# *BULKLEY VALLEY*

# *AIR QUALITY MANAGEMENT PLAN:*

# *INHALABLE PARTICULATE*

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# *Abstract*

The Environmental Protection Programme of BC Environment (Skeena Region) has responded to public concern regarding the environmental impacts of airborne particulate matter in the Bulkley Valley. Much of this particulate matter comes from the burning of wood: from beehive burners, wood burning stoves, and open burning of land clearing debris. Over the past several years, BC Environment has implemented air quality monitoring programmes in the communities of Houston, Smithers, and New Hazelton. These programmes have yielded data on inhalable and total suspended particulate concentrations as well as other parameters such as polynuclear aromatic hydrocarbons and dustfall. Assessment of these data have pointed to a need to manage the emissions of the products of combustion.

The initial monitoring programmes demonstrated a need for continuous, real time, inhalable particulate monitoring ($PM_{10}$). BC Environment responded by deploying such analysers in the communities of Houston and Smithers. These facilitate air quality episode management and allow for assessment of air quality trends. The New Hazelton monitoring programme cannot be used for episode management, but can be used for trend analysis. These two components, episode management and trend assessment, are the core of the management plan developed by BC Environment to minimise air quality impacts in the valley. The ultimate goal of BC Environment is to eliminate such air quality impacts by means of regulation of various emission sources and public participation in responsible wood-burning practises.

The episode management component of the plan is an important one as it is the key to minimise and/or prevent significant health impacts resulting from emissions of $PM_{10}$. The plan calls for

escalating restrictions on $PM_{10}$ emissions as air quality deteriorates. The restrictions are explicitly linked to British Columbia environmental protection air quality impact criteria. The first restrictions, a requested ban on recreational wood burning and a legal ban on the open burning of land clearing debris, are preventative in nature and come into effect at $PM_{10}$ concentrations of 40 $\mu g\ m^{-3}$ averaged over a 24 hour period. When the draft Level A impact criterion of 50 $\mu g\ m^{-3}$ is reached, a Stage 1 Alert is declared with those burning wood in non-CSA/US-EPA emission-certified stoves and fireplaces being requested to stop burning. A Stage 2 Alert comes into effect at the draft Level B impact criterion of 100 $\mu g\ m^{-3}$ where all residential wood burners with alternative heat sources are requested to stop burning and all Waste Management permitted emissions will be inspected to ensure they are in compliance with their air emission permits. At the draft Level C impact criterion (150 $\mu g\ m^{-3}$), a Stage 3 Alert is declared and it is incumbent on the Regional Waste Manager to assess the situation in the context of reducing or eliminating the $PM_{10}$ loading in the airshed for all sources under his/her jurisdiction.

This document is an update of and supersedes the 1992 Smithers Air Quality Management Plan (Johnson, 1992). It incorporates changes in impact criteria associated with inhalable particulate, new legislative initiatives undertaken by the province, and integrates these with BC Environment's expanded monitoring programme in the Bulkley Valley. Collectively, these components comprise the Bulkley Valley Air Quality Management Plan. After extensive consultation with the valley community and review by senior regional staff of BC Environment, the plan was declared as being Policy of BC Environment, Skeena Region, at the 16 January 1995 meeting of the Senior Executive Committee.

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# *Introduction*

Wood smoke: the very term conjures up different images. To some, there is the frontier-type image of self-reliance for home-heating needs or the romantic image of a roaring fireplace and a chilled bottle of wine. To others, there is the image of an acrid pollutant irritating the lungs, tearing the eyes, and making life miserable for parents and their children. British Columbian households are the second highest users of wood for primary or secondary space heating in Canada (38%) (Bethell, 1986). Wood burning stoves, combined with other sources of wood smoke such as beehive burners and open burning of land clearing debris, comprise 60% of the particulate emissions in the province (including those from automobiles) (Stevenson, 1994). Most of the wood burning residential households are in rural areas and communities of less than 10 000 people (Bethell, 1986). Therefore, it should not come as a surprise that wood smoke air pollution is an issue in communities where there are significant sources of biomass (wood) burning and poor atmospheric dispersion: Houston, Smithers, and New Hazelton are such communities.

BC Environment frequently receives complaints and comments regarding perceived poor air quality during periods when wood smoke is evident in the air. These periods coincide with incidents of slash burning, land clearing burning, residential wood stove use, and from beehive burner emissions and other industrial activity in the valley. These smoke sources, combined with poor dispersion meteorology, can result in elevated concentrations of pollutants in the Bulkley Valley.

Air quality monitoring has been undertaken to assess air quality in communities all along the Highway 16 corridor (Burns Lake, Houston, Smithers, New Hazelton, and Terrace). From this monitoring BC Environment has documented occurrences of degraded air quality and is,

therefore, concerned that environmental impacts are occurring. These impacts range from the nuisance (e.g., soiling of cars and laundry) through to the serious (e.g., affecting people's respiratory function and even increased mortality rates).

Smithers has had the longest history of continuous inhalable particulate monitoring in the valley. Initial assessment (1990-1991) of these data indicated that ambient air quality in Smithers was degraded for approximately one month per year. Periods of impaired air quality only occurred during winter months; a period coincident with residential home heating with wood and poor dispersion meteorology. Frequently, annual averages indicate inhalable particulate concentrations exceed or are not significantly less than desirable levels.

As a result of the demonstrated impaired air quality in Smithers, BC Environment, with the support of the BC Lung Association and Environment Canada, intensified the ambient monitoring programme with the deployment of a continuous, real-time, inhalable particulate monitor. This monitor, a TEOM (Tapered Element Oscillating Microbalance), began operation in the spring of 1992. Given the real-time nature of this monitor, BC Environment developed and implemented an air quality management plan for Smithers in the fall of 1992. It defined how BC Environment would use the TEOM to issue air pollution indices and advisories to the people of Smithers during periods of degraded air quality. These advisories formed the core component of BC Environment's Smithers Air Quality Management Plan (Johnson, 1992) for particulate matter.

In the late winter of 1993, BC Environment initiated an inhalable particulate sampling programme in Houston, 60 km up-valley of Smithers and in New Hazelton, 80 km down-valley of Smithers. Data from these programmes indicated that Houston and, to a lesser extent, New Hazelton, had high magnitudes of inhalable particulate which occurred frequently during winter and spring months. In 1994, BC Environment's Atmospheric Monitoring Steering Committee assessed Houston, along with Quesnel, as being the top community in British Columbia in need of continuous inhalable particulate monitoring. As a result, BC Environment allocated resources for the installation of a TEOM in Houston in the fall of 1994. Thus, an air quality management

plan could also be implemented in Houston as per the existing one in Smithers. New Hazelton could be included in the assessment aspects of the plan, thereby completing coverage of the larger communities anchoring the Bulkley Valley.

Meteorological monitoring stations were established in Houston and Smithers in the late fall of 1994. These provide data to assess the role of meteorological controls on air quality in the valley.

In the following sections air pollution potential is assessed for the Bulkley Valley. This is followed by a presentation of the environmental impacts of particulate matter and the BC Environment air quality monitoring programme. Subsequent are the management strategies. These strategies are defined, environmental impact criteria and objectives are presented, and air quality assessment criteria are defined. A glossary is appended at the end of this document containing definitions of acronyms and technical terms.

# *Air Pollution Potential*

Earth's atmosphere is a resource utilised by humans and other lifeforms. We extract oxygen from the air to fuel our bodies. When we exhale we use the atmosphere to dispose of our waste (carbon dioxide). While the breathing process is rather benign in terms of environmental impacts, we also use the atmosphere to dispose other wastes such as those from industrial activity, transportation, and from heating our homes and places of work. These human-related activities, also known as anthropogenic activities, have the potential to substantially alter or impair the usefulness of the environment. When this happens, the air is said to be *polluted (Waste Management Act,* 1982). The atmosphere in the Bulkley Valley may become polluted at times due to three factors: meteorology, topography, and sources (emissions).

## *Meteorology*

The Bulkley Valley is located 250 kilometres inland from the west coast of North America. Smithers, a central community in the valley, is located at 54° 46′ latitude and 127° 10′ longitude. The valley is commonly under the influence of stable air masses. In winter this is in the form of a continental polar air mass, 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, a vertical temperature profile develops that is characterised by the ground surface being 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 profile (temperature decreasing with height). Skiers on Hudson Bay Mountain will recognise this phenomena 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.

The net result of atmospheric temperature inversions from an air quality perspective is a very stable atmosphere characterised by little mixing. Such atmospheres cannot 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 compounds continue to be emitted into the atmosphere but are not transported away. If the resulting build-up of emissions result in environmental impacts (including human health impacts), *air pollution* is said to occur and the emissions thus become classified as *air pollutants*.

When the air begins to mix, (e.g.,) from thermal turbulence generated by morning solar heating 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 the pollutants are drawn down to ground level. This is termed *fumigation* and can result in short-lived, but extremely high, concentrations of air pollutants.

It is only when the regional air mass as a whole is changed that built-up pollutants are removed. Such conditions are marked by the passage of a frontal system which define the boundaries between air masses[1]. Fronts are often associated with precipitation. When in the form of rain, precipitation can act as a very efficient scrubber, thereby removing aerosol pollutants, such as inhalable particulate, from the atmosphere.

These meteorological conditions are typical of any central interior community in British Columbia. They are contrasted by coastal communities, such as Prince Rupert, that are largely under maritime polar air masses for much of the winter. Maritime polar air masses are characterised by cool and damp air that is unstable. Such unstable (windy) and relatively warm

[1]Occasionally, air mass changes can have the opposite effect of bringing in pollutants from other areas.

(less particulate loading from wood burning stoves) environments tend to have excellent dispersion characteristics: air quality problems, such as the wood smoke ones experienced by the interior communities, tend to be much less frequent in such environments.

## *Topography*

Houston, Smithers, and the Hazeltons are located in the Bulkley Valley. As such, local topography 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., smoke from a broadcast burn) can be drawn down into the valley with the air under such conditions.

Mountainous terrain also can act to detach the valley air from the regional air masses. For example, cold air can collect in the valley through the processes of radiative temperature inversions 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 the 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.*

## *Emissions*

From an air pollution perspective, all the above factors would be insignificant without atmospheric inputs. These inputs are in the form of emissions, usually from human activity. Simply put, in the absence of smoke (and other) emissions, there can be no air pollution. In the Bulkley Valley, biomass (wood) combustion is a significant source of particulate and other emissions into the local airshed.

Particulate emissions from biomass burning result only when combustion is not 100% efficient. In theory, a hot fire with adequate oxygen supply will emit only carbon dioxide and water vapour. As efficiency is reduced from 100%, increasing amounts of particulate matter and other gases are generated and emitted. These gases include polynuclear aromatic hydrocarbons (PAHs), oxides of nitrogen, carbon monoxide, acrolein, formaldehyde, volatile organic compounds, dioxins, and furans.

### *Air Pollution Potential*

To summarise, if pollution occurs, it can affect everyone in the community as we are all dependent on clean air. The Bulkley Valley's combination of meteorology, topography, and emission sources all act together to produce an environment that exhibits significant air pollution potential.

# *Particulate Matter*

## *Definition*

Particles suspended (floating) in the atmosphere come in a variety of shapes and sizes. Larger (heavier) particles tend to drop out relatively quickly and impact the environment in the form of a nuisance pollutant known as dustfall. This includes fly ash and sooty combustion products. Finer particulate can remain airborne for longer periods of time, buoyed by atmospheric turbulence (winds). This airborne component is termed total suspended particulate (TSP). Very fine (small) particulate matter can be inhaled into the human respiratory system including the lungs. These are known as $PM_{10}$ (particulate matter less than 10 μm in diameter[2]). It is these fine particles that provide the most significant environmental impact: human health effects.

## *Sources*

Background sources of airborne particulate matter include forest fires, dust storms, and volcanic eruptions. Emissions from human activity in the Bulkley Valley include significant amounts of material resulting from biomass (wood) burning. Such activities include burning of sawmill 'waste' (emissions from beehive burners), residential wood stove and fireplace emissions, broadcast and slash burning of clear-felled forest debris, and burning of land clearing and backyard debris. Automobile exhaust represents another anthropogenic source.

Significant inhalable particulate sources in the valley, ranked according to their relative *provincial* (outside the lower Fraser Valley) significance include (from Stevenson, 1994):

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[2]μm denotes "micrometre". A micrometre is $10^{-6}$ metres (a millionth of a metre; there are 1 000 micrometres in a millimetre). A human hair is between 25 and 200 micrometres in width (Stern *et al.*, 1973).

- **Prescribed Burning (40%).** Includes silviculture, range management, agricultural, wildfire hazard reduction, and habitat 'management'.
- **Wildfires (28%).**
- **Point (e.g., Beehive Burners) (17%).** Two beehive burners in Houston, one in Smithers, one in Morristown, and one in New Hazelton; Pannelboard plant in Smithers.
- **Road Dust (7%)**. 50% of road particulate emissions are $PM_{10.}$
- **Mobile (e.g., Automobile Exhaust) (6%).** Thousands of trucks and cars throughout the valley. Provincially, mostly railways and heavy duty diesel engines, >99% of whose particulate emissions are $PM_{10}$.
- **Area (2%).** Thousands of wood burning stoves throughout the valley. Provincially, more than 98% of space heating particulate emissions are $PM_{10}$.

Of course, local sources vary in proportion from the provincial averages. While small on a provincial scale, local sources (e.g., point, mobile, and area) can be significant in a local or valley-scale context. Conversely, large sources such as prescribed burning can be a small component locally (over the long term) as they are managed specifically to avoid impacts on certain areas.

It is extremely difficult to apportion different sources of biomass burning on a valley-scale (e.g., fraction of wood smoke attributable to wood stoves relative to that from a beehive burner). Estimates for the Houston area done by BC Environment's Air Resources Branch indicate that the two beehive burners (and other sawmill emissions) put out 92% of the $PM_{10}$ emissions in the community, excluding the large area sources such as prescribed burning (Wakelin, 1994). Similarly, in Smithers an estimated 70% of particulate emissions from the town come from the sawmill which continues to dispose of its wood 'waste' in a beehive burner.

Source apportionment studies have been conducted in other communities, largely in the USA, where particulate sources were relatively straightforward (e.g., metal smelting versus wood burning stoves versus automobiles). Bennett *et al.* (1989) report that between 66 and 84 percent

of the airborne particulate in the Seattle and Tacoma areas of the USA were attributable to residential wood burning. Not surprisingly, industrialised areas had a much lower proportion of particulate matter attributable to wood burning (16-32%). In a residential area of Olympia, USA, Khalil (1986, in Bennett *et al.,* 1989) found that at high airborne mass concentrations (above 150 $\mu g\ m^{-3}$), between 80 and 90 percent of the mass was wood smoke (all sources). Edgerton *et al.*, (1986) report that residential woodstoves and fireplaces contributed 73-100% of the total mass of fine particles in the air on winter evenings in Hillsboro, Oregon, USA. Emissions from woodstoves accounted for an estimated total of 64% of all $PM_{10}$ emissions in Klamath Falls (population 37 500), Oregon, USA (in winter the figure is 81%; Oregon Department of Environmental Quality, 1990). In Missoula City, Montana, USA, 68% of respirable particulates have been attributed to residential wood burning (2% due to industrial wood burning, 6% due to auto exhaust, 9% due to road dust, and 15% due to all others; Missoula City County Health Department, No date). Watts *et al.*, (1987) and McCandless (1984; both in Reid, 1992) note that slash plumes and wood waste burners cannot match the environmental impact of hundreds of residential wood stoves operating at low efficiency in a valley under strong nocturnal inversion conditions. Experience in the Bulkley Valley has indicated that this is not always the case: for example, open burning of land clearing debris (e.g., forestry site preparation) have literally 'smoked out' the valley. Such incidents, while no longer common, can have widespread and visually dramatic impacts when they do occur.

In summary, experience from other communities indicates that residential wood burning can contribute significant amounts of particulate matter into the atmosphere. This can be the dominant source of particulate in non-industrialised airsheds and can be one of a number of smoke sources in airsheds with industrial activity. With respect to the Bulkley Valley, three components exist that point to a serious air pollution potential: poor dispersion meteorology, poor dispersion topography, and a variety of point (e.g., beehive burners) and area (wood burning stoves, automobiles) sources of inhalable particulate.

## *Environmental Impacts: Human Health*

Fine particulate matter suspended in the atmosphere can penetrate to the lung's alveolar region. Thus, there is the associated possibility of affected pulmonary lung function. This environmental impact is the most serious impact associated with particulate matter. 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 tobacco smokers and children. 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. Heumann (*et al.*, 1991) concluded that there was a significant decrease in average pulmonary function measurements among children in high exposure areas during winter months in Klamath Falls, Oregon, USA. Fairley (1990) found an association between high particulate concentrations and increased mortality. In fact, for "the San Francisco Bay Area, this risk is much greater than the risks from any toxic identified so far" (p. 167). The Fresno County Department of Health and the American Lung Association of Central California (no date) reports that jogging (and any strenuous outdoor activity) may be hazardous to human health when the air is contains smoke.

Young children (school and pre-school), the elderly, those with chronic obstructive cardiovascular disease (heart patients and those with arteriosclerosis), asthmatics, those with influenza or bronchitis, smokers, and orinasal (mouth) breathers are the portions of the population most sensitive to airborne particulate matter (Hilborn and Still, 1990). Browning *et al.* (1990) found that young children (ages 1-5) develop more symptoms of respiratory illness if they live in an area with large amounts of wood smoke pollution.

Some of the most worrisome data concern the health effects of particulate matter come from studies showing an association between mortality rates and suspended particulates. One set of studies found approximately a 7% increase in mortality rate per 100 $\mu g\ m^{-3}$ (Fairly, 1990; Schwartz, 1991; and Schwartz and Dockery, 1992; all in Pierson and Koenig, 1992). Other studies have suggested that about 8% of the variation in annual mortality across metropolitan

areas may be associated with air pollution; in particular, with TSP and sulphates (Lave and Seskin, 1977 in Spengler *et al.*,1990).

The toxic component of wood smoke contains traces of many known organic carcinogens. These include PAH (polynuclear aromatic hydrocarbons), TCDD (dioxins), and TCDF (furans). For example, PAH adsorb onto particulate matter and are thus an additional component of the fine particulate originating from biomass (wood) burning. Many experts believe there is a small, but not insignificant, cancer risk associated with prolonged exposure to wood smoke.

The effective toxicity of small particles may be of greater significance (than that associated with large particles), since the concentrations of toxic substances increase as particle size decreases. The long retention time of particulates in the alveolar region (the lungs) permits toxic substances to be extracted and transported to other parts of the body.

Most significant for British Columbia, the Office of the Provincial Health Officer released a report in the fall of 1993 summarising the health risks associated with airborne particulate (Vedal, 1993). The following effects were noted to be associated with exposure to particulate matter:

- decreased levels of lung function in children;
- increased respiratory symptoms in children and adults;
- increased functional limitations as reflected by school absenteeism and restricted activity days;
- increased physician and emergency visits for asthma (20% for emergency room for asthma and bronchitis for each 50 $\mu g\ m^{-3}$ increase in particulate levels);
- increase in hospitalisations for respiratory conditions;
- increased mortality on days after those with high particulate levels (8% for each 50 $\mu g\ m^{-3}$ increase in particulate levels).

### *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. Thus, visibility is degraded resulting in what is largely an aesthetic, yet highly visible, environmental impact.

These aesthetic impacts may be of economic concern. For example, a clean-looking environment may be considered an essential component to various tourism ventures. Similarly, there can be significant impacts if visibility is degraded such that aircraft traffic is affected.

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.

# *Bulkley Valley Air Quality Monitoring Programme*

In response to particulate loading in the Bulkley Valley Airshed, BC Environment has operated a number of air quality monitors over the years. Recent monitoring sites, the air quality variables being measured, the sampling location, and their SEAM[3] site identifier are presented in Table 1. (Note that acronyms and technical terms are defined in the glossary). Additional monitoring sites along Highway 16 include Burns Lake and Terrace $PM_{10}$ high volume samplers.

[3]SEAM (System for Environmental Assessment and Management) refers to the Ministry of Environment, Lands, and Parks' in-house database.

**Table 1: Bulkley Valley Ambient Air Quality Monitoring Programme.**

Houston and Smithers TEOMs provide continuous real-time inhalable particulate data. These air quality analysers are essential to air quality episode management.

| Location (SEAM Site Number) | | Instrument-Parameter | Sampling Frequency | Dates Monitored |
|---|---|---|---|---|
| **Houston** | Silverthorne School (E218458) | HiVol-$PM_{10}$ | NAPS | February 1993-January 1995 |
| | Fire Hall | TEOM $PM_{10}$<br>Meteorology<br>HiVol-$PM_{10}$ | Continuous<br>Continuous<br>NAPS | September 1994-<br>November 1994-<br>January 1995- |
| **New Hazelton** | Spooner Residence (E216334) | HiVol-$PM_{10}$ | NAPS | 1991-1992 |
| | DFO Building (E218578) | HiVol-$PM_{10}$ | NAPS | March 1993- |
| **Smithers** | St. Joseph's School (E206589) | HiVol-TSP<br>HiVol-$PM_{10}$<br>PAH<br>Dustfall<br>TEOM $PM_{10}$<br>Meteorology | NAPS<br>NAPS<br>NAPS<br>Monthly<br>Continuous<br>Continuous | Jan. 1986 -1992<br>July 1990 -1993<br>July 1990 -1994<br>July 1990 -1992<br>May 1992-<br>November 1994- |
| | Chandler School (E207908) | Dustfall | Monthly | June 1989-1992 |
| | Railway Avenue (east) (E207909) | Dustfall | Monthly | June 1989-1992 |
| | Raspberry Hill-<br>BC Environment Building | Transmissometer<br>Visibility | Hourly | Fall 1990-1992 |

NAPS (National Air Pollution Schedule) denotes a sampling duration of 24 hours run once every six days.
Monthly dustfall are continuous passive monitors.
Hourly transmissometer observations are based on 10 minute integrations.

# *Air Quality Management Plan*

## *Definition*

Emissions to the atmosphere from the earth-atmosphere interface occur from a variety of sources, over various timescales, and at various intensities. Emission sources can be both anthropogenic (human) or from other natural components (e.g., dust from the earth's surface or terpenes from trees). When these emissions result in ambient concentrations exceeding limits that define environmental impact thresholds, then air pollution is said to occur. In most cases, pollution results from some form of emissions related to human activity.

Plans may be developed to manage emissions to the atmosphere with the objective of minimising and, ultimately, preventing environmental impacts. The specific objectives of such an air quality management plan are to:

- set impact criteria (limits) that define when air quality impacts occur;
- define how air quality is assessed on a real-time basis;
- define an action plan in response to degraded air quality or the threat of degraded air quality (episode management);
- define criteria to assess the effectiveness of the air quality management plan in the context of protecting airshed air quality (long term air quality management).

BC Environment has been monitoring particulate matter on a continuous basis in the Town of Smithers and the District of Houston, largely in response to public and Ministry concern about woodsmoke emissions. Discontinuous, non-real time sampling occurs in New Hazelton. Therefore, this Air Quality Management Plan is directed at concentrations of inhalable

particulates in these communities. It is acknowledged that there may be subsequent additions and/or revisions to this plan.

## *Environmental Impact Criteria and Objectives*

British Columbia's ambient air quality 'standards' are in the form of objectives and guidelines and are comprised of two or three levels. Canadian objectives are also defined for two or three levels. Drawing on BC Environment's Pollution Control Objectives, these three levels are defined in Table 2 (with the terminology of the Government of Canada in parentheses).

**Table 2: Definition of British Columbia's and Canada's Air Quality.**

| Air Quality Objective | Definition |
|---|---|
| ***Level A*** (Maximum Desirable) | Designed to provide **long term protection for all environments**. The maximum desirable objective is intended to provide the basis for an anti-degradation policy for undeveloped areas with an adequate safety margin; is reasonable for polluted areas to aim for and to achieve; and is for unpolluted areas to avoid. This objective takes a conservative approach *of protecting the most sensitive receptor*, thereby providing a wide margin of safety to protect other less sensitive receptors. (Ministry of Environment and Parks, 1986, p. 3). |
| ***Level B*** (Maximum Acceptable) | Intended to be the **acceptable interim objective**. This 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**. Concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population. |

Table 3 presents the ambient particulate-related air quality objectives for British Columbia using the terminology defined in Table 2.

**Table 3: Ambient Particulate-Related Air Pollution Control Objectives for British Columbia.**

DF denotes dustfall; $PM_{10}$ denotes inhalable particulate; TSP denotes total suspended particulate. Both British Columbia (BC) and National (Can.) objectives are presented. Note that the older draft $PM_{10}$ objectives (Anonymous, 1991) are bolded. Air Resources Branch have recently halved the Level B impact criteria associated with 24 hour $PM_{10}$ (McTaggart-Cowan, 1994) which, therefore, can be considered to supersede the older Draft B criteria. This revision is appropriate, yet incomplete, in light of the Vedal (1993) findings. The Bulkley Valley air quality monitoring programme has evolved over the years to focus on $PM_{10}$.

| PARAMETER | AVERAGING PERIOD | UNITS | LEVEL A | | LEVEL B | | LEVEL C | |
|---|---|---|---|---|---|---|---|---|
| | | | BC | Can | BC | Can | BC | Can |
| **DF** | 2 weeks | | | | | | | |
| | Residential | mg $dm^{-2}$ | 1.75 | | 1.75 | | | |
| | Other | $day^{-1}$ | 2.90 | | 2.90 | | | |
| | 30 day | | 1.75 | | 2.90 | | | |
| **$PM_{10}$** | 24 hour | µg $m^{-3}$ | **50** | | **100** 50 | | **150** | |
| | 1 year | | **20** | | **30** | | **40** | |
| **TSP** | 24 hour | µg $m^{-3}$ | 150 | | 200 | 120 | 260 | 400 |
| | 1 year | | 60 | 60 | 70 | 70 | 75 | |

mg $dm^{-2}$ $day^{-1}$ represents mass per unit area per unit time
µg $m^{-3}$ represents mass per unit volume

Given that inhalable particulate are the most significant concern to BC Environment because of their potential human health impacts, BC Environment has focused on monitoring and reporting of this parameter to the public. This has been facilitated by adapting the $PM_{10}$ environmental protection criteria into an air quality index. This index is a relative measurement of air quality. It effectively reduces the mass per unit volume (µg $m^{-3}$) Level A/B/C (Desirable/Acceptable/Tolerable) objectives for the various timescales into a relative measure (0 to 100+) and qualitative description (Good, Fair, Marginal, Poor, and Very Poor) of air quality. For example,

> the running 24 hour average of 15 micrograms of suspended inhalable particulate matter per cubic metre of air is within the provincial Level A and federal Maximum Desirable air quality limits

is simplified to:

> the air quality index is 15; this represents Good air quality.

Thus, the air quality index and description represents a user-friendly, jargon-free, air quality reference[4]. The Bulkley Valley Air Quality Management Plan air quality index is presented in Table 4.

**Table 4: Upper-Bulkley Valley $PM_{10}$ Air Pollution Indices.**

Indices are derived from proposed and existing provincial ambient air quality criteria, existing environmental impact literature, and guidance from Air Resources Branch. They are explicitly tied to the air quality objectives, where possible. The definitions of BC Environment action in response to degraded air quality (three Stage Alerts) is defined in the subsequent sub-section and in Table 5. Related air quality objectives are from Table 3. Note that the practicality of the actions listed below is largely limited to 24 hour average $PM_{10}$ concentrations (episode management). An index value for one hour $PM_{10}$ from the previous plan (Johnson, 1992) has been dropped due to its inapplicability to episodic air quality management in the valley.

| Pollutant | Description | Index Value | Related Air Quality Objective (upper limit) | 24 Hour Average ($\mu g\ m^{-3}$) | Annual Average ($\mu g\ m^{-3}$) | BC Environment Action |
|---|---|---|---|---|---|---|
| **Inhalable Particulate ($PM_{10}$)** | GOOD | 0-25 | | 0-25 | 0-15* | N/A |
| | FAIR | 26-40 | | >25-40 | | N/A |
| | MARGINAL | 41-50 | Draft A; Interim B | >40-50 | 15-20* | Air Quality Notice |
| | POOR | 51-100 | Draft B | >50-100 | 20-30 | Stage 1 Alert |
| | VERY POOR | 100+ | Draft C | >100-150 | 30+ | Stage 2 Alert |
| | VERY POOR | 150+ | | >150 | 40+ | Stage 3 Alert |

*"15" is approximate: the actual lower bound is defined statistically as: "not significantly different from the 20 $\mu g\ m^{-3}$ objective (cf. Table 3)." The actual number varies from year to year depending on variability in air quality and sample size.

Table 4 represents a core component of the air quality management plan. It defines an air quality index for inhalable particulate matter using corresponding air quality descriptions of *Good, Fair, Marginal, Poor,* and *Very Poor* and BC Environment's response to such air quality. Stage 3 Alert is a special case whereby when air quality deteriorates to extremely poor levels special action by BC Environment may be warranted to reduce permitted emissions.

[4]It is pure coincidence for $PM_{10}$ that 1 index value equals 1 $\mu g\ m^{-3}$. This was not the case in the original Air Quality Management Plan for Smithers (Johnson, 1992). The new scale was mandated by the Director of Air Resources Branch (McTaggart-Cowan, 1994).

The 24 hour indices are explicitly linked to the provincial air quality impact objective criteria (Table 3). Therefore, they will change as the objectives are refined. Note that the old draft Level A and the current Interim Level B impact criteria are equal (Table 3 and Table 4). Skeena Region await new Level A and/or Level C impact criteria from Air Resources Branch or the Federal Government before revising the management plan in this context.

It is the Environmental Protection Programme's goal to achieve the Level A environmental protection criteria (Table 2, Table 3, and Table 4) or less in the Bulkley Valley and elsewhere in Skeena Region. The Level A (Maximum Desirable) impact criteria reflect environmental impact levels that are well below those at which any health effects would be anticipated; that are reasonable for polluted areas to aim for and to achieve; and are for unpolluted areas to avoid. Most importantly, Level A criteria protect the most sensitive receptor. In the case of inhalable particulate, the most sensitive receptors are young children (lungs are still developing), the elderly, and anyone predisposed to lung disease (e.g., asthmatics). Thus, air quality adhering to the Level A objective should provide a healthy environment and clean air for the residents of the Bulkley Valley. Level A (and better) air quality represents the Marginal, Fair, and Good air quality categories in Table 4 and denotes the key air quality management threshold.

## *BC Environment Action Plan*

Depending on the air quality, BC Environment may switch over from a passive monitoring strategy to actively communicating air quality information to the community in an effort to prevent or to minimise air pollution. These actions, first classified in Table 4 (stages of Alert), are defined in the paragraph below and in Table 5.

The most significant revision of the new action plan compared to the one developed for Smithers in Johnson (1992) is its increased emphasis on pollution prevention. Experience with the Smithers plan showed that episodes of Poor air quality were still occurring even with the management plan in place. In the current plan, this emphasis on pollution prevention is manifested in the new "Marginal" air quality category (cf. Table 4 and Table 5) with its burning

ban request and order. These are now implemented before the 50 $\mu g\ m^{-3}$ (Level A) impact threshold is reached.

**Table 5: Definition of BC Environment Air Quality Environmental Protection Activities.**

Note that the practicality of the actions defined below is largely limited to 24 hour average $PM_{10}$ concentrations. Preventative action takes priority over any of the strategies below.

| Index | Air Quality Status | Action Description |
|---|---|---|
| 0-25 | N/A | Air quality is classified **Good**. |
| 26-40 | N/A | Air quality is classified **Fair**. |
| 41-50 | Notice | Air quality is classified **Marginal**. If it is the home heating season and the forecasted dispersion meteorology is poor, BC Environment will issue an Air Quality Notice to local news media. This Notice will advise that air quality has deteriorated to the point where any further significant degradation in air quality will result in Air Quality Alert status. Residents will be reminded to ensure that they are employing good wood burning techniques if heating with wood and to be prepared for any subsequent burning ban request or requirement. A recreational wood burning ban will be requested.<br><br>In addition, the Regional Waste Manager may suspend the exemption from the requirement to hold a permit or approval provision of the Open Burning Smoke Control Regulation (BC Regulation 145/93, Section 2) under the Authority of a Manager Section (4) of this regulation. Under the same provision, the Manager may require that burning debris be extinguished. These actions will be in effect until air quality returns or is forecast to return to the Good category and shall apply to all source areas of the valley that can impact on the community. |
| 51-100 | **STAGE 1 ALERT** | Air quality is classified **Poor**; Air Quality Alert sent out to local news media. If it is the home heating season, and the forecasted dispersion meteorology is poor, BC Environment will request that all wood burning for home heating be suspended. The exception to this request will be those who have stoves and fireplaces which are certified to meet CSA or US EPA emission standards[5] or those who have no alternative heat source[*]. People with reactive lung diseases such as asthma should be aware that strenuous activity could trigger breathing problems. |
| 101-150 | **STAGE 2 ALERT** | Air quality is classified **Very Poor**; Air Quality Alert sent out to local news media. If it is the home heating season and the forecasted dispersion meteorology is poor, the public will be requested to stop all wood burning. The only exception to this request will be those who have no alternative heat source[*]. In addition, BC Environment will ensure that all permitted sources of particulate emissions are in compliance with their Waste Management Permits. People who have lung diseases such as asthma or bronchitis could experience a worsening of symptoms and may wish to consult a physician |
| 151+ | **STAGE 3 ALERT** | Air quality is classified **Very Poor**. The Regional Waste Manager will assess the situation and, if warranted, issue a Pollution Abatement Order to reduce $PM_{10}$ loading in the airshed. |

[*]In a survey of residential wood stove users, Lloyd and Wilkes (1990) found that 99.8% of Smithers residents have back-up heat sources. For rural residents, this figure is 90%.

[5]These standards are defined in the glossary (see Canadian Emission Standard and US Emission Standard).

Air quality status will be considered to apply valley-wide when similar. For example, with an air quality index of 55 in Smithers and 75 in Houston (both Poor), a Stage 1 Alert for the entire upper-Bulkley Valley will be issued. Where air quality status differs between the two communities, the lower of the two shall be in effect valley-wide, excepting the community in question. For example, with an air quality index of 109 (Very Poor) in Smithers and 75 (Poor) in Houston, a Stage 1 Alert would be in effect for the upper-Bulkley Valley (including Houston) and a Stage 2 Alert would be in effect for Smithers (only).

On a continuous basis between November and March[6], BC Environment will maintain an air quality index, updated daily, available to the public on local telephone answering machines in Smithers (847.7679) and in Houston (845.3269). In addition, when air quality deteriorates to poor or worse, BC Environment will issue air quality alerts to the local news media (summarised in Table 5) and update the answering machines at least twice daily. If a Stage 3 Alert is declared, the Regional Environmental Protection Manager may act to eliminate any or all emissions regulated by the Waste Management Act until air quality improves significantly.

Air pollution indices will be issued during the rest of the year on an incident-basis. For example, if September broadcast burning activity indicates potential environmental impacts, BC Environment will act in accordance with the procedures outlined in this section.

Much of this air quality management work is new to the province. Draft air pollution indices have been proposed by the province for the 1 hour $PM_{10}$ concentration; 24 hour indices have recently been set by Air Resources Branch; indices for annual time scale have been left to individual regions. The City of Cranbrook advises residents with alternate heating devices to cease operation of wood burning stoves and fireplaces at 25 $\mu g\ m^{-3}$ (Mignacca, 1994).

Outside the province, initiatives tend to be older (based on previous environmental impact literature protection criteria). The Puget Sound Air Pollution Control Agency (PSAPCA)

declares a first stage impairment when $PM_{10}$ concentrations exceed 75 $\mu g\ m^{-3}$. A second stage impairment is declared when concentrations exceed 105 $\mu g\ m^{-3}$. During a first stage impairment, burning is prohibited in any solid fuel burning device (other than certified or pellet stoves) in residences or commercial establishments with an alternate, adequate source of heat. During a second stage impairment, burning is prohibited in any solid fuel burning device in residences or commercial establishments with an alternate, adequate source of heat. (Maykut and Fry, 1993).

Missoula, Montana, USA designates the Good/Marginal air quality threshold at 50 $\mu g\ m^{-3}$, the Marginal/Poor threshold at 75 $\mu g\ m^{-3}$, the Poor/Stage 1 Alert at 100 $\mu g\ m^{-3}$, and the Stage 1 Alert/Stage 2 Warning at 150 $\mu g\ m^{-3}$. During a Stage 1 Alert only those with valid burning permits are allowed to heat their homes with wood. During a Stage 2 Warning only those with a Sole Source of Heat Permit are allowed to burn.

50 $\mu g\ m^{-3}$ is the 24 hour standard used by the California Air Resources Board.

## *Air Quality Environmental Protection Criteria*

The above text describes the context of particulate-related air quality and BC Environment's monitoring programme and response to various air quality levels. There are criteria that can be used to examine air quality over a longer time period. Such examination should result in an overall characterisation of airshed air quality and could be used as an indicator of BC Environment's success or failure in managing pollution-causing emissions.

BC Environment will assess Bulkley Airshed air quality on an annual basis using the pollutants and criteria listed in Table 6. This assessment will be made public in the form of statistical summaries and, ultimately, a State of the Atmospheric Environment Report. It is the long term objective of BC Environment to ensure that the environmental protection criteria defined in Table 6 are attained for the Bulkley Airshed.

[6]The initial plan (Johnson, 1992) also called for October and April. Experience has indicated that daily updates are generally not required during these months.

**Table 6: Bulkley Valley Air Quality Management Plan: Pollutants and Environmental Protection Criteria.**

The criteria are based on existing Ministry of Environment environmental protection criteria (presented above). They afford greater environmental protection to those exceedance frequency objectives outlined in Ministry of Environment (1986) and previously adopted in Johnson (1992). The NAPS schedule consists of a 24 hour sample acquired approximately every six days. The TSP and Dustfall objectives are redundant with respect to BC Environment's current monitoring programme. They are retained, however, in case of any future monitoring initiative by government or industry.

| Pollutant | Averaging/ Sampling Period | Environmental Protection Criteria |
|---|---|---|
| $PM_{10}$ | 24 Hr. Continuous (maximum daily) and NAPS (midnight) | 50 $\mu g\ m^{-3}$ (Level A) never to be exceeded. |
| | Annual | 20 $\mu g\ m^{-3}$ (Level A) never to be exceeded. |
| TSP | 24 Hour NAPS | 150 $\mu g\ m^{-3}$ (Level A) never to be exceeded. |
| Dustfall | One Month Continuous | 1.75 mg $dm^{-2}$ $day^{-1}$ (Level A) never to be exceeded. |

Note that one hour average $PM_{10}$ concentrations are not used in the environmental protection criteria with respect to annual air quality assessments of the Bulkley Valley Airshed. It was felt that the dearth of scientific research into environmental impacts (human health) of such short term exposures does not warrant its inclusion at this time.

Inherent in the definition of an air quality management plan is reference to air quality issues that are indeed manageable. For example, particulate emissions from a volcanic eruption or lightning strike-induced forest fire are not manageable in the sense that wood stove, beehive burners, and slash burn emissions are. Therefore, any violations of the assessment criteria in Table 6 that are clearly not related to human pollution events will not count as a criteria violation, where such assessments are possible (such qualification is most amenable with respect to episode management, as opposed to an annual assessment). However, such incidents can cause poor air quality and they will be labelled as such during their occurrence (i.e., as per the criteria outlined in Table 4 and Table 5).

## *Limitations*

A number of potential pollutants are not addressed in this Air Quality Management Plan. This is largely a result of a lack of monitoring capability and/or a lack of any clearly established environmental protection criteria. BC Environment (Victoria and Skeena Region) is working to address some of these issues. These potential pollutants are listed in Table 7.

**Table 7: Potential Pollutants Not Addressed in the Bulkley Valley Air Quality Management Plan.**

| Pollutant/Issue | Potential Sources | Why Excluded From Smithers Air Quality Management Plan |
|---|---|---|
| CO (Carbon Monoxide) | Biomass (wood) burning; automobile exhaust. | No monitoring programme. |
| CHCO (Formaldehyde) | Pannelboard Plant. | No monitoring programme. |
| $NO_x$ (Nitrogen Oxides) | Biomass (wood) burning; automobile exhaust. | No monitoring programme. |
| PAH (Polynuclear Aromatic Hydrocarbons) | Biomass (wood) burning; automobile exhaust. | Very complex issue with respect to risk assessment. Few environmental standards established. (Some historical monitoring exists). |
| Hourly $PM_{10}$ (Inhalable Particulate Matter) | Biomass (wood) burning; automobile exhaust. | Lack of scientific research into environmental impacts of such short term exposures. |
| Visibility | Aeolian (wind blown) dust; biomass (wood) burning; automobile exhaust. | No federal or provincial standards. Human health impacts are a much higher priority. |

It should be noted, however, that many of the pollutants listed in Table 7 are highly correlated with particulate emissions in the context of biomass (wood) burning. That is, the same processes that promote excessive emission of inhalable particulates (incomplete combustion) also promote the formation of (e.g.,) carbon monoxide and polynuclear aromatic hydrocarbons. Therefore, if communities are successful in limiting $PM_{10}$ emissions such that inhalable particulate-related air quality is good, then there should also be a significant improvement in (e.g.,) carbon monoxide and PAH air quality.

Perhaps the most significant limitation in the plan is the voluntary nature of the wood burning stove and fireplace burning ban requests. BC Environment simply does not have the legislative mandate to regulate these appliances in this context: hence the voluntary nature of the requests. This restriction places a very important emphasis on the educational aspect of good wood burning. It is hoped that the media advisories and public forums and presentations will continue to keep this issue at the forefront of environmental issues in the Bulkley Valley. It should be noted, however, that local government can regulate wood burning stove emissions and BC Environment is willing to assist any such initiative by any community in the Bulkley Valley .

# *Conclusions*

It is the Environmental Protection Programme's goal, with the assistance and co-operation of local government and the residents of the Bulkley Valley, to meet the provincial Level A environmental protection criteria for the Bulkley airshed. BC Environment has developed this Air Quality Management Plan for inhalable particulates to meet this goal. A co-operative venture with the Atmospheric Environment Service of Environment Canada and the British Columbia Lung Association has been arranged to monitor inhalable particulate in Smithers on a continuous basis with a real-time monitor. In Houston, BC Environment has also established such a monitoring station. New Hazelton has a discontinuous, non-real time, bulk sampler.

The real time continuous analysers allow BC Environment to assess and inform the public of air quality episodes and trends as they occur. BC Environment has also developed criteria by which Bulkley Valley air quality can be assessed on an annual basis for the communities of Houston, Smithers, and New Hazelton. It is anticipated that this Air Management Plan will facilitate cleaner air for all residents of the Bulkley Airshed.

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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.

**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. Production is favoured by an oxygen-deficient flame.

**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 at concentrations that substantially alter or impair the usefulness of the environment (as defined in the BC *Waste Management Act*).

**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.

**SEAM**
System for Environmental Assessment and Management, a BC Environment data base.

**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.

**μg $m^{-3}$ 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.