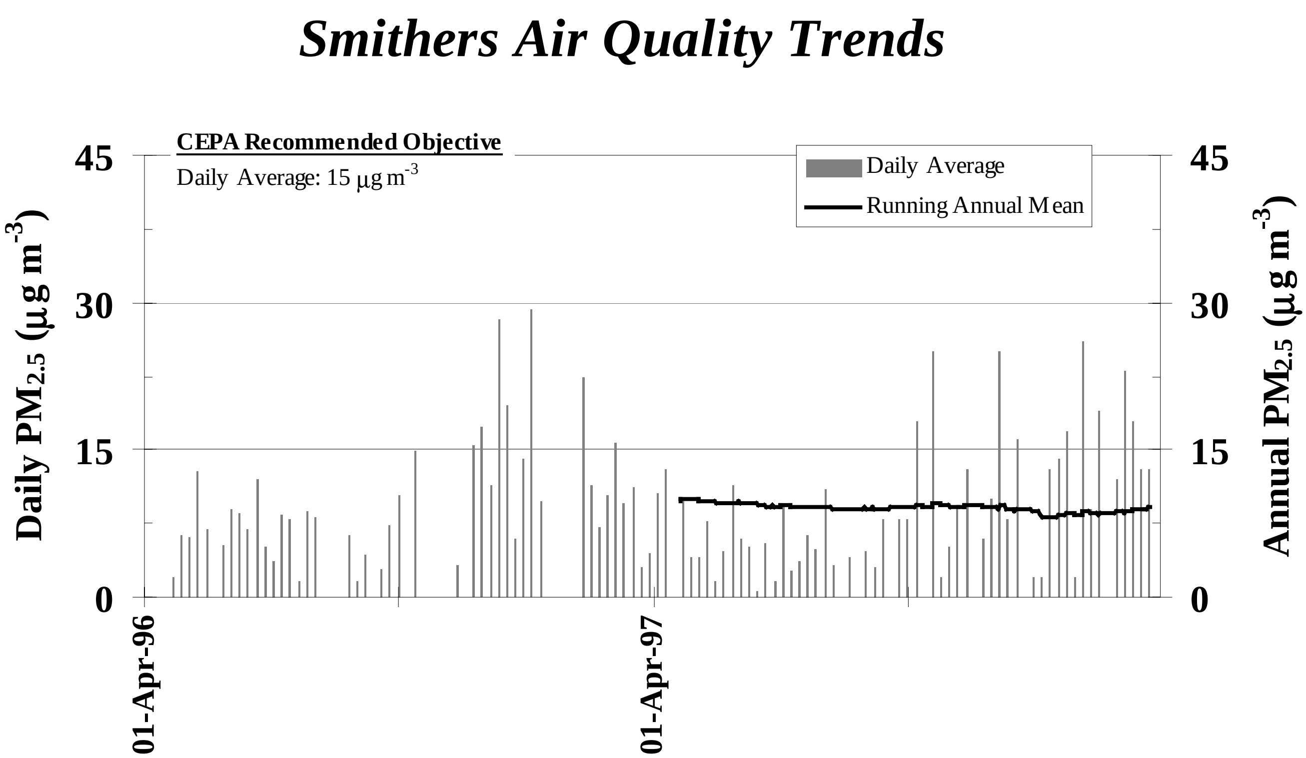


Figure 28. Smithers $PM_{2.5}$ Air Quality Trends.
Partisol $PM_{2.5}$ samples are midnight-to-midnight averages from the NAPS schedule. Running annual mean is based on midnight-to-midnight daily averages.



Impact Assessment

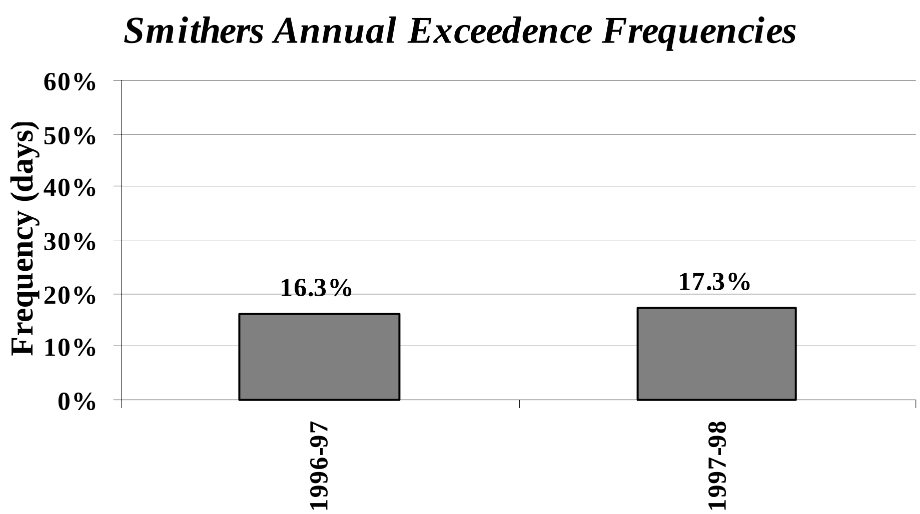
Figure 29 and Table 10 depict exceedence frequencies of the Recommended Reference Level. Figure 29 depicts the frequency distribution of $PM_{2.5}$ concentrations.

Table 10. Measures of Smithers Fine Particulate Impacts.
Total exceedences refers to the number of exceedences of the Federal-Provincial Working Group on Air Quality Objectives and Guidelines recommended daily Reference Level (15 µg m^{-3} averaged over 24 hours) recorded at midnight.

$PM_{2.5}$ Impacts

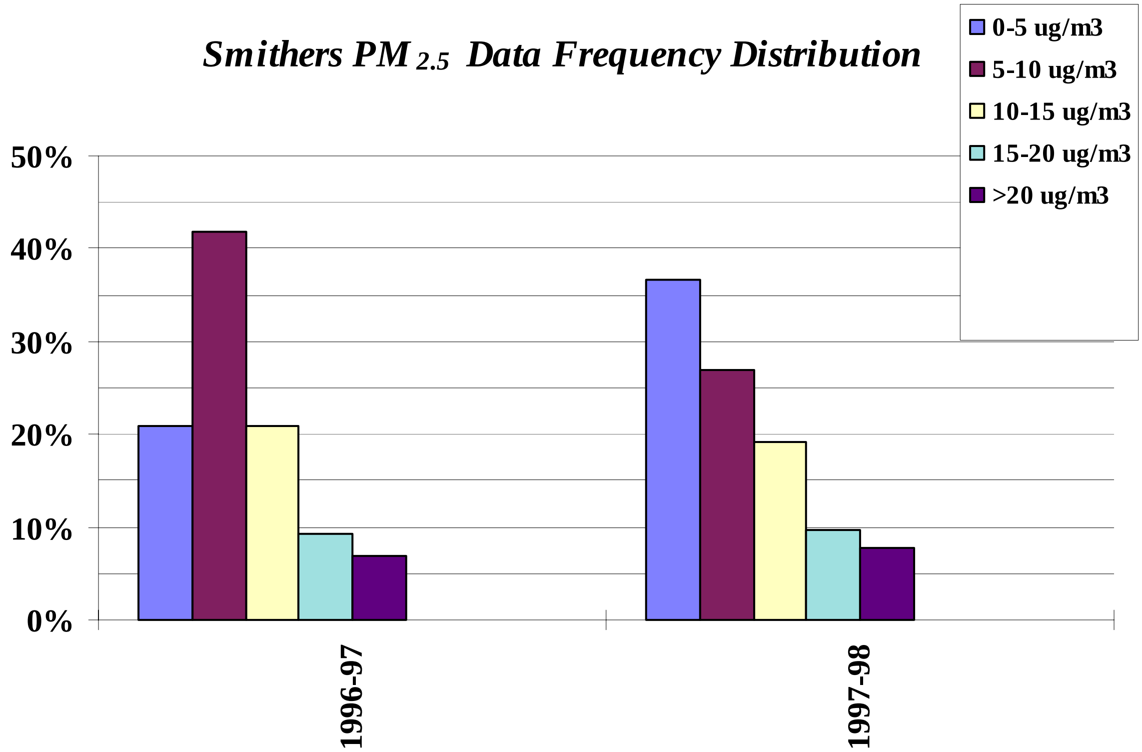
	1996-97	1997-98
Total Exceedences	16.3%	17.3%
Samples	43	52
Sample Days	61	61
Data Capture	71%	85%

Figure 29. Smithers $PM_{2.5}$ Recommended Reference Level Exceedence Frequencies.
Exceedences refers to the number of exceedences of the Federal-Provincial Working Group on Air Quality Objectives and Guidelines recommended daily Reference Level (15 µg m^{-3} averaged over 24 hours) recorded at midnight.



An examination of the frequency distribution of $PM_{2.5}$ data from Smithers (Figure 30) yields one noteworthy trend: is that intermediate concentrations (5-10 µg m^{-3}) have generally decreased in their proportion such that they are offset by the 0-5 µg m^{-3} category. Note, however, this comparison is only over two years and current trends cannot be inferred.

Figure 30. Fine Particulate Data Frequency Distribution.
The chart depicts the distribution of all 24 hour average observations over a range of concentrations. Based on midnight daily averages.



Summary

PM_{10} patterns show great variability over the years, however, there appears to be a decreasing exposure/impact long-term trend superimposed on this pattern. The $PM_{2.5}$ Recommended Reference Level was exceeded both sample years.

Discussion

We have the ability to improve air quality in our communities by changing the quantity of particulate matter emitted into the atmosphere and the period in which it is emitted. 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, 1995) 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 could 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 January 2000, there have been 22 such bans, covering 133 days in total. Recent developments in air quality management and the assessment of PM_{10} and $PM_{2.5}$ have, however, rendered parts of this plan outdated. It is acknowledged that an update be completed once the forthcoming Canada Wide Standards for Particulate Matter have been proclaimed.

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 it's 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.

In 1999/2000 West Fraser and BC Environment negotiated and implemented a beehive burner episode management plan. The plan allows for the burner to be shut down when directed by BC Environment in response to periods of poor air quality and/or dispersion meteorology. In addition, West Fraser shuts down the burner at their discretion for air quality improvement purposes.

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. The data record does indicate the early years of the monitoring programmes had the worst 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 11. 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 11. 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^2)	Pop/km^2 (1996)
Bulkley-Nechako	**RD**	**41642**	**8.6**	**14292**	**72101**	**0.6**
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
Kitimat-Stikine	**RD**	**43618**	**5.0**	**14687**	**91909**	**0.5**
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 several years it is evident that there is qualified improvement. In Houston, measures of central tendency show reduced exposure to particulate matter; measures associated with human health impacts indicate general recent improvements. In

Smithers, measures of particulate matter show great variability over the years with some evidence of improvement superimposed over the longer term. 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 µg m^{-3} in any given monitoring year. Consequently, there are also exceedences of the Recommended Reference Level and a number of exposure increments in any given year.

While not a measure related to health impacts, the *Bulkley Valley Air Quality Management Plan's* annual air quality objective of 20 µg m^{-3} may be considered as a relative benchmark to assess long term trends in central tendency (average concentrations of PM_{10}). In Smithers, annual means have been significantly less than the Plan's objective of 20 µg m^{-3} for six of the past seven years monitored. In Houston, five of the seven years monitored have been significantly less than the annual objective; all of the past four have been significantly less than the annual objective.

Examination of seasonal patterns of $PM_{2.5}$ and PM_{10} shows some differences. Figure 31 shows $PM_{2.5}$ exceedences are limited to winter months (October-March) and peak in December. Meanwhile, December has the second *lowest* PM_{10} exceedence frequency (Figure 32). Figure 32 also shows PM_{10} exceedences occur year round, peaking in frequency during March (Figure 33 shows the Houston pattern is similar). In a general sense, $PM_{2.5}$ exceedences represent those driven by combustion sources; PM_{10} exceedences are driven by combustion sources plus crustal sources (e.g., road dust). The $PM_{2.5}$ exceedences generally occur during those months when unpaved road dust is locked up (only one of the March exceedences occurred on a day where temperatures exceeded zero for more than an hour); the peak exceedences occur when open burning generally does not occur.

Figure 31. Smithers Average $PM_{2.5}$ Exceedences of the Recommended Reference Level.

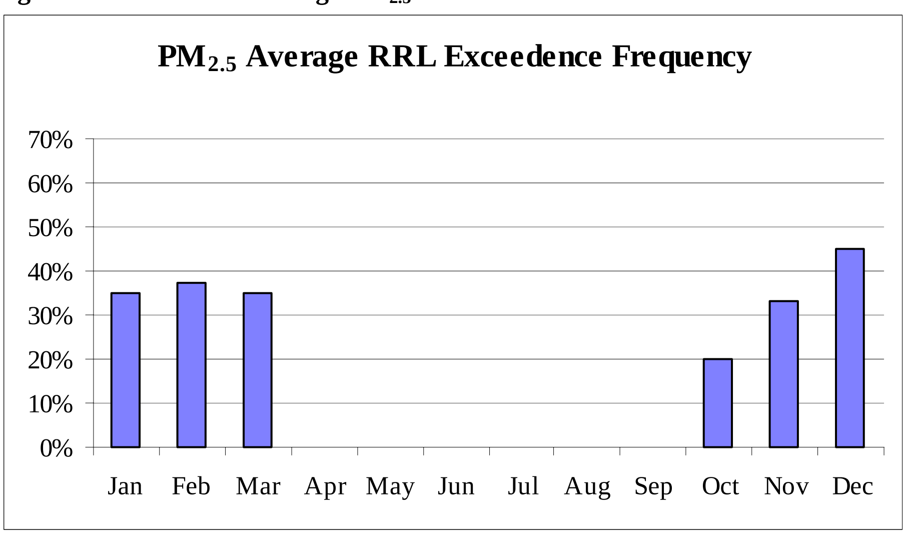


Figure 32. Smithers Average PM_{10} Exceedences of the Recommended Reference Level.

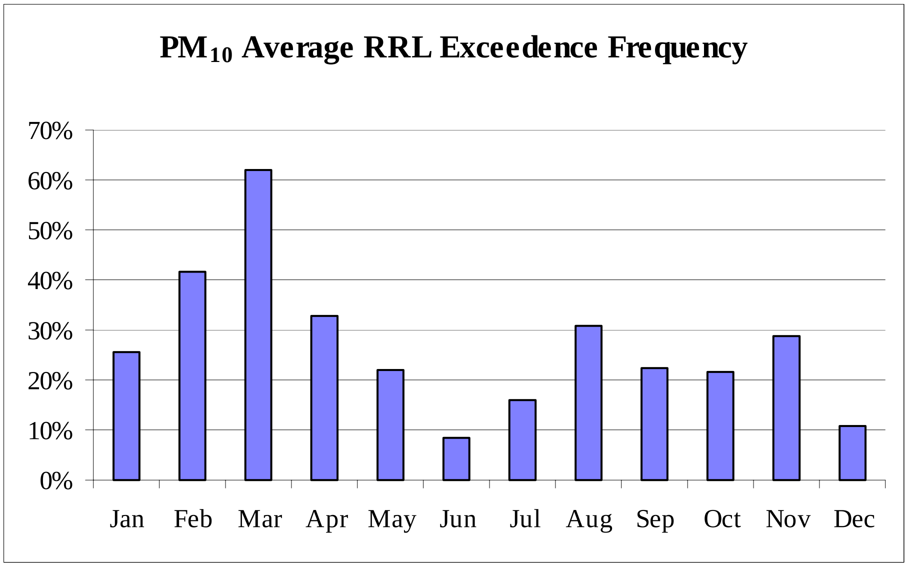
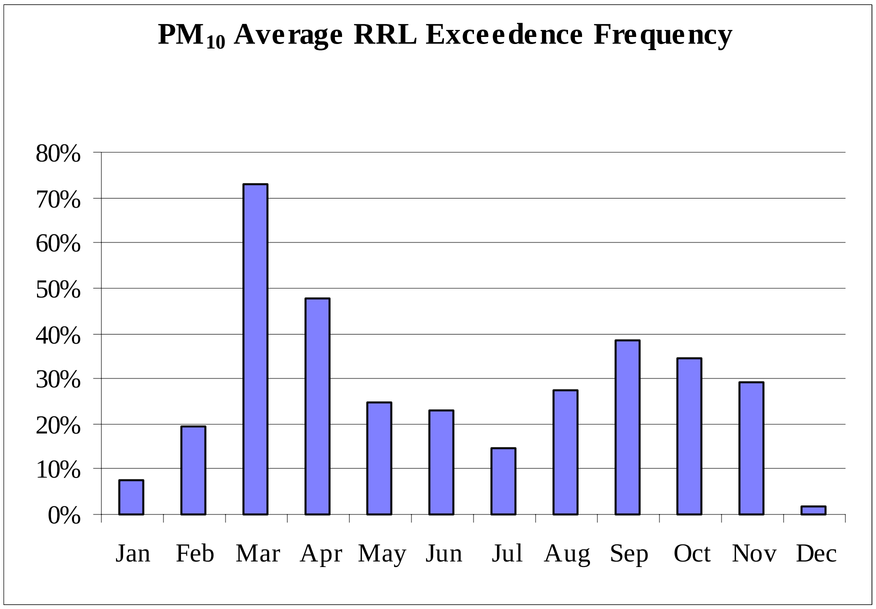
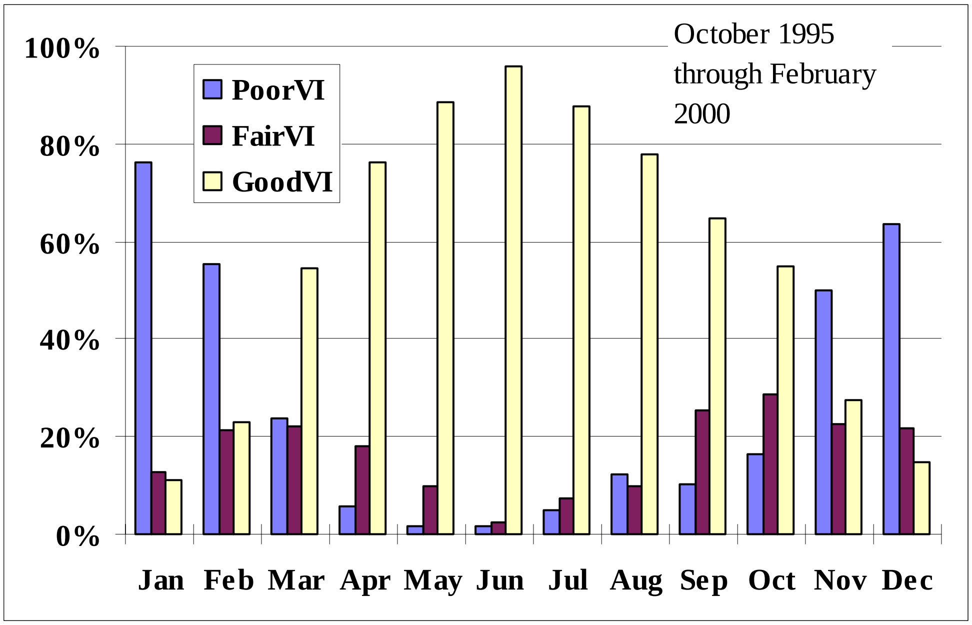


Figure 33. Houston Average PM_{10} Exceedences of the Recommended Reference Level.



The patterns depicted in Figure 31and Figure 32 can also be found on the Summary of Ventilation Conditions chart (Figure 34). Fair ventilation conditions show two peaks in frequency of occurrence: spring and fall. The PM_{10} exceedences generally peak during these periods. Poor ventilation conditions frequency of occurrence build from less than 20% beginning October and peak in January. $PM_{2.5}$ exceedences build from October and peak in December. They continue to March and stop in April: the month in which Poor ventilation conditions frequency of occurrence drops below 20%.

Figure 34. Summary of Smithers Monthly Ventilation Conditions.
Data extracted from the Environment Canada Smoke Control Forecast; VI denotes ventilation index.



Therefore, the December-February period can be one characterised as one dominated by open burning-excluded combustion sources during periods of poor dispersion meteorology. These sources include Permitted point sources, transportation, and home and business space heating (also refer to Table 1, Table 2, Table 3, Figure 2, and Figure 4). $PM_{2.5}$ exceedences generally do not occur during the period of good ventilation (April-September).

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 over the years. However, Interim Air Quality Objective and Recommended Reference Level 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. Two distinct air pollution seasons occur: (i) winter dominated by open burning-excluded combustion sources ($PM_{2.5}$), and (ii) year-round (peaking in the spring) driven by combustion and crustal sources (PM_{10}).

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. This could, for example, take the form of a wood stove emissions regulation or a code of practice for springtime street and parking lot sweeping. 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 $PM_{2.5}$ monitors with the TEOM PM_{10} monitors would help apportion the combustion component of PM_{10}. This would allow regulatory agencies to better focus their emission management strategies.

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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_{10} and TSP) over a 24 hour period. They, unlike the TEOM, are not real time nor are they typically run continuously.

Inhalable Particulate (PM_{10})
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 reach hour during a 1 am-to-midnight period.

Meteorology
The physics of weather processes.

mg dm^{-2} day^{-1}
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^{-6} metres (one millionth of a metre; there are 1 000 micrometres in a millimetre).

μg m^{-3}
Micrograms per cubic metre. A microgram is 10^{-6} 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^{-6} 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_{10}
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 looses 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_{10} 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.

$\mu g\ m^{-3}$ 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.