Every breath you take...

Provincial Health Officer's Annual Report 2003

Air Quality in British Columbia, a Public Health Perspective

British Columbia
Ministry of Health Services
Office of the
Provincial Health Officer

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Air Quality in British Columbia, A Public Health Perspective

BRITISH COLUMBIA

Ministry of Health Services
Office of the Provincial
Health Officer

Ministry of Health Services

Victoria, BC

December 9, 2004

The Honourable Colin Hansen

Minister of Health Services

Sir:

I have the honour of submitting the Provincial Health Officer's Annual Report for 2003.

P.R.W. Kendall, MBBS, MSc, FRCPC

Provincial Health Officer

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Highlights

By Canadian and world standards, British Columbians enjoy good air quality. Compared with people in more populated and industrialized parts of the world, most British Columbians are exposed to lower concentrations of air pollutants.

The major sources of outdoor air pollutants are from the burning of fuels such as gas, oil, coal, and wood for generating energy or heating; emissions from cars, trucks, and other motor vehicles and machinery; emissions from industrial manufacturing and processing plants; and the emissions from burning of agricultural and forestry materials. Major indoor pollutants include: second-hand smoke (also known as environmental tobacco smoke), volatile organic compounds, radon, and bioaerosols such as mold and spores.

From a health perspective, significant outdoor pollutants are particulate matter (PM) and gaseous air pollutants including ozone, nitrogen oxides, sulphur dioxide, and carbon monoxide. Particulate matter has been conventionally classified into two sizes: PM_{10} (≤ 10 µm) and $PM_{2.5}$ (≤ 2.5 µm). Due to its finer particles, $PM_{2.5}$ tends to be deeply inhaled into the lungs, and can cause health effects in the part of the lung where respiration takes place. Numerous studies have shown a consistent relationship between $PM_{2.5}$ and deaths or hospitalizations from cardiac and respiratory diseases such as asthma, bronchitis, and emphysema.

Ozone is produced in the atmosphere by the chemical reaction of other air pollutants. Ozone reduces lung function by damaging the cells that line the airspaces in the lungs and thus exacerbating health problems such as asthma, bronchitis, coughing, and chest pain. Other gaseous air pollutants such as sulphur dioxide and nitrogen oxides can produce effects similar to those described for ozone.

Air pollution and air pollutants are not distributed equally or evenly across BC. Some parts of the province, such as the Interior, North and the Lower Fraser Valley, experience higher exposure to pollutants relative to others although contrary to popular belief, residents of the Lower Fraser Valley are not living in a highly polluted airshed, and it is in fact the Interior and Northern regions that experience worse air quality. Particulate pollution is more of an issue in the North and Interior, where industrial and domestic sources predominate. Transportation sources are greater contributors to air pollution in the Lower Mainland. The most recent data do not show any clear differences in ozone concentrations inside and outside the Lower Mainland. It should be noted that significant "natural" sources of particulate matter and ozone also exist within BC and periodically contribute to levels at which adverse health effects might be anticipated.

No comprehensive studies of the adverse health effects of air pollution in BC have been carried out. In this report we have reviewed BC studies that looked at the health impacts of PM, Ontario studies of air pollution, and international data. From this review, we have extrapolated an approximation of the burden of ill health from air pollution in BC.

We have conservatively estimated that the premature death toll from air pollution in BC is between approximately 140 and 400 deaths per year, of which approximately half are due to outdoor air pollution, and the other half due to indoor air pollution. The largest single contributor to deaths from indoor air pollution is second-hand smoke. In addition, but not included in this count, would be the estimated 100 lung cancer deaths attributable to radon exposures (Bigham & Copes, unpublished, n.d.). We have also estimated that between 700 and 2,000 hospital admissions and 900 and 2,700 emergency room visits may occur annually due to air pollution.

A very imprecise (but conservative) estimate of the annual health care costs of air pollution is approximately $167 million. A modest 10 per cent reduction in these costs, amounting to $16.7 million, would be sufficient to pay for a cervical cancer screening program or 40 per cent of BC's immunization budget.

Over the years, governments at all levels have engaged in activities to protect public health and the environment. The federal government's role has encompassed Canadian interests in international negotiations, cooperation with provincial and territorial governments, and legislative authority. Internationally, the federal government has engaged in multilateral agreements such as the Kyoto Protocol on climate change and the World Commission on the Environment and Development.

In British Columbia, the *Environmental Management Act* (EMA) was implemented in July 2004. The EMA gives the British Columbia government overall responsibility for waste management and air emissions, as well as providing the legislation for air quality-related regulations including industrial point sources, mobile sources, and area sources.

Airshed plans are in place or near completion in a number of BC communities, including the Greater Vancouver Regional District, Fraser Valley Regional District, City of Prince George, Resort Community of Whistler, City of Quesnel, and Bulkley Valley-Lakes District.

In addition to regulating air pollution sources and supporting airshed planning, the BC Government also provides tax incentives to encourage the use of alternative fuels and alternative fuel vehicles. The *Social Services Act* provides tax concessions for alternative fuel vehicles while the *Motor Fuel Tax Act* provides exemptions and preferential tax rates for alternative fuels that are environmentally preferable to gasoline or diesel, such as ethanol, natural gas, propane, and high-level alcohol blends. A new exemption was created for a diesel alternative fuel in 2001.

Under the *Motor Vehicle Act*, the first mandatory vehicle inspection and maintenance program for light-duty vehicles in Canada (AirCare) was instituted in 1992. An independent review conducted in 1994 concluded that AirCare was the single largest contributor to improved air quality in the Lower Mainland. It is important to note that this review was based on estimated reduction in mass emissions. The trend data from areas with heavy traffic, which may provide stronger evidence for an effect, was not available at the time of publication of this report.

Under the province's *Environmental Assessment Act,* certain large-scale project proposals are required to undergo an environmental assessment and obtain an environmental assessment certificate before proceeding with development. The Environmental Assessment Office (EAO) is a provincial agency that coordinates assessment of such proposals in British Columbia. The site of a project may have a significant impact on the dispersion of emissions and resultant ambient concentrations of pollutants. The EAO relies on the appropriate ministry to provide advice on the need for dispersion modelling and the acceptability of predicted air quality impacts. Requirements for pre- and post-ambient monitoring of air quality are generally stipulated as a condition of the Ministry of Water, Land and Air Protection's permit to determine whether significant deterioration is occurring. Usually, there is an ability through the permit to reduce emission sources if unacceptable deterioration is occurring.

Municipal and regional governments have the authority to pass by-laws that may restrict certain emission-causing activities in their jurisdictions, such as backyard burning and residential wood combustion. Local authorities can also influence type and location of emission sources and their future growth through zoning, transportation and land-use planning, regional growth strategies, and sustainability plans.

In 2004, it has become clear that the interventions whose impact will result in the greatest decrease in air pollution must involve greater engagement of the public. There are some areas where actions will result in a significant, short-term beneficial impact on air quality (both outdoor and indoor). These include: eliminating indoor tobacco smoke from all buildings, reducing wood smoke from domestic and industrial burning, upgrading ventilation in buildings with substandard ventilation, and controling moisture to decrease indoor mold growth. For longer-term impact, attention needs to be focused on further reduction in industrial and commercial emissions, use of cleaner energy, and a focus on emissions associated with transportation including marine and, diesel as well as the number and emissions of light-duty vehicles on the road.

Given our current dependence upon resource-based industries and our personal use of fossil fuels for heat and transportation, British Columbians are faced with trade-offs between economic benefits and health/quality of life issues. These can only be resolved over time and through dialogue.

For residents of the Lower Mainland, while it may be relatively easy to focus on a potential point source like the proposed Sumas 2 project, a far greater challenge to air quality improvements lies in the energy use and emissions that will inevitably be associated with the planned doubling of the region's population base.

Reducing the burden of ill health secondary to air pollution in BC requires action in five priority areas:

- Reducing exposures to second-hand smoke across the province;
- Reducing exposures to $PM_{2.5}$ in the Interior and Northern regions;
- Reducing Aboriginal people's exposure to particulates, molds, and second-hand smoke, particularly in reserve communities;
- Reducing exposures to transportation-related pollution in the Lower Fraser Valley;
- Providing public education programs on what individuals can do to improve air quality for themselves and for future generations.

Reducing exposure to gaseous pollutants and particulate matter is desirable. Accomplishing this task however, requires identifying and agreeing on target levels of ambient pollutants and taking action to meet them. The relationship between tonnage of emissions and ambient levels of pollutants is not simple and care must be taken so that emission reduction measures will actually result in reduced concentrations of pollutants in the air people breathe. In some communities, ambient pollutants may not be that different from background concentrations and maintenance of existing air quality may be more of a realistic goal.

It is important to note that we have a collective responsibility to engage and participate in efforts to reduce the negative effects of air pollution on our own health and the health of others around us. From a public health perspective, we should be focusing our attention on educating the public on the sources of air pollution and their associated health impacts, stimulating public support for regulatory changes that affect air quality, and encouraging individuals to make small but positive changes in their day-to-day activities.

Provincial Health Officer's Reports

Since 1993, the Provincial Health Officer has been required by the Health Act to report annually to British Columbians on their health status and on the need for policies and programs that will improve their health. Some of the reports produced to date have given a broad overview of health status, while others have focused on particular topics such as drinking water quality, immunization, injection drug use, Aboriginal health, injury prevention, and school health. Provincial Health Officer's reports are one means for reporting on progress toward the provincial health goals, which were adopted by the province in 1997.

Copies of the Provincial Health Officer's reports are available free of charge from the Office of the Provincial Health Officer by calling (250) 952-1330 or electronically (in a PDF file) from: http://www.healthservices.gov.bc.ca/pho/

Chapter 1: The Air We Breathe

Air is one of the critical requirements for human life; without air, we can only survive for a few minutes. The composition and quality of air may be affected by the presence of harmful gases, particles or biological agents in high enough concentrations to affect human health. Poor air quality can lead to a greater prevalence of illness, increased absenteeism in the workforce, or reduced enjoyment of the environment.

Air quality can have individual impacts such as being exposed to tobacco smoke or other toxic chemicals at work; local or community impacts, such as living downwind from a refinery or beside a busy highway; or global impacts, such as the long-distance transportation of air pollutants across a continent or from one continent to another. This report outlines the relationship between air quality and human health, with an emphasis on issues and actions of special concern to British Columbians.

The term *atmosphere* refers to the envelope of gases that surround the Earth. It is mainly comprised of nitrogen and oxygen, with small amounts of other gases, including water vapor and carbon dioxide. The concentrations of these gases become thinner the further one is from the Earth's surface, and the concentrations required to support most life are found only near the surface.

Variations in the composition of the Earth's atmosphere began with the geological and physical origins of our planet. Natural processes such as volcanic activity, wind erosion, dust storms, chemical reactions in the atmosphere, and forest fires continue to affect the composition of the atmosphere. For example, compared to other years, 1992 had the coldest month of July. This was precipitated by the eruption of Mount Pinatubo in the Philippines, which spewed 20 to 30 million tons of sunlight-deflecting dust into the atmosphere (Strauss, 2004, August 18).

The emergence of vegetative and animal species has also influenced atmospheric change. Over the past two centuries, human activity such as widespread forestry burning has helped to change the composition of the atmosphere by releasing greater proportions of some of the naturally-occurring gases and chemicals, as well as new ones, into the atmosphere.

Air pollution due to human activity dates from the first use of fire (Hong, Candelone, Turetta, & Boutropn, 1996). The widespread clearing and burning of vast forests has affected the natural balance between oxygen, nitrogen, and carbon dioxide in the atmosphere, and has resulted in a reduction in the variety of biological species either through toxicity or by removal of delicate ecosystems. In addition, industrialization and the resulting increase in airborne emissions have compounded the threat to our ecosystem. While much of the immediate impact is local, there are also long-term effects due to long-range spread of pollutants by air currents, and their eventual deposition and accumulation around the world.

Some factors that impact air quality are anthropogenic. Examples include the linkage of traces of lead found in

Table 1.1 Common Air Pollutants – Typical Levels in "Clean" and "Polluted" Air

Pollutant	"Clean Air"	"Polluted Air"	Sources
Sulphur dioxide (SO_2)	*1-10*	*20-200*	*Power generation; smelting*
Carbon Monoxide (CO)	*120*	*1,000-10,000*	*Internal combustion engines; cars*
Nitrogen oxide (NO)	*0.01-0.05*	*50-750*	*Combustion processes*
Nitrogen dioxide (NO_2)	*0.4-9.4*	*50-250*	*Combustion processes*
Ozone (O_3)	*20-80*	*100-500*	*Secondary atmospheric reactions of precursor Nitrogen oxide (NOx) and hydrocarbons*
Nitric acid (HNO_3)	*0.02-0.3*	*3-50*	*Atmospheric reactions of NO_X*
Ammonia (NH_3)	*1*	*10-25*	*Natural processes; agriculture*
Total suspended particulates (TSP)	*20*	*60-200*	*Soil; forest fires*
Particulate matter less than 10 microns (PM_{10})	*20*	*60-200*	*Combustion processes; industrial processes*
Particulate matter less than 2.5 microns ($PM_{2.5}$)	*5*	*50-200*	*Combustion processes; secondary chemical reactions in the atmosphere*

Source: Adapted from A Citizen's Guide to Air Pollution, by D.V. Bates and R.B. Caton, 2002, Vancouver: David Suzuki Foundation.

Note: Units are parts per billion (ppb) for gases, and micrograms per cubic meter ($\mu g/m^3$) for TSP, PM_{10} and $PM_{2.5}$. Approximate orders of magnitude for illustrative purposes only.

Greenland ice to atmospheric pollution two thousand years ago, mostly attributed to Roman smelting in the Rio Tinto region of Spain (Rosman, 1998). Lead levels of that era were about four times the natural level. This illustrates the long distance that air pollutants can travel and their persistence in the environment. Legislation and policies ending the use of lead additives in gasoline have resulted in recent reductions in lead emissions in ice core measurements (Delmas & Legrand, 1998).

Clearly, air pollution has an impact on human health. The World Health Organization (Fact Sheet No. 187, 2000) estimates that three million people die each year due to air pollution, and many others become ill from asthma, chronic bronchitis, circulatory disorders, and other conditions.

What is Air Pollution?

Air pollution is defined as the state of atmosphere where substances are present at concentrations that harm humans or other life forms. Air pollutants therefore are not necessarily foreign substances but are often substances that are naturally found in the atmosphere. A "clean" atmosphere may contain the same pollutants as a "polluted" atmosphere; however, the concentrations of the pollutants in the "clean" atmosphere may be so low that they do not cause undesirable effects (Bates & Caton, 2002).

Table 1.1 illustrates the most common air pollutants and their typical concentrations in "clean" and "polluted" air, as well as their major sources, where "clean" and "polluted" references are for comparison purposes only.

Awareness of Air Pollution in the Past

The role of the environment in health has been recognized since ancient times. The Greek physician Hippocrates (circa 400 BC) wrote about air pollution in his treatise on Airs, Waters, Places (Hippocrates, trans.). The Egyptian, Ibn Ridwan, wrote about the adverse effects of the urban environment in the city of Cairo at the turn of the first millennium (White, 2001). The European scholars Agricola (1494-1555) documented the health hazards of mining and smelting in his treatise De Re Metallica (White, 1994). His contemporary, Paracelsus (1493-1541), became recognized as the founder of the modern science of toxicology with his dictum "everything is toxic, depending on the dose", which became an important principle underlying the concept of the "exposure-response curve" (Murphy, 1986). Diarist John Evelyn alerted the English-speaking world to air quality issues in London, England, with his 1661 submission to King Charles II and parliament: Fumifugium: the Inconvenience of the Aer and Smoake of London Dissipated (Bates & Caton, 2002). In 1713, in Italy, Ramazzini published his treatise De Morbis Artificum, on air quality and other hazards faced by workers, revealing the importance of occupational health and indoor air quality (Wright, 1964).

Global Climate Change – Greenhouse Gases and Chlorofluorocarbons

Some of the natural forces and human activities that affect atmospheric composition and local air quality also affect the global climate, with direct and indirect impacts on human health. In 2001, the United Nations Intergovernmental Panel on Climate Change concluded that most of the increase in temperature of the past 50 years was due to human activities – primarily land clearing and burning of fossil fuels – that release greenhouse gases into the atmosphere.

The term *greenhouse gases* (GHGs) refers to a group of gases that trap heat in the atmosphere and thus affect the temperature of the Earth. The main GHGs include carbon dioxide released by burning fossil fuels, methane from digestion or decomposition of vegetation, nitrous oxide, and a mixture of chlorofluorocarbons (CFCs), perflurocarbons (PFCs), sulphur hexafluoride (SF), and other gases (United States Department of Energy, 2003). While GHGs and the greenhouse effect are essential to life on Earth, an increase in the concentration of GHGs in the atmosphere, due to human activity and the warming of the global atmosphere, are reasons for concern.

An important group of anthropogenic chemicals are the chlorofluorocarbons (CFCs), which are largely responsible for depletion of the ozone layer. The Earth's stratospheric ozone layer protects humans from solar radiation, including ultraviolet-B (UV-B) radiation. The most important factor affecting the level of UV-B exposure is the amount of ozone in the atmosphere. For every one per cent reduction in stratospheric ozone concentration, there can be up to a two per cent increase in UV-B radiation (Scotto, 1996). CFCs were used for decades as propellants in spray cans and as freon gas in refrigerators and air conditioners until a Canadian-led global suspension of their manufacture and use in 1987. A global increase in the incidence of skin cancers has been attributed in part to the use of CFCs, which deplete the ozone layer and thereby increase the intensity of UV-B exposure.

Atmospheric warming affects other parts of the climate system, including precipitation, air, wind, ocean currents, and the water cycle. Climate change in turn affects other closely related physical systems, biological systems, and the human communities that depend on these systems. For example, atmospheric warming can contribute to an earlier spring snowmelt, increased spring flooding on many rivers, and a corresponding decrease in summer flows.

According to BC's Ministry of Water, Land and Air Protection, average annual temperatures in BC increased by 0.6 degrees C at the Coast, 1.1 degrees C in the Interior, and 1.7 degrees C in the North during the 20th century (Figure 1.1). It is estimated that by the end of the 21st century, British Columbia could expect average annual

The Impact of Industrialization

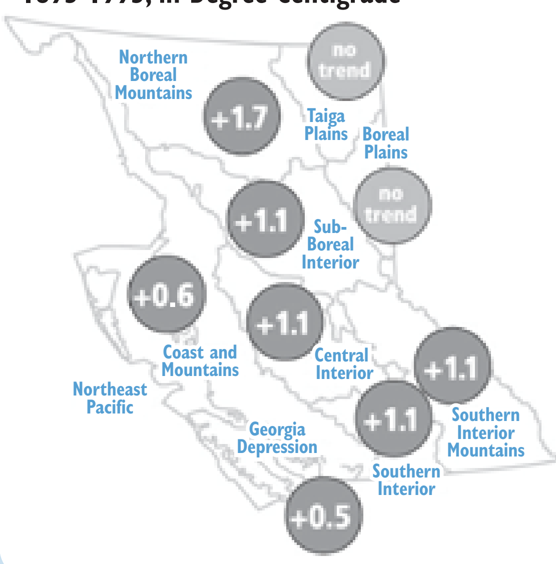
Industrialization over the past two centuries led to the establishment of a large number of "smokestack industries", first in Western Europe, then in North America, and now around the world. Air pollution disasters in the mid 20th century (1930 - Meuse Valley, Belgium; 1948 - Donora, Pennsylvania; and 1952 - London, England), in which multitudes perished within days from the acute effects of intense smog, drew attention to the serious effects of air pollution, and provoked the introduction of clean air legislation, first in the United Kingdom (1956), then in the United States (1970), and other countries (Bates & Caton, 2002). In 1967, British Columbia introduced the Pollution Control Act, which provided the first piece of provincial legislation to control pollution in BC. The Act further delegated the authority for air quality management to the Greater Vancouver Regional District.

However, despite these efforts, severe air pollution still occurs in a number of major cities in developing countries, such as in Kathmandu, Shanghai, Sao Paulo, and Mexico City. A global threat is emerging from accumulating emissions.

temperatures to increase by another 2 to 7 degrees C, with northern BC experiencing relatively warmer temperatures than the rest of the province.

Warmer temperatures and changes in precipitation have the potential to adversely affect human health.

FIGURE 1.1 **Average Air Temperature Change from 1895-1995, in Degree Centigrade**



Source: B.C. Ministry of Water, Land and Air Protection. Data from Environment Canada. Analysis by Canadian Institute for Climate Studies, 2001. http://wlapwww.gov.bc.ca/soerpt/pdf/ET2002Oct221.pdf

For example, summer heat waves will likely occur more frequently, leading to an increase in heat-related deaths and hospitalizations. More frequent flooding events may strain municipal drainage and sewage systems and increase the risk of contamination, and the transmission of disease from animals to humans. Warmer temperatures may allow new disease vectors—and new diseases—to enter BC.

It is also likely that very hot days will occur more frequently in the 21st century, particularly in urban areas where buildings and pavement absorb and retain heat. Between 1951 and 1980 in Victoria, an average of three days per year were warmer than 30 degrees C. In the 21st century, this number is expected to more than quadruple, to 13 days per year. Hot days will become even more frequent in the Lower Mainland and the Interior of BC. A component of smog – ground level ozone – is linked to respiratory irritation, possible chest pain, and coughing. Although healthy individuals can experience these conditions, those with asthma and chronic lung disease are most vulnerable.

Outdoor and Indoor Air Pollution: Is There a Difference?

Although we distinguish between outdoor and indoor air pollution, most people are exposed to a mixture of outdoor and indoor pollutants in their daily lives.

Pollutants from outdoor sources can reach indoors, and can impact those who spend most of their time indoors. Some examples include those who live close to wood burning or a major traffic intersection. Similarly, although to a lesser extent, indoor pollutants can contaminate outdoor environments. For example, air conditioning exhausts from factories, subways, tunnels, and office buildings may contain gases and particles that contribute to outdoor pollution.

Outdoor Air Pollution

While an area's geography and weather conditions are important in determining air quality, the extent and composition of outdoor air pollution can be affected by human activity, social values, and economics within the area. In BC, the types of human activities, or sources, that affect local air quality include industrial point sources; transportation or mobile sources; and space heating, prescribed burning, and other smaller area sources. The relative importance of different source types will vary from community to community, and even across individual communities depending on one's proximity to these sources.

Atmospheric conditions may aggravate local situations, resulting in a build-up of pollutants. For example, temperature inversions are common in BC, often in the bottom of valleys during calm, clear nights with light winds. This makes the many valleys in BC more susceptible to periods of poor air quality.

Indoor Air Pollution

Air pollution is not only an outdoor concern, but also an indoor matter. The complex range of human activities and resulting effects generate various indoor pollutants. Due to the duration of human exposure to indoor air, pollutants may pose significant health concerns. Factors impacting air quality include inadequate ventilation and tobacco smoke. Indoor air pollution has a long history that includes cooking and heating with woodstoves, and the natural emission of radon gas in some settings, such as caves and basements. Poor indoor air quality due to a lack of proper ventilation and use of biomass fuels is a major cause of morbidity and mortality among children in developing countries (Smith, Samet, Romieu, & Bruce, 2000). Similarly, the growth of microbes or pollutants in enclosed spaces may be facilitated by failure to adequately control moisture indoors.

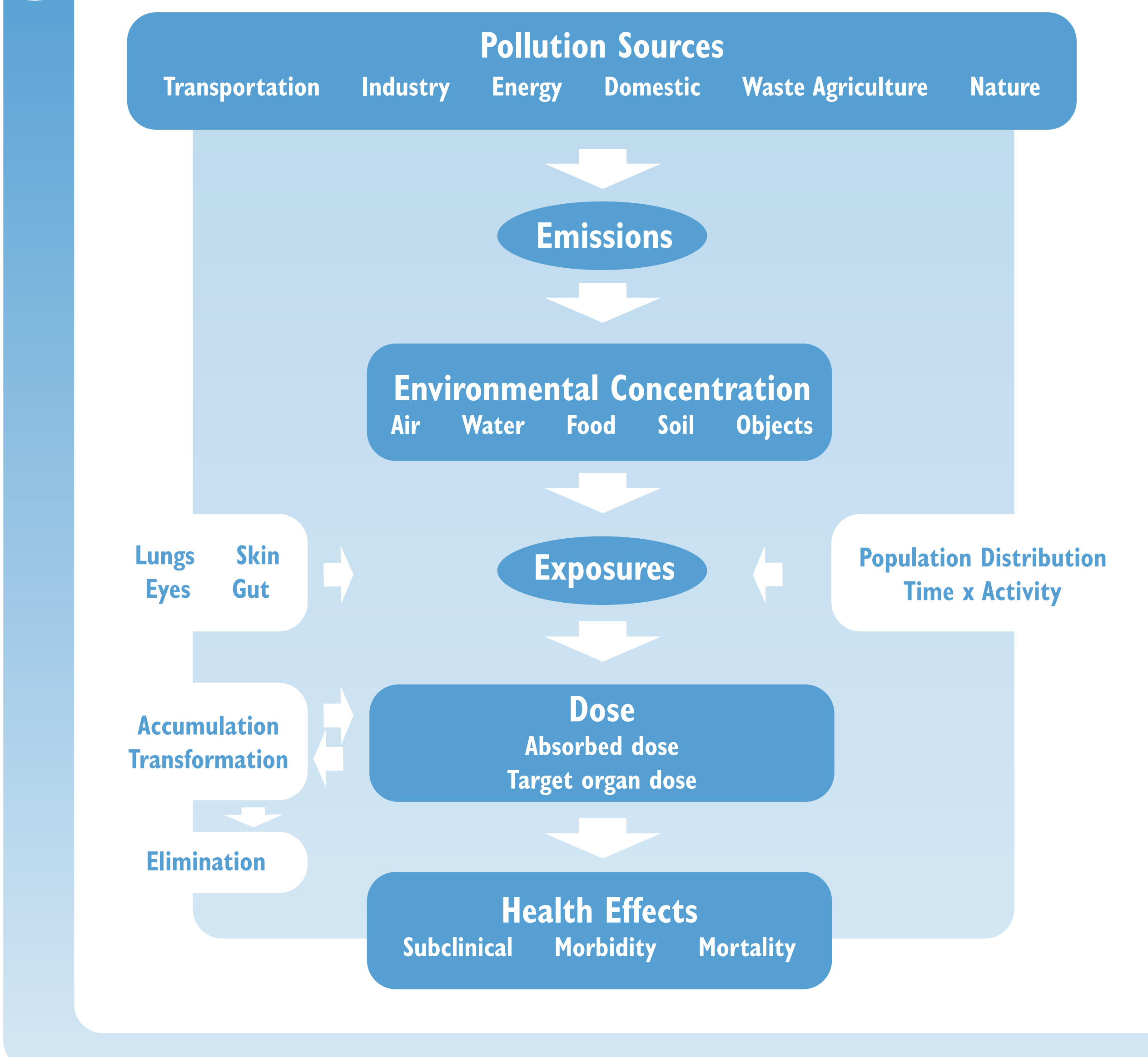
Exposures and Pathways

Exposure is defined as the time an individual spends in a setting with a specific pollutant concentration. In studying the health effects of air pollution, it is important to consider the total exposure rather than separating exposure assessment into air, food, and water components (National Research Council, 1991). In this regard, the health effects of air contaminants may be either direct (e.g., ozone) or indirect (e.g., lead in soil).

Pollutants or hazardous substances move from the environment or other source to individuals through exposure pathways. A model of toxicant sources, exposures, and pathways is presented in Figure 1.2.

It can be challenging to assess and monitor exposures to pollutants in air, food, or water and determine and attribute health effects. Assessing the potential impact of exposures from many sources (i.e., as a "toxic mixture") can be even more challenging. Many variables influence exposure to pollutants and health effects. These include the amount of hazardous materials in the air, pathways of pollution, length of time of exposure, as well as individual characteristics such as age, nutrition and other behaviours. Such complexity requires integrating research methods,

FIGURE 1.2 **Pathways of Pollution Sources**



Source: Adapted from Loomis, 1978; National Research Council, 1991; and Briggs, 2003.

including data from studies of the environment and of exposed animal and human populations, and combining these in mathematical models.

Methods of Study

Our understanding of the health effects of air pollution depends largely on the sciences of *toxicology* and *epidemiology*. Toxicology is the study of the characteristics and effects of poisons; epidemiology is "the study of the distribution and determinants of health-related states and events in specified populations and the application of this study to the control of health problems" (Last, 2001). As applied to environmental health, these disciplines study the potential harmful effects of pollutants in water, food, or air as well as exposures to toxicants in occupational or residential settings.

Epidemiology and toxicology have strengths and limitations in assessing environmental health impacts. Toxicology obtains its data mostly from experimental studies in animals and then extrapolates (based on the available data) its findings to humans under given assumptions and mathematical methods. The advantage to this is that human exposure need not have occurred, and that, with certain assumptions, *exposure-response relationships* can be modeled over relatively shorter periods of time. In contrast, epidemiology examines human populations for whom exposure has already taken place or is currently occurring, and the findings are then applied to that setting or extrapolated to other situations. Simply put, toxicology asks *could this happen*? while epidemiology asks *did it happen*? or *is it happening*? In practice, the two sciences are complementary.

Toxicological Studies

Toxicological studies use experiments with small numbers of animals or cell culture systems. These are randomized into exposure and non-exposure groups, using exposure levels much higher than normal for humans, so that a result is obtained which may then be extrapolated to humans. In interpreting animal studies, especially in terms of applicability to humans, one must examine exposure levels, route(s) of administration, absorption, metabolism, translocation, storage, and excretion of the chemical or its metabolites.

Epidemiological Studies

Epidemiological studies use research methods ranging from experimental to observational, with each method having advantages and disadvantages. The evolution of these methods is reflected by variations in terminology, standardized in recent years by the International Epidemiological Association (Last, 2001)[1].

The preferred method in clinical research is the *randomized controlled trial*, which involves randomly assigning similar individuals to treatment or non-treatment groups and examining the difference in outcomes. In the environmental context, one cannot deliberately expose people to toxic materials, with the exception of *controlled clinical studies*—also known as human inhalation studies (Utell & Frampton, 2000)—where volunteers (healthy or with pre-existing disease) submit to controlled levels of selected pollutants for short periods of time and are monitored closely for physiological effects.

In reality, human exposures to air contaminants occur in more complex ways. Consequently, environmental epidemiology depends almost entirely on observational methods, which focus on observing the effects of air pollution on people going about their normal lives in particular settings, such as communities, workplaces, or schools. These studies characterize health events in terms of time, place, and person.

One of the most common study designs in air pollution epidemiology is *time series analyses*, which involve observations of the effects of day-to-day pollution patterns on a population in a defined geographic area. Another approach measures the differences between people in different locations exposed to similar types of air pollution, taking into consideration their current state of health. These studies are relatively inexpensive, but are sometimes misleading, since the reasons for differences between individuals may not be fully examined. For

[1] *Because of varying use of terms even by epidemiologists, the International Epidemiological Association dictionary is taken in this report as correct usage.*

Higher Mortality Rates Near Busy Roads and Highways in Hamilton, Ontario

A recent study at McMaster University showed an 18 per cent increase in mortality rates of residents in Hamilton, Ontario who lived within 50 metres of a major highway or 100 metres of a city road carrying 35,000 to 75,000 vehicles daily. The majority of the increase in death rates was due to heart conditions as opposed to respiratory disorders (Strauss, 2004, August 6).

example, fluctuations in respiratory morbidity can be due to causes other than air pollution levels, such as epidemics of respiratory diseases or variations in meteorological conditions. In cross-sectional studies, area differences in morbidity correlated with air pollution patterns could also be attributed to variations in the prevalence of other risk factors such as smoking and socio-economic status, or some combination of these and air pollution. Epidemiologists must take such variables into account when interpreting data from such studies.

Prospective studies involve observation of the exposed individuals over a long period of time to see if they develop conditions such as heart attacks or chronic lung disease, taking into account residential area, pollution exposure levels, and personal habits such as smoking. Such studies are usually more costly and time-consuming since it is difficult to follow the same individuals for many years. An alternative is the *panel study*, usually involving a smaller group of individuals monitored more frequently to see if there are any changes in their health conditions (e.g., lung function, the amount of toxic material in blood or urine, etc.).

Another type of observational epidemiological study is the *case-control study*. This study identifies individuals with a particular outcome of interest, such as a disease, and compares this group with another that is similar but not affected by the outcome. The groups are compared with regard to the frequency of particular exposures. This approach is particularly useful in looking for personal or household factors such as indoor pollutants that may vary between groups. For example, this method reveals second-hand smoke as a risk factor for adult-onset asthma (Jaakkola, Piipari, Jaakkola, & Jaakkola, 2003). It is not as useful in studies of outdoor air pollution, as this type of pollution may affect all population groups in the same way with only subtle differences.

When compared with experimental design, observational studies have strengths and weaknesses. The weaknesses of these studies relate to the control of bias and accurate assessment of exposure and outcome. However, the advantage of observational over experimental method is that it is possible to study individuals in their community and measure their responses to the mixture of pollutants.

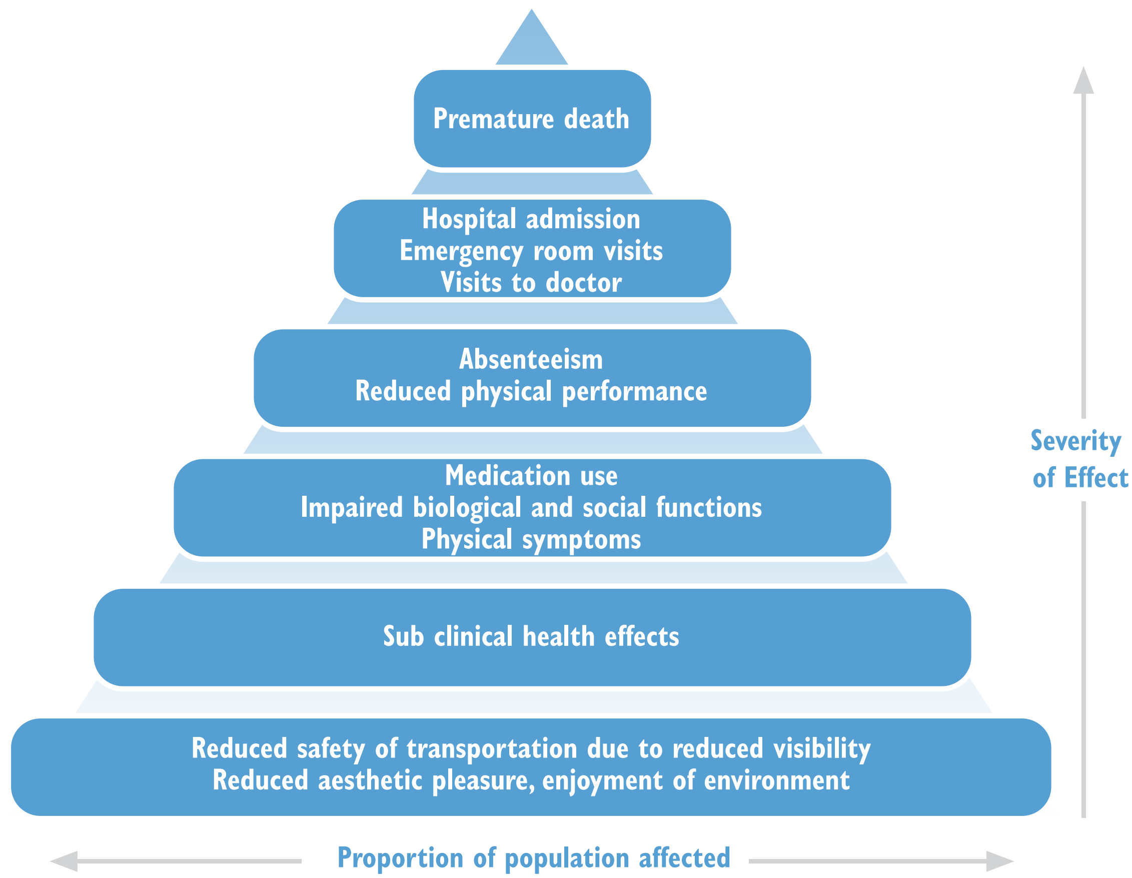
In the end, it is not one study but the combination of evidence from many studies that is used to estimate the overall impact of air pollution. Ultimately the weight of evidence allows you to draw a conclusion about the health effects of a particular type of pollution. One example of this is tobacco smoke, which has been well established as a major health hazard.

Health Impacts of Air Pollution

Overview – *"From Intuition to Evidence"*

Even before air pollution became recognized as a public health issue, there was plenty of anecdotal evidence of a link between pollution and health effects for certain occupations such as coal mining, and its effect on pulmonary functions and associated premature deaths. However, unscientific approaches can sometimes lead to incorrect conclusions. In science, it is now accepted that the best method of gaining evidence is to study a problem in a rigorous manner to establish its existence, its order of magnitude, and other characteristics. Internationally, air pollution has been extensively studied in the context of respiratory and circulatory diseases. It is now also known that an array of other adverse outcomes are associated with poor air quality, and that relevant exposures occur indoors as well as outdoors.

FIGURE 1.3 **Effects of Pollution on Health and Well-Being**



Source. Adapted from Health Effects from Air Pollution (Pyramid of Health Effects), by Health Canada, n.d., Ontario: Health Canada.

Direct Health Effects

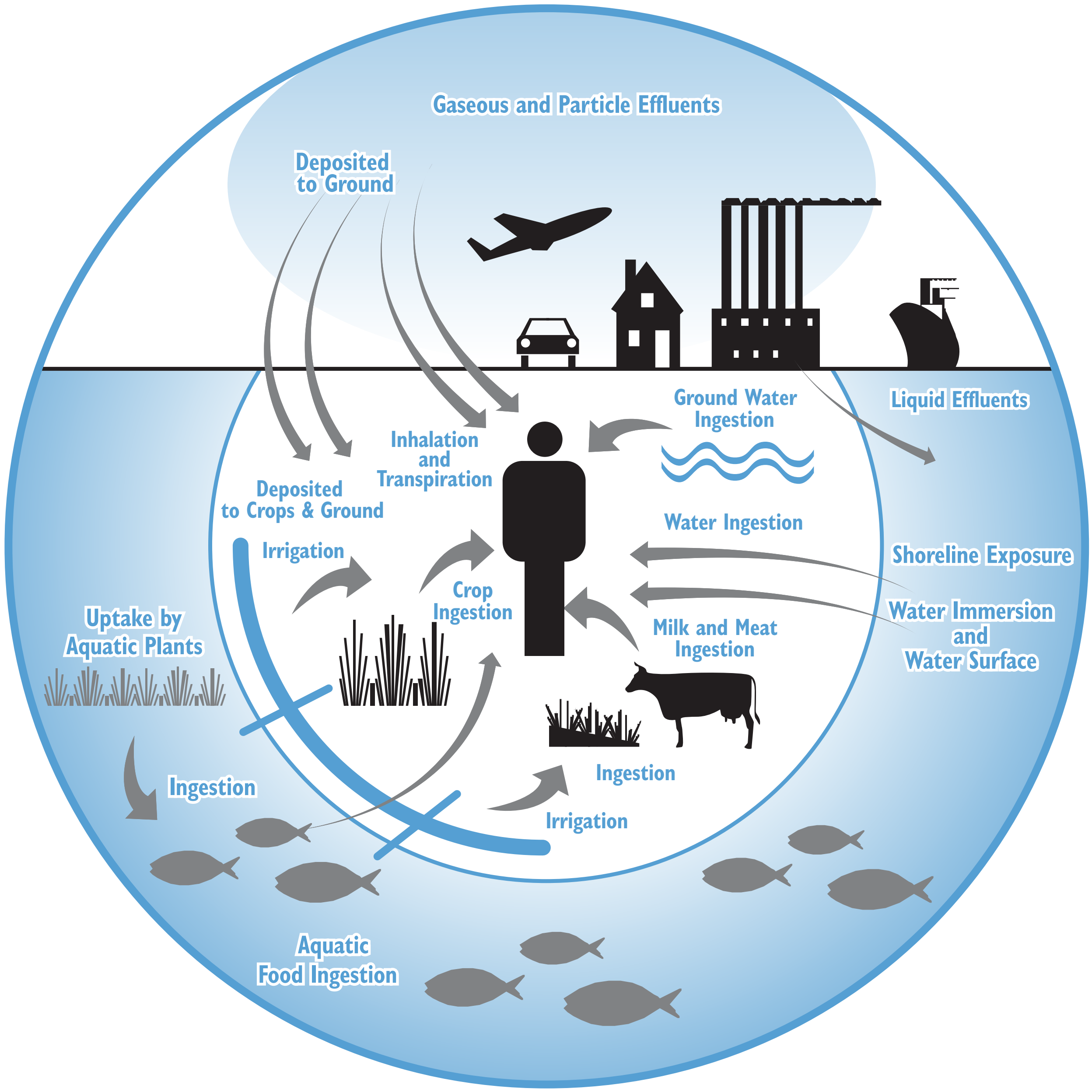
The *direct health effects* of air pollution consist mostly of respiratory and cardiovascular illness and premature death. Some contaminants also have serious indirect effects, such as heavy metals like lead, cadmium, and mercury (intellectual impairment, metabolic and blood disorders, organ damage) and pesticides (neurological impacts).

In general, the pyramid shown in Figure 1.3 illustrates the effects of pollution on the health and well-being of individuals. The most common direct health effects of air pollution are respiratory and cardiovascular illnesses; premature death can also occur. It is important to note that the pyramid also demonstrates the cascading effects of air pollution, in that the most severe effects (mortality) occur the least frequently and may only represent the tip of the iceberg. A greater burden of illness may result from less severe but more widespread effects that can also impair quality of life.

Indirect Health Effects

The relationship between air pollution and human health is complex. The impact of air quality on an individual will vary depending on the pollutant concentrations and the

FIGURE 1.4 **Multiple Environmental Pathways of Toxicant Exposure**



Source: Adapted from United States Department of Energy 1989 (as cited in *Frontiers in Assessing Human Exposures to Environmental Toxins,* by National Research Council, 1991, Washington DC: National Academy Press).

time, place, and biological and social characteristics of persons. Research on ecology and human health effects in different settings provides greater understanding of the effects of air pollution and human health and it also helps in making decisions on how to prevent or reduce these effects (Bates, Koenig, & Brauer, 2003). It is important to consider air pollution in the broader context of the ecological cycle. Through gravity or precipitation, air pollutants may ultimately contaminate soil, agricultural produce, and water supplies. This may lead to indirect health effects, such as heavy metal poisoning in children who play in contaminated soil.

In addition, air pollutants at lower latitudes reach northern food chains through a process called global distillation. This results in emissions from warmer parts of the globe condensing in cooler areas. Some volatile organic chemicals have been shown to affect arctic animal and human populations (Shindler, 1999). The pathways by which pollutants can enter the human body are shown in Figure 1.4.

Air Quality: Risks vs. Benefits

The impact of human activities on air quality goes beyond individual or personal boundaries. A good example of this principle is smoking in an enclosed space. An individual who smokes assumes the health risks. However, smoking in an enclosed space may expose others to toxic air and health risks related to second-hand smoke. As the health consequences of second-hand smoke have become scientifically documented, and after much public debate, many jurisdictions, including British Columbia, have introduced legislation against smoking in public spaces (Brigden, Peck, & Coy, 1993).

Many jurisdictions have adopted the practice of requiring impact assessments to determine potential risks, benefits, and impacts when making decisions or before moving forward with the development of projects. An important and complex question to ask is: who should decide what is an acceptable, tolerable, or a detrimental risk – or a potential benefit? Ideally, all individuals who may be subjected to a risk should have an opportunity to provide input and feedback in order to reach a fair decision that represents a broad perspective. However, in practice this is not always possible and for this reason governments at each level need to ensure that proper mechanisms are in place for an assessment and communication of potential risks, benefits, and their impacts in a timely and efficient manner.

Air quality and pollution can have trans-boundary effects at all levels, including interpersonal, interprovincial and international. In the mid-20th century, England built higher stacks for their coal-burning industry, which resulted in a shift of air pollution eastward to Europe. Similarly, building higher stacks had the same effect to the east of Sudbury, Ontario, before improved technologies such as scrubbers and electrostatic precipitators were introduced to reduce emissions at the source.

Sometimes the evaluation of risks and benefits is a function of geography. BC has prevailing winds predominantly from the west and is not immediately downwind from any major international source of air pollution (notwithstanding refinery emissions from Washington State). From the perspective of the rest of Canada, BC is usually considered upwind. For example, the highest dust-fall recorded in Canada following the eruption of Mt. St. Helens in 1980 was in Manitoba, even though the source was closer to BC.

However, at the beginning of the 21st century, British Columbia has found itself downwind of new sources of long-range pollution originating from Asia. This Asian haze is a combination of particles and gases caused by various activities, such as land degradation due to overgrazing and burning of agricultural wastes, and the rapid increase in the burning of fossil fuels which accompanies economic development. Rising nitrogen dioxide emissions in Asia are predicted to impact the west coast of North America with higher background ozone levels (Akimoto, 2003; Holloway, Fiore, & Hastings, 2003). The immediate impact is much greater in Asian countries; the long-term trend may have an impact on Canada's West Coast over the next 30 years.

Air Quality is Everybody's Business

British Columbia has committed to the goal of protecting human health and safety by ensuring clean and safe water, land, and air (Ministry of Water, Land and Air Protection [MWLAP], 2004). In British Columbia, surveillance of air quality is a primary responsibility of the Ministry of Water, Land and Air Protection. Since 1969, BC has also participated in a National Air Pollution Surveillance Network that monitors air pollutants in urban centres across Canada. Although all levels of government have some jurisdiction over the issue of air quality, as individuals, we also have responsibilities. When we make choices and take actions such as reducing the number of trips we take alone in our cars, choosing alternative transportation, or buying more fuel-efficient vehicles, we demonstrate the will to significantly improve air quality (Environment Canada, 2002).

At the 1992 United Nations Summit on Sustainable Development in Rio de Janeiro, Canada agreed to work with the global community to restore the balance between environmental sustainability and economic development for the majority of people. This agreement has required a commitment to a range of interventions around the world: education, resource and environmental planning; actions to prevent or reduce emission sources; monitoring, surveillance, standards and regulation, and evaluation. Air quality is everybody's business – and a major challenge for the 21st century. We must be prepared to think globally and to act locally.

Chapter 2: Outdoor Air Pollutants and Their Health Effects

Types of Outdoor Air Pollutants

In general, there are two types of outdoor air pollutants: criteria pollutants and non-criteria pollutants. Although each category will be addressed separately, it is important to note that air contaminants rarely fall exclusively in one category.

Criteria Pollutants

Criteria pollutants are air pollutants for which national ambient air quality criteria have been established. These include: particulate matter, sulphur dioxide, carbon monoxide, nitrogen dioxide, and ozone.

Particulate Matter

- Particulate matter (PM) refers to airborne liquid and solid particles. Primary PM is emitted directly into the atmosphere by natural and human-caused sources such as wildfires, wood stoves, agricultural burning, transportation, manufacturing, and power generation and includes pollen and spores, and road dust. Secondary PM is formed through chemical reactions involving various precursor gases such as nitrogen dioxide, sulphur dioxide, volatile organic compounds and ammonia. The term total suspended particulates (TSP) is a measurement of PM made with a high-volume sampler, and typically includes particles up to about 40 µm (micrometer) in diameter.
- Typically, suspended particles fall within two size categories (Foster, 1999). The larger size (3 to 30 microns in aerodynamic diameter) deposits in the upper airways and is mostly of natural origin; examples include pollens and geological dust. The smaller size (less than 3 microns) consists mostly of secondary sulphate and nitrate aerosols, organic carbon and elemental carbon. These can cause reduced visibility and are more hazardous to health as they are inhaled deeply and tend to deposit in the airways and tissues of the lung, where they contribute to chronic lung conditions.
- For the purpose of exposure studies and regulation, PM is assessed in two fractions: PM_{10} refers to particles 10 µm or less (about 1/8 the diameter of a hair) while $PM_{2.5}$ refers to particles 2.5µm or less. The distinction between fine ($PM_{2.5}$) and course (PM_{10}) fractions is critical, not only due to their differences in relation to health outcomes, but also because the two fractions tend to arise from different sources, which has implications for their management (for example, $PM_{2.5}$ arises mainly from industrial and combustion sources directly or indirectly, while PM_{10} tends to derive more

from crustal materials and mechanical processes such as road dust and construction) (Canadian Council of Ministers of the Environment [CCME], 2003a). New research is focusing more on the role of $PM_{2.5}$ and ultrafine particles, and on particle composition (metals and organics, combustion versus crustal-derived), as well as the interactions between PM and gaseous pollutants.

- In terms of health effects, $PM_{2.5}$ levels of 15 $\mu g/m^3$ and higher have also been associated with hospitalization and emergency room visits for both respiratory and cardiovascular diseases. A review of recent studies for the Canadian Council of Ministers of the Environment in 2003 showed positive associations between PM and respiratory mortality (CCME, 2003a). These studies strengthened the evidence that the fine fraction ($PM_{2.5}$) is more toxic than the coarse fraction. It is also important to note that the risk of health effects increases proportionally with exposure.

Sulphur Dioxide

- Sulphur, both inorganic and organic, is present everywhere in nature. Sulphur compounds enter aquatic and marine environments from the weathering of rocks and soil, from atmospheric precipitation and fallout, and through the bacterial decay process (Moss, 1994).
- The burning of fossil fuels from smelters, power plants, refineries, and internal combustion engines (including automobiles) results in a range of sulphur oxides in the atmosphere, with sulphur dioxide (SO_2) being the dominant air pollutant. In addition, the production of wood pulp produces sulphur-based contaminants such as hydrogen sulphide and SO_2 (Goyer & Lavoie, 2001). In studies of the health effects of air pollution, exposure to SO_2 is often presented together with exposure to particulate matter and acid aerosols, especially when they have common origins (e.g., burning of fossil fuels) and because many of the health effects reflect their combined actions when they mix together in air (Lambert, Samet, & Dockery, 1998).

Carbon Monoxide

- Carbon monoxide (CO) is especially associated with urban areas around the world, and is a by-product of burning fossil fuels—gasoline, natural gas, and coal—and other carbon-containing matter such as wood.
- Generally, CO levels have declined throughout North America; however, higher levels have been recorded close to roadways—particularly during peak hours at intersections in city centres. Higher CO levels have also been found in persons in close proximity to small internal combustion engines such as lawn mowers, chain saws, and snow blowers, especially in sheltered or partially enclosed areas.
- CO exposures may also derive from other sources, such as cigarette smoking. CO binds with hemoglobin, reducing the oxygen-carrying capacity of blood and thereby reducing the amount of oxygen that can be delivered to working muscles, including the heart.

Nitrogen Dioxide

- Nitrogen dioxide (NO_2) is the main pollutant of interest within a group known as the *nitrogen oxides* (NO_X). NO_2 is produced from nitrogen and oxygen during fuel combustion. Ambient NO_2 originates from combustion of coal, fuel oil, diesel, and gasoline.
- NO_2 can cause pulmonary irritation and also contributes to respiratory health effects.
- This corrosive gas is also chemically reactive. For example, when it combines with water vapor, it forms *nitric acid* (HNO_3). HNO_3 may then react with ammonia and other organic chemicals to produce secondary particles such as ammonium nitrate, which contribute to the toxicity of particulate pollution and reduced visibility.
- Another example of the reactivity of NO_2 is its ability to react with hydrocarbons in sunlight to produce the criteria pollutant ozone and other photochemical by-products.

Ozone

- Ozone (O_3) is a natural by-product of photochemical reactions in the upper atmosphere. These reactions form the ozone layer, shielding the earth's surface from the intense ultraviolet radiation from the sun.
- Although ozone also occurs naturally at lower levels, additional amounts are produced by photochemical reactions involving NO_2 and volatile organic compounds (VOCs) in the presence of sunlight. Many VOCs are natural emissions of vegetation; however, industrial processes and products also produce VOCs. As a result of the complex chemistry involved in ozone formation, the highest ozone concentrations are typically observed downwind of urban areas.
- O_3 affects the pulmonary function and high concentrations may trigger asthmatic attacks as well as increasing the risk of pneumonia in the elderly. Ozone can be toxic to lung tissue. Symptoms can include coughing and breathing difficulties particularly among people with respiratory conditions.
- Effects have been documented in infants and children (decreased lung function, school absenteeism), while persons involved in outdoor activities (e.g., hikers, field workers, joggers) show decline in lung function after exposure to elevated O_3 levels. Ozone was also recently reviewed for the Canadian Council of Ministers of the Environment (CCME, 2003b). Animal and in vitro studies (utilizing cultures from animal and human cell lines) showed tissue injury and inflammation in response to levels as low as 100 ppb. Adverse effects on lung defense (e.g., reduced clearance, immunological impacts) and on lung function tests were also documented. New studies indicate that genetic differences might play a role in toxicity in both healthy and asthmatic individuals, which could account for predisposition to harmful effects. New studies of "co-exposures" showed interactions with other chemicals (e.g., PM, NO_2, cigarette smoke) that enhance the lung toxicity of O_3. Other studies suggest effects on the central nervous system (e.g., memory) although this may be indirect and requires further research.
- In clinical studies, O_3 induces airway responsiveness to allergens, SO_2, and NO_2. While this supports the possibility of health effects and hospitalization, especially in susceptible persons (e.g., asthmatics), it may not explain the association between O_3 and mortality found in epidemiological studies (CCME, 2003b). Controlled human experimental studies have clarified patho-physiological responses to O_3 and the relevance of an *effective dose* (concentration x ventilation rate x exposure duration) to reduced lung function (CCME, 2003b). While a lower threshold has not been defined, with moderate exercise, an hour of breathing air with 60 ppb of O_3 reduces lung function (Bates et al., 2003).
- Epidemiological studies demonstrate an association between ambient O_3 levels in urban centres and mortality after adjusting for time trends, season, weather, day of the week, and other factors (CCME, 2003b). Seniors and persons with congestive heart failure appear to be more susceptible than the population as a whole. Hospital admissions and emergency room visits are consistently associated with acute respiratory disease, while association with cardiovascular admissions is less consistent (and a biologically plausible mechanism has not been established). Asthmatics are viewed as a vulnerable group as their airway responsiveness is already increased, and their lung function is lower than the normal population. While most studies do not demonstrate a threshold, the appearance of this result in three recent studies indicates the need for further research and analysis on this question, which is vitally important to impact assessment and risk management strategies.

Selected Non-Criteria Pollutants

The number of outdoor non-criteria pollutants is vast, as they include all air contaminants not considered criteria pollutants. Relatively few have been studied sufficiently to determine their health effects. Non-criteria pollutants with well-developed information on their health effects are: lead; benzene; dioxins, furans, and polychlorinated biphenyls

(PCBs); pesticides; ammonia; hydrogen sulphide; and pollens and spores. It is important to note that some of these pollutants, such as pesticides, can be grouped as either outdoor or indoor pollutants depending on their use. Others, such as spores, may be brought indoors by shoes, clothes, or through open doors or windows.

Lead

- Lead is a naturally occurring element that is found in metallic, organic, and inorganic forms. It was first introduced into gasoline as an "anti-knock" agent in 1923 and remained in use as a gas additive until the 1970s, when it was phased out due to adverse effects on pollution control devices on automobiles.
- Under pressure from medical and public health authorities, lead was phased out as a gas additive over a decade and a half ago. By 1990, it was removed entirely from gasoline in North America, although it is still in use in other parts of the world. Its removal from gasoline in North America was accompanied by a dramatic fall in blood lead levels in children throughout the continent, which stands as a major public health achievement.
- Despite this success, and the elimination of lead in paints, pottery, cooking utensils, and children's toys, some challenges still remain.[1] Air pollution with lead still occurs at point sources such as mines, primary and secondary lead smelters, and recycling facilities.
- Lead is an important commodity in world trade, and a significant export of BC, specifically from Cominco smelter in Trail. Later in this report, we will examine lead exposure of children in Trail over the years, and the dramatic impact of control measures.
- Lead interferes with red blood cell formation and diminishes cognitive development in infants and children. It also contributes to hypertension and chronic renal disease in adults.
- In the public health context, the main concern is the potential for lead exposure that would result in impaired intellectual development, especially in early childhood when brain development is critical. In 1991, the US Centers for Disease Control (CDC) issued a statement establishing 10 μg/dl as the blood lead level at which individual children should receive nutritional and educational interventions and more frequent screening. This replaced an earlier level of 25μg/dl, that itself had replaced an even earlier level of 40μg/dl (Centres for Disease Control and Prevention [CDC], 1991; Bernard, 2003). This new level was based on the Lowest Observable Adverse Effect Level (LOAEL) for lead-related health effects that indicated that IQ deficits and *in utero* effects may occur in the range of 10-15 μg/dl. Evidence of a decrease of 4.6 points in the IQ level with an increase of 10μg/dl in the life time average blood lead concentration level has recently been reported (Canfield et al., 2003), but following considerable scientific debate – the consensus remains that 10μg/dl is appropriate for children from a public health perspective. However, it has been independently recommended that infants aged 1 year or less, with blood levels of 5μg/dl or higher, be followed up with further testing and that universal education about lead exposure risks be sustained. Further, the regulatory agencies should not interpret 10μg/dl as necessarily implying a "safe" target exposure (Bernard, 2003).

Benzene

- Benzene is one of the groups of chemicals known as volatile organic compounds (VOCs). Benzene is found outdoors in automobile emissions, and the main indoor source is tobacco smoke (Rushton & Cameron, 1999).
- Because benzene is associated with vehicle emissions, ambient levels are higher in urban areas than in rural areas.
- Microenvironments—areas where benzene is more concentrated—are of concern. For example, benzene exposures are higher for persons involved in refueling motor vehicles, while vehicle occupants may also

[1] *Other exposures include soil contamination from old paint chips and water contamination from old lead pipes. Indoor firing ranges are also a source of risk, and police firing ranges have improved ventilation since this risk was observed (Lofstedt, Selden, Storeus, & Bodin, 1999).*

experience elevated benzene exposures due to higher concentrations found inside vehicles than in ambient air. This can be attributed to exhaust emissions being drawn into vehicles from the traffic stream.

- Studies of gas station attendants in Italy and the United Kingdom have revealed benzene exposures ranging from 60 to 150 ppm (Rushton & Cameron, 1999). At these levels, mutagenesis and cancers of the blood and lymphatic systems have been observed (Rushton & Cameron, 1999; Golding & Watson, 1999). High exposure concentrations may also result in other blood disorders and neurotoxicity. Such health effects have also been recorded in association with historical practices in industrial environments, including the manufacture of petrochemicals and rubber, coke production, and in association with printing and shoemaking.
- Canada-wide Standards for benzene emissions identify a phased approach to benzene reduction, where the first phase seeks a 30 per cent reduction in 5 targeted sources: oil and gas industry, petroleum industry, transportation, chemical manufacturing, and steel manufacturing.

Dioxins, Furans, and Polychlorinated Biphenyls

- This group contains 210 dioxins and furans and polychlorinated biphenyls (PCBs) (Rushton & Cameron, 1999b). These related compounds are by-products of: combustion processes; thermal processing of metals; manufacturing of chlorinated chemicals, including some pesticides; pulp and paper processing; municipal waste incinerators; and coal and wood burning from industrial and domestic sources. It is also possible for these to occur naturally for example as a result of forest fires.
- These compounds are chemically stable and therefore difficult to remove from the environment.
- Human exposure to these compounds occurs mainly through the consumption of food, with the food chain being the main pathway source. Exposure can also occur through inhalation or absorption through the skin.
- Dioxins are fat-soluble and can accumulate in foods such as dairy products and human breast milk. Most human studies have been done following industrial disasters (eg., Seveso) or the use of compounds, such as *Agent Orange*, an aerosol defoliant used by the United States in the Vietnam War. Agent Orange consisted of a 50-50 mix of the phenoxyherbicides 2,4-D and 2,4,5-T, which was highly contaminated with the dioxin 2,3,7,8-TCDD[2].
- Documented health effects of dioxins include: chloracne (skin lesions), liver enzyme changes, and adverse effects on the immune system and on reproductive outcomes. The International Agency for Research on Cancer (IARC) has classified 2, 3, 7, 8-TCDD as carcinogens.
- The World Health Organization has established tolerable daily intakes for these compounds. Most exposures today fall within this range, although they can be higher for some groups, such as breast-fed infants.
- Canada-wide Standards for dioxins/furans target emission reductions in specific source sectors such as municipal waste incinerators and coastal pulp and paper mill boilers that are burning salt-laden wood.

Canada-wide Standards

The development of Canada-wide Standards (CWSs) was a significant step forward in an effort to harmonize standards. These standards are a set of common minimum targets acceptable for all provinces and the federal government; however, they may not be sufficient to achieve the level of air quality desired by an individual province, and it is possible that conforming to CWS could lead to a deterioration of air quality in some areas.

[2] *2,4,5-T is 2,4,5-trichlorophenoxyacetic acid; 2,4-D is 2,4-dichlorophenoxyacetic acid; 2,3,7,8-TCDD is 2,3,7,8-tetrachlorodibenzo-p-dioxin; an estimated 19 million gallons of Agent Orange were used during the Vietnam War.*

- Crematoria have been identified as a source of dioxins and furans by the United States and United Nations Environment Programme and were also identified in the 2003 report entitled *Status of Activities Related to Dioxins and Furans Canada-wide Standards*.[3] Jurisdictions are encouraged to promote the use of good combustion practices in cremation processes in new and existing facilities (CCME, 2004).

Pesticides

- The acute toxicity of pesticides can range from practically non-toxic to highly toxic. This is usually determined by effects on animals and on the environment. Chronic toxicity is generally based on observations in animal studies and on occupational exposures and, depending on the pesticide, can range from no observable adverse effects to carcinogenic effects. The frequency and seriousness of both acute and chronic effects are generally related to the amount, duration, and exposure pathway.
- Pesticides sprayed on fields or plants can be deposited on the soil or into the water. Their consequent effects depend on many factors including the chemical family of the pesticide, its chemical properties, its rate of degradation (half-lives in the field, water, or air), the type of formulation, climatic conditions, and the potential to accumulate in the ecosystem.
- Acute toxicity from airborne pesticides has generally occurred in occupational settings, from use in enclosed spaces (such as in a greenhouse) or from accidental poisonings. Chronic toxicity has generally occurred in occupational settings.
- Very careful reading of product labels, and knowledge and application of safety recommendations, are important in reducing any unnecessary exposures.

Ammonia

- Ammonia (NH_3) is a colorless gas that has a pungent, sharp odour and is generally produced as a result of

Forest Fires

Forest fires are an important source of natural air pollution, and for persons directly exposed, the hazards are considerable. Fires produce particles, carbon monoxide, nitrogen oxides, aldehydes, and other toxic substances (Anderson, 1999). Although there are no published autopsy studies from forest fire victims, autopsies from urban fires show that a large proportion of smoke inhalation fatalities are explained by carbon monoxide poisoning. Other acutely toxic compounds (e.g., acrolein, hydrogen cyanide) and the physical displacement of oxygen also play a role. Repeated or prolonged exposures pose longer-term risks; chronic respiratory disease is more common among urban fire-fighters (Smith, 1987). The first major investigation into the health effects of forest fires appears to be a community study in California, which showed an association with hospital admissions for asthma and chronic obstructive pulmonary disease (Duclos, Sanderson, & Lipsett, 1990). By contrast, studies into a major peri-urban bushfire in Australia revealed no clinically significant reductions in lung function among children, and no increase in health care presentations for asthma (Jalaludin, Smith, O'Toole, & Leeder, 2000; Smith, Jalaludin, Byles, Lim, & Leeder, 1996). However, residents of the Hoopla Valley National Indian Reservation in the US were studied in relation to a wild land fire in 1999, and medical visits were found to increase by 52 per cent over the same period of the previous year, while those with pre-existing cardiopulmonary conditions reported more symptoms (during and after). Increased health care utilization for respiratory ailments in several countries were associated with the south-east Asian "haze" episodes of 1997 and 1998, following the extensive forest fires in Indonesia (Kunii et al., 2002).

The overall impact of forest fires on population health is likely to be smaller than that of tobacco and wood smoke, as forest fires are relatively infrequent events, and mostly take place in areas where human density is low. However, long distance transportation of smoke from forest fires inevitably adds to the burden from other sources (e.g., urban pollution).

[3] *This report was prepared by the Dioxins and Furans CWS Development Committee of the Canadian Council of Ministers of the Environment.*

Agricultural Burning

Agricultural burning also generates particulate pollution (composition varying with the crop), as well as CO, NO_2 and VOC emissions (Long et al., 1998). Increased respiratory symptoms have been documented in response to burning straw and stubble; persons with asthma or chronic bronchitis were more likely to be affected (Jacobs, Kreutzer, Smith, & 1997). Burning rice stubble also has been associated with increased hospital admissions from asthma in California and Japan, while sugar cane burning has been associated with pediatric hospital admissions in Brazil, with risks three times greater in the burning season (Cancado et al., as cited in Bates et al., 2003).

agricultural activities such as livestock and poultry housing, manure land-spreading, and fertilizer application.

- This pollutant is known to react with other pollutants such as nitrogen and sulphur oxides and results in the formation of $PM_{2.5.}$
- In BC, agriculture and farming activities contribute 75 per cent of the total ammonia emissions in the Lower Fraser Valley.
- Dimethylsulfide, a substance emitted from the ocean surface, produces natural sulphur into the atmosphere. Once oxidized, the sulphur oxides combine with ammonia and produce a white haze which can greatly reduce visibility. Evidence of the combination of ammonia with nitrogen and sulphur oxides from industrial pollution and vehicle emissions has also been documented. (Greater Vancouver Regional District [GVRD], 2003b)

Hydrogen Sulphide

- Hydrogen sulphide (H_2S) is a gas commonly found near oil refineries, sewage treatment facilities and pulp and paper plants using the "kraft" process.[4]
- This gas is sometimes called *sewer gas* or *rotten egg gas* due to the smell caused mainly by *mercaptans*, which are by-products often found with H_2S, but which by themselves are not thought to have serious health effects. However, H_2S is acutely toxic, causing neurological, respiratory, and blood disorders.
- H_2S odor may be detectable below 0.13ppm. It is easily perceptible at 0.77ppm, while most people find it offensive at 3-5ppm (Bates & Caton, 2002). Sufficient concentration can cause eye irritation—*gas eye*—and can produce pulmonary edema (Klassen & Watkins, 1999).
- Exposure to very high concentrations produces comparable effects to those caused by cyanide. Health effects include reduced oxygen-carrying capacity of the blood (Smith, 1986).
- Elevated atmospheric levels can occur following sour gas well blowouts, which have happened in Alberta and elsewhere in the world. The main concern in BC to date has been with olfactory pollution in communities close to pulp mills; however, as the gas industry in BC expands, the potential for greater exposures from gas well blowouts increases.

Pollens and Spores

- Pollens and spores, known as *bioaerosols*, are released seasonally from plants. Together with airborne plant debris, especially in rural areas, they may account for a substantial amount of particulate pollution during warmer months (Shaw & Paul, 1983, as cited in Ghio & Samet, 1999).
- Pollens are fine powdery substances that are released by flowers, and then are carried by air currents to fertilize other plants of the same species. Some people may experience allergies upon exposure to pollens and symptoms may include hay fever, eye irritation, runny nose, or asthma.

[4] *In the kraft process, wood chips are cooked in a solution of caustic soda and sodium sulphide to separate wood fibers from the lignin.*

Automotive Emissions

With the removal of lead from gasoline, Canada has achieved major reductions in blood lead levels, thereby optimizing brain and cognitive development for future generations of children.

Cohort studies have associated increased mortality with mobile sources of particulate matter and proximity to high volume traffic. Proximity to traffic is associated in asthmatics with increased respiratory symptoms, hospitalizations, and medical visits. Lung cancer, lymphoma, pre-term births, and low birth weights have also been associated with traffic density and/or traffic-related pollutants. Introduction of emission standards for the North American auto industry two decades ago appeared to be a fine start in reducing these hazards, but this was thwarted in part by the successful marketing of sports utility vehicles (SUVs) and minivans, which qualified for a "light trucks" tax exemption. SUVs have fuel efficiency levels 40 per cent lower than that of standard passenger vehicles. In 2004, in response to concerns, all new vehicles in this class will be required to meet the same Tier 2 EPA emission standards that have applied all along to standard passenger vehicles. (www.epa.gov/oms/tr2home.htm).

Nonetheless, in all countries, the larger issue of automotive pollution remains unsolved and is inextricably linked to dependence on the internal combustion engine as the vehicle of choice for personal transportation.

A promising start in reducing this dependency has been made in expanding public transportation systems, especially in Japan and Western Europe. By contrast, in some developed countries (e.g., United States) only limited progress has been made due to minimal investment in alternative systems when compared with the expansion of infrastructure for private vehicles. When compared with our neighbours, British Columbia looks energy-efficient. This is mostly due to our province's more compact communities and choice of more fuel-efficient vehicles. Still, BC's locally favourable comparative record does not come close to the best being achieved in developed countries such as Germany, Japan, and the United Kingdom, who use a third as much gasoline per person. The following table lists gasoline use in selected locations. Clearly more must be done everywhere, as the currently excessive automotive emissions are a significant factor in climate change, and pose a risk to our health. Although comparing well against nearby US cities, Vancouver and Victoria rank below Montreal and Toronto (both of which have more developed public transportation systems), and far behind such European cities as Vienna, Zurich, and Munich. As our urban populations grow, we must come to recognize automobile pollution as a health issue now, and as a survival issue for the planet in the longer term. We need more attractive public transportation options, and more innovative urban and work planning approaches that minimize dependence on private automobiles.

Trends in Gasoline Use: Pacific Northwest and Selected Countries

Idaho	9.0	*Canada*	5.9
Washington	8.4	*Japan*	2.3
Oregon	8.2	*United Kingdom*	2.3
British Columbia	5.3	*Germany*	2.2
United States	8.8		

Note: Weekly US gallons per capita; data for Canada, Japan, United Kingdom, and Germany from 2001; all others 2002.

Source: Northwest Environment Watch, 2003

- Spores are single-celled organisms capable of individual development. They may cause allergic responses upon inhalation, and some may cause fungal infections of the lungs. Travel to dusty areas that contain such organisms may lead to severe outcomes. For example, Canadian travelers have developed *coccidioidomycosis*[5] while visiting the San Joaquin Valley in California.
- *Cryptococcosis*[6] has been identified in both animals and humans in British Columbia (Stephen, Lester, Black, Fyfe, & Raverty, 2002; Sekhon et al., 1990). Industrial pollutants such as irritant gases like SO_2 can be absorbed by pollens and spores, and enhance their toxicity (Shaw & Paul, 1983, as cited in Ghio & Samet, 1999). Rain may fragment spores into smaller particles, which can increase the incidence of acute asthma (Bates & Caton, 2002).

Diesel Exhaust

In recent years, attention has turned to diesel exhaust (DE). While used less than gasoline, this fuel type is used extensively in mass transit buses, heavy transport (trucks, rail, and marine) and more numerous small applications. In the United States, diesel particulate matter (DPM) makes up approximately 6 per cent of ambient $PM_{2.5}$ levels (23 per cent if natural sources are excluded) with higher levels in urban centres. DE is a complex mixture of hundreds of gases such as CO_2, O_2, N_2, H_2O, CO, NO_X, SO_X numerous hydrocarbons (eg., aldehydes, benzene, 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs), nitro-PAHs), and DPM. DPM exists as both fine (<2.5 μm) and ultrafine particles (<0.1 μm), offering a large surface area for absorption of organic compounds as well as of inorganic compounds (e.g., sulphates, nitrates, heavy metals). As the range of particle size is highly respirable, it reaches deeply into the lungs.

Symptoms of acute exposure to DE include: acute irritation (eyes, throat, bronchial), neuro-physiological symptoms (light-headedness, nausea), and respiratory symptoms (cough, phlegm, wheezing) (Sydbom et al., 2001). Based on animal studies (histopathological changes in rats), DE can also cause chronic respiratory conditions. Epidemiological studies of occupations using diesel engines have shown an increased risk of lung cancer. On the basis of human and animal studies, DE is classified as a probable carcinogen, although the evidence for causal relationship at typical exposure levels is controversial. In the Multiple Air Toxics Exposure Study II in Los Angeles, monitoring programs revealed about 70 per cent of the carcinogenic potential of air contaminants to be attributable to diesel particle emissions (South Coast Air Quality Management District, 2000). A prudent approach therefore is to continue efforts to reduce emissions and to limit exposures (Comstock, 1998). Some progress in addressing diesel emissions is presented in a later chapter.

This chapter illustrated outdoor criteria and non-criteria pollutants and their health effects. The amount of emissions and trends of these and other pollutants in British Columbia will be discussed in Chapter 4.

[5] *Coccidioidomycosis, also known as Valley Fever, is a respiratory disease of humans and domestic animals in North America, marked by flu-like symptoms. It is caused by inhalation of spores from the fungus Coccidioides immitis.*

[6] *Cryptococcosis is an infectious disease that affects parts of the body, especially the brain and central nervous system, with lesions or abscesses caused by the fungus Cryptococcus neoformans.*

Chapter 3: Indoor Air Pollutants and Their Health Effects

Indoor Air Pollution

Indoor air pollution is receiving more attention in Canada and other countries where most people live and work predominantly indoors. Indoor levels of certain pollutants can be much higher than those in the outdoors (e.g., second-hand tobacco smoke, infectious agents, and allergens) which may pose a greater risk for some individuals. For example, children in indoor environments (houses, schools) contaminated with molds are at risk of developing respiratory conditions such as coughing and wheezing. In BC and other provinces, initiatives are underway to address air quality in schools.

Globally, human effects from air contaminants largely result from exposures in indoor settings where people spend a lot of time (Samet, Spengler, & Mitchell, 1998). This includes most people living in developed countries, and those using biomass fuel with little ventilation such as in Nepal, northern Pakistan, and Tibet (Smith et al., 2000). In addition to outdoor pollutants getting trapped indoors, pollutants of concern include combustion by-products, volatile organic compounds emitted by synthetic materials, and microbial pollutants from air-conditioning systems. In certain areas, radon gas may be released into basements in significant amounts, and infiltrate other areas of the house. Asbestos (now banned for use in construction in Canada) is also a pollutant that can disperse fibrous dust to the indoor air if it becomes old and friable. Both radon and asbestos increase the risk of cancer. In addition, the popular use of traditional wood stoves and fireplaces exposes people to smoke and other wood fuel emissions indoors.[1]

Indoor emissions may be concentrated by "tight building" designs or modifications intended to conserve energy. These may also limit air exchange with the outdoors and affect air quality and attributes such as comfort, temperature, draftiness, humidity, odor, and lighting. Air quality is influenced by building design, windows, maintenance, and cleanliness.

Indoor air pollutants discussed in this section include combustion by-products and tobacco smoke, volatile organic compounds, formaldehyde, toluene, asbestos, radon, microbiologic agents, second-hand smoke (also known as environmental tobacco smoke), and molds.

[1] *Wood smoke is also the outdoor air pollutant of greatest concern in many BC communities and will be discussed in more detail in Chapter 4.*

Combustion By-Products and Tobacco Smoke

- Combustion sources such as woodstoves, fireplaces, natural gas stoves, and heaters emit a range of particles and gases that are also common outdoors. As emissions from these sources become trapped indoors, their concentrations are usually much higher than those found outdoors.
- Gas appliances may also emit pollutants. Unventilated gas appliances can lead to high indoor NO_2 levels.
- Tobacco smoke consists of some 4,500 identified chemicals, of which at least 42 are known or suspected carcinogens.

Volatile Organic Compounds

- This term is used for a variety of compounds that form vapours at room temperature. Some are outdoor pollutants from various sources such as chemical industries and products, as well as diesel exhaust. Most are indoor contaminants released from synthetic materials, such as particleboard, carpets, wall paint, glues, and cleaning agents (Bates & Caton, 2002).
- Volatile organic compounds (VOCs) can be inhaled and deposited on mucous membranes. Depending on the chemical or the concentration and duration of the exposure, the health effects can vary from eye irritation to lung damage, although the public health significance is not fully assessed in most instances.
- Benzene is a VOC, and an ingredient in tobacco smoke. For more information, see the discussion under non-criteria pollutants in Chapter 2.

Formaldehyde

- Although this VOC occurs naturally, atmospheric levels of formaldehyde have risen due to emissions from incinerators, degassing of foams, adhesives, pressed-board products, and tobacco smoke.
- Inhalation and contact with the eye may produce irritation while long-term exposure may lead to a reduced capacity of the lungs to clear foreign material.
- Formaldehyde is classified as a probable carcinogen as it has been associated with increased rates of nasal and nasopharyngeal cancer in studies of animals and pathology staff (Samet & Cohen, 1999).
- Longer baking of pressed-board products and sealing of their surfaces reduce the formaldehyde. In addition, materials containing formaldehyde lose their potential to release formaldehyde over time.

Toluene

- Although toluene is found in nature from sources such as forest fires, volcanoes, and natural gas, it is widely manufactured and is also found in tobacco smoke (Rushton & Cameron, 1999).
- Toluene is used extensively in producing benzene and gasoline. As a solvent, it is used in paint, rubber, printing, cosmetics, and adhesive industries. Toluene is a starting material for the synthesis of other chemicals such as toluene-diisocyanate (TDI), which is used in polyurethane production. Some individuals exposed to TDI have experienced allergic pulmonary reactions.
- Toluene levels are usually much higher indoors due to the widespread use of toluene-releasing products in residential, commercial, and industrial settings.

Urea Formaldehyde Foam Insulation

A main concern regarding formaldehyde in Canada is its emission from urea formaldehyde foam insulation (UFFI). UFFI was used extensively in the late 1970s during the energy crisis to retrofit insulation into mostly older buildings. The federal government also launched a program promoting home insulation. Following complaints from consumers and based on risk assessments at the time, federal grants were made available to assist in the removal of UFFI, followed by a ban on its use in 1980.

- Ambient levels of toluene in outdoor air are much lower than those at which health effects appear to be experienced. However, adverse effects resulting from higher exposures indoors have been documented among persons in certain occupations (e.g., painters).
- Health effects resulting from exposure to toluene are uncommon and are difficult to identify due to their relatively non-specific nature.

Asbestos

- Canada is a leading producer of asbestos, a mineral fiber mined mainly in Quebec.
- Asbestos was once used ubiquitously in construction in wall board, roofing, ceiling panels, floor tiles, and pipes, as well as in fire and heat insulation, modeling materials, filters, and textiles.
- The various types of asbestos differ in their physical properties and their potential for health effects, although all are considered hazardous.
- In the past, those installing asbestos insulation, as well as miners and millers, were most at risk from health effects, while bystanders close to these activities were also at risk. Health risks among persons exposed to asbestos on the job include chronic bronchitis and lung cancer (the risk increases when combined with smoking), as well as *asbestosis* (diffuse scarring of the lungs). Mesothelioma—a rare cancer of the membrane enveloping the lungs—is also associated with a history of asbestos exposure.
- Since the risks of exposure to asbestos dust became widely recognized about three decades ago, non-essential applications have been phased out, and research is ongoing for substitute products.
- Removal of asbestos, in demolishing or upgrading buildings, may result in exposure to its fibrous dust and has given rise to community concerns regarding health risks. Generally it is best to leave asbestos that is in good condition intact, as it indicates no exposure and no significant risk.

Radon

- Radon gas is produced from the radioactive decay of radium, itself a decay product of a particular type of uranium present in trace amounts in most rock and soil.
- Exposures can be elevated in basements and other underground settings such as mines and tunnels, depending on the amount being released in a specific location. It can also be released from water when run from taps and showers. Inhalation of radon leads to radiation exposure of bronchial tissue, resulting in a risk of cancer.
- Radon also releases its own decay products, small particles called *radon daughters*, which can be inhaled. These products are carcinogenic and have been associated with lung cancer in uranium miners. The increased risk of lung cancer is based on occupational studies of miners (latency of 5 to 25 years following exposure) and with supporting evidence from experimental studies (Howe, Nair, Newcombe, Miller, & Abbatt, 1986; Health Canada, 1989).
- Efforts to reduce heat loss from buildings have resulted in reduced ventilation, which has led to increased radon concentrations in enclosed areas. At the lower domestic concentrations found in residential housing, radon exposure in combination with cigarette smoking results in lung cancer rates greater than would occur from either radon or cigarette smoking alone (McClellan & Jackson, 1999).
- Radon's overall contribution to lung cancer may fall within the range of 10-15 per cent of the total (Bates & Caton, 2002). In BC and other specific locations, the proportion would be lower (closer to 5 per cent) due to fewer people living close to radon sources.

Microbiologic Agents

- The spread of microbiologic agents involves inhaling them from persons coughing or sneezing, having direct contact with infected persons, or having indirect contact through the use of common utensils, toys, and other objects. While such risks are more frequently found in developing countries due to malnutrition and low immunization rates (Fatmi & White, 2002), they are continuing realities in other countries as well, especially for vulnerable groups.

- Research from the University of British Columbia involving a survey of bioaerosols in 39 elementary schools revealed that naturally-ventilated rooms had higher fungal and bacterial counts than mechanically-ventilated rooms. (Bartlett, Kennedy, Brauer, Van Netten, & Dill, unpublished, 2004).
- Ventilation systems are essential to air quality and they must be well maintained in order to prevent illnesses.

Second-hand Smoke

- Second-hand smoke (also known as environmental tobacco smoke), refers to the combination of gases and particles emitted in smoke from cigarettes, pipes, and cigars. It is similar to what smokers inhale, but some compounds are in greater concentrations because of lower combustion temperature. Second-hand smoke also contains higher levels of carbon monoxide and nicotine and second-hand smoke have shown to be a major source of health problems at all stages of life in numerous studies in recent years. Second-hand smoke is the primary risk factor for lung cancer among non-smokers (Brennan et al., 2004), and increases the risk of ischemic heart disease and stroke, as well as chronic obstructive lung disease (Law & Wald, 2003; Jaakkola, 2002). In pregnant women, it is associated with pre-term birth and small-for-date babies, as well as spontaneous abortion (Goel, Radotra, Singh, Aggarwal, & Dua, 2004). In infants and children, it is associated with asthma, sudden infant death syndrome, leukemia, respiratory infections, and the later development of adult obstructive lung disease as well as breast and cervical cancer (Becker, Watson, Ferguson, Dimich-Ward, & Chan-Yeung, 2004; Svanes et al., 2004).

Molds

- The general term *mold* is usually applied to fungal organisms that grow readily indoors on damp surfaces, unrefrigerated foods, and plant containers, especially where housekeeping and ventilation are less than adequate (King & Auger, 2002). Exposure is by inhalation of spores or contaminated materials. Some are hazardous primarily for their allergenic properties (e.g., penicillium, aspergillus), or for their potential to produce pulmonary infections (e.g., aspergillus).
- About five per cent of individuals may experience some allergic airway symptoms from molds over a lifetime; reactions include rhinitis (similar to common cold symptoms) and sinusitis, as well as asthma and hypersensitivity pneumonitis, which can be clinically severe (Hardin, Kelman, & Saxon, 2003). The pneumonitis may develop over months or years, and is sometimes associated with particular vocations (e.g., pigeon breeders' disease). Associated health problems may include headache, fatigue, joint pain, and depression.
- Vulnerable groups include children, individuals with a history of allergies, those with underlying lung damage (e.g., bronchiectasis), and immuno-compromised persons (Gent et al., 2002). Molds also produce mycotoxins, which are metabolites that can cause short-term irritation, or other symptoms.

Legionnaire's Disease

In modern buildings, allergenic and infectious agents may be more widely spread by ventilation systems. A classical example of this is Legionnaire's Disease, an acute febrile bacterial disease that may result in pneumonia, and even death from respiratory failure. Outbreaks have been associated with convention hotels, cruise ships, and other similar institutions. Transmission is primarily airborne as the organism legionella pneumophila is usually found in places such as air conditioning cooling towers, evaporative condensers, humidifiers, hot water systems (e.g., showers), whirlpool spas, and fountains (Chin, 2000). The disease occurs more frequently among older people, smokers, and persons with lung and other chronic disorders.

Wood Smoke

Wood smoke is increasingly recognized as a global concern, especially in developing countries, where wood fuel is commonly used both outdoors and indoors, often with inadequate provision for smoke to exit. The North American health effects literature for wood smoke was recently reviewed by a BC Lung Association panel. In communities where wood burning is common, wood smoke forms a major component of outdoor particulate pollution, as well as indoor air pollution from heating and cooking. Although, in these settings, wood smoke is generally emitted outdoors, substantial indoor infiltration has been documented, such that outdoor woodstove emissions are also a source of indoor air pollution. Regarding indoor sources, the contribution to indoor air contaminants depends on the type and condition of the heating source (i.e., it differs for furnaces, woodstoves, or open fireplaces). However, more critical to the outdoor sources of indoor wood smoke pollution is ventilation. Studies have shown a link between poorly maintained wood stove use and increased symptoms and signs of respiratory illness in children, as well as an increased risk of asthma in adults, associated with health care contacts (e.g., emergency room visits, hospitalization) (Bates et al., 2003).

Indoor Home Pollution

Various aspects of air pollution in the home have been covered so far. It is important to emphasize that "home" is where most individuals have their greatest control over both environmental quality and interventions. In addition to second-hand smoke, molds, volatile organic compounds, and wood smoke trapped indoors, indoor home pollution includes other potential hazards, such as allergens and infectious agents. For example, house dust is allergenic, and can account for a high frequency of respiratory symptoms (e.g., wheezing, coughing). It usually contains dust mites, microscopic parasites that set up camp in bed linen, carpets, and other fabrics, or may simply reside in the dust itself. House dust itself is a mixture of physical and biological matter, some drawn from the outdoors, and always including *dander*, the debris that is constantly shed by humans and their pets. There is always enough dander, even from humans, to provide a growth medium for micro-organisms, such that, a typical household may serve as a reservoir for a wide range of microbes, some of which also produce toxins.

Mention was made earlier to mycotoxins produced by molds; similarly, gram negative bacteria produce *endotoxins*, inflammatory agents which can contribute to the severity of an asthma attack. For example, contaminated humidifiers have been shown to cause health effects such as fever, headache, chills, myalgia, and malaise, typically within hours of exposure. These conditions tend to subside within 24 hours, do not require medical attention and are related to exposure to amoebae, bacteria, and fungi found in humidifier reservoirs and air conditioners.

Extreme outcomes such as humidifier fever and pulmonary edema are rare, but less severe conditions are fairly common. A study of women employed in domestic cleaning in a community revealed conditions of induced or aggravated asthma. As house cleaning is required in all homes, these findings apply to all people undertaking cleaning tasks at home (Medina-Ramon, Zock, Kogevinas, Sunyer, & Anto, 2003). However, it should also be noted that without good housekeeping practices, houses would otherwise pose even more of a health hazard.

While not all asthma is attributable to indoor hazards, certainly some cases may be triggered by a large variety of indoor contaminants, although to what extent has not yet been quantified. As the direct and indirect costs of asthma in Canada would be greater than $1 billion[2] today, more systematic study of this question would appear to be warranted, not only on health but also on economic grounds (Krahn, Berka, Langlois, & Detsky, 1996).

Many other air pollutants exist which were not reviewed in this chapter. Reduction in exposures to these pollutants is also warranted.

[2] *These costs were estimated in 1990 at greater than $0.5 billion and have been adjusted for inflation.*

Sick Building Syndrome and Building-Related Illnesses

Sick Building Syndrome (SBS) is an entity in which occupants experience acute health and comfort disorders that appear linked to time spent in the building, but no specific illness or cause can be identified. In SBS, occupants complain of acute discomfort (e.g., eye, nose, or throat irritation, headache, fatigue, reduced attention span, irritability, nasal congestion, difficulty breathing, nosebleeds, dry skin, nausea) (Klassen & Watkins, 1999). Most symptoms diminish when an affected person leaves the building. Possible causes include molds, combustion products, emissions from furnishings (e.g., VOCs), or cleaning agents, and can be exacerbated by poor ventilation and other comfort factors. One must recognize that SBS, by virtue of being a loosely defined "syndrome", may have many causes, some more resolvable than others. By contrast, Building Related Illnesses (BRI) consists of well-documented conditions with well-defined diagnostic criteria and causes such as airborne agents or contaminants. Examples were discussed earlier in the report (e.g., Legionnaire's Disease, hypersensitivity pneumonitis).

Illnesses associated with office buildings (SBS and BRI) have been increasingly observed over the past three decades, especially subsequent to the energy crisis of the mid-1970s which led to efforts to reduce energy losses from buildings to save fuel, unintentionally resulting in reduced air exchange (the problem of "tight buildings"). Connected to this trend was an increasing use of construction, insulation, and furnishing materials that emit VOCs.

Resolution of BRI is usually straightforward, assuming that a causal mechanism has been identified. However, resolution of SBS is usually more complex and may require multiple interventions, related to both the building and work environment. Attention may be needed in common areas (e.g., restaurants, print shops, dry-cleaning stores), and to sources of outdoor contamination (e.g., motor vehicle exhausts, building exhausts), as well as to management practices and the culture of the workplace.

Chapter 4: Air Pollutants and Their Health Effects in BC

Compared with people in more populated and industrialized parts of the world, most British Columbians are exposed to lower concentrations of air contaminants. Over the years, many communities have worked hard to improve air quality in British Columbia. Nonetheless, many parts of BC have unresolved air quality issues, especially in the Interior where some of the highest air pollution levels occur.

Current Status - Where Are We?

Our current response to air pollution in BC is driven largely by our knowledge, attitudes, and beliefs. Attitudes often reflect short-term considerations, taking into account how an issue affects us personally and the consequences of "doing something versus doing nothing". Whether we choose to respond to longer-range threats to public health also reflects our cultural beliefs. While attitudes may shift rapidly—as reflected in public opinion surveys on the issues of the day—our beliefs tend to be more stable, take longer to evolve, and are linked to our system of values. This observation can be illustrated by a decade-old report comparing North and South American attitudes towards the environment. A survey indicated that fewer that 10 per cent of Brazilians considered ecological problems among the 3 major national problems, while 40 per cent of respondents in British Columbia considered ecological problems to be the most serious problem, ahead of unemployment, the economy, or social services. Immediate concern for economic survival in the developing world may have played a part in the contrast between the two regions. However, even in BC, opinion is divided on issues such as clear-cutting, preservation of old forest, or pollution controls, revealing the challenges inherent in protecting the environment without greatly disturbing the economy (Worcester & Corrado, 1992).

Canada has had its share of air quality problems: air pollution in major cities, air quality concerns in the grain transport industry, and high concentrations of particulate matter from wood smoke in many valley communities. Early work on air quality focused on outdoor or community air pollution, although effort was also devoted to the health of miners at risk from pneumoconiosis. In BC, investigations into the health effects of air pollution have been conducted for at least four decades. Some of these investigations include: the community study of respiratory effects in Chilliwack (Ferris & Anderson, 1964), an investigation into horses poisoned by airborne lead contamination of pastures (Schmitt et al., 1971), and the discovery of elevated lead levels in children living in proximity to a lead smelter and to urban transportation (Schmitt, Philion, Larsen, Harnade, & Lynch, 1979). In 1995, a BC Clean Air Research Fund was set up to promote research on air quality. This program is managed by the Canadian Petroleum Products Institute, the GVRD and the BC Ministry of Water, Land and Air Protection (MWLAP, Water, Air and Cliamate Change Branch, n.d.). For more information please consult the Clean Air Fund at: http://wlapwww.gov.bc.ca/air/airquality/carf/

In 2003, a BC Lung Association panel reviewed community studies of air contaminants such as nitrogen oxides, sulphur, carbon monoxide, ozone, and PM that were thought to cause cardio-respiratory health effects (Bates et al., 2003). Specifically, the panel noted that in parts of BC, the levels of particulate air pollution, particularly $PM_{2.5}$ and ozone, were in the range where effects on health may be expected. They noted the associated risks of angina, heart attacks, pneumonia, and lung cancer, as well as increased symptoms and use of health care resources by persons with pre-existing chronic lung conditions such as chronic bronchitis or asthma.

Studies of Seattle, Washington State neighbourhoods reveal that wood stoves are a major source of fine particle mass, particularly during the winter season. These findings support the findings of the BC Lung Association panel, and the similarity in geographic and climate characteristics between the two areas make this study of interest in BC. Some BC communities, such as Vernon, have embarked on programs to replace old wood stoves with new versions that are 90 per cent more efficient.

Patterns of Mortality and Air Pollution

Data from BC Vital Statistics Agency show that mortality from chronic obstructive pulmonary disease in BC, adjusted for variations in age distribution, is higher in interior regions than in the Southern Mainland and Vancouver Island. The Northern Interior also has the highest rate of lung cancer, and the lowest proportion (20.6 per cent) of people rating their health as "excellent". This region also ranks third in BC for prevalence of second-hand smoke (Provincial Health Officer, 2003). These findings indicate the need to improve respiratory conditions in this region.

In making this observation, one should exercise caution. Just because a region has a higher rate of chronic lung disease and higher levels of air pollution does not necessarily imply a cause and effect relationship; for example, the high smoking rates and radon in the Interior and Northern regions might also explain the high rates of lung cancer. However, international studies have shown that a relationship between the high rates of disease and air quality is possible.

Specific Air Pollutants

The Ministry of Water, Land and Air Protection operates an extensive air quality monitoring network in BC that measures the following common outdoor air contaminants: $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, and total reduced sulphur[1]. Some sites also monitor meteorological conditions such as temperature, wind speed, and wind direction. Further details on specific site locations and air quality monitoring methodologies can be found in Appendices C and D.

The following is intended to provide a brief summary of air quality levels measured in the provincial monitoring network. The greatest focus is placed on $PM_{2.5}$ and ozone. Also described are ambient levels of PM_{10}, nitrogen dioxide, sulphur dioxide and carbon monoxide. Current air quality objectives and standards are provided for comparison purposes, and are summarized fully in Appendix E.

Particulate Matter

Prior to the late 1990s, the most common measure of particulate matter (PM) levels in BC was the inhalable fraction consisting of particles 10 µm or smaller in diameter (i.e., PM_{10}). With increasing evidence that the finer particles—2.5 µm or smaller—are more harmful to human health, a number of $PM_{2.5}$ monitors have since been deployed. In 2003, approximately 50 continuous PM_{10} monitors and 30 continuous $PM_{2.5}$ monitors were operating in the province, with approximately one-quarter

1 *Total reduced sulphur (TRS) levels are not included as TRS is largely an odor issue in this province.*

located in the Lower Fraser Valley (LFV)[2] and operated by the GVRD. More recently, PM speciation monitors have been introduced into the network on a limited basis. These monitors enable samples to be collected on different filter types to allow for different types of chemical analyses.

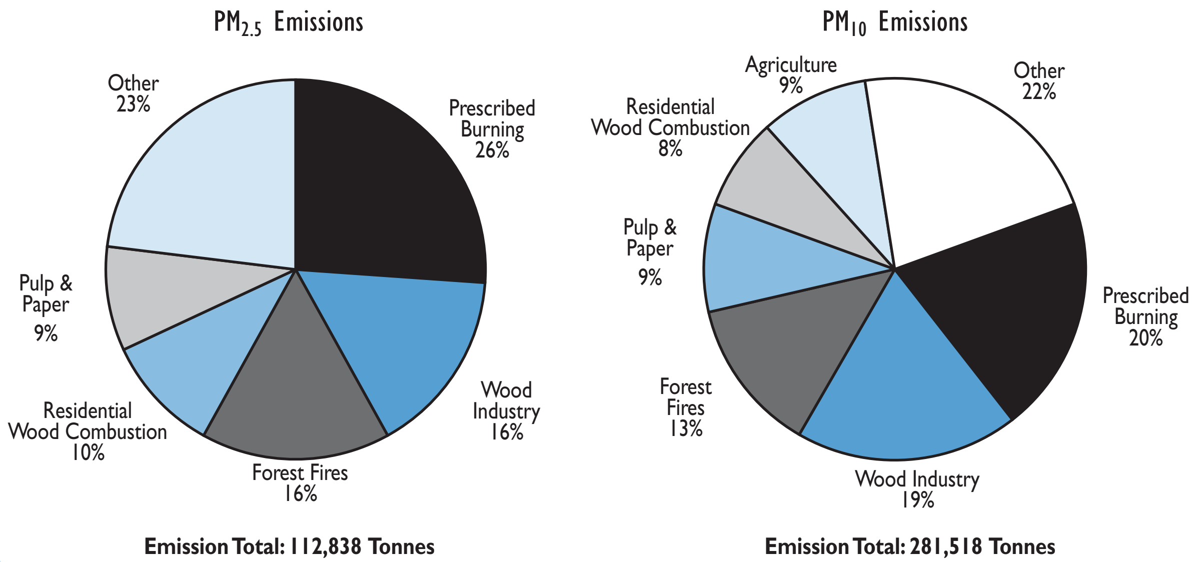
As shown in Figure 4.1, in 2000, the largest source of $PM_{2.5}$ and PM_{10} was prescribed burning at 26 per cent and 20 per cent respectively, with wood industry contributing 16 per cent and 19 per cent respectively. The pulp and paper industry was responsible for 9 per cent of the emissions of PM_{10} and $PM_{2.5}$ in BC. [3]

$PM_{2.5}$

Figure 4.2 shows the range of annual mean $PM_{2.5}$ concentrations observed between 1999 and 2003 at community monitoring sites in BC. Median values were typically 5 to 6 µg/m³. From year to year, the minimum and maximum values varied by approximately 5 to 8 µg/m³ across the province. The highest annual mean concentrations were consistently observed in Prince George (8 to 11 µg/m³), whereas the lowest values were found in Powell River and Kitimat (3 to 4 µg/m³). [4]

Trends in annual mean $PM_{2.5}$ concentrations in five cities are shown in Figure 4.3. The relatively short monitoring history of $PM_{2.5}$ in this province limits interpretation of trends over time, although comparison between communities can be made. It is clear that annual mean levels in Prince George are often twice as high as those in Vancouver, Nanaimo, or Powell River. In 2003, Prince George and Kelowna had the highest levels while Powell River had the lowest. The specific factors contributing to these findings have not been fully examined, but the extensive forest fires that occurred during the summer of 2003 influenced the elevated $PM_{2.5}$ levels in Kelowna for that year.

FIGURE 4.1 Sources of Particulate Emissions in BC, 2000



Source: Environment Canada, 2004.

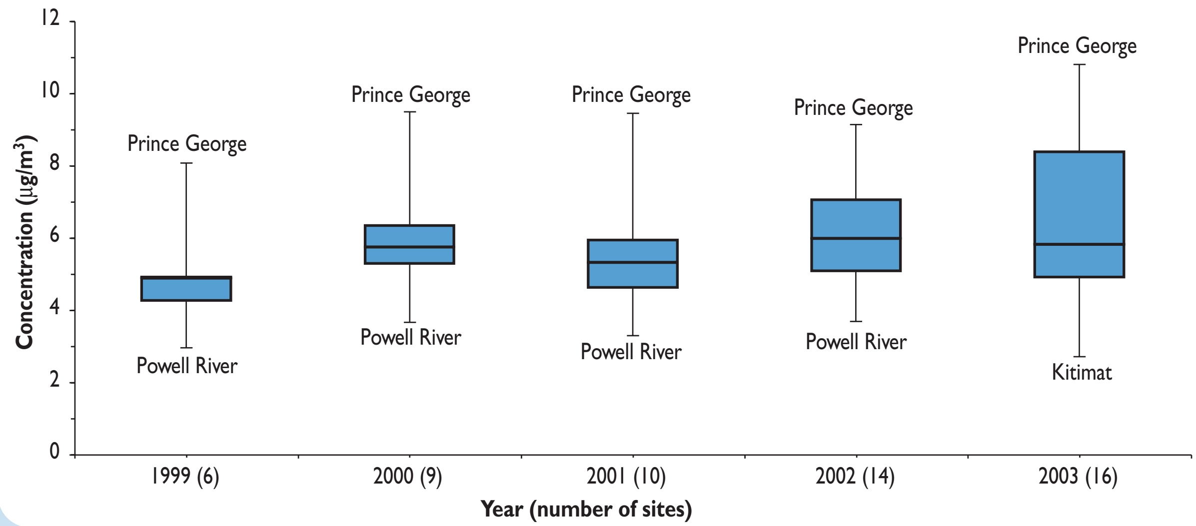
2 *The Lower Fraser Valley includes the Greater Vancouver Regional District and the Fraser Valley Regional District.*

3 *Road dust estimates were excluded due to the large uncertainties associated with these numbers. Based on estimates for 2000, road dust from paved and unpaved roads accounted for 61 per cent of total PM_{10} emissions and 30 per cent of $PM_{2.5}$ emissions.*

4 *The $PM_{2.5}$ monitor in Prince George is the only provincial monitor that uses the old URG cyclone inlet, which is believed to result in slightly higher measurements than the R&P sharp cut cyclone (SCC) inlets used elsewhere in the province. The SCC inlets were introduced in 2000.*

FIGURE 4.2

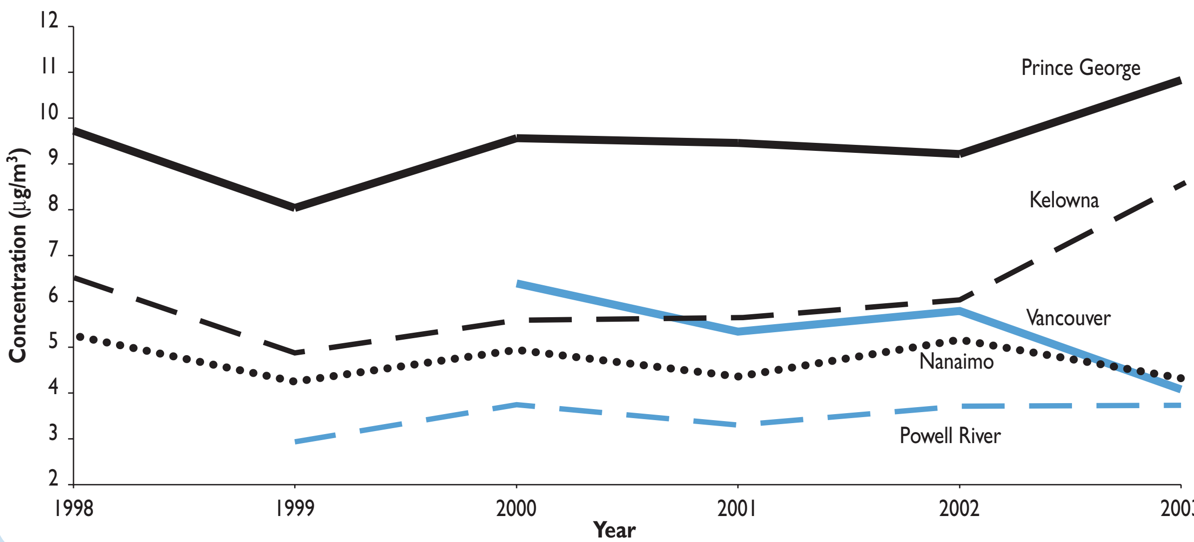
Range of Annual Mean $PM_{2.5}$ Concentrations Across BC, 1999 - 2003



Note: The box plots are intended to provide a sense of the range or distribution of average, or *mean* concentrations recorded in communities across the province each year. The whiskers identify the minimum and maximum concentrations. Associated place names indicate where these minima and maxima are recorded. The boxes define the 25th and 75th percentile values, and the horizontal line within each box shows the median or 50th percentile concentration (where the xth percentile refers to the value greater than x percent of all samples). The number of sites that contributed data to each box plot is shown in parentheses following the year. Where more than one monitoring site is located in each community, the site considered the most representative of community air quality has been selected. Hence, sites located within industrial areas are not generally included in these plots.
Source: BC Ministry of Water, Land & Air Protection, 2003.

FIGURE 4.3

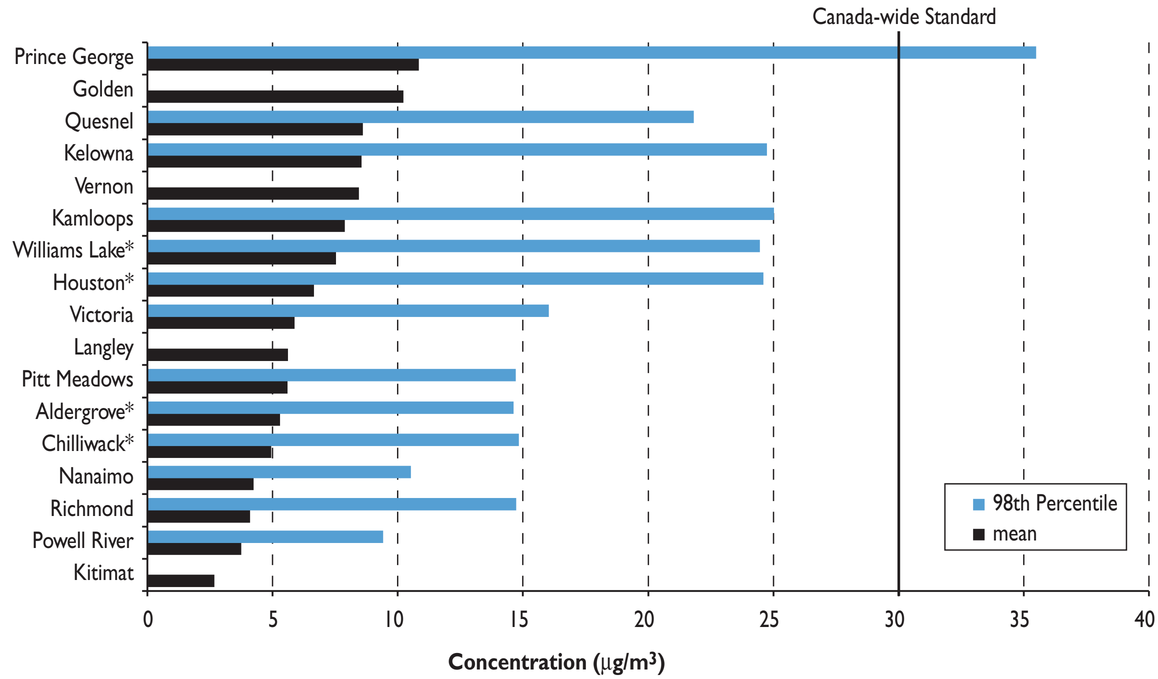
Annual Concentrations of $PM_{2.5}$ for 5 Cities Over Time, BC, 1998 - 2003



Note: The line plots show trends in mean concentrations at specific monitoring sites across a number of years.
Source: BC Ministry of Water, Land & Air Protection, 2003.

FIGURE 4.4

The Annual Mean and Canada-wide Standard for $PM_{2.5}$ Concentrations, BC, 2003



* The Canada-wide Standard (CWS) is based on the annual 98th percentile of 24 hour averages over two instead of three consecutive years.

Note. The bar charts provide a snapshot of ambient concentrations at a number of specific monitoring sites for the most recent complete monitoring year (2003). The sites shown are those for which a complete year of data is available. Solid line indicates the CWS of 30 µg/m³ (24-hour average).

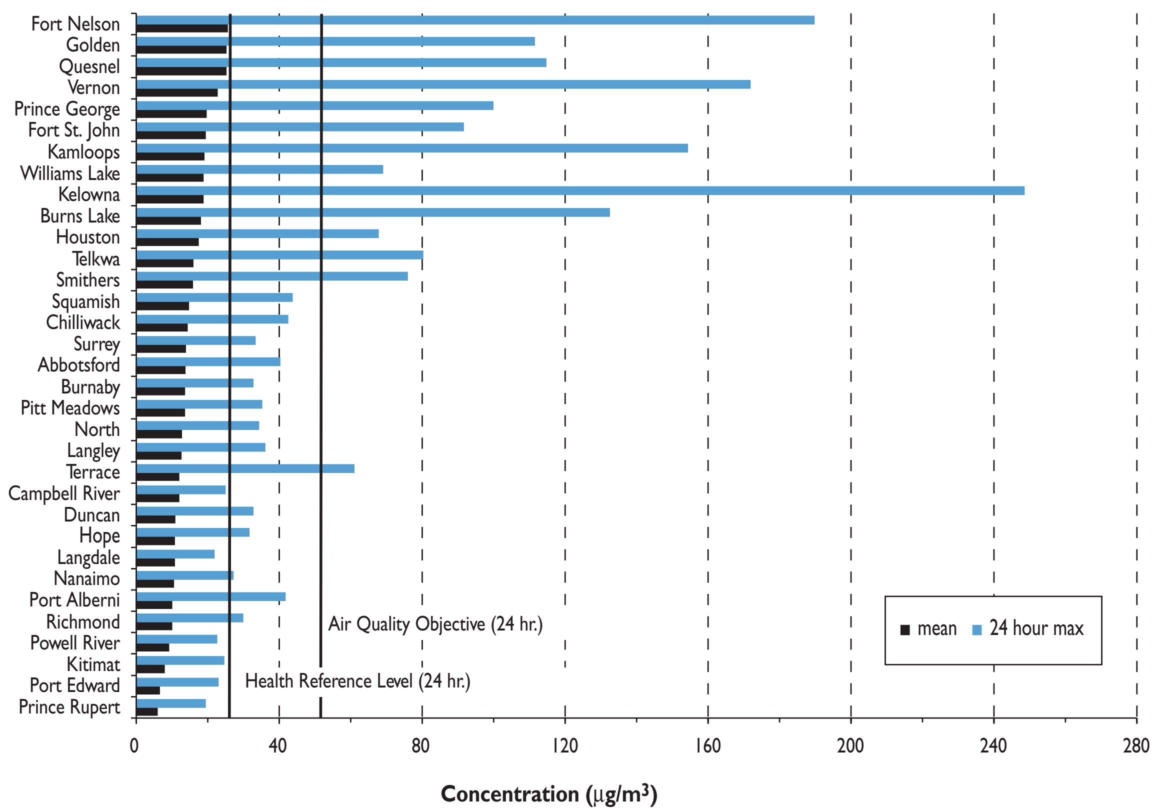
Source: BC Ministry of Water, Land & Air Protection, 2003.

Figure 4.4 shows the annual mean concentrations for 2003 for various sites across the province, as well as the Canada-wide Standards (CWS) values (24-hour average), which are based on the annual 98th percentile value averaged over three consecutive years. A CWS for $PM_{2.5}$ of 30 µg/m^3 was ratified by the Canadian Council of Ministers of the Environment in June 2000. In 2003, the only site exceeding the CWS for $PM_{2.5}$ was Prince George. The annual mean concentrations ranged from 3 to 11 µg/m^3, with the highest concentrations in Prince George and the lowest concentrations in Kitimat. In general, $PM_{2.5}$ levels were highest at sites in the interior of the province and lowest in coastal communities. The elevated levels in the Interior are believed to be a function of local sources such as industry, wood combustion, and/or transportation sources; rugged terrain; and periods of stagnant weather that result in a temporary build-up of air pollutants in these communities.

Given that scientists have not been able to determine a no-effects threshold, and that health risks are known to increase with exposure, even areas below the standard will require some degree of action to maintain or reduce $PM_{2.5}$ levels. This is in keeping with the provisions under the CWS for "Continuous Improvement" and "Keeping Clean Areas Clean" to ensure areas below the standard take remedial and preventive actions to reduce ambient concentrations to the extent that is possible and practical.

FIGURE 4.5

The Annual Mean and Maximum Daily Average for PM_{10} Concentrations, BC, 2003



Note: Solid lines indicates the health reference level of 25 µg/m³ and ambient provincial air quality objective of 50 µg/m³ (both 24-hour averages).
Source: BC Ministry of Water, Land & Air Protection, 2003.

PM_{10}

Figure 4.5 shows annual mean and daily maximum concentrations of PM_{10} for 2003 for a number of communities across the province. Also shown are the provincial air quality objective of 50 µg/m³ [7] and the health reference level of 25 µg/m³.[8]

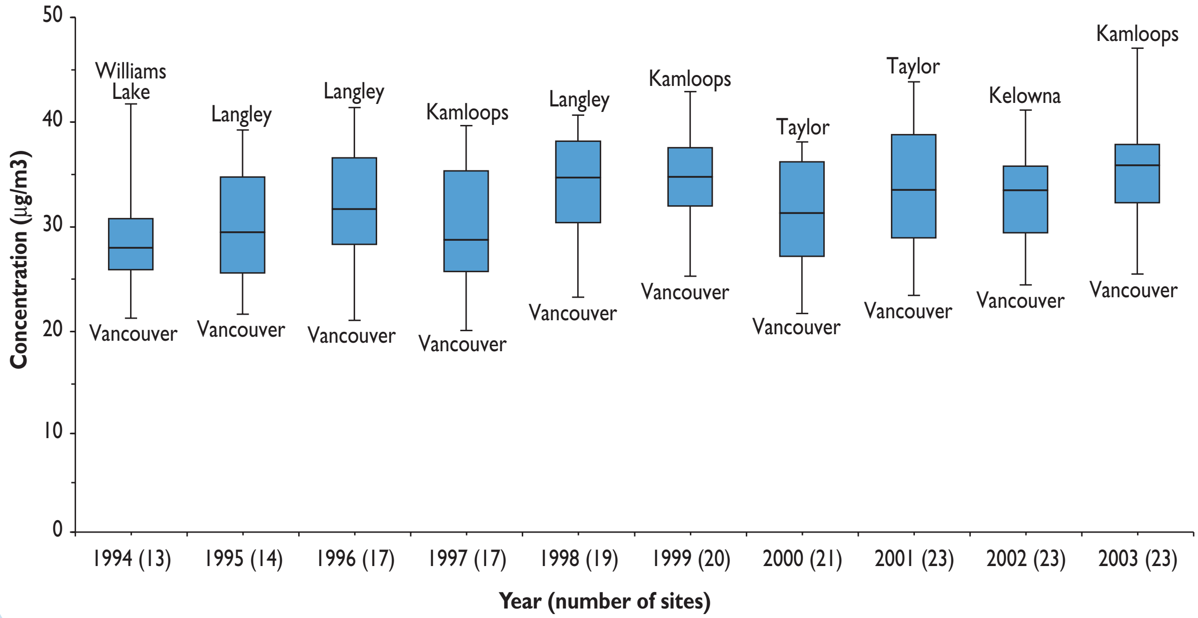
Annual mean concentrations in 2003 ranged from approximately 6 to 25 µg/m³. The lowest concentrations were typically observed at coastal sites such as Prince Rupert, Port Edward, Kitimat, and Powell River. The highest concentrations were found in the interior of the province, in communities such as Fort Nelson, Golden, Vernon and Prince George.

7 *24-hour average.*

8 *The health reference level (24-hour average) is a recommendation by the Federal-Provincial Working Group on Air Quality Objectives and Guidelines. It represents an estimate of the lowest ambient PM_{10} level at which statistically significant increases in health effects have been demonstrated, based on the current state of knowledge. It is not to be interpreted as an effects threshold, nor is it intended to be used as a management target. (Federal-Provincial Working Group on Air Quality Objectives and Guidelines, 1999).*

FIGURE 4.6

Range of Annual Mean Ozone Concentrations Across BC, 1994 - 2003



Note: The number of sites contributing data to each box plot are shown in parentheses following the year.
Source: BC Ministry of Water, Land & Air Protection, 2003.

Maximum 24-hour concentrations (measured midnight-to-midnight) ranged from less than 20 µg/m^3 in Prince Rupert, to more than 240 µg/m^3 in Kelowna)[9]. Approximately one-third of these sites exceeded the provincial air quality objective at least once, whereas most exceeded the health reference level at least once.

Ozone

In 2003, ground-level ozone was monitored at approximately 32 sites within the province. About one-half of these sites were within the Lower Fraser Valley (LFV) and were operated by the GVRD, reflecting the fact that ozone has historically been an air quality issue associated with large urban areas.

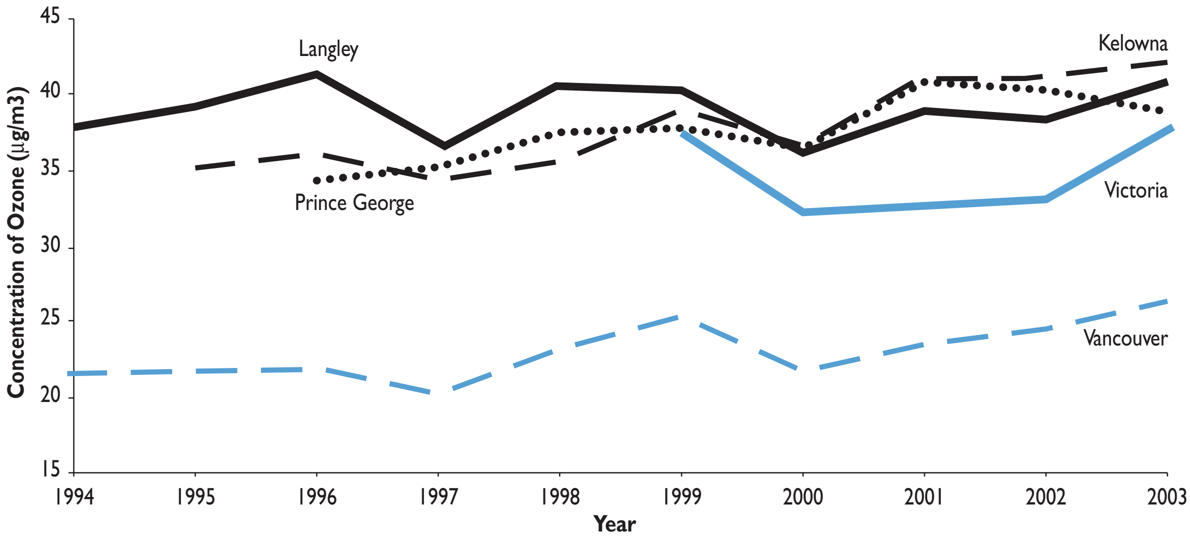
Figure 4.6 shows the range of annual mean ozone levels between 1994 and 2003 at representative community monitoring sites in BC. During this 10-year period, the highest annual mean concentrations (38-47µg/m^3) were typically associated with sites in the eastern LFV or the interior of the province. In contrast, the lowest annual mean concentrations (20-25 µg/m^3) were found at urban sites in Vancouver. This is consistent with the general understanding that in urban areas, nitric oxide emissions from motor vehicles and other combustion sources tend to remove ozone from the atmosphere, whereas downwind of these areas, may contribute to ozone formation.

Trends in annual mean concentrations of ozone at specific sites in BC are shown in Figure 4.7. Again, ozone levels in Vancouver are low relative to those observed at other sites. All sites appear to show increasing trends in annual mean ozone concentrations. Because ozone levels are a function of both precursor emissions and meteorology, more detailed analyses would be needed to characterize

9 *Measured during the forest fires in August 2003.*

FIGURE 4.7

Annual Concentrations of Ozone for 5 Cities Over Time, BC, 1994 - 2003



Source: BC Ministry of Water, Land & Air Protection, 2003.

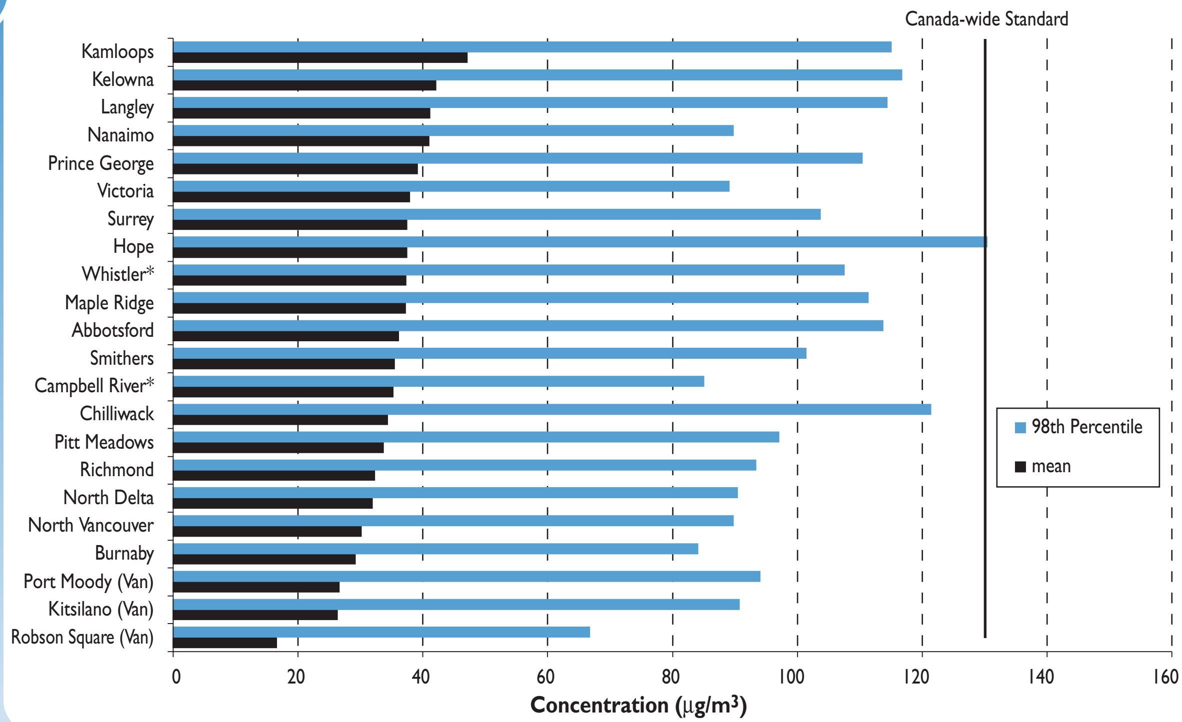
the significance of these trends. Such studies performed on data in the LFV (Vingarzan & Taylor, 2003) have indicated that while maximum daily concentrations measured during the summer are declining, background concentrations (typically the average concentrations measured at sites not impacted by regional or local emissions) are increasing. The latter observation is supported by similar findings in the United States (Jaffe, Price, Parrish, Goldstein, & Harris, 2003; Lin, Jacob, Munger, & Fiore, 2000), which point to a global increase in nitrogen oxide emissions—a precursor to ozone—as a contributing factor to the increase in ozone levels.

Figure 4.8 shows the annual mean ozone concentrations and CWS ozone values for 2003 for a number of sites across the province. Also shown is the ozone CWS of 65 ppb, or approximately 130 µg/m^3 [10], which was ratified by the Canadian Council of Ministers of the Environment in June 2000. Large variations are observed across the province, and within individual airsheds. Annual mean concentrations ranged from 16 to 47 µg/m^3, with the lowest concentrations at sites in or near Vancouver, and the highest concentrations in Langley, Kelowna, and Kamloops. No site exceeded the ozone CWS, although Hope equaled the standard, and values in Chilliwack and Kelowna were within 10 per cent of the standard.

Similar to the situation for $PM_{2.5}$, even areas below the standard may require action to maintain or improve air quality, in order to reduce exposure levels and therefore potential health impacts. Based on a review of the most recent information on the health effects of air pollution, the World Health Organization reported evidence that "average" day-to-day concentrations may provide a greater burden on public health than infrequent very high concentrations as expressed by the CWS metric, suggesting the need to focus not only on short-term episodes but also on reducing ozone levels throughout the summer period.

[10] *Fourth highest daily 8-hr maximum value, averaged over 3 consecutive years.*

FIGURE 4.8 **The Annual Mean and Canada-wide Standard for Ozone, BC, 2003**



* CWS is based on a two (instead of three) year consecutive average of the 4th highest annual measurement.
Note: Annual mean ozone concentrations are shown by the black bars, and CWS ozone values are shown by the blue bars. Solid line indicates the CWS of 65 ppb or approximately 130 µg/m^3 (8-hour average).
Source: BC Ministry of Water, Land & Air Protection, 2003.

Other Common Air Pollutants

Nitrogen Oxides

Nitrogen oxides (NO_X) are produced from high temperature combustion processes. The largest source sector of NO_X emissions in BC, as shown in Figure 4.9, is marine transportation (17 per cent). Other NO_X emissions are from heavy-duty diesel vehicles (12 per cent), biogenic (vegetation) sources (12 per cent), off-road use of diesel (11 per cent) and upstream oil and gas industry (drilling, gas production, well service and testing, etc.) (11 per cent).

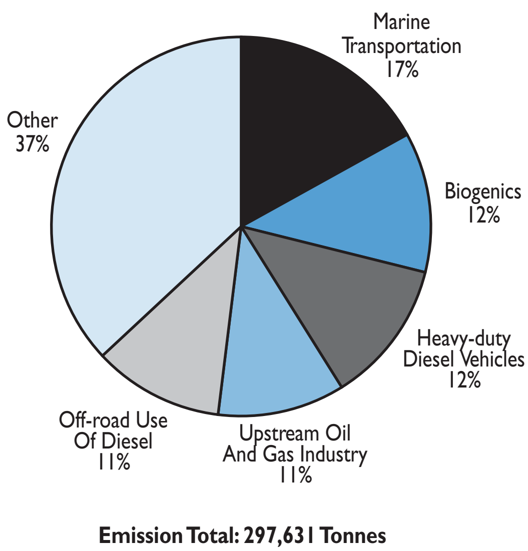
Nitrogen Dioxide

From a health perspective, nitrogen dioxide (NO_2) is one of the most important gases of all nitrogen oxides (NO_X).

National data reveal that BC's emissions of nitrogen dioxide increased over the past decade—up 12.8 per cent, from 242 kilotons in 1990 to 273 kilotons in 2000—and account for an increasing proportion of Canada's total, from 11 per cent to 13 per cent over the same period. The trends for Alberta and Saskatchewan are similar, while the absolute amounts and proportions were either stable or had fallen for all other provinces (Environment Canada *Projections and Analysis*, n.d.). Nitrogen dioxide is monitored in approximately 32 sites across the province with 20 of these sites within the LFV.

In Figure 4.10, mean and maximum one hour concentrations for NO_2 are shown for a number of community sites for 2003. Also identified is the most stringent National Ambient Air Quality Objective (the

FIGURE 4.9 **NOx Emissions, BC, 2000**



Source: Environment Canada, 2004.

Maximum Desirable Level) of 60 μg/m^3 (annual average). The sites with the highest NO_2 levels at the one hour maximum were Vancouver, Burnaby, and Richmond, while the lowest levels were found in Powell River, Kitimat, and Smithers.

In 2003, all sites were well below the existing air quality objectives. Annual mean concentrations ranged from approximately 5 μg/m^3 in Powell River and Kitimat to in excess of 40 μg/m^3 in Vancouver. This is a marked contrast with the pattern for ozone and reflects the intensity of fuel combustion in the Lower Mainland. Maximum one-hour concentrations ranged from 63 μg/m^3 in Smithers to 151 μg/m^3 in Coquitlam.

Sulphur Oxides

Sulphur oxides (SO_X) are produced from natural sources as well as from burning of sulphur-bearing fossil fuels from smelters and refineries.

As shown in Figure 4.11, the largest source of SO_X emissions in BC is the upstream oil and gas industry (61 per cent), followed by the pulp and paper industry (12 per cent) and marine transportation (11 per cent).

Sulphur Dioxide

Sulphur dioxide (SO_2) is one of the major components of SO_X that is responsible for causing acid rain and also combines with other substances to produce smog.

Canadian SO_2 trends are encouraging, with a decline of 13 per cent projected from 1990 to 2010. This reflects reductions in emissions from coal and oil-fired processes, especially related to power generation. Transportation continues to be a significant source of SO_2 throughout the country (Environment Canada, *Projections and Analysis*, n.d.). Sulphur dioxide is monitored in approximately 39 sites across the province, with 14 sites located within the LFV.

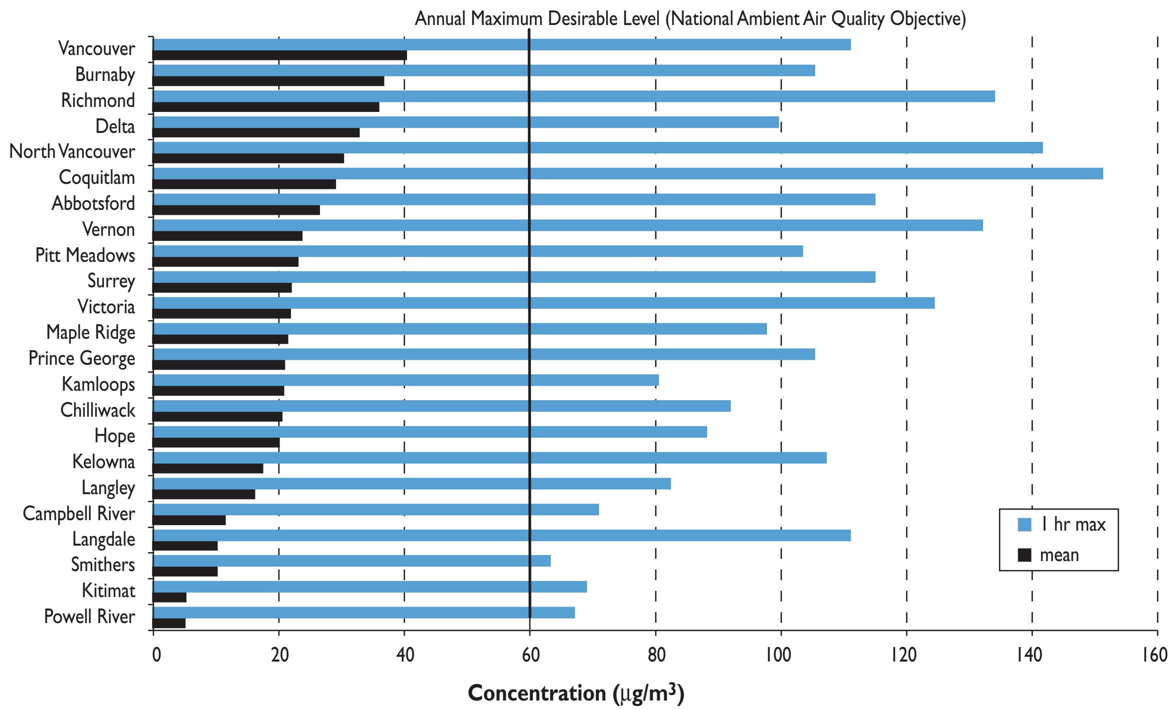
Figure 4.12 shows annual mean and maximum daily SO_2 concentrations in 2003 for a number of representative community sites in BC. The most stringent (Level A) provincial air quality objective of 160 μg/m^3 (24-hour average) is also shown for comparison purposes. Not shown is the annual Level A provincial objective of 25 μg/m^3.

Annual mean concentrations across the province typically ranged from less than 1 μg/m^3 (e.g., Chetwynd, Kelowna and Fort Nelson) to 6 μg/m^3 (e.g., Vancouver, Prince George, and Port Alice). The lone exception was Trail, which reported concentrations just below the Level A provincial objective at 24.6 μg/m^3 . The highest maximum daily concentrations were observed at sites in close proximity to major industrial sources such as in Trail, Port Alice, and Prince George. However, none of the sites exceeded the daily Level A objective. [11]

[11] *Data are not shown here, but excursions above the most stringent (Level A) 1-hour provincial objective of 450 μg/m^3 were measured in Trail, Port Alice, and Prince George.*

FIGURE 4.10

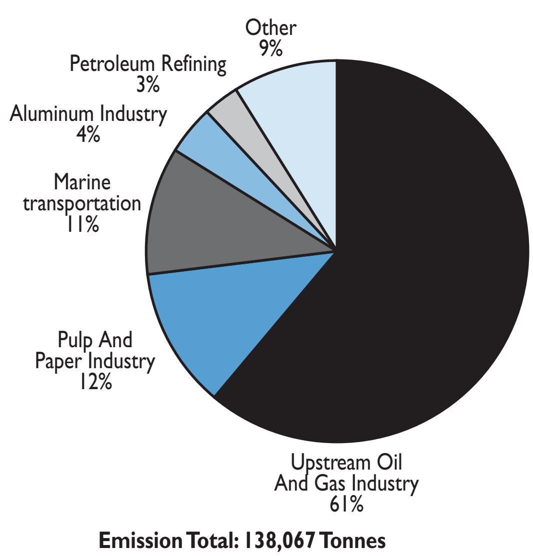
The Annual Mean and 1 Hour Maximum for NO_2 Concentrations, BC, 2003



Source: BC Ministry of Water, Land & Air Protection, 2003.

FIGURE 4.11

SO_X Emissions, BC, 2000



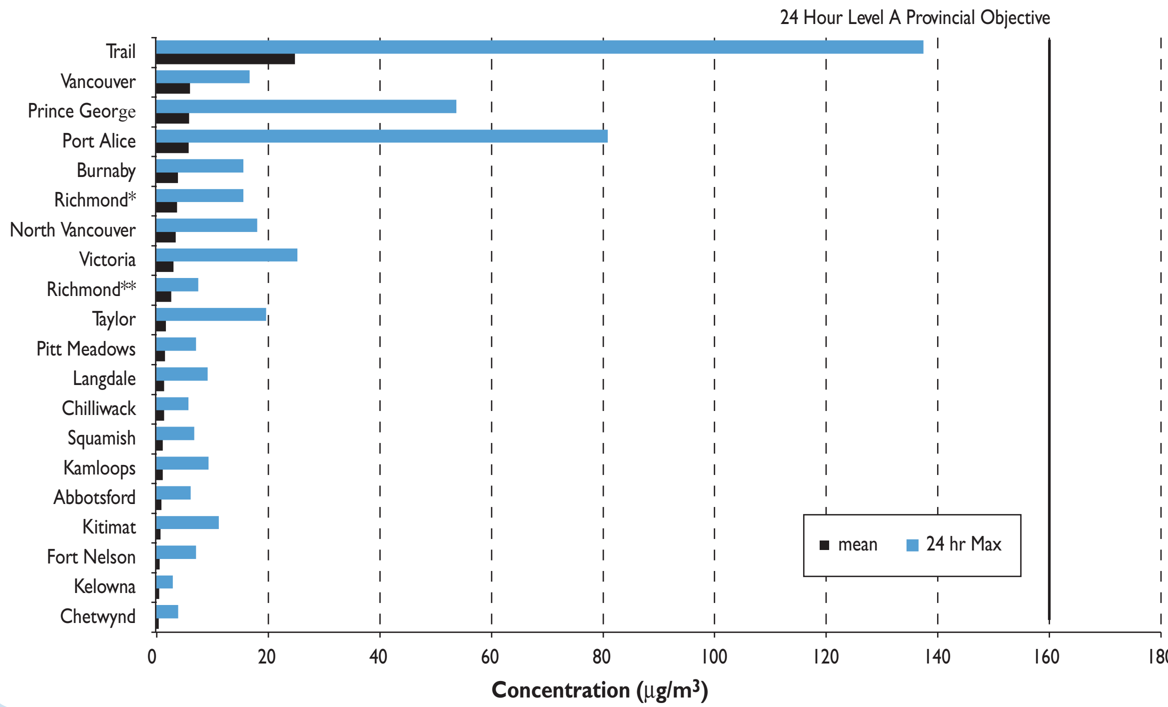
Source: Environment Canada, 2004.

Carbon Monoxide

Among human-caused sources, the major contributors of carbon monoxide are off-road use of gasoline (18 per cent), light-duty gasoline vehicles (18 per cent), light-duty gasoline trucks (16 per cent), the wood industry (16 per cent), and prescribed burning (12 per cent) as shown in Figure 4.13.

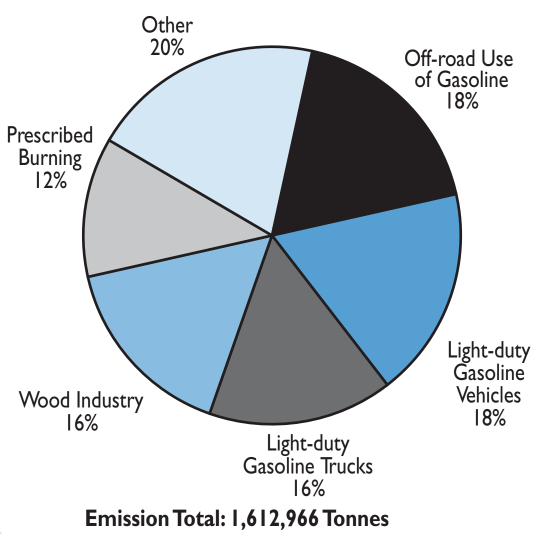
Ambient levels of CO reveal a pattern similar to that described for nitrogen dioxide. In 2003, there were 21 sites with sufficient data for reporting purposes. The majority of these sites (16) were located within the LFV. Figure 4.14 shows the annual mean and maximum one-hour CO concentrations in 2003 for representative community sites in BC. In general, the lowest mean concentrations were observed in Kamloops, Prince George, and Kelowna. The highest concentrations were found in Vancouver, Richmond, and Coquitlam reflecting the strong association between ambient CO levels and motor vehicle emissions. The trends of annual mean and concentration in Figure

FIGURE 4.12 **The Annual Mean and 24 Hour Maximum for SO_2 Concentrations, BC, 2003**



* Monitoring site in Vancouver Airport.
** Monitoring site in Richmond South.
Source: BC Ministry of Water, Land & Air Protection, 2004.

FIGURE 4.13 **CO Emissions, BC, 2000**



Source: Environment Canada, 2004.

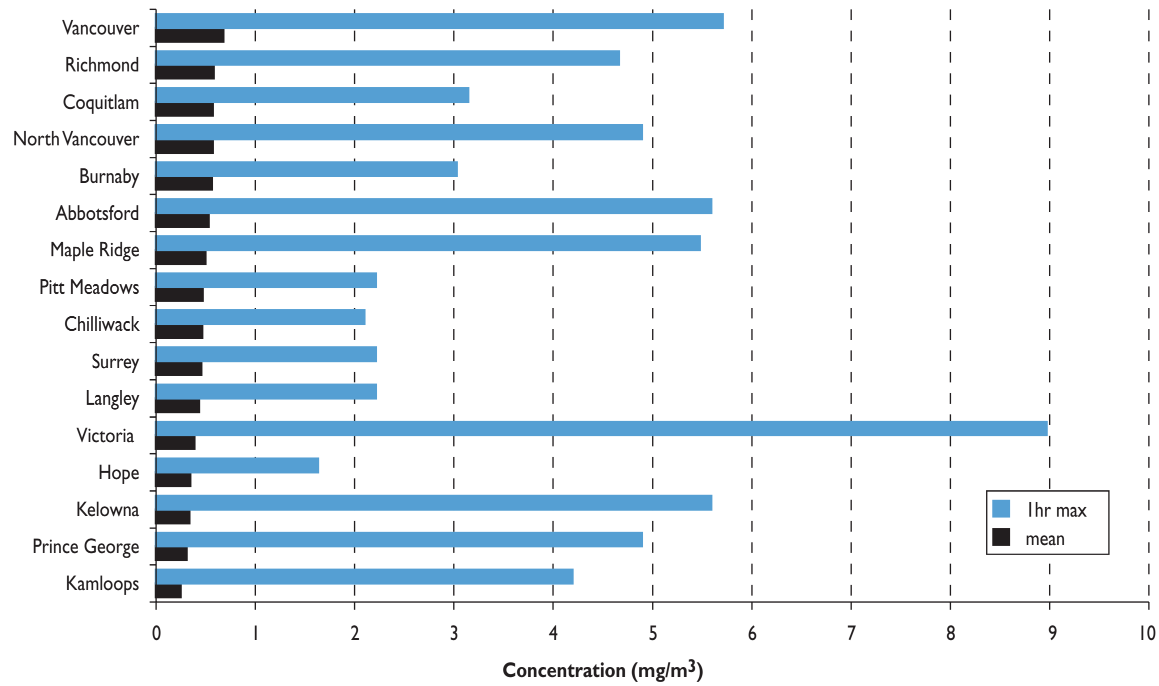
4.14 shows that none of the sites exceeded the most stringent (Level A) provincial air quality objective of 14.3 mg/m^3.[12] The highest one hour concentrations were observed at the Victoria site (9.0 mg/m^3), which is located in close proximity to a major thoroughfare. The lowest one-hour maximum concentrations were generally found in communities to the east of Greater Vancouver (e.g., Hope, Chilliwack, Surrey, Langley, and Pitt Meadows), which recorded maximum levels of 2.2 mg/m^{3}or lower.

Case Study: Lead Levels in Trail

During late 1960s, Dr. Nick Schmitt discovered that the lead poisoning of horses in Trail was directly connected to a contaminated pasture near Trail (Schmitt et al., 1971).

[12] *Although not shown in Figure 4.14, no site exceeded the most stringent (Level A) provincial 8-hour objective of 5.5 mg/m^3. This is another objective based on a different averaging period.*

FIGURE 4.14 The Annual Mean and 1 Hour Maximum for CO Concentrations, BC, 2003



Source: BC Ministry of Water, Land & Air Protection, 2003.

Recognition of air pollution as an issue in Trail was not new when Schmitt reported his findings in horses. In the mid 1960s, Cominco Limited, the operator of the smelter in Trail, had recognized the significance of air pollution and the need to respond (Snowball, 1966).

In 1975, a study of blood lead levels (BLLs) of children one to three years of age was carried out by the BC Ministry of Health and Health Canada. The study revealed elevated BLLs (22 µg/dl) and concluded this to be a result of the emissions of the nearby smelter.

In 1989, a team from the University of British Columbia (UBC) examined children two to five years of age and found that their average BLLs were 13.8 µg/dl (ranging from 4 to 30 µg/dl) (Hertzman, Ward, Ames, Kelly & Yates, 1991). While this level was 40 per cent lower than in 1975, it was still high relative to other locations in Canada.

Part of the purpose of the 1989 UBC study was to define a basis for protection against future lead exposure. The study recommended the implementation of a comprehensive lead awareness and education campaign, and thus provided the impetus for creating the Trail Community Lead Task Force which was composed of representatives from the BC Ministries of Health and Environment, the City of Trail, Cominco Limited, the general public, the local School District, United Steelworkers of America Locals 480 and 9705, and a local network of environmental groups (Hilts, Bock, Oke, Yates, & Copes, 1998).

The Trail Community Lead Task Force created the Trail Lead Program that was funded and supported by the BC Ministries of Environment and Health, Cominco Limited, and the City of Trail. Since 1991, the Task Force has carried out BLL screening, case management, dust abatement, exposure pathway studies, and remedial trials, and implemented education programs for early childhood groups and the general community.

From 1989 to 1996, a decline in BLLs in Trail was seen and was largely attributed to community intervention. After 1996, BLLs fell more rapidly to 5.9 µg/dl in 1999 with average rate of decrease from 0.6 µg/dl per year (1989 to 1996) to 1.8 µg/dl per year (1997 to 1999) (Hilts, 2003). This accelerated reduction was attributed to the introduction of the new lead smelter in May 1997. Mean air levels of lead fell from 1.1 µg/m^3 in 1996 to 0.28 µg/m^3 in 1998, and lead concentrations in outdoor dust, street dust, and indoor dust decreased by 50 per cent (Hilts, 2003). Since 1998, yearly ambient lead levels have been substantially below guideline levels set by Ministry of Water, Land & Air Protection, the US Environmental Protection Agency, and the World Health Organization.

It is important to note that "averages" do not apply to everyone and some children have BLLs above the mean. For example, during the period 1991 to 1995, based on a locally-determined screening level of 15µg/dl, many Trail children had BLLs that ranged from 17.4 to 20.4 µg/dl, implying potential neurological impact (Hilts et al., 1998).

The Trail Lead Task Force has set a goal of achieving BLLs of 10µg/dl or less for at least 90 per cent of children 6 months to 6 years of age in neighbourhoods closest to the smelter by 2005. With this goal, it is anticipated that at least 99 per cent of the same children will have blood levels less than 15 µg/dl by 2005 (Ames, 2001).

Selected Indoor Pollutants

Second-hand Smoke

The Provincial Health Officer's 2002 *Report on the Health of British Columbians* (2003) included information on second-hand smoke (also known as environmental tobacco smoke).[13] Table 4.1 confirms that the highest prevalence of second-hand smoke exists in the interior regions of BC, which also show the highest rates of mortality from chronic bronchitis. The large differences seen across the regions can be explained by factors such as variations in smoking rates, exposure in the home, and the strictness of municipal regulatory by-laws.

BC was among the first jurisdictions in the world to introduce municipal by-laws to control second-hand smoke in public places, a policy trend that has occurred in other developed countries. This trend is also happening in many developing countries, despite the tobacco industry's efforts to expand its markets in the face of declining sales in developed countries. Leadership by municipalities such as the Capital Regional District in Victoria involved promoting awareness, public consultation, and political acceptance in the interest of public health (Brigden et al., 1993). The initial impact of partial restrictions was subsequently studied by a group of UBC researchers, who showed particulate concentrations to be 70 per cent

Table 4.1: Per cent of Non-Smoking Population Exposed to Second-Hand Smoke, Age 12 Years and Over, by BC Health Service Delivery Area (HSDA), 2000/01

HSDA	%	HSDA	%
Northeast	*32.3*	*Vancouver*	*19.1*
East Kootenay	*30.3*	*Central Vancouver Island*	*18.8*
Northern Interior	*26.2*	*Richmond*	*18.7*
Thompson Cariboo	*24.1*	*Okanagan*	*18.5*
Fraser Valley	*23.2*	*Simon Fraser*	*17.4*
Northwest	*23.0*	*South Vancouver Island*	*16.5*
Kootenay/Boundary	*21.4*	*North Shore/Coast Garibaldi*	*15.4*
South Fraser	*21.0*	***British Columbia (overall)***	***19.8***

Source: Statistics Canada, Canadian Community Health Survey, as cited by Provincial Health Officer 2003.
Note: Sample size for North Vancouver Island HSDA was insufficient for reliable reporting.

13 *These observations are based on Statistics Canada's Canadian Community Health Survey 2000/2001.*

higher in establishments without smoking restrictions compared with those with partial restrictions, while concentrations in non-smoking restaurants were reduced by an additional 20 per cent to 30 per cent (Brauer & Mannetje, 1998).

In 1998, the Workers' Compensation Board (WCB) established regulations to prohibit workplace exposure to second-hand smoke, which effectively protected about 85 per cent of BC workers. In 2001, the WCB proposed a total ban on smoking in all workplaces. In January 2002, in response to concerns expressed by businesses in smaller and northern communities, the BC Government introduced regulations for the hospitality industry, with provision for designated smoking rooms. While reductions in exposure were attained as a result of this provision, some serving staff continue to be exposed to second-hand smoke. As in the 2002 Report of the Provincial Health Officer, we reiterate that, *as any exposure to second-hand smoke is associated with some degree of risk, and as studies continue to demonstrate no adverse economic impact from smoking bans, workplace bans should be reinstated*.

Another critical indoor air quality issue is the exposure of people to uncontrolled second-hand smoke in the home setting. It is reasonable to state that, from a health standpoint, second-hand smoke in the home is one of the most serious indoor air quality problems of our times. Children are exposed to second-hand smoke in one out of five BC homes every day, and children are more likely to develop asthma, ear and respiratory infections such as bronchitis or pneumonia as a result of exposure. Although BC has the lowest overall smoking rate in Canada, and the trend continues downward, some 6,000 British Columbians still die every year from smoking-related illnesses.

Molds

By world standards, much of BC has a damp climate conducive to the growth of molds both indoors and outdoors. Pulmonary infection due to mold is uncommon while mold allergies are much more common. Judging by the limited literature, compared to outdoor criteria pollutants, molds as a source of health problems in BC have not attracted much systematic study. Until more work is done on the health effects of indoor molds in particular, it will not be possible to determine the full dimensions of this as a clinical or as a public health issue.

Nonetheless, available studies indicate that we do have a problem. A Health Canada team noted that the frequency of substandard housing in First Nations communities was associated with humid, damp conditions which contributed to poor air quality and health problems, notably asthma (Lawrence & Martin, 2001). Molds are commonly found in many indoor environments including homes and schools. Four elementary schools in southwest BC – Signal Hill, Stawamus, Squamish, and Mamquam (Sigler & Abbot, 1998) – showed moderate to high levels of airborne molds at most sites in all four schools, including potential mycotoxin producers, such as aspergillus and stachybotrys chartarum. The mold growth was related to leaks and moisture control problems at the schools and was subsequently rectified.

Exposure to contaminated dusts in workplaces can result in diseases with complex pathology that combine allergic and irritant components. Work has been done by UBC researchers on the respiratory health of dockworkers who load grain cargoes in Vancouver and Prince Rupert. This group was compared with two other groups: grain elevator workers who were also exposed to high dust levels, and civic workers who were included as an unexposed control group. The prevalence of cough and phlegm was at least as high in dockworkers as in grain elevator operators, and eight times higher than in civic workers. Durations of exposure to grain dust were associated with less favourable results on lung function tests (Dimich-Ward, Kennedy, Dittrick, DyBuncio, & Chan-Yeung, 1995). This study extended earlier work by the same team, comparing grain elevator workers with civic workers. Although dust in Ports Canada grain terminals has been reduced over the years, these findings confirm that persons exposed to recent levels of grain dust experience adverse effects (Chan-Yeung, Dimich-Ward, Enarson, & Kennedy, 1992).

Radon

In the late 1970s, homes in 14 cities across Canada were surveyed by Health Canada for radon levels (McGregor et al., 1980). Vancouver recorded the lowest levels of emission among all cities surveyed. Although no other city in BC was included, subsequent limited surveys within the province—Castlegar, Cranbrook, and the GVRD—together with data on soil radioactivity, revealed a wide variation of conditions (British Columbia Centre for Disease Control [BCCDC], 2003).

Early in 1989, the Ministry of Health Services issued an advisory about the hazards of radon in homes, and ways of reducing it. The Ministry then funded a two-phase regional study of radon in homes, carried out by UBC (BCCDC, 2003). The first phase commenced in late 1989 and involved installing radon detectors in selected homes in each of seven locations in the southern interior, including the Okanagan Valley and the West Kootenays, with an eighth site in Kamloops subsequently added.

The second phase commenced a year later, with the installation of detectors in homes in eight locations in the northern interior and coastal regions. Results showed considerable variation of levels between and within locations, but interior regions generally showed higher levels. The GVRD was confirmed as having very low levels, while cities such as Castlegar, Nelson, Penticton, and Prince George showed levels much higher than documented for Vancouver.

Overall, one per cent of all homes in the Interior—approximately 3,000 homes—exceeded the Canadian guidelines for corrective action within a year. However, despite the health advisories, the general public still does not consider radon to be a significant health risk.

It is reasonable to project that, in areas where homes have high levels of radon, the same may apply to schools in the vicinity. In 1991, a program of testing schools for radon was launched, commencing with a pilot study in three schools districts of the BC Interior. The tests revealed one school district to be highly prone and the others moderately prone to elevated radon levels (BCCDC, 2003). These results indicated the need for similar investigation of schools in other radon-prone areas, with remedial action taken where indicated.

By 1999, all radon-prone schools in the province had been tested and the problem mitigated; further action was required in two schools and a monitoring program was put in place (Morley & Phillips, unpublished, 1999).

While there has been success in reducing radon levels in schools, the provincial initiative to reduce radon exposure in homes remains a "work in progress" that requires the active participation of homeowners. While smoking is easily the most important preventable cause of cancer, and accounts for the vast majority of lung cancers, estimates of risk indicate that about 5 per cent of lung cancers deaths (approximately 100 per year) in BC may be attributable to indoor radon (Bigham & Copes, unpublished, n.d.)

Major Air Quality Situations

The Forest Fire Disaster of 2003

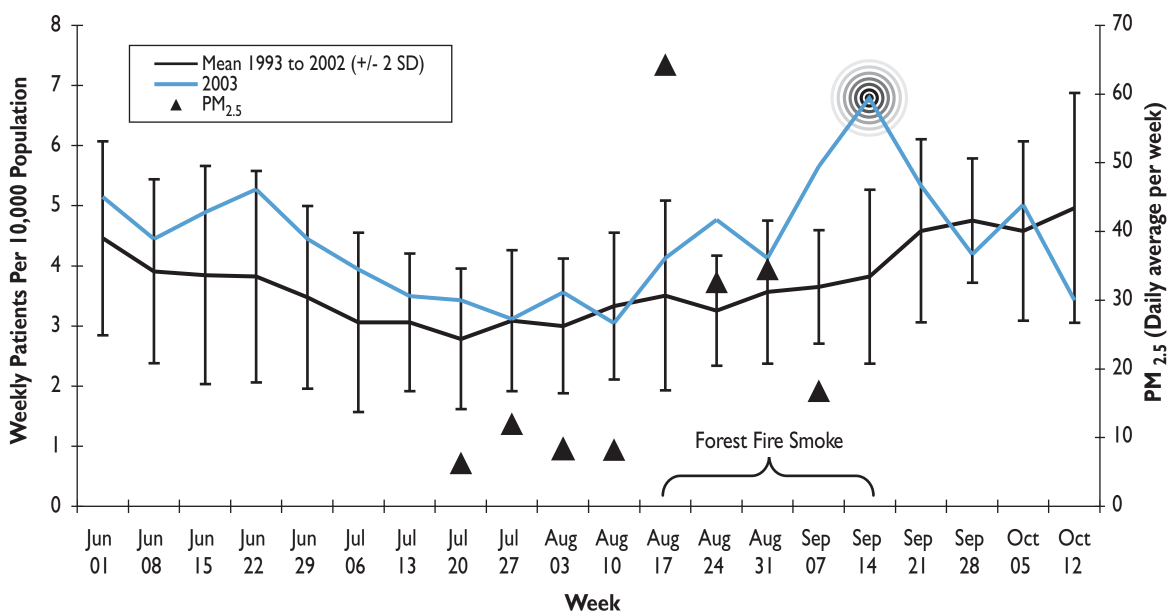
Two areas that were heavily affected by the forest fires of 2003 were Kamloops, from early to mid-August, and the Central Okanagan, including Kelowna, from mid-August to mid-September. The worst of the impact was brought under control by early September, after 244 homes had been destroyed. By that time, it was possible to assess the immediate impact on the region's 100,000 residents and the firefighters. Mental and physical exhaustion among residents and firefighters had surfaced as health problems and resulted in increased demand for health services, including psychological counseling (Mackay, 2003). Due to the dislocation of normal services and associated threats to utilities (electricity, water pipes), there were also concerns regarding safety and security of food and water supplies (Interior Health Authority, 2003). Health workers themselves were among the most affected, which compounded the difficulties felt by health services in responding to these demands.

It was recognized from the onset that the dense smoke spread by the 20,000-hectare blaze posed widespread respiratory risks. Time-series analyses, carried out by the Population Health Surveillance and Epidemiology Program, BC Ministry of Health Services, contrasted patient utilization of the Medical Services Plan (MSP) for the period June 1 to October 12, 2003, with average levels for the same periods from 1993 to 2002. Three categories were considered: respiratory disease, circulatory disease, and respiratory and circulatory combined, for the two catchment areas of Central Okanagan and Kamloops, both in close proximity to the forest fires. No unusual trend in MSP utilization for either condition was evident in Kamloops, but a significant excess was seen in the Central Okanagan for respiratory conditions, with onset one week after the fires commenced. The same analysis for circulatory conditions was followed and no impact on these conditions was observed. These trends are shown in Figures 4.15 and 4.16.

While both areas experienced major forest fires, the ones in the vicinity of Kelowna (Central Okanagan) lasted longer (4-5 weeks) than in Kamloops (about two weeks). The $PM_{2.5}$ levels in Central Okanagan were also higher than recorded in Kamloops[14], which may explain why only one of these areas experienced the observed increase in MSP utilization. The total health costs of the disaster are difficult to assess, as the direct costs have been absorbed by increased utilization of health services across a wide range of categories, while much of the indirect costs were borne by those personally affected; however, all these costs will

FIGURE 4.15

Respiratory Disease, MSP Patients, LHA 23 - Central Okanagan, BC, Weeks of June 1 to October 12, 1993-2003



Notes: 1. Specialties included are General Practice, Pediatrics, Internal Medicine, Public Health, Geriatric Medicine and Emergency Medicine Services for ICD9: 460-519 billed through the Medical Services Plan (MSP). Service codes included are regional and complete exams, consultations, and home and emergency visits. These data represent the number of individual patients per week, provided by FFS or PCDP practitioners. Pathology services by general practitioners were excluded.

2. The accuracy of the diagnostic coding data, as entered on billing claims submitted to MSP, is unknown, but is believed to be adequate for the purposes of retrospective general community surveillance.

3. Inter-area and intra-area variations must be interpreted with caution, as data relating to physician services utilization may be influenced by many factors, including severity of symptoms, physician access, and diagnostic coding practices. MSP data are current as of November 4, 2003, but the last few weeks may be incomplete due to the lag time in bill processing activities.

Source: Population Health Surveillance & Epidemiology, Ministry of Health Services, 2003.

14 *Between June and October 2003,* $PM_{2.5}$ *concentrations averaged 10 μg/m³ in Kamloops and 12 μg/m³ in Kelowna.*

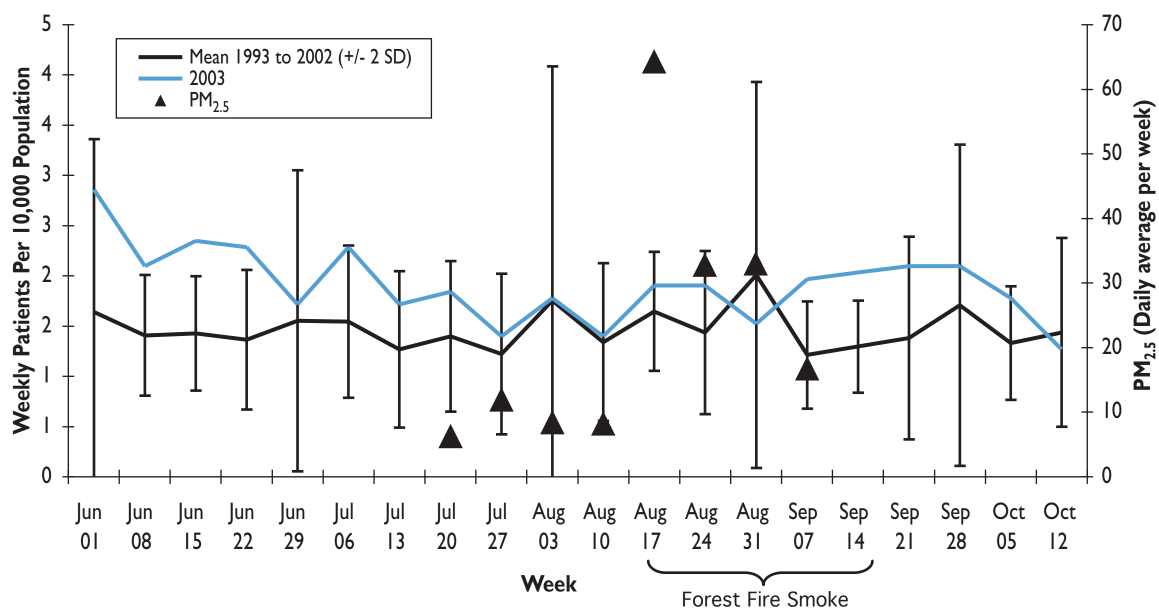
have been substantial. To illustrate an order of magnitude, the immediate cost to the province of the fire fighting, evacuee relief and cleaning was estimated to be in excess of $0.5 billion (Beatty, 2003).

Automotive Pollution and the Lower Fraser Valley

Despite the 21 per cent reduction in emissions from 1985 to 2000, the haze or smog often blanketing the Lower Fraser Valley is a continuing concern. In 1985, the GVRD developed emission inventories in order to support an Air Quality Management Program in the LFV. In 2000, the inventory was expanded to include Whatcom County in Washington State, representing the US portion of the airshed (GVRD, & Fraser Valley Regional District [FVRD], 2002).

Taken together, mobile sources account for 53 per cent of smog-forming pollutants, while area sources account for 35 per cent, and point sources a modest 12 per cent.

FIGURE 4.16 **Circulatory Disease, MSP Patients, LHA 23 - Central Okanagan, BC, Weeks of June 1 to October 12, 1993-2003**



Notes:
1. Specialties included are General Practice, Pediatrics, Internal Medicine, Public Health, Geriatric Medicine and Emergency Medicine Services for ICD9: 390-459 billed through the Medical Services Plan (MSP). Service codes included are regional and complete exams, consultations, and home and emergency visits. These data represent the number of individual patients per week, provided by FFS or PCDP practitioners. Pathology services by general practitioners were excluded.
2. The following specific ICD9 codes are included, as entered on billing claims submitted to MSP. The accuracy of the diagnostic coding data is unknown, but is believed to be adequate for the purposes of retrospective general community surveillance.
3. Inter-area and intra-area variations must be interpreted with caution, as data relating to physician services utilization may be influenced by many factors, including severity of symptoms, physician access, and diagnostic coding practices. MSP data are current as of November 4, 2003, but the last few weeks may be incomplete due to the lag time in bill processing activities.
4. Data are compiled by postal code address of the patient, as stated in MSP records, irrespective of the location of the physician providing the service.
5. For reasons noted above, it is believed that the data are probably more reliable for larger communities than for smaller communities.

Source: Population Health Surveillance & Epidemiology, Ministry of Health Services, 2003.

Mobile sources refer to both on-road and off-road vehicles, including marine, which itself accounts for a surprising 12 per cent of the total. Area sources are generally a multitude of small emissions (e.g., gas fired home furnaces, vehicle refueling, farming operations, solvent use, etc.). Point sources refer to large industrial and commercial operations, such as oil refineries, sawmills, and cement plants.

The 2000 LFV inventory showed that light-duty and off-road vehicles now account for 83 per cent of carbon monoxide pollution of the airshed, this being the largest contaminant overall. Light duty vehicles also account for the following proportions of other contaminants: nitrogen oxides (23 per cent), volatile organic compounds (23 per cent), sulphur dioxide (4 per cent), $PM_{2.5}$ (3 per cent), and ammonia (6 per cent). Marine emissions account for 22 per cent of nitrogen oxides, and 33 per cent of sulphur oxides. These estimates are useful in highlighting the role of the transportation sector, in particular light vehicles, as well as the very substantial contribution of marine sources, that have until recently escaped public attention.

When analysed by political region, the GVRD contributed 56 per cent of smog-forming contaminants, with the remainder coming from Whatcom County (29 per cent), and the Fraser Valley Regional District (15 per cent). These three jurisdictions make up 83 per cent, 10 per cent, and 7 per cent of the LFV population, respectively. The larger than expected contribution of Whatcom County emissions (relative to population) is explained by the existence of more heavy industry and greater per capita vehicle-kilometres traveled in that area; it also underscores the importance of air quality planning on an international basis.

Regarding the contribution of particulate matter to impaired visibility in the valley, a study carried out in the Central Fraser Valley indicates that motor vehicles may contribute to as much as 40 per cent of the fine particle mass and up to 30 per cent of particle light-scattering (Pryor & Barthelmie, 2000).

Although the trends of overall emissions is encouraging, studies of the health impact of air pollution must also take into consideration individual risk tolerance and behaviour. Researchers at the University of British Columbia have factored human behaviours into measuring and modeling pollution exposures for risk analysis; for example, in hot weather many people tend to stay indoors where exposure levels could be very different from what is being measured outside (Zidek & Le, 1999).

Another example of the importance of considering actual exposures in studies of the health effects of air pollution can be seen in a study of exhaust particles and other traffic pollutants in the Lower Mainland. The researchers noted that a large percentage of the Vancouver population resides in relatively close proximity to roads carrying 15,000 or more vehicles per day. When examining air quality data from traffic monitoring sites compared to background levels, the biggest differences were derived for estimated elemental carbon, the primary source being diesel vehicles (Brauer & Henderson, 2003). The importance of diesel exhaust in relation to human residential exposures is proportionally greater than its relatively small overall contribution to air pollution. Public health policy must be formulated within the context of human risk, where interventions are likely to be most effective.

In general, automotive pollution in BC is a challenging problem. This is largely a matter of personal choice. For example, over the past decade sales of sport utility vehicles (SUVs) have increased by nearly 80 per cent (David Suzuki Foundation, 2003), and they have become larger, heavier, and more powerful, with fleet fuel efficiency falling and safety compromised in order to meet consumer demand for acceleration (Bradsher, 2002).

A requirement that all passenger vehicles meet fuel efficiency standards was passed by the federal government in 1982, but not proclaimed in favour of a strategy to engage the voluntary compliance of the auto industry. Although the fuel efficiency of gasoline engines has improved, and in 2004 light trucks (including minivans and SUVs) will have to meet the same (Tier 2) emission norms as regular passenger vehicles, the Canadian fleet average fuel efficiency has deteriorated due to a major shift towards light trucks, vans, and SUVs (Schingh, Brunet, & Gosselin, 2000).

SUMAS 2 vs. Anthropogenic (Human) Sources Emissions that Affect Human Health in BC's Fraser Valley Airshed

Since 1993, Sumas Energy Inc. has operated an electrical generation plant (Sumas 1) in Sumas, Washington, just south of the Canadian border. Using natural and diesel gas-fired steam turbines, it produces 125 megawatts of power for the local area.

In 1999, Sumas Energy 2 Inc. submitted an application to Washington State's Energy Facility Site Evaluation Council (EFSEC) to build a second plant (Sumas 2), capable of producing 660 megawatts, over five times that of Sumas 1. At the same time, they applied to the National Energy Board of Canada for a permit to construct and operate the Canadian portion of an International Power Line that would link Sumas 2 to BC Hydro's Clayburn substation in Abbotsford.

Washington State's EFSEC initially denied the application, but upon reapplication, the project was approved in 2002. The Province of BC, the Sumas First Nation, local municipalities, and several community groups petitioned the National Energy Board to deny Canadian approval of the International Power Line, due to concerns about how emissions would affect air quality in the Fraser Valley airshed. In March 2004, the National Energy Board denied the Sumas 2 application. In fact, the Board denied the proposal because they were not satisfied that the power line was necessary or beneficial for Canadians.

Can this be considered a victory for defenders of air quality in the airshed? When one looks closely at the projected annual health-related emissions from Sumas 2, they would contribute a significantly smaller amount to the airshed than anthropogenic sources produced in the Lower Mainland (e.g., motor vehicle emissions), as projected in the following table. Plans for further residential development in the Fraser Valley to absorb double the population over the next 20 to 30 years halve the percentage of emissions contribution by a Sumas 2.

*Projected yearly emissions by Sumas 2 and Vehicle emissions in tonnes,*** Lower Fraser Valley, 2000*

Source	VOC	SO_x	NO_x	PM_{10}
Sumas 2	138	62	131	189
Light-Duty Mobile*	25,770	775	22,712	431
Municipal Lower Mainland**	70,911	8,706	82,501	10,064

** Generated using data for light duty vehicles operated by gasoline and diesel.*

*** Includes all municipality/electoral areas, and marine areas.*

**** Tonnage, though not specific to a particular time or place, is useful on a broad comparison level.*

The effect of a Sumas 2 plant in the Fraser Valley airshed, though significant, is relative. Of more importance is our own contribution of emissions from passenger vehicles and housing developments. With regard to housing, our interest in residential development contrasts with the negative reactions to industrial development. Similarly, the convenience of personal motorized transportation seems to outweigh the impacts vehicles have on air quality. In 2002, British Columbians purchased approximately 107,000 passenger cars and 87,500 light trucks. Over ten years, these vehicles will produce six times more health-related emissions than a single Sumas 2.

While the evaluation of the environmental impact of new industry point source development on our airsheds is essential, other human sources play a larger role. Responsibility for clean air does not only lie with government and industry, but with individuals as well.

"To make an impact on the health effects of our mountain airshed we must take a keener interest in our own backyard, house, and driveway." (Corneil, 2004).

Thanks to the GVRD Air Quality Management Program, emission controls on heavy industry in the LFV have worked, but when we look to the expanding population of the province, and our love affair with low occupancy, low fuel-efficiency vehicles, we must now be prepared to take on the challenge of making responsible personal decisions.

Building-Related Illnesses and Occupational Exposures

Building Related Illness is diagnosed only when other possible illnesses have been investigated and ruled out, and there remains an unexplained excess of reported ill-health. An investigation of BC Liquor Stores in 2001 was carried out by a UBC team in response to a request from the Liquor Distribution Branch (LDB), the BC Government and Service Employees Union (BCGEU), and the Workers' Compensation Board (WCB). Liquor store employees were reporting respiratory symptoms, and it was felt that the workplace may have been responsible.

The protocol for the investigation was developed by UBC in consultation with a project advisory committee made up of LDB, BCGEU, and WCB representatives (Kennedy et al., 2001). Thirty-six liquor stores, with 226 employees, were randomly selected. Attention was given to the use of glass-breaking equipment, the concern being that the resulting dust and biological contaminants such as molds and endotoxins might explain the symptoms. Each store was tested twice approximately one month apart, and in half of the stores, the glass-making equipment was shut down between visits so as to examine this as a factor in the analysis. Dust and endotoxins were measured in employee breathing zones, while fungi were sampled at various locations. Acute and chronic symptoms were evaluated using standardized, interviewer-administered questionnaires. The study attempted to relate symptoms to measured levels of dust, endotoxins, and fungi, and findings were compared with those from BC Ferry employees, as a reference group (Kennedy et al., 2001).

Average dust levels were found to be below WCB exposure limits, about the same as for office-based employees in the lumber and grain industries, and within non-dusty areas in lumber mills. Most variability in dust and endotoxin was unaccounted for by the factors studied, although exposure was higher among employees spending more time in the back of the store and closer to glass-breaking machines or glass recycling. Viable fungal counts were associated with glass-recycling activities; the most important factor was moldy bottles being broken in the store, but counts were not lower on days when glass-breaking equipment was not operating (Kennedy et al., 2001).

Overall, LDB employees reported more chronic chest tightness (31 per cent versus 17 per cent) and nasal symptoms (61 per cent versus 49 per cent) than BC Ferry employees. Increased chest symptoms were significantly

Ammonia Emissions in the Lower Fraser Valley

For years, residents of the Lower Fraser Valley experienced the appearance of a white haze on warm sunny days. The source of this haze was recently identified by Environment Canada as the ammonia released from agricultural activities, in particular poultry and other livestock manure. Through specialized sampling, it was discovered that ammonia tends to combine with nitrogen and sulphur oxides from industrial and vehicle emissions — and with dimethylsulfide, a substance emitted from the ocean surface — and tends to result in the formation of $PM_{2.5}$*.*

In 2000, 75 per cent of all ammonia emissions in the Lower Fraser Valley were due to cattle, pig, and poultry housing; manure land-spreading and storage; and inorganic fertilizer application. Environment Canada is working with agricultural producers and other stakeholders to find solutions to the ammonia emissions. Some options being considered include transporting manure to areas that have lower levels of nitrogen, changing poultry diets to reduce nitrogen content of manure, or using nitrogen as an additive to commercial fertilizer. Airshed plans and stricter control of nitrogen and sulphur oxide emissions in this region are also recommended. (Environment Canada, Manure Causing White Haze, n.d.).

Community Concerns Over the Crofton Mill

The Crofton Mill, situated on the east coast of southern Vancouver Island, was a focus of attention in the Capital Regional District's Healthy Atmosphere 2000 report (1992), which suggested that emissions from the mill were noticed by residents throughout the region, particularly on the Saanich Peninsula and Saltspring Island. Although the Crofton Mill was considered to be one of the cleanest mills in BC, it was noted that even within stack emission standards, it was possible for weather conditions to trap and concentrate pollutants at ground level, causing emission levels to exceed ambient standards. Residents raised concerns over possible health effects and in 2004 NorskeCanada, owners of the Crofton Mill, conducted a study of the emissions and provided an assessment of the potential health impacts.

The study, which was reviewed by a third party, Senes Consultants Ltd, reported that of the 106 pollutants, 102—including PM_{10} *and total reduced sulphur—were at levels within Canadian and international guidelines. The study recommended further monitoring of four pollutants- sulphur dioxide, hydrogen chloride, nitrogen oxides, and hydrogen sulphide - that had higher predicted concentrations close to the fence line of the mill property. The review concluded the following about the potential for health effects:*

- *Sulphur dioxide – health effects are unlikely but cannot be ruled out at this point.*
- *Hydrogen chloride – very unlikely to cause health effects.*
- *Nitrogen oxides – no acute health effects expected.*
- *Hydrogen sulphide – unlikely but cannot be ruled out at this point.*

The review also reported on polycyclic aromatic hydrocarbons (PAHs) and concluded that there was no increased cancer risk above a bench mark of 1 in 100,000.

Overall, the review concluded that the emissions from Crofton Mill did not pose health threats to those communities with significant populations in the vicinity of the Mill. (NorskeCanada, 2004)

associated with fungal contamination (i.e., visually contaminated bottles being broken in the store) regardless of whether or not glass-breaking machines were in operation. Some symptoms such as increased eye and skin irritation and somatic symptoms (e.g., headache, nausea, dizziness, fever, and tiredness) were associated with increased job strain (i.e., relatively poor balance between perceived psychological demands of work and individual control over tasks, reduced work satisfaction, and poor communication between management and workers) (Kennedy et al., 2001).

In conclusion, despite some evidence that dust exposures were associated with an increase in acute irritation of the nose and throat, the source was not clear. While dust control may have some positive effect, the investigators noted the need to improve the psychosocial dimensions of the work environment.

Personal and Societal Choices

With regard to outdoor and indoor air pollution many of the causes are, to some extent, within our control. Personal choice in the type of automobile we drive and the amount it is used certainly affect the level of air pollution to which we are subjected. Smoking, use of woodstoves, and even the products we use in the home, such as cleaning chemicals, paint, furniture, and carpets, all produce air pollution. While the types of products offered by industry, and the level of government regulation do have an affect on our choices, as a society, we must take some responsibility for our decisions.

Chapter 5: Estimates of the Impact of Air Pollution on Health in BC

Determining the health effects of environmental pollutants can be challenging. In general, too little is known about the causal links between pollution and adverse health effects, and about the levels of exposure across populations. In this chapter, we will use limited data from BC and Ontario studies as well as international estimates to derive an approximation of the health impact of both outdoor and indoor air pollution on British Columbians.

Measures of morbidity (illness) and mortality (death) are used for analyzing the health status of populations. Estimates of mortality and mortality-derived measures such as loss of life expectancy are used in studying the effects of air pollution on the population. Morbidity may be assessed using hospitalizations, emergency room visits, or absences from school or from work. Mortality and morbidity measures can also be combined to analyze measures such as disability-adjusted life years (DALYs), which incorporate years of life lost prematurely and years suffered with a disability.

When attempting to measure the impact of air pollution on health, we should take into account all diseases to which poor air quality is a contributing factor; however, this has rarely been done and would potentially involve a broad number of conditions. In many instances, especially for indoor air pollution, there is little scientific information on which to base these estimates.

Global Estimates of Adverse Health Effects of Air Pollution

It is difficult to separate and analyze the overall impact of poor environments into individual components such as lack of food or clean water; inadequate hygiene and sanitation; and poor air quality in the home, at work, or in the community. Table 5.1 presents best estimates of the global magnitude of environmental and occupational air pollution.

Global estimates of mortality due to urban outdoor air pollution range from 200,000 to 799,000 deaths, representing about 0.4 to 1.4 per cent of all annual deaths (World Resources Institute, 1998a; Ezzati et al., 2002). The World Bank, however, estimates that exposure to particulate levels exceeding the World Health Organization (WHO) guideline accounts for roughly two to five per cent of all deaths in rapidly expanding urban areas of the developing world. On average, the level of particulate pollution in low-income countries is double the concentration of that found in high-income countries.

Indoor air pollution may be even more damaging in terms of overall disease burden. It is estimated that between two and four per cent of disability-adjusted life years lost is due to indoor air pollution. Together, indoor and outdoor

Table 5.1: Global Burden of Disease Attributable to Selected Sources of Environmental and Occupational Pollution

	Deaths		Disability Adjusted Life Years (DALY'S)	
	Number	(%)	Number	(%)
Total Mortality	*55,861,000*	*100*	*1,455,473,000*	*100*
Risk Factors				
Water, sanitation & hygiene	*1,730,000*	*3.1*	*54,158,000*	*3.7*
Urban outdoor pollution	*799,000*	*1.4*	*6,404,000*	*0.4*
Indoor smoke from solid fuels	*1,619,000*	*2.9*	*38,539,000*	*2.6*
Lead	*234,000*	*0.4*	*12,926,000*	*0.9*
Occupational carcinogens	*118,000*	*0.2*	*1,183,000*	*0.1*
Occupational airborne particulates	*356,000*	*0.6*	*5,354,000*	*0.4*
Occupational Noise	*0*	*0.0*	*4,151,000*	*0.3*
Sub-Total (pollution-related)	*4,856,000*	*8.7*	*122,715,000*	*8.4*

Source: Adopted from "Selected Major Risk Factors and Global and Regional Burden of Disease" by M. Ezzati, A. D. Lopez, A. Rodgers, S. Vander horn, C. J. Murray, and Comparative Risk Assessment Collaborating Group, 2002, *Lancet, 360*, pp.1353-1354.

Table 5.2: Estimates of Deaths due to Indoor Air Pollution, by World Region, 1996

Region or Country	Deaths from Indoor Air Pollution	Deaths from Outdoor Air Pollution	Total
China	*373,000*	*70,000*	*443,000*
India	*589,000*	*84,000*	*673,000*
Other Asian Countries	*403,000*	*40,000*	*443,000*
Latin America and Caribbean	*293,000*	*113,000*	*406,000*
Sub-Saharan Africa	*522,000*	-	-
Arab States	-	*57,000*	-
Industrialized Countries	*32,000*	*147,000*	*179,000*
Total	***2,212,000***	***511,000***	***2,723,000***

Source: Based on United Nations Development Programme data. From "Population and the Environment: The Global Challenge", by D. Hinrichsen and B. Robey, Fall 2000, *Population Reports, 28* (Series M, No. 15). Retrieved September 20, 2004, from http://www.infoforhealth.org/pr/m15/m15chap2.shtml

London Fog of 1952

Around 12,000 people died in the London "fog" of 1952, which was mainly associated with the widespread use of coal (Bell & Davis, 2001). Pollution levels were 5 to 19 times higher than current regulatory guidelines. While this event triggered concerns and actions throughout the industrialized world, similar pollution levels and events occur in many large cities in developing countries, particularly in the Asia-Pacific region.

air pollution are estimated to be responsible for nearly five per cent of the global burden of disease (United Nations Environment Programme, 2002).

In 1998, the Johns Hopkins School of Public Health published estimates of deaths due to indoor air pollution by global region, shown in Table 5.2 (Hinrichsen & Robey, 2000). This table indicates that indoor air pollution produces the larger burden of disease in developing countries, mostly due to the practice of burning biomass fuels for domestic heating and cooking in poorly ventilated homes. The ratio of deaths from indoor pollution to deaths from outdoor pollution for all developing countries is 6.7 to 1. By contrast, the developed countries experience proportionately more deaths as a result of outdoor pollution, a ratio of 1 to 4.6, reflecting use of other fuels for cooking and heating, and possibly greater dependence on industrialized economies. The burden of illness from indoor pollutants other than fuels has not been well assessed.

Developing countries carry a greater share of the global burden of disease, disability, and death from both outdoor and indoor air pollution. These countries continue to face a serious public health challenge from increasing air pollution. However, developed countries, with 15 per cent of the world's population, presently consume 50 per cent of the world's energy.

The Situation in Europe

A recent assessment by the European Environment Agency found that over 70 per cent of 105 European cities surveyed failed to meet WHO air quality guidelines for at least one pollutant (World Resources Institute, 1998a).

WHO has identified particulate pollution as an important contributor to ill-health in Europe. In cities where data are available, WHO has estimated that short-term particulate pollution episodes account for 7 to 10 per cent of all lower respiratory illnesses in children, increasing to 21 per cent in the most polluted cities. Furthermore, 0.6 to 1.6 per cent of deaths were attributable to short-term pollution events, increasing to 3.4 per cent in cities with the most polluted air (World Resources Institute, 1998b).

The Situation in the United States

In the United States, an estimated 80 million people live in areas that do not meet US air quality standards, which are less stringent than WHO guidelines. Mortality rates are 17 to 26 per cent higher in US cities with the dirtiest air compared to those with the cleanest air, due to higher rates of lung cancer and cardio-pulmonary disease. The increased risks translate roughly to a one to two year shorter life span for residents of the most polluted cities.

Effect of Air Pollution on Lung Development of Children in California

Published in 2004, a study in California examined 1,759 children, 10 years of age (on average) and measured their lung function annually for the next 8 years. These children lived in communities exposed to a wide range of pollutants such as ozone, acid vapor, nitrogen dioxide, and particulate matter. After 8 years, most of those tested showed clinically and statistically significant reduction in their respiratory growth as a result of exposure to nitrogen dioxide, acid vapor, particulate matter ($PM_{2.5}$), and elemental carbon. The study concluded that the current levels of air pollution have chronic, adverse effects on the lung development in children from the age of 10 until they reach adulthood at 18 years of age. (Gauderman et al., 2004)

Air pollution receives significant attention in the US, and the Environmental Protection Agency (EPA) estimates that the benefits of the 1990 Clean Air Amendments out-weigh the costs by a four-to-one (4:1) margin. The associated programs "prevent thousands of premature deaths related to air pollution, and millions of asthma attacks as well as a wide range of additional human health and ecological effects" (Environmental Protection Agency [EPA], 1999).

EPA's 2003 report to Congress projected that early reductions in $PM_{2.5}$ and ozone levels under the Clear Skies Program would result in 7,800 fewer premature deaths and $55 billion in annual health and visibility benefits nationwide each year. In addition, by 2020, Americans would experience annually 14,100 fewer premature deaths, 8,800 fewer cases of chronic bronchitis, 30,000 fewer hospitalizations/emergency room visits for cardiovascular and respiratory symptoms, and 12.5 million fewer days lost from work due to absenteeism. The monetary benefits would total approximately $113 billion annually by 2020, substantially outweighing the annual cost of $6.3 billion (EPA, 2003).

The Situation in Canada

There have been many studies on particular aspects of air pollution in Canada, but few on disease burdens. An Air Quality Valuation Model (AQVM), incorporating health effects estimates, has been used to generate data for setting Canada-wide Standards (CWSs) and other regulations (Environment Canada, Economic and Regulatory Affairs, n.d.), but to date only Ontario and British Columbia have published actual estimates of disease burden attributable to air pollution.

Ontario

In 2000, a study for the City of Toronto estimated that 1,000 premature deaths and 5,500 hospitalizations per year were due to air pollution (Basrur, 2000). The report noted that if the city were to meet current Ontario criteria for ozone and particulate matter (PM_{10}), little improvement would occur (a reduction of only about 1 per cent of the premature deaths and less than 3 per cent of respiratory hospital admissions). The Toronto report states that reducing particulates to a background level (lower than CWS) would result in a 20-25 per cent reduction in deaths (approximately 243) and a 10 per cent reduction (548) in hospitalizations from respiratory disease (Basrur, 2000).

In another study, the Ontario Medical Association (OMA), examined the costs of illness due to air pollution in Ontario, based on an analysis of mortality data, hospital admissions, emergency room visits, and visits to doctors' offices.

In the year 2000, 1,900 premature deaths were forecast to have occurred as a result of air pollution. As well, 9,800 hospital admissions, 13,000 emergency room visits, and 47 million minor illness days attributable to air pollutants were estimated. By the year 2015, premature deaths were forecast to increase to 2,600, hospital admissions and emergency room visits to 13,000 and 18,000 respectively, and minor illnesses to increase to 53 million. Air pollution has been estimated to cost Ontario's citizens more than $1 billion a year in hospital admissions, emergency room visits, and absenteeism.

Both the City of Toronto and the OMA study methodologies have been critiqued and may over-estimate the adverse health impacts of air pollution.

Although BC has significantly better air quality than Ontario (Annual Mean average of $PM_{2.5}$ of 6.3 vs. 14.2 respectively), these Ontario studies can be useful in illustrating the potential health burden attributable to air pollution in British Columbia. By simply prorating the OMA study to British Columbia on the basis of population size — in 2003, population was 12.3 million in Ontario and 4.1 million in British Columbia — and accepting all the OMA assumptions, we could estimate the following health burden of air pollution: 644 premature deaths, 3,323 hospital admissions, and 4,408 emergency room admissions. However, since most British Columbians are less exposed to air pollution than are residents of Ontario, this will very likely be an overestimation of the BC burden.

British Columbia

In British Columbia, the most recent global estimate of air quality-related burden of disease was published in 1995 (Vedal, 1995). Another study with BC relevance concentrated on the effect of urban ambient air pollution mix on daily mortality rates in 11 Canadian cities (Burnett, Cakmak, & Brooke, 1998). In this study, Vancouver (the only BC city included) was intermediate within the range, ranking sixth. The data from this study came mostly from the period 1980-1991, and major reductions in ambient carbon monoxide levels have been made in Vancouver's air quality since that time.

More relevant to the present is a study of estimated air pollution-attributable deaths in the Lower Mainland (1994-1998) using local epidemiological findings, which placed the mortality burden within the range of 0 to 600 deaths per year (Brauer, Brumm, & Ebelt, 2000). The Medical Health Officers (MHOs) in the Lower Mainland, for whom the report was produced, concluded on further analysis that the most likely range for air quality-related mortality was 15 to 150 deaths per year (Fraser Health Authority, 2001). The Lower Mainland comprises about 60 per cent of the provincial population, so extrapolating these MHO estimates to the province as a whole would attribute 25 to 250 annual deaths for BC to air pollution. Using Brauer's original assumptions, the upper estimates would be 1,000 deaths.

The only other independent estimate of the health burden from outdoor air pollution in British Columbia was made by Vedal (1995), who calculated that increases in PM_{10} above a defined base level were projected to cause an additional 82 deaths each year. He also estimated hospitalization and emergency room visits. For the purpose of the mortality estimates, he used a baseline of 24,750 deaths per year.

Health Effects of $PM_{2.5}$ in BC

In order to further refine the estimates of morbidity and mortality in BC due to air pollution, we reviewed the methodology in the report, *Health and Air Quality 2002- Phase 1, Methods for Estimating and Applying Relationships*

Table 5.3 Annual Mean Concentrations of $PM_{2.5}$ for Various Communities in BC, 2003

Community	$PM_{2.5}$ (µg/m^3)
Kitimat	2.7
Powell River	3.7
Richmond	4.1
Nanaimo	4.2
Chilliwack	4.9
Aldergrove	5.3
Pitt Meadows	5.6
Langley	5.6
Victoria	5.9
Houston	6.6
Williams Lake	7.5
Kamloops	7.9
Vernon	8.4
Kelowna	8.5
Quesnel	8.6
Golden	10.2
Prince George	10.8

Source: Ministry of Water, Land & Air Protection, 2003.

Table 5.4 Improving Life Expectancy by Reducing $PM_{2.5}$ Levels, BC, 2004

Communities	Deaths delayed by reduction of $PM_{2.5}$ to 6 µg/m^3	Deaths delayed by reduction of $PM_{2.5}$ by 1 µg/m^3
Coastal	-	26
Fraser Valley	-	7
GVRD	-	49
Interior	71	28
Total	**71**	**110**

Source: Population Health Surveillance & Epidemiology, Ministry of Health Services, 2004.

$PM_{2.5}$ and Cardiovascular Effects in State Highway Troopers in North Carolina

Past studies have shown that exposure to elevated levels of $PM_{2.5}$ is associated with increased risks of morbidity and mortality. In a recent study of young, healthy, non-smoking State highway troopers in North Carolina, it was shown that in-car exposures to $PM_{2.5}$ — at levels below both ambient outdoor concentrations and well below threshold levels established for occupational exposures — were found to be associated with changes in heart rate and ectopic beats due to enhanced vagus nerve activity, and changes in blood inflammatory and coagulation markers. Both these changes have been associated with an increased risk of heart disease. The authors suggest that exposure to elevated levels of $PM_{2.5}$ in-car should be minimized. (Riedliker et al., 2004)

between Air Pollution and Health Effects, (Bates et al., 2003) and applied it to the annual mean concentration level for $PM_{2.5}$ for communities in BC which was provided by the Ministry of Water, Land and Air Protection. (Table 5.3).

As seen in Table 5.3, the mean concentrations for $PM_{2.5}$ were less than 6 μg/m^3 for coastal communities, Vancouver Island, parts of GVRD, and the Fraser Valley[1]. Values available for other communities ranged from 7.5 to 10.8 μg/m^3. Where values were not available, the median of 8.5 μg/m^3 was used as an estimate. For the purpose of this study, the value of 6 μg/m^3 was chosen as the current "best attainable result" for the rest of the province. Of the 27,557 recorded provincial deaths in 2003, 71 could have been delayed[2] if the $PM_{2.5}$ levels were no higher that 6 μg/m^3. It was also found that if the $PM_{2.5}$ concentrations were decreased by only 1 μg/m^3 throughout the province, approximately 110 deaths in the Province would have been delayed (See Table 5.4).

It is interesting to note that at a "background" level of 6 μg/m^3, the benefits of reducing $PM_{2.5}$ accrue to the Interior region of BC – reflecting their air pollution burden secondary to PM. However, reducing $PM_{2.5}$ by 1 μg/m^3 has a benefit in all the regions across the province. If we were to target the level of $PM_{2.5}$ to 6 μg/m^3 for the Interior and reduce the levels of $PM_{2.5}$ by 1 μg/m^3 elsewhere in the province we would achieve 153 delayed deaths.

Indoor Air Pollution

Attributable mortality and morbidity from indoor air pollution have not been estimated in BC, or elsewhere in Canada. In the absence of such an estimate however,

Second-hand Smoke

Using 1998 data and contemporary methodology, Health Canada researchers recently estimated that 30,230 men and 17,351 women died in 1998 due to active or passive smoking, including 96 children under the age of 1 year. Of these, 1,107 deaths were attributable to second-hand smoke. This study also generated BC-specific estimates: 3,381 smoking-attributable deaths among males, and 2,349 among females, and 29 and 79 deaths respectively from passive or second-hand smoke (Makomaski Illing & Kaiserman, 2004).

Not all exposure to second-hand smoke is indoor. Epidemiological studies of the impact of second-hand smoke are based on the health outcomes of non-smokers who live with smokers, implying exposures in all settings including indoors, frequent proximity to a smoker outdoors, and in other settings.

[1] *Mean concentration values are based on communities with monitoring stations for $PM_{2.5}$ as indicated in Table 5.3.*

[2] *Although the report entitled Health and Air Quality 2002-Phase 1, Methods for Estimating and Applying Relationships between Air Pollution and Health Effects (Bates et al., 2003) did not specify a meaning for the delayed mortality, they have cited one study – National Ambient Air Quality Objectives For Particulate Matter, by the Federal/Provincial (Working Group on Air Quality Objectives and Guidelines (1998) – which measured the delayed mortality as an average loss of 2 years over a 14 year period.*

it is possible to adjust estimates of outdoor pollution to represent indoor pollution. If we apply the ratio of almost 1 to 4.6 (deaths due to indoor pollution to deaths from outdoor pollution) derived earlier from United Nations estimates for developed countries, to the revised estimate of 95 deaths from outdoor pollution from the Vedal study, we arrive at an estimate of 21 deaths representing the magnitude of the mortality burden of indoor pollution. However, as the ratio is based on the practice of burning biomass fuels for domestic heating and cooking in poorly ventilated homes, and does not take into account the burden of second-hand smoke.

Table 5.5 displays six extrapolations of the mortality burden of air pollution in BC.

At the global level, estimates of mortality due to outdoor air pollution vary across sources, from about 0.4 to 1.4 per cent of total annual deaths (Ezzati et al., 2002; World Resources Institute, 1998a). Applying these estimates to BC's total mortality in 2002 (28,686 deaths), yields a range of 115-402 deaths (the High Intermediate Estimate in Table 5.5).

The estimate of 82 deaths attributable to particulate pollution (Vedal, 1995) lies below the lower end of this range, as does the $PM_{2.5}$ extrapolation from the *Health and Air Quality 2002 Phase I* study (Bates et al., 2003). Similarly, the estimates cited by the Medical Health Officers in the Lower Mainland overlap with the lower end of this range.

These lower estimates are not necessarily unreasonable given that air quality in BC compares favourably with many other areas of the world, including elsewhere in North America.

A high estimate was also obtained by pro-rating the Ontario Medical Association study to BC. The mean

Table 5.5: Differing Estimates of the Mortality Burden of Air Pollution in British Columbia

	Low Estimate (1)	Low Intermediate Estimate (2)	High Intermediate Estimate (3)	High Estimate (4)	Health Canada Estimate for Second-hand Smoke (5)	Estimates of Delayed Mortality for $PM_{2.5}$ (6)
Outdoor air pollution	*82*	*25-250*	*115-402*	*644*	*NA*	*71-110 (6)*
Indoor air pollution	*21*	*5-45*	*25-89*	*141*	*NA*	*NA*
ETS	*108 (5)*	*108 (5)*	*108 (5)*	*108 (5)*	*108*	*NA*
Total	*224*	*138-403*	*248-599*	*893*	*108*	*71-110*

Notes:

1) This estimate is based on Vedal's 1995 estimate for outdoor particulate pollution in BC, adjusted for total deaths (2002) and the global ratio of burden from indoor to outdoor air pollution for developed countries.

2) This low intermediate estimate is derived from Brauer's estimate for the Lower Mainland, as interpreted by the Lower Mainland Medical Health Officers, pro-rated to BC as a whole and adjusted for the global ratio of burden from indoor to outdoor air pollution for developed countries.

3) This high intermediate estimate is based on the published range of global estimates for mortality from outdoor air pollution, pro-rated to the total number of deaths annually in BC.

4) This outdoor air pollution estimate is derived from pro-rating Ontario estimates to BC; the figure given for indoor pollution is extrapolated from a global ratio of indoor to outdoor air pollution.

5) This figure for indoor pollution is an independent Health Canada estimate for mortality from ETS in BC.

6) Extrapolation of report entitled *Health and Air Quality 2002-Phase 1, Methods for Estimating and Applying Relationships between Air Pollution and Health Effects,* (Bates et al., 2003) based on provincial $PM_{2.5}$ data from Ministry of Water, Land and Air Protection.

concentration for $PM_{2.5}$ for Ontario was 14.2 μg/m^3 (based on 1996 data) while the mean concentration for BC was approximately 6.2 μg/m^3. It should be noted that the BC value only included the communities with monitoring stations as shown in Table 5.3.

We have, therefore, derived high and low estimates from a variety of published sources and consider the mid-range estimates to be plausible for BC. Although these estimates can be debated, none differs by an order of magnitude. Even the extreme estimates reflect less than a seven-fold difference, and it must be noted that the low estimate is based on only one component, particulate pollution. The highest estimate is derived by extrapolation from another jurisdiction (Ontario), for which air quality generally is not as favourable as in BC. The Health Canada estimate for second-hand smoke is based on BC data on the prevalence of smoking and exposure, and supports the plausibility of the indoor extrapolations, which are generally conservative. The high-intermediate estimate range is roughly comparable to the range given by the World Health Organization for European cities. Both the low and the low intermediate estimates are based on work done in BC, using BC data, and the low (single level) estimate derived from Vedal's work in 1995 actually fits within the range of the low-intermediate estimate derived from Brauer's work in 2000. It is therefore reasonable to conclude that the low estimate is too conservative, as Vedal's work and the *Health and Air Quality 2002-Phase 1* study (Bates et al., 2003) consider only particulate pollution, and do not address the independent effect of ozone or other pollutants.

Taking these considerations into account, we can conservatively conclude that air pollution in all its forms in BC most likely causes between 138 and 403 deaths per year (the new intermediate estimate), of which about half is due to outdoor pollution, and the other half from indoor pollutants, the most important being second-hand smoke. The average of the low intermediate estimates are 271 deaths, with 138 due to outdoor, 108 due to ETS, and 25 due to indoor air pollution. Interestingly, the average for outdoor and indoor air pollution are at the low end of the range given for the high-intermediate estimates derived from international sources. We use these average estimates in the next section when comparing air pollution mortality with other public health issues.

How Does BC's Air Pollution Mortality Compare With Other Diseases?

Table 5.6 compares estimated air pollution mortality in BC with selected other causes of death. Each cause of mortality is considered a distinct public health or social

Table 5.6: Comparison of the Low-Intermediate Estimate Range for the Burden of Air Pollution and Other Causes of Mortality in British Columbia

Outdoor Air Pollution	*25 - 250*
Indoor Air Pollution	*5 - 45*
ETS Estimate (1998)	*108*
Total Air Pollution	*138 - 403*
Homicide	*37*
Cervical Cancer	*43*
AIDS	*104*
Motor Vehicle Accidents	*399*
Lung Cancer	*2015*
Female Breast Cancer	*600*
Cardiovascular Diseases (ICD I00-I51)	*6893*
*Work-Related Deaths**	*149*

**Note:* Work-related deaths reported by the Workers' Compensation Board (2003).

problem with a considerable preventable component that attracts considerable public resources for specific programs. It should be noted that in the absence of a screening program, cervical cancer mortality would be about 4 times higher than it is at present (e.g., approximately 172 deaths rather than the 43 deaths actually recorded in 2002). (A. Coleman, BC Cancer Agency, personal communication).

If we compare the burden of air pollution mortality with all causes of mortality in BC, air pollution is a relatively small problem. In 2002, there were 28,686 deaths, of which the 271 from all forms of air pollution (range 138-403) would comprise less than 1 per cent (range 0.5-1.4 per cent), or about 1 in 106 deaths.

However, when we compare the mortality from total air pollution to the other causes selected, we see that this burden is over 3-9 times the burden of cervical cancer (43 deaths) or homicide (37 deaths), and up to 4 times the mortality burden of AIDS (104) and may equal the burden of deaths from motor vehicle accidents (399).

Deaths attributable to second-hand smoke are about equal to deaths from AIDS and more than two-thirds the size of work-related deaths accepted by the WCB. The remaining deaths from indoor air pollution are equal to about two-thirds of the deaths from homicide, almost half those from cervical cancer, and a quarter of the number of deaths from AIDS.

Life Expectancy Lost or Gained

While some researchers have attempted to estimate the numbers of excess deaths attributable to air pollution, their work has been criticized as simplistic, since mortality data does not take into account the age at time of death (McMichael, Anderson, Brunekreef, & Cohen, 1998). Loss of life expectancy has been proposed as a more meaningful measure of the death burden from air pollution. A reduction of 50 to 70 per cent of PM_{10} is calculated to add 4 months to life expectancy in the European Union and the United States (Rabl, 2003). A study in the Baden Wurttemberg region in Germany produced an estimate of 5.5 months loss in life expectancy attributable to PM_{10} (Szagun & Seidel, 2000). Urban areas produce even higher estimates, such as 1.3-1.7 years lost in Athens, Greece (Economopoulou & Economopoulou, 2002), while in the United States the increased risks in urban areas have been translated into a 1 to 2 year shorter life span for residents of the most polluted cities (World Resources Institute, 1998a).

Estimates of potential life expectancy gains from other public health interventions are also useful for comparison purposes. For example, a Canadian Cardiovascular Outcomes Research Team estimated a 4.5 year gain if all cardiovascular diseases (CVD) were eliminated in Canada (Manuel et al., 2003). Because CVD is the leading cause of death, even achieving a 10 per cent decrease would be significant.

United States estimates of projected gains in life expectancy through eliminating deaths from HIV/AIDS, heart disease, and malignant neoplasms were 0.34, 3.25, and 3.21 years respectively (Lai Tsai & Hardy, 1997). Against these, a burden of 4 months from air pollution (0.33 years) is about 10 per cent of that from CVD or cancer, and similar to the life expectancy lost due to HIV/AIDS in the United States.

Estimating the Morbidity Burden of Air Pollution in BC

While most people would interpret the number of air pollution-related deaths as substantial, it does not reflect the true burden of ill-health caused by air pollution. As most of the burden of ill-health is due to conditions that do not usually result in death, morbidity estimates are critical to assessing the full burden of ill-health. As with the estimation of mortality, arriving at possible morbidity estimates is also challenging.

As noted earlier, the Ontario Medical Association (OMA, 2000) examined the illness costs of outdoor air pollution in Ontario, based on an analysis of hospital admissions, emergency room visits, and visits to doctors' offices. In the year 2000, 1,900 premature deaths were forecast to occur as a result of air pollution. As well, 9,800 hospital admissions and 13,000 emergency room visits were attributed to air pollutants. Air pollution was estimated to cost Ontario's citizens more than $600 million a year in hospital admissions, emergency room visits, and

Table 5.7: Estimated Hospital Admissions and Emergency Room Visits Attributable to Air Pollution in British Columbia

	Mid-Point Estimate Outdoor Air Pollution	Mid-Point Estimate Indoor Air Pollution	Estimate Second-hand Smoke	Mid-Point Estimate TOTAL	Range
Hospital admissions	712	129	557	1398	712-2079
Emergency room visits	944	171	739	1854	943-2757

absenteeism. Although the Ontario estimates were used to generate a "high estimate" for BC, if one assumes that access to and standards of health care are similar between the two provinces, the ratios of morbidity measures (hospital admissions and emergency room visits) to mortality can be used to extrapolate the mortality estimates for BC, to a set of morbidity estimates. These ratios are: hospital admissions to premature deaths: 1 to 5.16 and emergency room visits to premature deaths: 1 to 6.84.

Given the average estimates and ranges of mortality derived earlier for BC, we have applied these ratios to produce estimates for hospital admissions and emergency room visits (Table 5.7).

Although the outdoor air pollution estimates are almost 2.5 to 5 times higher than those of Vedal (1995), who estimated 146 extra hospitalizations (69 lung disorders, 60 heart disorders, 17 asthma), and 354 extra emergency room visits (283 asthma, 71 chronic bronchitis or emphysema), we consider them reasonable as we consider that Vedal's estimates were conservative, since they were based only on particulate pollution, used a relatively high baseline PM level, and did not address the independent effect of ozone.

The Meaning of Mortality and Morbidity from Air Pollution in Relation to the Economy

As previously noted, there is no evidence of a threshold for the two main outdoor air pollutants — ozone and particulates — below which there is an absence of health effects. In addition, our dependence on automobiles and industries that produce emissions assumes that some level of anthropogenic air pollution is inevitable in our economy with its current technologies. To achieve fully both the economic and the environmental health goals of our society will be a challenge.

No formal costing exercise has yet been carried out for the burden of air pollution in BC, but our informal estimates place the health burden from outdoor air pollution in BC at about $85 million[3]. On this basis, assuming the same cost structures, one may extrapolate that second-hand smoke and indoor air pollution would cost an additional $67 million and $15 million respectively. In total the health burden and costs of outdoor and indoor pollution would be $167 million. A modest 10 per cent reduction would come to almost $17 million. For comparison, this approaches the cost of the 2003 vaccine budget for the province (approximately $20 million) and the annual cost of running the cervical cancer screening program in BC (approximately $12-13 million and estimated to save 130-150 lives per year). (A. Coleman, BC Cancer Agency, personal communication).

Vulnerable Population Groups

The burden of ill-health does not fall equally across society. This has been studied extensively in the United States, but only minimally in Canada. The magnitude and distribution of health benefits from emissions control were estimated in Washington DC by a Harvard University team, who found that 51 per cent of mortality occurred in the 25 per cent of the population with less than high school education, and that racial minorities and persons with immune-compromised conditions were at higher risk. (Levy, Greco, & Spengler, 2002).

[3] *This figure is extrapolated from Ontario's estimate of approximately $600 million annually for associated health-related costs, adjusted for the smaller population size in BC and the smaller relative disease burden attributable to air pollution, based on the low-intermediate estimate presented earlier.*

In New York City, a study of respiratory hospital admissions attributable to air pollution showed similar disparities. Most of the apparent differences were related to underlying socio-economic factors (Sexton et al., 1993). A study of residential areas in proximity to industrial pollution sources found similar relationships in West Virginia, Louisiana, and Maryland (Perlin, Wong, & Sexton, 2001). Previous US studies have indicated that disadvantaged groups experience higher than average exposures to air pollution due to their location in areas with higher density traffic and more environmental hazards (e.g., waste incinerators, diesel bus depots) (Sexton et al., 1993; Brown, 1995).

Similarly, there are reports from the United Kingdom which show that disadvantaged neighbourhoods are most likely to suffer from the effects of pollution, and that one out of every two municipal waste incinerators in England are in the poorest 10 per cent of the country (British Broadcasting Corporation, 2004). Although such disparities have not been studied in every country, the World Bank recognizes it as a serious worldwide problem (Johnson & Lvovsky, 2001).

Aside from socio-economic and other inequities, some people are more susceptible to the effects of air pollution than others. These include children and those who suffer from conditions such as asthma or heart disease. The elderly in particular are more susceptible to the harmful effects of air pollution. In light of such social variations, the California Environmental Protection Agency, Air Resources Board, has launched a Vulnerable Populations Research Program (California Air Resources Board, n.d.).

In British Columbia, regional inequalities in air pollution exposures exist. For example, Interior and Northern communities do not fare as well on health indicators, and are dependent economically on the pulp, paper, and wood products industries that give rise to heavy particulate pollution. Similarly, aboriginal communities in the province are more likely to experience substandard housing associated with a greater likelihood of indoor pollution. Both communities are also highly exposed to second-hand smoke and woodstove emissions.

Conclusion

There are both data gaps and acknowledged challenges in estimating the health burden of air pollution in any jurisdiction. However, using a variety of published studies as starting points we estimate that for BC approximately 271 deaths (range 138-403) can be attributed to air pollution in its three main forms: 51 per cent of deaths due to outdoor air pollution, 9 per cent related to indoor, and 40 per cent to second-hand smoke. The mortality burden is substantially larger than several other public health issues to which considerable public resources and attention are directed, such as cervical cancer, AIDS, and work-related deaths. In addition, the mortality burden from air pollution

Estimates of Premature Mortality and Air Pollution

Estimates of premature mortality involve the application of methodology—based on research results from credible studies—to the population of interest, in this case, British Columbia residents. Obviously, such methods cannot actually determine which individuals experience a premature death, but rather provide a theoretical estimate of how many people may experience a premature death based on the health risks of the population exposed to air pollution.

In BC, there is a low level of health risks associated with air pollution, and the population size is relatively small. In addition, research methods themselves differ from one study to another. As a result of all of these factors, mortality estimates in BC differ from one study to another, and wide ranges between the low and high estimates can result. As research methods continue to be developed and our knowledge of the adverse health effects of air pollution improves, it will be possible to make more accurate estimates.

The important lesson we can gain from the available research is that the direction of the studies is clear – air pollution is harmful to health, and if reduced/avoided, an improvement in population health can be expected.

is much larger than homicide, and is two-thirds the burden of deaths associated with motor vehicle collisions.

Furthermore, air pollution in BC is conservatively estimated to be responsible each year for 712 to 2,079 hospital admissions and between 943 to 2,757 emergency room visits, mostly from respiratory and cardiovascular conditions. Larger estimates would apply to activity restriction, absenteeism from work or school, and respiratory symptoms. The annual cost of the burden of disease from air pollution may be about $167 million, and a modest 10 per cent reduction would be valued at almost $17 million.

It is important to note that the health effects of air pollution disproportionately affect susceptible individuals and vulnerable groups, such as those with conditions like asthma, or the socially disadvantaged who are more likely to be exposed to pollution sources. Innovative approaches are required to make the difference, including more public information, participation in airshed planning, new transportation options, different personal choices around transportation and home heating options, promotion of health and fitness, and incentives to bring about needed changes.

Chapter 6: Roles and Responsibilities in Managing Air Quality

This chapter outlines the roles of various levels of government in air quality management, air quality management strategies, risk assessment, the role of information and education, and instruments to achieve compliance.

Due to the nature of air quality issues, it is imperative for jurisdictions to work together to ensure a coordinated response to manage air quality issues. We now look at the roles of the various levels of government in Canada, and how they work together to improve air quality.

The Federal Role

The federal role encompasses Canadian interests in international negotiations, cooperation with provincial and territorial governments, and legislative authority.

The trans-boundary nature of air quality makes it critical for jurisdictions to work together on air quality management. With regard to international cooperation, the federal government may enter into treaties on Canada's behalf.

Examples of international cooperation include the 1991 *US-Canada Air Quality Agreement*. This agreement is between Environment Canada and the US Environmental Protection Agency, and requires active communication, consultation, and prompt action regarding new sources of pollution, mapping trends, and patterns of pollution, as well as mutually recognized reduction goals and cooperative air quality management strategies (EPA, 2003). Common concerns include acid rain, which is a big problem for eastern Canada; and ground level

Think Locally, Act Globally

The inter-relationship of laws — local, national, and international — is a concept that is gaining support in our global society. An example is international tobacco marketing, where trade laws have an impact on health, and where both trade and health-related laws need to work in harmony (Von Schirnding, Onzivu, & Adele, 2002).

While "think globally, act locally" is a recognized principle, the converse, "think locally, act globally" is equally strong in environmental matters. We need to think about what happens locally when we act on a global scale. Both paradigms are required in order to resolve such long-range issues as global air pollution and climate change.

ozone, which is a concern for many areas including the Georgia Basin–Puget Sound airshed shared by BC and Washington State. Consideration is being given to developing an annex for particulate air pollution, which affects both eastern and western Canada, including BC. British Columbia actively participates in activities relating to this agreement and joint progress reports are issued every two years.

Turning briefly to the globalization of environmental management, a number of multilateral agreements have health implications. These include:

- Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal (1989);
- Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (1999);
- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998); and
- Stockholm Convention on Persistent Organic Pollutants (2001).

Despite weak enforcement measures, and a frequent lack of formal monitoring systems, a high level of compliance with multilateral environmental agreements has generally been achieved (Von Schirnding et al., 2002). A motivating factor is how action or lack of action on these agreements can affect a nation's international reputation.

International agreements require participating countries to sign, but often do not reach the status of binding law; more often they reflect levels of consensus. However, the concept of international law is gaining recognition, as the global impact of actions by individual countries becomes more recognized. An example of international law is the "Law of the Sea", a 200-mile economic zone that has been accepted worldwide.

Working with Provincial and Territorial Governments

While the federal government works bilaterally with provincial governments on a wide range of regional issues of common concern, the Canadian Council of Ministers of the Environment (CCME) is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national and international concern. The Council is comprised of environment ministers from the federal, provincial, and territorial governments. These 14 ministers normally meet at least once a year to discuss national environmental priorities and determine work to be carried out under the auspices of CCME.

CCME works to promote effective intergovernmental cooperation and coordinated approaches to interjurisdictional issues such as air pollution and toxic chemicals. CCME members establish consistent environmental standards, strategies, and objectives to achieve a high level of environmental quality across the country. While it proposes change, CCME does not impose its suggestions on its members since it has no authority to implement or enforce legislation. Therefore, each jurisdiction decides independently whether to adopt CCME proposals.

In 1998, with the exception of Quebec, the Canadian Ministers of the Environment signed the Canada-wide Accord on Environmental Harmonization and a sub-agreement on Canada-wide Standards (CWS). These standards are viewed as achievable targets to reduce health and environmental risks within specified timeframes, and were developed and implemented by working groups such as the Joint Action Implementation Coordinating Committee. A number of these standards address airborne contaminants that affect human health, such as fine particulate matter, and low ground level ozone.

Table 6.1 shows the CWS for ozone and $PM_{2.5}$, the major criteria pollutants for which health effects are best quantified. These standards were announced in 2000 (Health Canada, Canada-wide Standards, n.d.).

National Ambient Air Quality Objectives

The National Ambient Air Quality Objectives (NAAQOs) represent benchmarks to guide governments in making risk-management decisions (e.g., setting provincial objectives) (Health Canada, National Ambient Air Quality Objectives, [NAAQOs], n.d.). The intent is to work towards national goals for outdoor air quality in order to protect public health and the environment. While the federal government promotes NAAQOs, provinces may adopt them as they see fit, taking into account their priorities and circumstances.

Table 6.1: Canada-wide Standards for Ozone and $PM_{2.5}$

Pollutant	Averaging Time	Target for 2010
Ozone (O_3)[1]	*8 hours*	*65 ppb*
$PM_{2.5}$[2]	*24 hours*	*30 µg/m^3*

National Ambient Air Quality Objectives and the Canadian Environmental Protection Act

The federal government administers the *Canadian Environmental Protection Act* (CEPA, 1988) through which it sets *National Ambient Air Quality Objectives* (NAAQOs) (Health Canada, NAAQOs, n.d.).

The CEPA process of determining whether a substance is toxic, and therefore eligible for regulation under the Act, involves a National Advisory Committee with various working groups, which have provincial and First Nations representation.

A revised CEPA was proclaimed in 2000 after a five-year review process. The focus of the revised Act is pollution prevention and the protection of the environment and human health in order to contribute to sustainable development. Air pollutants identified as requiring management are now targeted for either National Ambient Air Quality Objectives or Canada-wide Standards, but not both. PM_{10}, ground-level ozone, and their precursors (NO_X, SO_2, VOCs, and gaseous ammonia) have been declared toxic substances under CEPA, giving the federal government the authority to take action to reduce these substances in the environment.

The Provincial Role

The provinces, including British Columbia, have broad authority to regulate air pollution sources, and thereby have primary responsibility for many aspects of air quality, which in turn may be delegated to regional or municipal jurisdictions (in Canada, only the city of Montreal and Greater Vancouver Regional District have full delegation of provincial air quality management authority). The provincial role also extends to setting environmental quality benchmarks, targets, and standards; developing strategies to reduce pollution; fostering partnerships with stakeholders; monitoring and reporting on the environment; inspecting and auditing; and enforcing provincial legislation.

Evolution of Air Management in British Columbia

1949 City of Vancouver initiated air pollution control program

1967 Established provincial regulatory program for air management

1972 Greater Vancouver Regional District given delegated authority for air management within its region

1982 Waste Management Act focused on point sources

1990 Shift to non-point sources with cleaner vehicles and fuels initiative and regulations to reduce smoke from open burning and residential woodstoves

2004 Environmental Management Act widens scope to include area-based planning

[1] *Ozone: Fourth highest daily 8 hour maximum, averaged over 3 consecutive years.*

[2] *$PM_{2.5}$: annual 98^{th} percentile of daily averages, averaged over 3 consecutive years.*

Environmental Management Act

The *Environmental Management Act* (EMA) came into force on July 8, 2004. The Act replaced the *Waste Management Act* and the *Environment Management Act* and brings provisions from both of those Acts into one statute. The EMA provides enabling provisions for modern environmental management tools such as area-based planning and administrative monetary penalties.

The EMA sets the legislative framework for waste management and air emissions, as well as providing the legislation for air quality-related regulations including:

- Industrial point sources (e.g., regulations such as Sulphur Content of Fuel, Wood Residue Burner and Incinerator, and Asphalt Plant);
- Mobile sources (e.g., cleaner gasoline,); and
- Area sources (e.g., regulations such as Open Burning Smoke Control regulation, and Solid Fuel Domestic Appliance).

A list of all regulations pertaining to air quality can be found at: http://wlapwww.gov.bc.ca/air/airregs.html

Under the EMA, industrial point sources may be regulated by the conditions of site-specific permits, such as limits on pollutant emission rates and concentrations. The new Act also contemplates regulation of classes of similar operations through legally enforceable codes of practice. In airsheds with multiple pollutant sources, permits and other tools allow sufficient flexibility to set emission controls and other conditions consistent with airshed plans. However, because case-by-case reviews may fail to provide for the cumulative impact of emissions from several sources, the Act also provides for area-based planning. This allows the Minister of Water, Land and Air Protection to designate an area for the purpose of developing an area-based management plan, and establishes a process for the development of such plans. Area-based planning can enable communities to better address cumulative impacts from both point and non-point sources (Williams & Bhattacharyya, 2004). Airshed plans are in place or near completion in a number of BC communities, including the Greater Vancouver Regional District (GVRD), Fraser Valley Regional District (FVRD), City of Prince George, Resort Community of Whistler, City of Quesnel, and Bulkley Valley-Lakes District.

Additional Provincial Responsibilities

Air quality objectives and standards can be used as benchmarks to determine the acceptability of contaminant levels in ambient air. As a signatory to the Canada-wide Standards, BC must address how compliance, continuous improvement, or prevention of significant deterioration will be achieved for both particulate matter and ground-level ozone (Williams & Bhattacharyya, 2004).

In addition to regulating air pollution sources and airshed planning, tax incentives are also provided to encourage use of alternative fuels and alternative fuel vehicles. The *Social Services Act* provides tax concessions for alternative fuel vehicles. The *Motor Fuel Tax Act* provides exemptions and preferential tax rates for alternative fuels to gasoline or diesel, such as ethanol, natural gas, propane, and high-level alcohol blends. A new exemption was created for a diesel alternative fuel in 2001.

Under the *Motor Vehicle Act*, the first mandatory vehicle inspection and maintenance program for light-duty vehicles in Canada (AirCare) was instituted in 1992. A review conducted in 1994 concluded that AirCare was the single largest contributor to improved air quality in the Lower Mainland. This program was transferred to TransLink, the regional transit authority, in 1999. More information on AirCare can be found at www.aircare.ca

Under the province's *Environmental Assessment Act*, certain large-scale project proposals are required to undergo an environmental assessment and obtain an environmental assessment certificate before proceeding. The Environmental Assessment Office is a neutral provincial agency that coordinates assessment of such proposals in British Columbia. The assessment process results in recommendations to either grant or refuse an environmental assessment certificate. The recommendations are considered, and a decision made by the Minister of Sustainable Resource Management, Minister of Water, Land and Air Protection, and a third appropriate minister. (Environmental Assessment Office website, www.eao.gov.bc.ca)

The *Growth Strategies Act* complements the province's clean air initiatives, ensuring that growth can take place while maintaining clean air, affordable housing, clean drinking water, protected farmland, wilderness and unique natural areas. Under this Act, some communities are developing general plans to prevent future air pollution (Williams & Bhattacharyya, 2004).

Local and Regional Government Role

Municipal and regional governments have the authority to pass by-laws that may restrict certain emission-causing activities in their jurisdiction, such as backyard burning and residential wood combustion. Local authorities can also influence type and location of emission sources and their future growth through zoning, transportation and land-use planning, regional growth strategies, and sustainability plans.

Under the *Environmental Management Act*, the GVRD is the delegated authority to control and manage air quality within its boundaries. Given the size of the population affected by its policies and permitting decisions, the GVRD plays a key role in the overall air quality management system in BC, and has added important components to the air quality management system. These include development of a formal airshed management plan, with specific goals, timelines, and emission reduction measures to meet the goals. The FVRD also has delegated authority to conduct airshed planning.[4] The FVRD is collaborating with the GVRD to develop an airshed-wide plan, while Whatcom County in Washington State recently joined this planning process for emission inventory purposes (Williams & Bhattacharyya, 2004; GVRD, 2003b).

Within the GVRD, TransLink is responsible for policy and program development and the administration of all regional roads and public transit operations within the GVRD. In addition to its role in managing AirCare, TransLink is also involved in transportation demand management efforts, including commuter trip reduction programs, transit priority measures, and cycling paths.

Inter-Related Air Quality Management Approaches

It is important to be aware that air pollution is a global problem, and the standards and practices of one jurisdiction can affect the conditions in another. For example, the long-distance transportation of pollutants globally, such as Asian haze, affects us even as we achieve some degree of harmonization in policies and practices both across Canada and with US jurisdictions on trans-boundary issues. The same could apply between one local jurisdiction and another. There is a tension here between what may be desirable and what may be feasible across such widely diverse settings.

The process of harmonization can be difficult to achieve since the make-up of air pollution may differ substantially across jurisdictions, so what is important or feasible to correct in one setting may be less important elsewhere. For example, as noted earlier, the Canada-wide Standards (CWS) are only a set of common minimum targets acceptable to all provinces and the federal government,

Federal-Provincial-Territorial Working Group on Air Quality

Up to 1999, Canada had a Federal-Provincial-Territorial Working Group on Air Quality that carried out reviews of scientific information and developed recommendations for national air quality objectives to protect human health. The last working group assessments focused on PM and ozone, which formed the scientific basis for setting Canada-wide Standards for these substances.

The federal-provincial-territorial governments are moving to re-establish a scientific working group on air quality, particularly with regard to reviewing the health effects of exposure to sulphur dioxide and nitrogen dioxide.

4 *This authority does not extend to managing air quality.*

Table 6.2: Authority Delegated to Different Levels of Government for the Control of Various Air Pollutants

Air Issue	International	Federal	Provincial	Regional/Local
Wood Combustion	*Canada/US Air Quality Agreement for visibility degradation*	• *Open burning on federal lands* • *Woodstove regulation (under development)*	• *Provincial* PM_{10} *standards* • *Prescribed burning* • *Open burning of wood residues* • *Woodstove emission regulations*	• *Backyard burning* • *Approval of incinerators, including "burn barrels"* • *Inspection of woodstove installations to ensure they meet air quality emission and fire safety standards*
Ozone-depleting Substances	*Montreal Protocol*	*Montreal Protocol*	• *Enhanced regulations governing ozone-depleting substances*	
Greenhouse Gases	*Kyoto Accord*	*Kyoto Accord*	• *Provincial climate change policy (action plan under development)*	• *Federation of Canadian Municipalities partners for Climate Change*
Acid Rain, Ground-Level Ozone and Fine Particles	• *Long-range transport of air pollution* • *Canada/US Air Quality Agreement*	*Canada-wide Standards (CWS)*	• *Development of jurisdictional plans to CWS, including provisions for continuous air quality improvement and to "keep clean areas clean"*	• *Local by-laws (such as background burning and residential woodstoves)* • *Supporting provincial plans for CWS implementation*
Transportation	*Marine emissions for PM are currently unregulated, and need to be addressed through actions at the national and international level by Canada in cooperation with the U.S. and through the International Maritime Organization*	• *Vehicle emission standards* • *Fuel standards* • *Regulations pertaining to rail, aircraft and marine emissions*	• *Vehicle and fuel quality regulations* • *Roads, engineering, and traffic control* • *Construction specifications*	• *Zoning and community planning* • *Transportation planning* • *Transit, and transportation demand management programs*
Industrial Point Sources	• *Notification requirements under Canada/US Air Quality Agreement*	• *Specific air quality objectives for specific industries* • *Environmental assessment*	• *Specific air quality objectives for specific industries* • *Environmental assessment* • *Permits*	• *Zoning and community planning*
Miscellaneous	*Canada/US Air Quality Agreement*	• *Air quality objectives* • *Building codes*	• *Point source permits for large industrial emitters (covered above)* • *Air quality objectives* • *Building codes*	• *Zoning and community planning* • *Local by-laws* • *Building codes*

Note: From *Guide to Airshed Planning in British Columbia*, by R.J. Williams and K.K. Bhattacharyya, March 31, 2004. Adapted with permission.

and may not be sufficient to achieve the air quality goals of a given province. Because the Council of Ministers of Environment recognized that there were health effects below the CWS and that allowing pollution to up to the CWS could even lead to a deterioration of air quality in some settings, they endorsed development of jurisdictional plans for Keeping Clean Areas Clean/Continuous Improvement. BC is developing a provincial approach to implementing the Keeping Clean Areas Clean/Continuous Improvement commitments in the CWS.

As demonstrated from the various government roles relating to air quality management, the control of various air pollutants falls within an inter-related set of provisions. This is illustrated in Table 6.2.

Approaches to Air Quality Management and Exposure Reduction

From a health perspective, the goal of air quality management is to maintain the air quality that protects human health and welfare (World Health Organization [WHO], Guidelines for Air Quality, 2000). This is achieved through various approaches to air quality management, including regulatory and non-regulatory interventions. All jurisdictions within Canada have relevant air quality goals and policies embodied within acts, regulations, by-laws, standards, and objectives. Here, we address strategies that are effective in managing air quality management.

There are many different approaches to air quality management, including those referred to in the context of BC's *Environmental Management Act*, such as the provision of site-specific permits, applying common practices or requirements to groups of similar sources through regulation or codes of practice, and area-based planning for areas with multiple pollution sources. Other approaches include growth strategies, community energy plans, greenhouse gas action plans, and economic incentives used to encourage clean air solutions.

Air quality management requires a logical array of intervention options. Exposures to air pollutants may be prevented at the outset, or otherwise managed, reduced, or eliminated; alternatively, protective devices may be used (e.g., face masks, usually in the context of occupational exposures[5]), or duration of exposure may be reduced, or people may have to remove themselves from proximity to the source. The following are six common approaches with examples of possible actions:

- **Preventing the exposures from occurring in the first place**
  An example of this approach in an outdoor situation is the recent decision by the National Energy Board to deny Sumas Energy 2 Inc. of Washington State a license to build a power line from the United States to a BC Hydro substation in Abbotsford. This made it unlikely that the Sumas 2 project would proceed (although the decision is under appeal).
- **Restricting approval, to limit the conditions under which emissions may occur**
  An example of this approach is the permits issued to wood products mills that require them to have the capacity to divert wood residue which would allow beehive burners to shut down for a specified number of production days for air quality management purposes (MWLAP, Skeena Region, n.d.)
- **Reducing emissions from known sources using technological improvements**
  Examples include hybrid-electric vehicles with double the fuel-efficiency of standard vehicles; and the development of cleaner fuels and improvements in diesel technology to reduce particulate emissions, with some success through improvements in engine design, catalysts, and traps (Hamerle, Scheutzle, & Adams, 1994).
- **Strengthening people's ability to withstand the impact of exposures**
  Programs promoting healthier lifestyles, such as smoking prevention and cessation programs, result in healthier people who are less susceptible to the impact of toxic substances.

[5] *Face masks are of dubious value unless designed to be effective for a particular exposure.*

- **Diagnosing early and intervening to reduce ongoing exposures**
  An example would be the diagnosis of a child with asthma, which then prompts an inquiry into the household environment to reduce potential exposure to dusts, molds, and other allergens.

The Role of Information and Education in Air Quality Management

The success of any approach to air quality management requires public education and participation. When people understand the basis for recommended or required actions, they may be more motivated to participate or comply. Public information and education programs help support the public and community to manage and improve air quality.

The most widespread educational approach to protect people's health from outdoor air pollution is based on the Air Quality Index (AQI). Based on this indicator, individuals may modify their activities, much as they do in response to weather forecasts.

While Canada has no national AQI system[6], there are a set of federal guidelines that have been followed in establishing AQIs in most major Canadian cities (Environment Canada, 1996). The GVRD has developed its own AQI (GVRD, 2003a). Environment Canada maintains a system that produces air quality forecasts and reports using the provincial AQI for regions in BC outside of the GVRD, such as the Central Interior, Southern Interior, and Vancouver Island. Environment Canada also provides ultraviolet (UV) forecasts — an index of solar radiation relevant to potential for skin damage — at major centres (Environment Canada, Environment Canada's Official Canadian Text Forecasts, n.d.).

Canadian AQI systems take into account the main criteria pollutants, including ozone. In British Columbia, the AQI[7] numbers are interpreted as follows: 0 to 25 - GOOD, 26 to 50 - FAIR, 51 to 100 - POOR, and 100+ - is VERY POOR. An AQI in excess of 50 is intended to represent the point at which human health is affected. For example, the ozone level of 82 parts per billion is a level capable of producing health effects in some people, and this is expressed as an index value of 50. When the index reaches 51, unusually sensitive people should consider limiting prolonged outdoor exposures, and when it reaches 101, active children and adults, and people with respiratory disease such as asthma, should limit prolonged outdoor exertion.

The current AQI does not recognize that pollutants may act synergistically – i.e., the sum of the effects is greater than the contributions from individual pollutants. Other factors, such as elevated temperatures, may also worsen the effects of air pollutants, such as observed among the elderly in Paris in 2003. Better AQI systems are a focus for research and development around the world, including a national effort underway in Canada, which is supported by BC. The new AQI is expected to be based on health risks.

Airshed Planning

An *airshed* is an area where the movement of air (and pollutants) can be hindered by local geographical features (such as mountains) and by weather conditions. Since air pollution knows no boundaries, airshed planning can focus on a single community or a group of neighbouring communities faced with similar air quality problems. Airshed planning integrates a number of different approaches outlined earlier (e.g., preventing exposure, restricting approval, etc.) into action within a specific area. Airshed planning in BC is a multi-stakeholder, multi-source approach to coordinating actions within a distinct geographical area (recognizing that action is needed across a number of sources and by a number of agencies/groups).The airshed plan can provide a blueprint to help communities manage development and control air contaminant sources and it can also ensure that air quality goals of various levels of government are met. (Williams & Bhattacharyya, 2004).

6 *In the United States, a national AQI system is maintained by the Environmental Protection Agency. A new national AQI is under development by a federal/provincial working group.*

7 *For more information on the AQI, access: http://wlapwww.gov.bc.ca:8000/pls/aqiis/air.info*

Airshed Planning in Quesnel

In the winter of 1998, a community health survey was conducted in Quesnel. One out of three Quesnel residents responded yes when asked, "During the past 12 months, do you think any indoor or outdoor pollution issues have affected your health?" Among these individuals, 89 per cent said they thought outdoor air pollution was the cause.

Air quality measurements in Quesnel and elsewhere in BC confirmed this view. In 1998, out of 28 residential continuous monitoring locations in BC, air quality in downtown Quesnel was the worst in the province. This situation was characterized by high levels of fine particulate air pollution from a wide range of sources, including wood waste burners; pulp mills and other industrial and commercial processes; open and backyard burning; road dust; automobile and truck emissions; and domestic woodstoves. Not only were these levels of fine particulates significant from a health perspective, they also impaired visibility in affected areas. In addition, there were other indicators such as total reduced sulphur reflective of emissions from the pulp and paper mills in the area.

In response to this situation, in December 1999, an airshed management planning process was launched. The plan is being developed by an "Air Quality Roundtable", a committee with participation from local industry, local and provincial government, regional and community health authorities, environmental groups, and concerned citizen groups. The Quesnel Environmental Society presently chairs the Roundtable.

The new plan is expected to address the region's health concerns by measuring all inhalable particulates on a continuous basis, reporting those levels to the public, and consequently reducing overall particulate levels in the community. Once air quality monitoring and assessment have identified emission sources and their contributions to poor air quality, the goal will be to ensure that all sources of air pollution are addressed.

In addition to responding to air quality health concerns, the plan is essential for encouraging the development of value-added industry and tourism, and for promoting the region to prospective employees and persons entering retirement. Development and implementation of the plan will take approximately five years, although some components will take longer. A draft plan is expected to be completed in 2004.

An example of a successful airshed plan can be found within the GVRD and Lower Fraser Valley. More detailed information on this approach is provided in *A Guide to Airshed Planning in BC* recently developed by the Ministry of Water, Land and Air Protection (Williams & Bhattacharyya, 2004).

From Regulation to Risk Assessment – A Transformation in Regulatory Thinking

The Origin and Nature of Regulations

A regulation is designed to control or govern conduct. The traditional regulatory approach rests on a "command and control" philosophy (WHO, Guidelines for Air Quality, 2000). This involves developing emission standards and bringing these into force as regulations, licensing emission sources, monitoring and reporting, and imposing penalties on non-conforming operations.

Regulations are generally based on scientific data as well as principles like best available control technology (BACT) and maximum achievable control technology (MACT). Regulatory agencies also consider economic feasibility, and input from government officials in setting discharge limits.

The Canadian experience in the development of regulations has been characterized by relatively closed decision-making, relying heavily on expert judgment with limited public debate. It has been argued that this approach, although incorporating scientific values, is not sufficiently participatory (Harrison & Hoberg, 1994). Opportunities for consultation have steadily increased over the years, although there is still room for improvement. While there may be new challenges in attempting an open approach, successful outcomes may be more likely as the general public become even better informed.

Air Quality Objectives and Human Health Risks

Our understanding of the relationship between air pollution and human health has changed dramatically in the last 30 years.

The effect of air pollutants on human health used to be evaluated by exposing volunteers to known concentrations of common gaseous air pollutants such as ozone or sulphur dioxide in a chamber. In these experiments, subjects were exposed to the pollutant for the duration of 10 hours or less while exercising, to determine the increased delivery of the pollutant to the lung. The health outcome of interest was usually a measured change in lung function, generally reversible, and too small to be associated with any symptoms.

These studies showed evidence of relatively minor health effects at the level of concentrations that would only occur on the worst days of the year. Therefore, it was believed that air quality objectives that were both completely achievable and protective of everyone's health could be established. The historical approach to setting air quality objectives in Canada which involved a three tiered approach of *Maximum Tolerable, Maximum Acceptable, and Maximum Desirable* reflected this belief.

However, advances in computing capability and the availability of large electronic databases with air pollution monitoring data and data on health outcomes such as deaths and hospitalizations made new research studies possible. These large scale studies, performed over the past two decades, have provided evidence of air pollution related health effects that are far more serious than the subtle effects on lung function at the concentrations of air pollutants that was previously believed to have no serious health effects.

It is important to stress that while our knowledge of this relationship between air pollution and health is new, the effects are not. As most of these pollutants are related to burning of different carbon-based fuels, exposure to these pollutants has been occurring as long as humans have been burning carbon-based fuels.

Our current knowledge indicates that even the relatively low levels of air pollutants found in many of our cleaner cities are associated with health effects. While higher levels of air pollution are clearly associated with greater risk, we are unable to find a level of air pollution at which there is no risk. Therefore, our air quality objectives and the Canada-wide Standards for particulate matter and ozone should not be viewed as levels at which there is no risk to human health. Like many environmental objectives and standards, these are set on the basis of protecting human health and the environment, the technical feasibility and the economic cost of achieving them as standards.

Susceptibility and Exposure

As noted in previous chapters not all humans are equally susceptible or vulnerable to given toxic exposures. *Susceptibility* refers to the potential for living organisms to be harmed by an agent, and varies between and within species. Susceptibility may reflect genetic, anatomical,

Georgia Basin Ecosystem Initiative

The critical balance between the environment and the economy is illustrated by a 1999 tourism study conducted for the Georgia Basin Ecosystem Initiative (GBEI). This study estimated that just one day of visibly bad air could result in future tourist revenue losses of $7.45 million in the greater Vancouver area, and $1.32 million in the Fraser Valley (Gilliard, n.d.). GBEI was recently renamed the "Georgia Basin Action Plan" to refocus attention on the seven million people now living within this area (57 per cent in the United States and 43 per cent in Canada) and the fact that continued rapid growth in population will inevitably produce environmental impacts (Environment Canada, 2003).

Relationship between Myocardial Infarction and Exposure to Traffic

A recent study conducted in Augsburg, Germany, showed a close relationship between myocardial infarction (heart attack) and exposure to traffic. Close to 700 patients who survived a heart attack were studied over a two-year period. The patients' exposure and the time spent in traffic were measured and recorded. Of all the time spent in traffic, 72 per cent was spent in a car, 16 per cent on a bicycle and 10 per cent on public transit. It was determined that patients with predisposing risk factors for a heart attack who were also exposed to traffic (particularly in cars) were more than twice as likely to suffer a heart attack compared to patients not exposed. The study concluded that although it is impossible to determine the relative contribution of risk factors like traffic, there is enough evidence to show that patients who are at risk of a heart attack will reduce their risk by living in areas with improved air quality, better city planning, and cleaner vehicles (Peters et al., 2004).

biochemical, or pathological and physiological variations. For example, persons whose respiratory systems are already damaged by cigarette smoke are less able to defend against the harmful effects of other inhaled toxic substances; persons genetically less able to metabolize a chemical may be more susceptible to its adverse effects. Risk assessment must consider individual susceptibility and the health interests of all persons exposed to air contaminants.

In addition to individual susceptibility, some groups of people may be considered more *exposed* than others. For example, people in lower income situations are least able to obtain housing in more desirable, and less polluted, neighbourhoods. These individuals are more likely to live in industrial areas, downwind from point-sources, or adjacent to major traffic routes. As a result, they are more likely to be exposed to both outdoor and indoor pollution. Both susceptibility and exposure must be taken into account in air quality management decisions.

Informed Consent

Informed consent is also an important component of effective air quality management, but it may be, and often is, argued that only in rare instances are all relevant facts made known to those affected. A major issue underlying this concern is how to determine, and who should determine what information is sufficient, and how to provide access to that information. The role of the expert is to provide information to support decisions, based on the best available evidence (often incomplete). The risk manager is obliged to make decisions taking into account ethical and political considerations, and the cost-effectiveness of alternatives. Persons affected by the risk should be involved in the decision-making, although how this is done will depend on the context. This process is especially challenging because even the views of risk managers and their consultants may be affected by their own values and experiences (Carlo, Lee, Sund, & Pettygrove, 1992).

Chapter 7: Choice of Intervention and Evidence of Effectiveness

The Nature of Our Choices

When faced with the need to make an air quality intervention, it is important to evaluate alternatives to account for costs, benefits, technical feasibility, and other trade-offs. These considerations also affect the pace at which change can be accepted and implemented. Public opinion about air quality takes into account concern for human health, the environment, the economy, or personal lifestyles. The way forward in practice requires a balancing of economic development, protection of public health, and protection of the environment.

The Citizen as Advocate

The general public is becoming more aware of air quality issues, due to the proliferation of information sources such as the Internet. For example, the Environmental Law Centre, at the University of Victoria, maintains a website and has published *Cleanair.ca: A Citizen's Action Guide*, in order to inform the public about pollution sources in their neighbourhoods (Tollefson, 2000). Such sources tend to be constructively critical, and deserve to be studied as they offer solutions that may fall "outside of the box" of the industry and the regulatory agencies. New solutions such as the airshed management approach offer more opportunity for public participation than the more traditional regulatory approach.

Responses to Outdoor Air Quality Issues

Point Sources

One option to improve air quality is to reduce emissions at the pollution source. The optimal time to do this is during the planning stages of a new facility (WHO, Guidelines for Air Quality, 2000). For example, site selection is critical to maximize dispersion, and to ensure a location away from current or projected residential neighbourhoods or areas of natural or commercial sensitivity, such as wildlife parks or shopping areas. Zoning decisions can help ensure that residential areas and commercial or industrial areas are kept apart.

For existing point sources, changes to current production processes or pollution control technology offer more limited options to control emissions. Source emission reductions can sometimes be cost-effective in achieving simultaneous savings in materials or energy. (WHO, Guidelines for Air Quality, 2000).

Management and operational changes may also help reduce emissions. These changes include ensuring better training and supervision of operators, paying more attention to equipment maintenance, and reducing fugitive emissions. For example, good maintenance of conveyor belts in grain elevators improves the economics of an operation while protecting health and safety through improved dust control (Brown & White, 1982). Designating a person with specific pollution control responsibility may also be an effective technique to ensure accountability.

Other approaches to emission reduction include process optimization, combustion modifications, and fuel modifications. Process optimization requires adjustment in variables like temperature, ventilation, or line speed, with the goals of achieving more complete combustion and reduced particulate matter from vegetative sources (e.g., wood residue). Combustion modifications, such as taking some burners out of service to make more efficient use of others, can be made to reduce emissions. Fuel modifications could include reducing the amount used, switching to cleaner fuel (e.g., natural gas), converting from high to low sulphur coal, and using waste fuel gases for secondary applications such as heating, drying, or power (WHO, Guidelines for Air Quality, 2000). Such approaches may be combined as in the case of the permit issued to pulp mills in BC. Under such permits, mills are required to have the capacity to divert wood residue to allow beehive burners to be shut down for a specified number of production days for air quality purposes, (MWLAP, Skeena Region, n.d.). These approaches can help to reduce source emissions of air pollution and improve air quality.

Aside from reductions at source, emissions may be collected before they are released. For example, wet scrubbers may be used to collect particles and may also reduce soluble gases. Electrostatic precipitators can reduce particles by charging the particles negatively and attracting them to positively-charged plates. Filters may be used to collect particles, and soluble gases can be collected through damp filters. Condensers may be used to remove heat from a gas stream thereby enabling the condensation and draining off of volatile liquids. Solid collecting media with large surface area to volume ratios (e.g., activated charcoal) may be used to absorb gaseous contaminants. Incineration may be applied to emission streams to oxidize combustible products (e.g., flares, catalytic converters). Such techniques can be very effective, but may also be expensive.

Higher stacks are still a recognized option, in combination with other methods. Local effectiveness depends on stack height; velocity; temperature and composition of stack gases; atmospheric conditions such as humidity, wind-speed, direction, and turbulence; local topography; and other variables such as other air pollution sources. Tall stacks — 200 to 400 metres in height — are reasonably effective in reducing ground level concentrations of pollutants when suitably sited (WHO, Guidelines for Air Quality, 2000); however, acid deposition and damage to vegetation will still occur, although the effects will be felt farther away from the source.

Emissions Trading

Emissions trading is a market-driven concept whereby a regulatory authority quantifies the total mass of emissions permitted in an area and issues an equivalent number of tradable emission entitlements. These tradable permits can be freely bought and sold. This concept has international support, in that it enables the marketplace to have a greater say in how to achieve objectives, such as the Kyoto objectives, rather than imposing regulations across-the-board in a command and control manner (WHO, Guidelines for Air Quality, 2000).

However, it is important to understand that allowing the marketplace to drive these decisions can also result in detrimental local situations. For example, a specific area may increase its air pollution in exchange for reaching overall air quality targets. This market approach can only work well if positioned within a framework of policy and legislation that is effectively administered by agencies to ensure some measure of equity in public health and environmental protection. It is also important that the market size be sufficient to support such a program. Previous analysis in the Lower Fraser Valley indicated that it was not an appropriate market to support emissions trading. [1]

[1] *Potential Economic Instrument Approaches to Air Quality Management in the GVRD, prepared for the GVRD, BC Ministry of Environments Lands and Parks, and Environment Canada by ARA Consortium and Sholtz & Associates; and Air Quality Management in the Year 2020: Airshed Emission Limits for the Lower Fraser Valley, prepared by Levelton Engineering, Margaree Consultants, and Cantor-Fitzgerald, 1996.*

Mobile Sources

Mobile source pollution comes from transportation options (e.g., vehicles, marine). Automobile emissions have become the largest source of outdoor air pollution in urban centres of BC. In total light-duty vehicle emissions account for approximately two per cent of total particulate emissions; however, these vehicle emissions account for other important pollutants such as 26 per cent of NO_X, 23 per cent of VOCs, and 63 per cent of CO. Technology improvements for these emissions include catalytic converters (NO_X, VOCs, and CO), exhaust gas recirculation (VOCs and CO), fuel injection (VOCs and CO, with some NO_X), and fuel evaporative systems (VOCs). In addition to private automobiles, commercial transport is also of concern. For example, commercial trucks are large emitters of PM, for which no routine emissions testing is required in BC. However, the AirCare On Road Program — an on-road testing program for heavy-duty vehicles — has been renewed in the Lower Mainland.

There are several options to help reduce overall vehicle emissions. These include new and improved technologies, options in the use of the automobile, and alternative forms of transportation.

Technological Improvements and Cleaner Fuels

Improvements in technology, such as fuel modification and engine design, can help reduce emissions, particularly for diesel vehicles. The emergence of alternative transportation options such as hybrid vehicles is also encouraging.

Options in the Use of Automobiles

There are several ways in which reductions in vehicle emissions can be achieved while maintaining the use of an automobile: the choice of vehicle, how well it is maintained, how often it is used, and how it is driven (Lanholz & Turner, 2003).

- **The choice of vehicle**
    - Light trucks, sport-utility vehicles, minivans, and commercial vehicles took over from passenger cars as the leading vehicle category sold in BC in 1995 (Statistics Canada, CANSIM II, 2002). The fuel efficiency of these vehicles is 40 per cent lower on average than standard passenger vehicles.
    - Not all vehicles achieve the same level of tailpipe emissions. When buying a new vehicle, individuals should find out how high a level of emission control the vehicle achieves. This can be done by checking the emission requirements the vehicle has met and by looking up the limits for the standard (e.g., Tier 2).
- **How well a vehicle is maintained**
  Proper maintenance of vehicles will deliver better mileage and will reduce air contaminants. This includes changing oil and filters as recommended, keeping drive belts tight, and maintaining correct tire pressure.
- **How often a vehicle is used and how it is driven**
  Driving habits may also help improve air quality. Combining trips and driving less, accelerating slowly and driving at 90 kilometres per hour or less will save fuel — 15 per cent less fuel is used at 90 kilometres per hour than at 105 kilometres per hour — and consequently will reduce air pollution. Keeping the vehicle light by not storing heavy items in it can also reduce fuel consumption. Reducing the amount of travel through alternative work arrangements, such as teleconferencing or working from home, can also help reduce tailpipe emissions.

Measures taken by the provincial and the federal governments, such as introducing more stringent emission standards for new model year vehicles and fuel quality regulations for both gasoline and on-road diesel fuel, have also contributed to the gradual reduction in emissions from on-road vehicles. Estimates indicate that the inventory of light-duty vehicle emissions was 66 per cent lower in 2002 compared to 1992; with 31 per cent resulting from new emission control technology and 35 per cent coming from repairs due to the GVRD's AirCare Program.

Ethanol Option

Ethanol is a renewable energy source that is made from agricultural products such as wheat and corn. In BC, the obvious source would be wood waste. Ethanol contains 35 per cent oxygen and when added to fuel it results in better fuel combustion and more efficient burning of the fuel, thus reducing harmful emissions. It is estimated that fuel containing only 10 per cent ethanol could reduce

The Greater Vancouver Regional District AirCare Program

One of the most important initiatives in the Greater Vancouver Regional District (GVRD) is an emissions inspection and maintenance program for light-duty vehicles, known as AirCare. Implemented in 1992, AirCare now operates 12 inspection centres and 42 inspection lanes (Greater Vancouver Transportation Authority, n.d.). AirCare inspection is required for all passenger cars and trucks with a Gross Vehicle Weight Rating of 5000 kg or less, registered in rating territories D,E, and H (as defined by the Insurance Corporation of BC), which cover the area from Lions Bay to Chilliwack.

Assessment reports confirm AirCare's pivotal role in achieving the GVRD's air quality plan emission reduction objectives. A conservative estimate is that the amount of air pollution from vehicles was reduced by more than 46,000 metric tonnes in 2002, and that such emissions were 35 per cent lower in 2002 than if AirCare had not been implemented.

In 2002, in the Lower Mainland, there were almost 1.2 million light-duty cars and trucks registered, up from 1.17 million in 2001. The number of vehicles tested by AirCare was 778,521 in 2002 and 748,068 in 2001. Of vehicles tested, 16.4 per cent failed their first test in 2002 and 15.3 per cent failed in 2001. In both years, most failures were from the 1991 and older model year group, which are a major concern. These cars make up about 34 per cent of the vehicles on BC roads, and account for only 29 per cent of total kilometres driven, but in 2002 they accounted for 62 to 76 per cent of the pollutants emitted by road vehicles and 58 per cent of the AirCare test failures.

Vehicle inspections alone do not produce emissions benefits. Benefits come from fixing high-emitting vehicles or removing them from use. AirCare has developed special programs to train, certify, and monitor repair shops to recognize the importance of making effective repairs and protecting the consumer. Substantial reductions in emissions were found in vehicles that were re-inspected after repairs. The costs of repairs were usually modest, and AirCare has found that successful repairs tend to last for years, resulting in continued reduced emissions. Of vehicles that failed AirCare tests, 24,335 and 22,604 were not brought back for re-inspection in 2002 and 2001 respectively. Investigation of a random sample of these vehicles shows that virtually all had been taken off the road. A voluntary scrappage program called Scrap-It has also been established in the Lower Fraser Valley that offers transportation alternatives in exchange for older, polluting vehicles.

In addition to the regular program, the AirCare On-Road (ACOR) Program, which tested heavy-duty diesel trucks and buses emitting black smoke, operated on a limited basis from 1996 until 2002, when funding for the program was suspended. Failing vehicles were given notice and orders requiring that they be brought into compliance and re-tested within 30 days. A review of the effectiveness of this mobile program was completed in 2002, and an expanded ACOR program has begun operation on a voluntary testing basis. The new program will test cars and light trucks, as well as heavy trucks that emit excessive smoke. [More information about AirCare can be found at www.aircare.ca.]

particulate matter by 50 per cent, CO by 25 to 30 per cent, and VOCs by 7 per cent. Although the ethanol-blended gas has been introduced and fully implemented in the US (one out of every three cars runs on ethanol-blended gasoline in the US), the initiative has not been implemented in Canada. (Teneycke, 2004)

Alternative Forms of Transportation

Alternative forms of transportation include public transit (e.g., buses, rapid transit), carpooling, or active transportation, which refers to human-powered locomotion: walking or jogging, cycling, in-line skating, or skateboarding (Health Canada, 2002). Using alternative transportation can save time and money in urban settings, while walking more often or riding a bicycle when conditions are suitable, offer avenues for reducing emissions as well as increasing fitness levels.

Most larger communities in BC have implemented a "park and ride" system, to enable people from outlying areas to park at public transport collection points, then travel to the inner-city by means of public transit. This strategy avoids overloading an already overburdened inner-city road system, although of course it requires integrated transportation planning with investment to match. For example, as more people are attracted towards using light rail transit, bus routes and "park and ride" locations also need to be expanded.

Support for Alternative Transportation

Alternative forms of transportation need to be supported by public and private sector policies that are health and environmentally friendly. For example, in 1992, the Capital Regional District issued a report entitled CRD Healthy Atmosphere 2000, in which a limited number of priority actions were outlined. These included: strengthening alternative transportation modes (public transit, cycling, walking); a vehicle trip reduction program; a "Green Transportation Fund" to be supported by a small increment to the regional gasoline tax and to be used to enhance alternative transportation modes; and a "true cost" parking strategy.

Similarly, in the private sector, support could include offering incentives for non-traditional transportation options, such as transit passes and carpooling opportunities. The provision of secure bike lock-ups, employee lockers, and showers are good examples of corporate support.

Urban Planning

Urban sprawl has recently been studied as a factor that affects physical activity, obesity, and morbidity. The study found that people living in sprawling communities are likely to walk less and weigh more than people living in less sprawling communities. They are also more likely to suffer from high blood pressure.

People who live in these areas may find that driving is the most convenient way to get things done, and are less likely to have easy opportunities to walk, bicycle, or take transit as part of their daily routine. The message here, primarily for urban planners, is to favour the development of more compact communities which would reduce dependence on automobiles and thereby improve air quality, physical fitness, and health (Ewing, Schmid, Kinningsworth, Zlot, & Raudenbush, 2003).

Area Sources

Area sources include open burning of waste material from agriculture, land clearing, and forestry. Other area sources include vehicle refueling and commercial and domestic fuel combustion, as well as fertilizer and animal operations, which produce ammonia emissions. Surface mining and overgrazing of land in semi-arid areas are additional sources of PM emissions, as are forest fires (WHO, Guidelines for Air Quality, 2000). Forest fires are periodically a major concern for BC, an example being the 2003 firestorm in the Southern Interior[2]. Strategies for addressing the more controllable area sources range from regulation to education, including technological solutions and market-based approaches.

Regulatory Strategies

Regulatory strategies may involve prohibiting some emissions (e.g., the banning of CFCs at the national and international level), banning open burning or restricting burn-offs to particular periods, and restrictions on the type of combustion equipment to be used.

Open burning in municipal areas is still practiced extensively in BC, although most GVRD municipalities and the city of Prince George have either banned the practice or severely limit it, as a result of citizen concerns. Regulations under the *Environmental Management Act* permit burning of debris from land-clearing under controlled conditions, while the Ministry of Forests similarly enables slash-burning (Ministry of Forests, n.d.). However, one sees open burning routinely in land clearing even in relatively built-up areas where landfill alternatives are available. There is a need to find ways to reduce or eliminate these outmoded practices, and public information and education can assist in this regard. Table 7.1 provides a summary of the types of heating and burning and the

[2] *A report on the 2003 BC forest fire disaster was recently delivered to the BC Government by the Honourable Gary Filmon. While the report notes that people can do little about such forces of nature when they get out of control, it also found that a successful record of fire suppression actually led to a build up of fuel. A number of recommendations, including controlled burning, address such issues. (Filmon, 2004).*

Table 7.1 Provincial Legislation, Municipal By-laws and Education and Awareness Programs Regarding Heating and Burning in BC, 2004

Type of heating /burning	Provincial legislation	Municipal by-laws	Education and Awareness programs
Residential wood heating	*Solid Wood Burning Domestic Appliance Regulation*	*GVRD, Central Okanagan, Saanich and others*	*Burn-it-Smart workshops and Air Quality Advisories* *Various wood stove exchange programs*
Outdoor burning	*Forest Fire Prevention and Suppression Regulation category 1 and 2*	*GVRD, Central Okanagan, Saanich and others*	*Composting facilities at various municipalities such as Saanich and Oak Bay as well as others*
Open burning	*Open Burning Smoke Control Regulation and Forest Fire Prevention and Suppression Regulation category 3 to 5*	*N/A*	*Guide to open smoke control regulation (http://wlapwww.gov.bc.ca/air/particulates/burning.htm)*
Prescribed burning	*Open Burning Smoke Control Regulation and Forest Fire Prevention and Suppression Regulation Category 6 to 8*	*N/A*	*Venting index (Regional hot line). (http://wlapwww.gov.bc.ca/air/particulates/agttobsc.htm)*

For further information on the above programs, please contact the Ministry of Water, Land and Air Protection.

provincial legislations, municipal by-laws and the education and awareness programs in place in British Columbia.

Rebates

The use of rebates is an innovative approach to control air pollution. In BC, woodstove change-outs have been held in a number of communities to provide homeowners with an incentive to replace old woodstoves with less polluting versions. The Ministry of Water, Land and Air Protection sponsors the programs throughout the province. These programs have typically been a cooperative effort involving the BC Ministry of Water, Land and Air Protection, regional/municipal authorities, and local woodstove retailers. A change-out program took place in 1995. Since then, change-out programs have occurred only at the local level. Plans for a province-wide change-out program may take place in the future.

Mow Down Pollution, an initiative of the Clean Air Foundation in partnership with Home Depot, is another example of a rebate program that provides incentives to replace polluting gas lawnmowers with cleaner electric, push power, or low-emission gas mowers.

By-laws

Another option for improving air quality for local governments is the creation of by-laws. For example, one by-law in the city of Vernon states: "No person shall install a wood burning appliance after date of adoption of this By-law that does not comply with the emission standards established by the Canadian Standards Association (CSA) and the United States Environmental Protection Agency as outlined in the Solid Fuel Burning Domestic Appliance Regulation enacted pursuant to the Environmental Management Act as amended from time to time…." Both a by-law and a rebate program in Vernon have resulted in the replacement of 600 old stoves with 600 CSA-approved models.

Beyond wood smoke, additional concern arises from the practice of households and construction companies of burning plastics and other garbage in open fires and incinerators, as this practice releases particulate matter and toxic chemicals. The resulting smoke is also much denser and more noticeable. Household garbage burning is exempt from provincial legislation; it is important therefore for municipalities to develop by-laws in this area. For example, the GVRD has had such a by-law on garbage burning since 1989.

Indoor Air Quality Interventions

Indoor air quality management requires attention to three main strategies: proper design and construction of buildings, control of indoor air pollution sources, ventilation, and adequate identification and management of problems associated with indoor air quality.

Design and Construction

Steps such as site selection, site preparation, building envelope design, ventilation, material selection, commissioning, and choice of appliances can be taken in order to prevent future problems with indoor air quality (WHO, Guidelines for Air Quality, 2000).

- **Site selection** - involves assessing sites, investigating previous uses such as industrial waste sites, and preventing building in high risk areas.
- **Site preparation** - helps to avoid future indoor air quality problems, especially with regard to drainage. Choosing dry and well drained building sites and properly grading the property can prevent accumulation of moisture, which favours growth of biological agents.
- **Building envelope design and ventilation** - entails balancing energy conservation with control over infiltration of air and movement of pollutants. In large buildings, a high-volume air conditioning system is required, while in smaller buildings, such as individual homes, encouraging natural ventilation can reduce energy demand and associated costs. Controlling internal loads by practices such as using natural light and energy-efficient appliances, also conserves energy, ultimately reducing the need to build more power stations.
- **Material selection** - offers an opportunity to choose materials that are minimal sources of indoor emissions, and to avoid surfaces that are difficult to clean and thus store dust particles.
- **Commissioning, inspections, and approvals** - should take place before occupancy so that potential problems may be identified and corrected in advance. This also offers a timely opportunity to train staff responsible for building operation and maintenance.
- **Choosing and installing appliances** - combustion sources such as stoves should be vented outdoors, particularly with gas stoves which emit nitrogen dioxide. Ventilation space around some appliances, such as refrigerators, is also important in maintaining indoor air quality. In terms of potential energy demand, some appliance choices are more efficient than others; for example, microwave ovens are more efficient than ovens for most purposes. With regard to woodstoves, the combustion efficiency of the stove is important, as energy efficiency can vary as much as ten-fold depending on the stove's design.

Control of Indoor Pollution Sources

- **Mold and Other Biological Contaminants**
  Regardless of the age of the building, biological contaminants will flourish wherever there is moisture. Because many building materials can serve as a nutrient for biological contaminants, it is critical to control moisture wherever possible.

  The key to preventing mold pollution in buildings and homes is moisture control (WHO, Guidelines for Air Quality, 2000; Environmental Protection Agency, 2003; Canada Mortgage and Housing Corporation [CMHC] About Your House, CE36, n.d.). This can be achieved usually by ensuring there is appropriate ventilation and maintaining building surfaces at a temperature that will prevent condensation. Where air conditioning units are used, these should be well maintained, as they can be a source of microbial growth (legionnella). Routine maintenance of air conditioning units, including replacing filters and clearing drain pans, is extremely important. Keeping horizontal surfaces to a minimum is also important as these collect dust, other nutrients, and moisture; if surfaces are rough they will provide microenvironments for organisms to proliferate. Ultimately, it is best to pay attention to the construction of buildings and homes in the planning stage to prevent problems from occurring in the first place, particularly in climates with moisture.

- **Volatile Organic Compounds (VOCs)**
  Careful selection of building materials can keep VOCs to a minimum. During the initial period of occupancy, or following renovations, "off-gassing" of VOCs will be at its peak, and more ventilation will be required.
- **Asbestos**
  When asbestos is found in good condition in an existing structure, the usual recommendation is not to disturb it. If the material is friable, it can be sealed.
- **Radon**
  To prevent migration of radon into a structure, any cracks or openings at the lowest level should be tightly sealed; ventilation can also be used at this level to dilute the gas, while exhaust fans can help remove it.
- **Vehicle Emissions**
  One should avoid outdoor intakes from areas already contaminated by a source of vehicle emissions, such as a road or garage. A study in Ottawa indicated that attached garages account for 13 per cent of total house leakage, and that most of the contaminated air seeped into the basement or main floor. Although the impact of this problem on health has not yet been determined (CMHC, Technical Series 01-122, n.d.), it is prudent to limit running engines to a minimum in garages, and to keep doors to the house closed and outside doors open.
- **Second-hand Smoke**
  In British Columbia, and most other parts of Canada, the largest overall improvement in air quality in buildings and homes will come from eliminating exposure of non-smokers to second-hand smoke where it occurs. While this is done increasingly in public and private buildings through organizational policy, the same has not happened in individual homes. If smoking cannot be eliminated in a home, one option is to restrict smoking to a separate room ventilated to the outdoors, to ensure that the tobacco smoke does not contaminate the rest of the home. Another is to insist that smokers only smoke outside.

Resolving Indoor Air Quality Problems

The health impacts related to indoor air quality are not as well understood as those associated with outdoor pollution. This is due primarily to the fact that outdoor air quality has been studied longer and more systematically. As we gain new information on indoor air quality issues, such as ventilation design, building envelope design, site preparation, and materials selection, this information should be incorporated into updated codes and training programs. There is also a need to promote product labeling that includes current information on the emission properties of materials, to redefine indoor air quality standards, to develop relevant maintenance protocols, and to ensure that consumers and building superintendents are familiar with how to use this information and why it is needed (WHO, Guidelines for Air Quality, 2000).

The following are some options for resolving indoor air quality issues.

- **Being Responsive**
  When complaints about air quality, comfort, or health problems are received from occupants of a building, building management needs to be responsive to these complaints. The first step should be a walk-through building inspection, focusing on environmental attributes of the building, such as temperature, relative humidity, and ventilation. If visual inspection does not lead to locating a probable cause, it may be necessary to seek outside assistance and carry out a more formal assessment, which could entail air sampling and gathering health information from occupants. Assistance in investigating the air quality of a building may be sought from private companies which specialize in these issues or from an appropriate government agency (e.g., local municipalities).

- **Addressing Issues Before They Arise**
  The ideal approach to resolving air quality problems is to address them before they start. This means developing a capacity for both public education and technical training for people involved in the design, construction, and maintenance of buildings. Indoor air quality design is a new area for research and development including materials research, field monitoring studies, and computer modeling. To do this effectively, research capacity and partnerships among academic researchers and industry is required, so as to determine the causes of problems and to evaluate alternative solutions. For example, there is a continuing need to develop materials resistant to fungal growth and to reduce the use of materials that "off-gas", while attending to other variables that also influence indoor air quality such as ventilation, air barriers, humidity control, and surface temperatures. The Association of Professional Engineers and Geoscientists of BC (APEG) is already showing leadership in supporting "LEED BC"[3], a proposed new environmental standard adapted from a successful system developed in the United States. In addition, Simon Fraser University has been supportive of the concept of "green buildings" through its hosting of related lectures and workshops (Association of Professional Engineers and Geoscientists of BC [APEG], 2004).

Evidence of Intervention Effectiveness

There are relatively few studies that show direct evidence of health improvements taking place following an intervention. This may be a result of the lack of situations to date where air pollution has been reversed, or where the situation has been studied to detect attributable changes in health outcomes at the population level. Direct evidence can result from "natural experiments". An example is the forest fire situation in BC in 2003. Visits to doctors' offices from respiratory conditions increased following the onset of the forest fires, and decreased after the fires were extinguished (the "intervention"). The change in the number of these visits provides evidence of the effectiveness of the intervention.

Most evidence for the effectiveness of interventions regarding air pollution is indirect. There are numerous published scientific studies that meet peer-review standards, documenting relationships between ambient outdoor concentration of air pollution and human health effects. From these studies, it is reasonable to assume that reducing exposure to the pollution should result in improved health status. Such indirect evidence is the basis for most of the calls for action over the past half-century.

Air Quality Management and Indirect Evidence in the Greater Vancouver Regional District and the Fraser Valley Regional District

In the highly populated urban and peri-urban areas of BC, there is ample indirect evidence of the potential effectiveness of interventions in managing air quality. The Greater Vancouver Regional District (GVRD) adopted its first Air Quality Management Plan in 1994, as a part of its "Creating Our Future" initiative, to address air quality issues. In addition, the Fraser Valley Regional District (FVRD) adopted the FVRD Air Quality Management Plan in February 1998.

The major objective of the GVRD's plan was to reduce total emissions of common air contaminants from the 1985 levels by 38 per cent by the year 2000. This objective was achieved a year ahead of schedule through implementation of a number of recommended emission reduction measures. Although a study of attributable impact on ambient concentrations of air pollutants or on health outcomess was not conducted, cost-benefit analyses for the full suite of measures indicated that between 1990 and 2020, these measures would avoid 2,100 premature deaths, prevent 27,000 emergency room visits, contribute 7 kilometres of improved visibility in the GVRD, and generate overall net benefits of $2.3 billion (MWLAP, 1995).

[3] *LEED stands for "Leadership in Energy and Environmental Design".*

Direct Evidence of Intervention Effectiveness

Outdoor Interventions

- **Atlanta**

  An example of direct evidence of an outdoor intervention's effectiveness is the alternative transportation strategy implemented during the 1996 Summer Olympics in Atlanta (Friedman, Powell, Hutwagner, Graham, & Teague, 2001). Successful efforts to reduce downtown traffic congestion in the city resulted in peak ozone levels falling 27.9 per cent (from a baseline of 81 ppb to 59 ppb during the Games). This was associated with a 41.6 per cent decrease in acute care asthma events as recorded in the Georgia Medicaid claims files, as well as substantial declines in other data sources examined, compared with virtually no change for non-asthma conditions. These data provide strong support for efforts to reduce air pollution and improve health via reductions in motor vehicle traffic.

  Atlanta's experience can serve as a challenge to BC, with the Winter Olympics upcoming in 2010. An equivalent initiative to Atlanta's reduction in ozone might be to lower winter particulate pollution in the Sea-to-Sky corridor during the Olympics.

- **Hong Kong**

  In Hong Kong, a government restriction of 0.5 per cent on the sulphur content of fuels from July 1990 onwards was followed by improved pulmonary function among primary school children, associated with favourable changes in air quality (Wong et al., 1998). For the population as a whole, cardiovascular, respiratory, and all-cause mortality also fell after this intervention (Hedley et al., 2003). Canadian low sulphur gasoline limits are scheduled to come in effect in 2005. (see http://www.ec.gc.ca/press/sulphur_b_e.htm)

- **Dublin, Ireland**

  A ban on coal sales in Dublin was followed by declining particulate air pollution levels and reduced mortality: non-trauma rates overall declined by 5.7 per cent, respiratory deaths declined by 15.5 per cent, and cardiovascular deaths by 10.3 per cent. This translated into about 116 fewer respiratory deaths and 243 fewer cardiovascular deaths per year in Dublin, a city of just over 1 million people (Clancy, Goodman, Sinclair, & Dockery, 2002; Goodman, Dockery, & Clancy, 2004).

- **Utah Valley**

  The impact of the closing and reopening of a steel mill was studied in relation to PM_{10} emissions and hospital admissions for pneumonia, pleurisy, bronchitis, and asthma. Admissions for both children and adults were correlated with PM_{10} levels and the operation of the steel mill. The effect on children was stronger than observed for adults, and stronger for asthma and bronchitis than for the other conditions included in the study (Pope, 1989).

- **Germany**

  Following the reunification of West Germany and East Germany, declines in particulate and sulphurous pollution in the eastern sector were associated with decreasing prevalence of respiratory symptoms in children (Heinrich et al., 2002).

- **California**

  In California, a study of the effects of personal relocation showed that children who moved to areas with lower levels of particulate pollution had higher rates of growth in lung function than those who moved to high pollution areas (Avol, Gauderman, Tan, London, & Peters, 2001). This study shows that if air pollution cannot be reduced, it may be possible for susceptible persons to remove themselves from it, which constitutes a form of personal intervention. However, the option of moving is often not available to people with low incomes, and raises fundamental questions of "environmental justice".

Indoor Interventions

It is more difficult to assess the effectiveness of indoor air quality interventions in reducing health impact, as studies are mostly organized on other related topics. In addition, most of the evidence for potential effectiveness is indirect in nature.

Although there are specific intervention studies on air quality, many do not examine the resulting health impacts. These include studies of home cleaning and reducing toxic dusts (Lioy, Tiin, Adgate, Weisel, & Rhodes, 1998), and of electrostatic and other filtration methods in reducing airborne dust in office settings (Richardson, Harwood, Eick, Dobbs, & Rosen, 2001; Croxford, Tham, Young, Oreszcyn, & Wyon, 2000). Some studies may focus on achieving behavioural change but still not measure health, such as a Toronto program to reduce indoor pesticide spraying in an apartment complex (Campbell, Dwyer, Goettler, Ruf, & Vittiglio, 1999). In the case of radon in some BC schools, impressive reductions in radon levels were achieved, with the median reduction being 86 per cent (BCCDC, 2003); however, it is difficult to demonstrate a health outcome in this instance due to the incremental nature of the risk of cancer attributable to radon and the long latency period between initial exposure and the development of cancer.

- **Home Interventions**

  Many small studies have been conducted into home interventions to reduce the incidence of childhood and adult asthma. For example, the effectiveness of "dust-free bedrooms" was assessed in 20 children allocated into two groups matched for severity of their condition; those with a dust-free bedroom experienced less wheezing, required less medication, and had better pulmonary function (Murray & Ferguson, 1983). However, the sample size here was too small for such results to be convincing.

  Larger and better-designed studies are now underway, with a Canadian asthma primary prevention study among the first to be published (April 2004). In this study, 545 infants classified as high-risk, based on an immediate family history of asthma, were randomized into intervention and control groups. Intervention measures included avoidance of house dust mites, pet allergen, and second-hand smoke. At two years of age, results showed significantly fewer children with asthma in the intervention group compared with controls (16.3 per cent versus 23 per cent), and there was a 90 per cent reduction in recurrent wheezing (Becker et al., 2004).

  Other larger scale studies are also underway, although only preliminary results have been published to date (Brunekreef & Holgate, 2002; Krieger et al., 2002).

  Many interventions have not yet been rigorously evaluated for home-related indoor pollution effects. One exception is a randomized trial for evaluating the effectiveness of home visiting by nurses to educate families to reduce infant exposure to tobacco smoke. Among 121 infants of smoking mothers who completed the study, there was a significant difference in exposure to cigarette smoke, and the prevalence of lower respiratory symptoms declined in an intervention subgroup of less educated households (Greenberg et al., 1994). Elsewhere, lead dust control was evaluated using a randomized trial, revealing that regular home cleaning, accompanied by education of mothers, is safe and partially effective and should be recommended for those lead-exposed children for whom removal to lead-safe housing is not an option (Rhoads et al., 1999).

- **Public/Private Building Interventions**

  These types of interventions have been studied more systematically than those directed toward home environments, although some of the issues would apply to both: moisture and mold control, ventilation and air conditioning, particle filtration, renovation strategies, and risk communication.

  - In one poorly maintained building with moisture problems, an initial intervention reduced mold contamination and symptom levels (Ebbehoj, Hansen, Sigsgaard, & Larsen, 2002).
  - In a school with chronic floor moisture problems, staff and students experienced symptoms of eye, airway, and skin irritation. After a ventilated floor was laid, pre- and post-intervention comparisons were made at the school and at a control school, and improved symptom levels were observed (Ahman, Lundin, Musabasic, & Soderman, 2000).
  - Air conditioning improvements in a building whose occupants suffered from respiratory complaints resulted in reduced rates of eye and airway

Impact of Smoking Ordinance in Helena, Montana

An important study just released examined the impact of a smoking ordinance in Helena, Montana (Sargent, Shepard, & Glantz, 2004). This geographically isolated community imposed a law in June 2002 banning second-hand smoke in public and work places. Opponents won a court order suspending enforcement of the law in December 2002.

Investigators examined the impact of the ordinance on admissions for myocardial infarction (heart attack) from within Helena and from outside Helena, where the ordinance did not apply. The excess risk of heart disease is already known to fall rapidly after the cessation of smoking (Fichtenberg & Glantz, 2000). Analysis focused on monthly hospital admissions from December 1997 through November 2003. During the six months the law was enforced, the number of admissions fell significantly from an average of 40 during the same months in the years before and after the law, to a total of 24 admissions during the six months the law was in effect. There was a non-significant increase in admissions from outside Helena during the same period. The authors concluded that the enforcement of laws for smoke-free work and public places may have been associated with an effect on morbidity from heart disease (Sargent et al., 2004).

symptoms and persistent coughs (Graudenz, Kalil, Saldiva, Latorre, & Morato-Castro, 2004).

- In another study, providing individually controllable ventilation (velocity, temperature) at each work station was followed by reduced symptoms and improved productivity (Menzies, Pasztor, Nunes, Leduc, & Chan, 1997).
- Increasing ventilation rates in another building resulted in improved perception of air freshness, reduced odor, reduced dryness of throat and easing of difficulties in thinking clearly, while objective measures of performance also improved (Wargocki, Wyon, Sundell, Clausen, & Fanger, 2000).
- In a study of enhanced particle filtration in an office building, repeated measures revealed improved performance-related mental states, while cooler temperatures resulted in reduced symptoms of chest tightness (Mendell et al., 2002).
- In a controlled study, new heating and air conditioning and the replacement of the carpet with a low-emitting vinyl material showed improved symptoms of environmental irritations (Pejtersen et al., 2001).

There is a growing body of evidence that air contaminants are not only harmful to human health in the concentrations found outdoors and indoors, but that interventions will make a difference in health outcomes. Reducing air pollution is or should be as important as supplying medical and hospital care for people who develop asthma, bronchitis, or pneumonia. It is clear that effective interventions may be made for air pollution, at all levels of society, involving individuals, governments, and corporations.

The relationship between air quality and health offers the potential for a win-win outcome. The prospect exists for creating new opportunities and for preventing costly burdens on the environment and the health of individuals. For example, BC could capitalize on new technologies, and become a world leader in "green technologies". BC already has researchers and innovators in this area (e.g., energy-efficient building designs, solar power options, and hydrogen cell and hybrid technologies). New initiatives on environmental choices would also entail new skills for designing, building, and maintaining the new systems, and new opportunities for education, training, and business development.

Chapter 8: Recommendations

While there are numerous ways to improve air quality in BC, it has become clear that in 2004, the interventions whose impact will result in the greatest decrease in air pollution will require action at the societal and individual level. This goal can be achieved further by developing partnerships between various levels of governments, communities, the private sector, non-governmental organizations, and individuals.

Actions are needed to reduce both the short-term and long-term impacts of outdoor and indoor air pollution. The short-term impacts on air quality can result from:

- Eliminating second-hand smoke (also known as environmental tobacco smoke) from all buildings.
- Reducing wood smoke from domestic and industrial burning.
- Upgrading ventilation in buildings with substandard ventilation.
- Controlling moisture to decrease indoor mold growth.

The longer-term impacts can result from:

- Further reduction in industrial and commercial emissions.
- Use of cleaner energy.
- Focusing on emissions associated with transportation, including marine and diesel.
- Reducing vehicle miles driven.

It is important to note that we have a collective responsibility to engage and participate in both efforts to reduce the negative effects of air pollution on health – both our own and the health of others around us. This responsibility must be represented within a sustainable public framework for action. From a public health perspective, we should be focusing our attention on:

- Educating the public on the sources of air pollution and their associated health impacts.
- Stimulating public support for regulatory changes that improve air quality.
- Encouraging individuals to make small but positive changes in their day-to-day activities.
- Developing a coherent provincial policy framework for managing air quality that will achieve reductions in ambient pollutants where current levels of pollutants are elevated, and prevent increases in ambient levels of pollutants where existing pollutant concentrations are not significantly elevated.

All levels of government (federal, provincial, and municipal) must continue to emphasize airshed management and regulatory control activities particularly in areas with known point sources such as wood burners and other sources of emissions such as on-road and off-road vehicles and marine traffic. However, on another level, changes need to occur with a shift in responsibility and ownership towards individuals, communities, corporations, and non-governmental organizations. The following recommendations provide a framework for such activities.

Improving Outdoor Air Pollution

What can individuals do?

As individuals we can:

- Stop smoking indoors or in outdoor areas where others are present (e.g., outside the entrance to buildings.)
- Replace non-certified wood-burning stoves and heat sources in the home with more energy-efficient and less polluting sources.
- Choose alternative modes of transportation, particularly for short trips (e.g., walking, bicycles, car-pools, or public transit).
- Keep track of your trips for shopping and other personal needs, and see how many you can eliminate with better planning.
- Adhere to any recommended maintenance schedules for your vehicle.
- When choosing a vehicle, ask about levels of tailpipe emissions. Although all cars have to meet standards, some have much lower tailpipe emissions than others. The Green Vehicle Guide at www.epa.gov/autoemissions/index.htm is an excellent source of information for all makes, models, and years.
- When choosing a vehicle, consider fuel efficiency.
- Check, and where necessary, adjust your tire pressure at every fill-up, as under-inflated tires can reduce fuel economy and can be a safety hazard.

What can communities do?

Communities can:

- Support community efforts to eliminate exposure to second-hand smoke indoors and outdoors.
- Become aware of the effects of air pollution on your airshed in your community; organize and speak-up about the air quality in your region.
- Engage in area planning that encompasses resource conservation, public transit, and physical activity, and that creates buffer zones between sources creating locally elevated levels of air pollutants (e.g., industrial sources, major traffic arteries) and areas where people live, learn, and play.
- Promote a community culture of clean air, for example de-normalizing "big truck syndrome".

What can corporations do?

Corporations can:

- Invest in new sources of renewable energy.
- Partner with government to improve standards and promote self-regulation.
- Take steps that exemplify corporate responsibility and use them to advertise and build consumer trust.
- Ensure fleet vehicles use pollution-minimizing technologies (low emission diesel or trip efficiency).

What can universities and colleges do?

Universities and colleges can:

- Engage in research activities to better define and describe outdoor air pollutants, estimate burden of disease, and support innovation in basic sciences like chemistry and physics that can be applied to industry point sources of air pollution.
- Study inequities and vulnerabilities in community exposure and health effects of air pollution.
- Explore air pollution in the Interior and other rural areas, with particular attention to forestry and

agricultural by-products, and the extent to which distinct health effects may be attributed.

- Devise approaches to study the costs and benefits of air quality improvement in BC.

What can governments do?

Governments can:

- Continue to reduce air pollution from industrial sources, particularly in the BC Interior where open burning practices, pulp mills, obsolete beehive burners, and a range of other sources continue to affect the air quality.
- Introduce new strategies to reduce vehicle use and continue to invest in public transportation.
- Address proactively the predicted increase in marine emissions secondary to the expansion of the port of Vancouver.
- Support corporate efforts by supporting self-awareness through grants (an energy audit is often the first step to setting and achieving efficiency goals).
- Achieve the Canada-wide Standards (CWS) for particulate matter and ozone in communities not currently meeting those standards, and adopt policies of continuous improvements and keeping clean areas clean.
- Create national consensus on more stringent vehicle emission standards for Canada. Partner with educational institutions to develop information programs alerting people to the problem of personal sources of air pollution and introducing solutions to reduce these sources.
- Ensure fleet vehicles use pollution-minimizing technologies (low emission diesel or trip efficiency).
- Create additional tax incentives to promote efficient energy use in transportation, building, heating, and industry.
- Support development that increases the use of public transit and decreases the use of automobiles.
- Incorporate site criteria in environmental impact assessments that consider dispersion of emissions, and where necessary, incorporate an adequate buffer between areas where people live, learn, and play and emission sources that may result in locally elevated concentrations of air pollutants. The concept of buffers is primarily a zoning issue, with local or regional government determining the acceptability of sites for development. The adequacy of a buffer separating the project from sensitive receptors would be an issue that would be considered in locating a project on the site.
- Support multi-sectoral airshed planning.
- Review ambient air quality data in communities with beehive burners (e.g., Smithers and Houston) with a view to control and reduce their contribution to air pollution.

Improving Indoor Air Pollution

What can individuals do?

As individuals we can:

- Stop smoking, and continue to support others to do the same.
- Stop smoking indoors or near others outdoors.
- Replace non-certified wood-burning stoves and heat sources in the home with more energy-efficient and less polluting sources.
- Fix water leakage in homes and basements and install dehumidifiers.
- Remove/replace old, damp carpets or underlay.
- If you live in a radon risk area (predominantly the interior regions of the province), take appropriate action to seal/vent your home. For more information, consult: www.bchealthguide.org/healthfiles/hfile42.stm or call David Morley at BCCDC (604) 660-6629.
- Support effective initiatives to reduce ambient levels of air pollutants in your community.

Replacing Old Woodstoves in Vernon

The major source of air pollution in many communities is smoke from woodstoves that are poorly designed and/or not managed efficiently. Some communities, such as Vernon, are reducing this source of pollution through innovative public-private partnership efforts, such as offering rebates for the replacement of older, less efficient stoves for newer models, and supporting public education initiatives. Such initiatives will assist individuals in making an affordable and cost-effective transition to more efficient burning, and will result in a reduction in this source of pollution.

What can communities do?

Communities can:

- Engage in group activities at the community level for peer support on individual health behaviours, and economy of scale when purchasing services (e.g., renovations) or large appliances.
- Support initiatives that improve indoor air quality in public spaces in your community.

What can corporations do?

Corporations can:

- Encourage company health programs (e.g., stop-smoking programs).
- Be aware of, and promote, quality indoor air in workspaces (rental or owned) with independent assessments, and follow-up with solutions to fix problems identified (e.g., replace toxic carpets/paint, install air scrubbers).
- Engage in research and development of products/tools that will support sustainable technology, increase consumer choice, and shift purchase standards (e.g., VOC-free paints/glues, etc.).
- Take steps that exemplify corporate responsibility and use them to advertise and build consumer trust.
- Step in where tobacco companies have been banned to support philanthropic activities that represent a consistent message regarding individual health practices (e.g., sports, arts, and community events).

What can universities and colleges do?

Universities and colleges can:

- Engage in research activities to better define and describe indoor air pollutants, estimate burden of disease, assess intervention strategies, understand the economics of air management, support innovation in basic sciences such as chemistry and physics that can then be applied to industry, and develop alternative sustainable technologies.
- Use their reputation and teaching capacity to participate in educating the public on indoor air pollution.

What can governments do?

Governments can:

- Continue to introduce legislative standards to promote clean air, in particular smoke-free indoor spaces that include the hospitality industry (Manitoba, Saskatchewan, New Brunswick, Northwest Territories, and Nunavut have each recently adopted smoke-free indoor regulations).
- Support the banning of tobacco advertising by replacing funds lost to sports, arts, and community events.

British Columbia's Air Quality Achievements and Initiatives

What has been done?

- British Columbia has the lowest smoking rate in Canada. Statistics Canada has reported that currently only 16.5 per cent of those age 15-19 smoke in BC.

Indoor Air Quality Initiative – Tools for Schools Action Kit for Canadian Schools

In 2003, a working group representing Provincial and Territorial Ministries of Environment, Health, and Occupational Health developed a program called Tools for Schools Action Kit for Canadians Schools, which was modeled after a similar program by the Environmental Protection Agency in the United States. The Tool Kit provides information on how to improve indoor air quality in schools and covers issues that include administration, health, air quality in classrooms, food services, waste management, renovation and repair, as well as design and building maintenance. Since its introduction, pilot studies have been provided to many schools in various parts of Canada. (Health Canada, 2003). For more information, please contact Dr. M.A. Kasam (M_A_Kasam@ hc.sc.gc.ca).

- The province has continued to pursue legal action against tobacco companies to carry some of the economic burden on health.
- In January 2001, British Columbia established a First Nations Tobacco Strategy to promote the health and well-being of Aboriginal people and to prevent and stop tobacco misuse.
- The City of Vancouver just celebrated its 10^{th} anniversary of a ban on wood-burning stoves/ fireplaces/heaters in new residential start-ups.
- The AirCare Program, the first program of it kind in Canada, requires that all light-duty vehicles in the Fraser Valley be inspected for exhaust emissions and emission-control systems. On January 1, 2001, AirCare II was implemented, incorporating the latest innovations in emissions systems technology and test procedures.
- The Scrap-it Program, which began in the Lower Mainland in 1996, has created incentives for individuals to trade in their high polluting vehicles for cleaner transportation.
- The BC Action Plan for Clean Air has resulted in new provincial policies, regulations, and standards for vehicle emissions and motor fuels.
- The BC Go Green Program is an awareness and education program aimed at reducing motor vehicle emissions in the Fraser Valley and other communities by promoting transportation alternatives and the reduction in use of private automobiles.
- Quesnel's comprehensive airshed planning was launched in 1999 and involved the participation of local industry, local and provincial government, regional and community health authorities, environmental groups, and concerned citizen groups working together to improve the air quality in Quesnel. Airshed plans are also in place in the GVRD, FVRD, Prince George, Bulkley Valley – Lakes District, and resort community of Whistler.

Priority Actions for Air Quality Improvement

In terms of priority actions for air quality improvement, the data presented in this report suggest that focusing on five policy/program areas would provide significant short-term and long-term benefits. These areas are:

- Reducing exposures to second-hand smoke across British Columbia.
- Reducing ambient concentrations of $PM_{2.5}$ in Interior and Northern regions in British Columbia.
- Improving Aboriginal people's living conditions when it comes to indoor air pollution sources such as second-hand smoke, molds, and others.
- Developing programs to prevent degradation of air quality that may occur with increased population growth in the Lower Mainland by:
  - Supporting the provision of rapid public transit;
  - Influencing community planning to make walking or biking safe and viable;

- Using tax policies and incentives to encourage efficient use of energy in transportation, residential, and industrial sectors;
- Providing diesel and alternative cleaner technologies; and
- Addressing marine emissions.

- Providing public education programs on what individuals can do to improve air quality for themselves and for future generations.

Glossary

A

Absorption: The uptake of water, other fluids, or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil).

Acid Rain: Rain containing dissolved acidifying compounds, resulting from chemical pollution of the atmosphere by sulphur and nitrogen compounds. When deposited, these increase the acidity of the soil and water causing agricultural and ecological damage.

Acidic Deposition: Refers to the deposition of acidic compounds, produced in the atmosphere from pollutants such as oxides of sulphur and nitrogen, to the earth as dry particles or with rain, snow or fog.

Acute: Occurring over a short time.

Acute Exposure: A contact between an agent and a target occurring over a short time.

Aerosol: System of solid or liquid particles suspended in a gaseous medium, having a negligible falling velocity.

Agent Orange: A toxic herbicide and defoliant used in the Vietnam conflict, containing 2,4,5-trichlorophen-oxyacetic acid (2,4,5-T) and 2-4 dichlorophenoxyacetic acid (2,4-D) with trace amounts of dioxin.

Air Pollution: The presence of contaminant or pollutant substances in the air at a concentration that interferes with human health or welfare, or produces other harmful environmental effects.

Air Quality: The state of the ambient air within an area.

Airshed (also air basin): An area where the movement of air tends to be limited to the bounds of that area as a result of specific geographical or meteorological conditions.

Allergen: A substance that causes an allergic reaction in individuals sensitive to it.

Ambient Air: Outside air, surrounding air, air occurring at a particular time and place outside of structures. All living beings are exposed to the ambient air.

Ambient Air Quality Objectives or Standards: Air quality levels for specific pollutants that are determined to be necessary to protect human health and/or the environment. Typically consists of a numeric pollutant concentration, averaging time, and rules or guidance on sampling methodology and how the objectives or standards are to be applied. May also be referred to as ambient air quality criteria or guidelines.

Glossary

Ammonia (NH_3): A compound containing nitrogen and hydrogen, and known for its sharp, pungent smell. It is emitted mostly from agricultural and animal husbandry activities. Other sources of ammonia are fuel and waste combustion, the chemical industry and refrigeration facilities. It contributes to the formation of inhalable particulate matter and visibility reducing particles.

Anthropogenic: Made by humans.

Area Source: A term used in emission inventories for sources that are not classified as specific point, mobile or biogenic sources.

Asbestos: Fibrous natural product used in asbestos cement, brakes and clutches, insulators and fireproof textiles. Asbestos is carcinogenic.

Asbestosis: Disease associated with inhalation of asbestos fibres. The disease makes breathing progressively more difficult and can be fatal.

Asthma: A chronic disorder characterized by symptoms of cough, shortness of breath, chest tightness and wheeze.

B

Background level: An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biogenic: Produced by actions of living organisms.

Biomass: The biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Bronchitis: Inflammation of the mucous membrane of the main airways of the lung, or the bronchial tubes.

Building Related Illness: Diagnosable illness whose cause and symptoms can be directly attributed to a specific pollutant source within a building (e.g. Legionnaire's Disease, hypersensitivity, pneumonitis).

C

Carbon Dioxide (CO_2): A colourless, odourless, non-combustible gas and a normal constituent of air. This gas is formed by certain natural processes, by the burning of fuels and wastes containing carbon and by heating of minerals or products containing carbonate.

Carcinogen: A substance that causes cancer.

Case-Control Study: A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

Chloracne: Acne-like eruption caused by exposure to certain chlorinated organic substances such as polychlorinated biphenyls or 2,3,7,8-tetrachlorodibenzo-*p*-dioxin.

Chlorofluorocarbons (CFCs): Potent ozone-depleting substances made up of carbon, hydrogen and chlorine atoms. These substances were used as coolants in refrigerators, freezers and air conditioners, foaming agents, solvents, aerosol sprays and propellants until 1987 when their production and use were prohibited under the Montreal Protocol.

Chronic: Occurring over a long time.

Chronic Exposure: Contact with a substance that occurs over a long time (more than 1 year).

Chronic Obstructive Pulmonary Disease (COPD) - Also known as chronic obstructive lung disease and encompasses two major disorders: emphysema and chronic bronchitis. Emphysema is a chronic disorder in which the walls and elasticity of the alveoli are damaged. Chronic bronchitis is characterized by inflammation of the cells lining the inside of bronchi, which increases the risk of infection and obstructs airflow in and out of the lung.

Climate Change: In the context of air quality management planning, it refers to any change in the earth's climate system due to emissions from human activities.

Combustion: Burning. Many important pollutants, such as *sulphur dioxide*, *nitrogen oxides*, and *particulates* (PM_{10}) are combustion products, often products of the burning of fuels such as coal, oil, gas and wood.

Contaminant: A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

D

Dioxins: The terms 'dioxin' or 'dioxins and furans' generally refers to a group of 210 chlorinated pollutants, chemically known as the polychlorinated dibenzo-p-dioxins and dibenzofurans. Dioxins are organochlorines and are regarded as among the world's most toxic organic pollutants. They are produced as by-products of industrial processes involving chlorine and all types of incineration. Once released into the environment, dioxins are environmentally stable and tend to become associated with sediments or suspended material.

Dose: the actual amount of a pollutant that is absorbed or inhaled by an individual. It is the quantity that determines adverse health outcomes.

Dose-response relationship: The relationship between the amount of exposure (dose) to a substance and the resulting changes in body function or health (response).

Dust: Small solid particles, conventionally taken as those particles below 75 micrometers in diameter, which settle out under their own weight but which may remain suspended for some time.

E

Ecology: The relationship of living things to one another and their environment, or the study of such relationships.

Ecosystems: Interacting system of a biological community and its non-living environmental surroundings.

Emission: The discharge of air pollutants from a particular source or group of sources into the environment.

Emission Standard: The maximum amount of discharge legally allowed from a single source, mobile or stationary.

Emissions Trading: The creation of surplus emission reductions at certain stacks, vents or similar emissions sources and the use of this surplus to meet or redefine pollution requirements applicable to other emissions sources. This allows one source to increase emissions when another source reduces them, maintaining an overall constant emission level. Facilities that reduce emissions substantially may "bank" their "credits" or sell them to other facilities or industries.

Environmental Tobacco Smoke (ETS): A combination of the smoke coming off a burning cigarette, pipe or cigar and the smoke exhaled by a smoker. Also known as second-hand smoke.

Exposure: The amount of time an individual or item is in the presence of certain concentrations of pollutants.

Exposure Assessment: Identifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number likely to be exposed.

Exposure Pathway: The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it.

Extrapolation: A scenario describing a future that is simply a continuation of current situations and trends.

F

Fertilizer: Substance applied to soil or hydroponic systems for improving the root nutrition of plants with the aim of increasing crop yields and/or controlling production.

Fine Particles or **Particulates:** Typically expressed as particles 2.5 micrometres in diameter and smaller. In earlier applications, may also have referred to particles of 10 micrometres in diameter or less.

Fossil fuel: Coal, natural gas and petroleum products (such as oil) formed from the decayed bodies of animals and plants that died millions of years ago.

G

Global Warming: Refers to observed and potential increase in the average temperature of the earth's atmosphere.

Greenhouse Effect: Warming of the atmosphere due to the reduction in outgoing solar radiation resulting from concentrations of gases such as carbon dioxide.

Greenhouse Gases (GHGs): Refers to gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Several ozone-depleting substances are also greenhouse gases. Water vapour is another major GHG, but human activities do not have a direct impact on its emission rate. They are natural components of the earth's atmosphere; however, in excessive concentrations they contribute to accelerated global climate change which may adversely affect various aspects of ecosystem. Natural sources of GHGs include volcanic eruptions, forest fires, lightening, living organisms, decomposition of vegetation and animal material, and soil. The major human-made sources include burning of fossil fuels, biomass and wastes, various industrial and commercial processes, land-clearing and deforestation, and agricultural and animal husbandry practices.

Ground-Level Ozone (O_3): A secondary pollutant formed as a result of atmospheric reactions involving nitrogen oxides and reactive volatile organic compounds in the presence of sunlight.

H

Hazard: A source of potential harm from past, current, or future exposures.

Hazardous Air Pollutants: Are released into the atmosphere as particles and volatile organic compounds, including the known carcinogens of benzene and toluene, from a variety of sources such as vehicle emissions, petrochemical products, and environmental tobacco smoke. Of particular concern are persistent organic pollutants that are not easily broken down, and can therefore travel great distances, as well as accumulate within living organisms.

Haze (Hazy): A phenomenon that results in reduced visibility due to the scattering of light caused by aerosols. Haze is caused in large part by man-made air pollutants.

Heavy Metals: Metallic elements with high atomic weights; (e.g. mercury, chromium, cadmium, arsenic, and lead); can damage living things at low concentrations and tend to accumulate in the food chain.

Hydrocarbons: Organic compounds containing primarily carbon and hydrogen, but also may contain nitrogen, sulphur, halogens, etc. These are mainly produced from coal, petroleum and natural gas use, solvent evaporation, and incomplete combustion of fuels, wastes and biomass. Vegetation is a major natural source of hydrocarbons.

I

Indoor Air Pollution: Chemical, physical, or biological contaminants in indoor air.

Inhalable Particulate Matter: In the context of this report, refers to particulate matter that is small enough in size to be breathed into the lungs. These particles are also referred to as PM_{10}, and $PM_{2.5}$ and are comprised of directly emitted particles and secondary particles formed in the atmosphere through interactions of directly emitted pollutants such as sulphur oxides, nitrogen oxides, ammonia and volatile organic compounds.

Internal Combustion Engine: An engine in which both the heat energy and the ensuing mechanical energy are produced inside the engine. Includes gas turbines, spark ignition gas, and compression ignition diesel engines.

Ischemic Heart Disease: Any condition in which heart muscle is damaged or works inefficiently because of an absence or relative deficiency of its blood supply; most often caused by atherosclerosis, it includes angina pectoris, acute myocardial infarction, chronic ischemic heart disease and sudden death. Also called coronary 'heart disease (CHD).

L

Light-Duty Trucks: This category includes pick-up trucks, mini-vans and SUVs with a gross vehicle weight rating (GVWR) of 3900 kg or less which are designated primarily for transportation of light-weight cargo or that are equipped with special features such as four-wheel drive for off-road operation.

Lowest Observed Effect Level: Lowest concentration or amount of a substance, found by observation or experiment, which causes an effect.

Lymphoma: Malignancy of lymphatic tissue usually arising in the lymph nodes but also in other tissue.

M

Meteorology (also Meteorological): The study of the atmosphere and its weather and climatic conditions.

Methane (CH_4): A colourless, flammable gas produced mainly from coal mining, oil and gas exploration, combustion of fossil fuels, wastes and biomass and waste, petrochemical production, anaerobic decomposition of sewage and organic compounds, and landfills.

Micrometre: One millionth or 10^{-6} of a metre and is a unit of size measurement.

Mobile Source: Moving source of air pollution, such as an automobile.

Monitoring: A combination of observation and measurement for the performance of a plan, programme or measure, and its compliance with environmental policy and legislation.

Morbidity: The number of sick persons or cases of disease within a particular population group.

Mortality: The death rate, the ratio of the number of deaths to a particular population group.

N

Nitrate: A substance naturally formed or produced from nitric acid and a base element. In the context of air pollution, ammonium nitrate is a secondary particle formed in the atmosphere from nitrogen oxides, water vapour and ammonia.

No Observed Adverse Effect Level: Greatest concentration or amount of a substance, found by observation or experiment, which causes no detectable adverse effect. Effects may be detected at this level, which are not judged to be adverse.

No Observed Effect Level: Greatest concentration or amount of a substance, found by observation or experiment, which causes no detectable effect.

Non-Point Sources: Diffuse pollution sources (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet). Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion and city streets.

O

Organic: 1. Referring to or derived from living organisms. 2. In chemistry, any compound containing carbon.

Ozone-Depleting Substances (ODS): Those substances responsible for depletion of the ozone layer in the stratosphere. These substances primarily contain chlorine, fluorine and/or bromine atoms. A single chlorine or bromine atom can destroy 100,000s of ozone molecules before it becomes inactive. These substances include carbon tetrachloride, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), brominated fluorocarbons (Halons), methyl bromide and methyl chloroform. These are widely used in refrigeration units, insulating foams, as well as cleaning agents, solvents and fire extinguishing agents. The production and use of CFCs have been banned under the 1987 Montreal Protocol, 1987. Some other substances are being used as transitional substances before their use is phased out because of high global warming potentials.

Ozone Layer: Very dilute atmospheric concentration of ozone found at an altitude of 10 to 50 kilometres above the earth's surface.

Ozone Layer Depletion: The depletion of a thin layer of ozone located in the stratosphere that protects the earth from harmful ultraviolet radiation of the sun. (see: ODS and Stratospheric Ozone Depletion)

P

Pathogenic: Description of an agent that induces illness.

Pathophysiology: The functional changes that accompany a particular syndrome or disease

Peak Level: Level of airborne pollutant contaminants much higher than average or occurring for short periods of time in response to sudden releases.

Perfluorocarbon: Family of industrial gases included in the basket of six greenhouse gases (GHGs) covered by the Kyoto Protocol.

Pesticide: Substances or mixture there of intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture intended for use as a plant regulator, defoliant, or desiccant.

Petrochemicals: Chemicals obtained by refining (i.e., distilling) crude oil. They are used as raw materials in the manufacture of most industrial chemicals, fertilizers, pesticides, plastics, synthetic fibers, paints, medicines, and many other products.

PM_{10}: Particles with a nominal aerodynamic diameter of 10 micrometres or smaller in diameter. PM_{10} particles are emitted directly and formed in the atmosphere through interactions of precursor pollutants such as sulphur oxides, nitrogen oxides and volatile organic compounds, and ammonia. PM_{10} particles can adversely affect human health and the receiving environment.

$PM_{2.5}$: Particles with a nominal aerodynamic diameter of 2.5 micrometres or smaller in diameter. Most $PM_{2.5}$ size particles are emitted directly by combustion sources, or formed in the atmosphere through interactions of precursor pollutants such as sulphur oxides, nitrogen oxides, volatile organic compounds, and ammonia. $PM_{2.5}$ can significantly compromise human health, as well as impede visible light.

Pneumoconiosis: Health conditions characterized by permanent deposition of substantial amounts of particulate matter in the lungs and by the tissue reaction to its presence; can range from relatively harmless forms of sclerosis to the destructive fibrotic effect of silicosis.

Point Source: A commonly used term for emission inventory compilation. It is a single stationary source of pollution, such as a stack or vent. Different agencies define a Point Source differently for the purpose of its emission inventory.

Pollen: The fertilizing element of flowering plants; background air pollutant.

Pollutant: Any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems..

Pollution: The presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects.

Pollution Prevention: A policy concept based on the fact, "*Prevention is often less expensive than after-the-fact measures.*" It is a proactive measure of preventing pollution generation at the outset, instead of cleaning-up after producing air pollutants. It includes the use of "win-win" methods such as cleaner production technologies, minimization of wastes, and efficient energy use. All these options offer the prospect of environmental protection at little or no cost.

Precursor: Substance from which another, usually more biologically active, substance is formed.

Pressed Wood Products: Materials used in building and furniture construction that are made from wood veneers, particles, or fibers bonded together with an adhesive under heat and pressure.

Primary Pollutants: Air pollutants generated during various processes and emitted directly from the sources as such.

Propellant: A gas with a high vapour pressure used to force formulations out of aerosol spray cans. Among the gases used are butanes, propanes and dinitrogen oxide.

Prospective Study: A study that involves observation of exposed individuals over a long period of time to see if they develop conditions such as heart attacks or chronic lung disease, taking into account residential area, pollution exposure levels, and personal habits such as smoking.

R

Radiation: Transmission of energy though space or any medium.

Radon Daughters/Radon Progeny: Short-lived radioactive decay products of radon that decay into longer-lived lead isotopes that can attach themselves to airborne dust and other particles and, if inhaled, damage the linings of the lungs.

Randomized control trial: A research study that involves choosing a number of people and measuring their response to a new treatment,

Receptor: The receiving medium of an air pollutant, or a location where an air pollutant is measured.

Respirable Particulate Matter: In the context of this report, refers to particles that are small enough in size that they can be taken deep into the lungs and deposited within it. Also referred to as $PM_{2.5}$.

Risk: The probability that something will cause injury or harm.

Risk Assessment: The procedure in which the risks posed by inherent hazards involved in processes or situations are estimated either quantitatively or qualitatively.

Risk Management: Process of evaluating alternative regulatory and non-regulatory responses to risk and selecting among them. The selection process necessarily requires the consideration of legal, economic and social factors.

Risk Reduction: Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

S

Scrubber: An air pollution device that uses a spray of water or reactant to reduce or remove pollution from air pollution sources.

Secondary Pollutants: Those pollutants that are generated in the atmosphere as a result of chemical reactions involving primary pollutants.

Second-hand smoke: Second-hand smoke, or environmental tobacco smoke, is a combination of the smoke coming off a burning cigarette, pipe or cigar and the smoke exhaled by a smoker.

Sick Building Syndrome: Building whose occupants experience acute health and/or comfort effects that appear to be linked to time spent therein, but where no specific illness or cause can be identified. Complaints may be localized in a particular room or zone, or may spread throughout the building.

Smog: The word "smog" originated in the U. K. in the mid-20th century to refer to the unique atmospheric condition resulting from a combination of smoke and fog. In winter the city of London often experienced dense, stagnant fog. The term "photochemical smog' originated in California in the early 1960s to describe the air quality problem caused by the ground-level ozone. The most recent definition of "smog" used in Canada includes two main constituents, namely ground-level ozone and $PM_{2.5}$.

Sour gas: Sour gas is natural gas that contains hydrogen sulphide (H_2S), a colourless flammable compound that has a distinctive "rotten egg" smell.

Stewardship (Environmental): Involves individuals or groups, not normally part of primary management structures, participating in the protection of the natural environment.

Stratosphere: The portion of the atmosphere 10-to-40 km above the earth's surface, and the layer above the troposphere.

Stratospheric Ozone Depletion: The depletion of a thin layer of ozone located in the stratosphere that protects the earth from harmful ultraviolet radiation of the sun.

Subclinical effect: Biological change following exposure to an agent known to cause disease either before symptoms of the disease occur or when they are absent.

Sulphur Oxides (SO_x): Includes all oxides of sulphur such as sulphur dioxide and sulphur trioxide. These pollutants contribute significantly to inhalable particulate matter, visibility degradation, acid precipitation, and global climate change.

T

Temperature Inversions: Weather conditions that are often associated with serious air pollution episodes. In a temperature inversion, an elevated layer of warmer air provides a cap for the upward mixing of air. Pollutants, especially smog and smog-forming chemicals, including volatile organic compounds, are trapped close to the ground. As people continue driving, and sources other than motor vehicles continue to release smog-forming pollutants into the air, the smog level keeps getting worse.

Teratogen: A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Threshold: The dose or exposure level below which a significant adverse effect is not expected.

Time-series analysis: A research study that involves observations of the effects of day-to-day pollution patterns on a population in a defined geographic area.

Tolerance: Ability of an organism to endure unfavourable environmental conditions; or, amount of a chemical in food considered safe for humans or animals.

Toxicant: A harmful substance or agent that may injure an exposed organism.

Toxicity: The degree to which a chemical substance elicits a deleterious or adverse effect upon the biological system of an organism exposed to the substance over a designated time period.

Toxicology: The study of the harmful effects of substances on humans or animals.

Transboundary Pollution: The phenomenon where air pollutants are carried thousands of miles across borders and oceans or from one urban area to another. This phenomenon is common around the world and is also referred to as long-range atmospheric transport.

U

Ultraviolet B (UVB): A type of sunlight. The ozone in the stratosphere, high above the Earth, filters out ultraviolet B rays and keeps them from reaching the Earth. Ultraviolet B exposure has been associated with skin cancer, eye cataracts and damage to the environment. Thinning of the ozone layer in the stratosphere results in increased amounts of ultraviolet B reaching the Earth.

Ultraviolet Radiation: Radiation in the wavelength range between visible light and X-rays, divided into wavelength bands A, B, C. Much of the ultraviolet radiations in bands B and C are prevented from reaching the earth's surface by the ozone layer present in the atmosphere.

V

Visibility: A term to describe how far or how much an individual is able to see in the ambient atmosphere. Fine particles, aerosols, and some gaseous pollutants contribute to the haziness of the atmosphere and impair the clarity of the visual images in the distance. These pollutants cause the degradation of visibility, or the clarity of the distant objects, by scattering and absorbing the light in the atmosphere.

Volatile Organic Compounds (VOCs): Include a variety of organic compounds, some of which are photochemically reactive, that may contribute to the formation of ozone on warm sunny days. Some hydrocarbons such as methane, ethane, acetone and several others are usually excluded as VOCs, but some of these are toxics or ozone depleting substances. A number of sources emit VOCs including fossil fuel combustion and petroleum production and storage facilities, and a wide variety of solvent uses. Some vegetation may also produce photochemically reactive VOCs.

Vulnerability: Measure of the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted, on account of its nature or location, by the impact of a particular disaster hazard.

W

Wind Erosion: The breakdown of solid rock into smaller particles and its removal by wind. It may occur on any soil whose surface is dry, unprotected by vegetation (to bind it at root level and shelter the surface) and consists of light particles. The mechanisms include straightforward picking up of dust and soil particles by the airflow and the dislodging or abrasion of surface material by the impact of particles already airborne.

Glossary terms adapted from the following sources:

Agency for Toxic Substances and Disease Registry – Glossary of Terms
http://www.atsdr.cdc.gov/glossary.html

Alberta Energy and Utilities Board
http://www.eub.gov.ab.ca/BBS/public/sourgas/home.htm

California Air Resources Board – Glossary of Air Pollution Terms
http://www.arb.ca.gov/html/gloss.htm

Environment Canada – Criteria Air Contaminants - Air Pollutant Emissions Glossary
http://www.ec.gc.ca/pdb/ape/cape_gloss_e.cfm?

Environment Canada – Greenhouse Gas Emissions - Glossary
http://www.ec.gc.ca/pdb/ghg/glossary_e.cfm

Environmental Protection Agency – Global Warming – Glossary of Climate Change Terms
http://yosemite.epa.gov/oar/globalwarming.nsf/content/Glossary.html

Environmental Protection Agency – Terms of Environment
http://www.epa.gov/OCEPAterms/

European Environment Agency – Environmental Glossary
http://glossary.eea.eu.int/EEAGlossary/

Health Canada - Centre for Chronic Disease Prevention and Control, Cardiovascular Disease
http://www.hc-sc.gc.ca/pphb-dgspsp/ccdpc-cpcmc/cvd-mcv/terms_e.html

Health Canada – Health and Air Quality – Health Effects of Air Pollution
http://www.hc-sc.gc.ca/hecs-sesc/air_quality/health_effects.htm

National Library of Medicine – Toxicology Glossary
http://sis.nlm.nih.gov/Glossary/main.html

United Nations, Department of Economic and Social Affairs, Economic and Social Development, Statistics Division, Environment Glossary
http://unstats.un.org/unsd/environmentgl/

Appendix A
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Appendix C
Summary of Air Quality Monitoring Technologies Used in the Provincial Monitoring Network

Parameter	Monitor Type	Methodology	MDL (μg/m³)
$PM_{2.5}$	TEOM	*Change in oscillating frequency of tapered element loaded with filter*	5.0 μg/m³
PM_{10}	TEOM	*Change in oscillating frequency of tapered element loaded with filter*	5.0 μg/m³
Ozone (O_3)	TECO/API	*Absorption of UV light at 254 nm*	1.2 μg/m³
Nitrogen Dioxide (NO_2)	TECO/API	*Chemiluminescence involving gas-phase reaction of NO and ozone and catalytic conversion of* NO_2 *to NO*	2.5 μg/m³
Sulphur Dioxide (SO_2)	TECO/API	*Fluorescent excitation of* SO_2 *by UV radiation*	2.5 μg/m³
Carbon Monoxide (CO)	TECO/API	*Non-dispersive infra-red radiation*	0.1 ppm

Appendix D
Description of Ambient Air Quality Monitoring Sites in British Columbia as of December 31, 2003

Table D1 $PM_{2.5}$ Monitoring Sites in British Columbia (Continuous Monitors)

STATION ID	STATION NAME	STREET ADDRESS	CITY
0110031	Victoria Royal Roads University	2005 Sooke Road	Victoria
0220204	Powell River Cranberry Lake	Wildlife Sanctuary	Powell River
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
0550502	Williams Lake Columneetza School	1045 Western Avenue	Williams Lake
0605020	Williams Lake Skyline School	225 Hodson Road	Williams Lake
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207418	Burnaby South	5455 Rumble Street	Burnaby
E208096	Quesnel Senior Secondary	585 Callanan Street	Quesnel
E209178	Langley Central	23752 52nd Avenue	Langley
E216667	Quesnel Maple Drive	950 Mountain Ash Road	Quesnel
E216670	Kitimat Riverlodge	651 Columbia Street	Kitimat
E220891	Chilliwack Airport	Airport Road	Chilliwack
E221885	Quesnel Pinecrest Centre	501 Pinecrest Road	Quesnel
E223827	Kitimat Rail	CN Rail Yard	Kitimat
E228064	Quesnel West Correlieu School	850 Anderson	Quesnel

STATION ID	STATION NAME	STREET ADDRESS	CITY
E229797	Nanaimo Labieux Road	2080A Labieux Road	Nanaimo
E231866	Victoria Topaz	923 Topaz	Victoria
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E235070	Golden Hospital	835 9th Avenue South	Golden
E246240	Abbotsford Airport - Aldergrove Walmsley Road	31790 Walmsley Road	Aldergrove
E248797	Williams Lake CRD Library	180 North Third Ave	Williams Lake
E249492	Vernon Science Centre	2704 Highway #6	Vernon
E249735	Langford Dogwood School	2720 Jacklin Road	Victoria
E253229	Saanich Stellys Cross Road	Tsartlip Band Property	Victoria
M107004	Houston Firehall	3382 11th Street	Houston
M107028	Terrace BC Access Centre	104 - 3220 Eby Street	Terrace

Table D2 PM_{10} Monitoring Sites in British Columbia (Continuous Monitors)

STATION ID	STATION NAME	STREET ADDRESS	CITY
0220204	Powell River Cranberry Lake	Wildlife Sanctuary	Powell River
0220205	Powell River Wildwood	Wildwood Motors	Powell River
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310172	Squamish	38075 2nd Avenue	Squamish
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0450270	Prince George Gladstone School	7005 Gladstone Drive	Prince George
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
0550502	Williams Lake Columneetza School	1045 Western Avenue	Williams Lake
0605020	Williams Lake Skyline School	225 Hodson Road	Williams Lake
E206271	Surrey East	19000 72nd Avenue	Surrey
E206589	Smithers St Josephs	4020 Broadway Avenue	Smithers
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207417	Richmond South	Williams and Aragon Road	Richmond
E207418	Burnaby South	5455 Rumble Street	Burnaby
E208096	Quesnel Senior Secondary	585 Callanan Street	Quesnel
E209177	North Vancouver Mahon Park	16th Street & Jones Avenue	North Vancouver
E209178	Langley Central	23752 52nd Avenue	Langley
E216667	Quesnel Maple Drive	950 Mountain Ash Road	Quesnel
E216670	Kitimat Riverlodge	651 Columbia Street	Kitimat
E220891	Chilliwack Airport	Airport Road	Chilliwack
E221199	Creston PC School	Prince Charles Secondary School	Creston
E221885	Quesnel Pinecrest Centre	501 Pinecrest Road	Quesnel
E222520	Elk Falls Dogwood	Adjacent to 660 Westmere	Campbell River
E222778	Langdale Elementary	Forres Road	Langdale
E223616	Kitimat Haul Road	Haulage Road	Kitimat
E223756	Hope Airport	62715 Airport Road	Hope
E223827	Kitimat Rail	CN Rail Yard	Kitimat
E224013	Prince George BC Rail Warehouse	1108 Industrial Way	Prince George
E225184	Port Edward Pacific	770 Pacific Street	Port Edward
E225267	Burns Lake Fire Centre	#8 4th Avenue	Burns Lake
E225377	Harmac Cedar Woobank	1624 Woobank	Harmac
E225378	Quadra Island Lighthouse	Lighthouse Road	Campbell River
E228064	Quesnel West Correlieu School	850 Anderson	Quesnel
E228065	Port Alberni Townsite	5410 Argyle Street	Port Alberni

STATION ID	STATION NAME	STREET ADDRESS	CITY
E229798	Campbell River Tyee Spit	2662 Tyee Spit	Campbell River
E230557	Telkwa	1304 Birch Street	Telkwa
E231838	Prince Rupert Galloway Rapids	Highway 16	Prince Rupert
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E234670	Duncan Deykin Avenue	6364 Deykin Avenue	Crofton
E235070	Golden Hospital	835 9th Avenue South	Golden
E238212	Abbotsford Central	32995 Bevan Avenue	Abbotsford
E243516	Fort St John NP Cultural Centre	10015 100th Avenue	Fort St John
E248021	Revelstoke Mt Begbie School	402 Downie Street	Revelstoke
E248797	Williams Lake CRD Library	180 North Third Ave	Williams Lake
E249492	Vernon Science Centre	2704 Highway #6	Vernon
E250350	Fort Nelson Chalo School	Chalo Road (First Nations Reserve)	Fort Nelson
E253229	Saanich Stellys Cross Road	Tsartlip Band Property	Victoria
M107004	Houston Firehall	3382 11th Street	Houston
M107028	Terrace BC Access Centre	104 - 3220 Eby Street	Terrace

Table D3 Ozone (O_3) Monitoring Sites in British Columbia

STATION ID	STATION NAME	STREET ADDRESS	CITY
0110031	Victoria Royal Roads University	2005 Sooke Road	Victoria
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310172	Squamish	38075 2nd Avenue	Squamish
0310174	Vancouver Robson Square	Robson and Hornby	Vancouver
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
0550502	Williams Lake Columneetza School	1045 Western Avenue	Williams Lake
E206270	Burnaby Mountain	Ring Road, SFU	Burnaby
E206271	Surrey East	19000 72nd Avenue	Surrey
E206589	Smithers St Josephs	4020 Broadway Avenue	Smithers
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207417	Richmond South	Williams and Aragon Road	Richmond
E207418	Burnaby South	5455 Rumble Street	Burnaby
E207723	North Delta	8544 116th Street	Delta
E208096	Quesnel Senior Secondary	585 Callanan Street	Quesnel
E209177	North Vancouver Mahon Park	16th Street & Jones Avenue	North Vancouver
E209178	Langley Central	23752 52nd Avenue	Langley
E220891	Chilliwack Airport	Airport Road	Chilliwack
E222520	Elk Falls Dogwood	Adjacent to 660 Westmere	Campbell River
E223756	Hope Airport	62715 Airport Road	Hope
E227431	Whistler Meadow Park	Meadow Park Sport Centre	Whistler
E229797	Nanaimo Labieux Road	2080A Labieux Road	Nanaimo
E231866	Victoria Topaz	923 Topaz	Victoria
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232245	Maple Ridge Golden Ears Elementary School	23124 118th Avenue	Maple Ridge
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E238212	Abbotsford Central	32995 Bevan Avenue	Abbotsford
E242892	Coquitlam Douglas College	1250 Pinetree Way	Coquitlam
E249492	Vernon Science Centre	2704 Highway #6	Vernon
E253229	Saanich Stellys Cross Road	Tsartlip Band Property	Victoria

Table D4 Carbon Monoxide (CO) Monitoring Sites in British Columbia

STATION ID	STATION NAME	STREET ADDRESS	CITY
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310174	Vancouver Robson Square	Robson and Hornby	Vancouver
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
E206271	Surrey East	19000 72nd Avenue	Surrey
E206589	Smithers St Josephs	4020 Broadway Avenue	Smithers
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207417	Richmond South	Williams and Aragon Road	Richmond
E207418	Burnaby South	5455 Rumble Street	Burnaby
E209177	North Vancouver Mahon Park	16th Street & Jones Avenue	North Vancouver
E209178	Langley Central	23752 52nd Avenue	Langley
E220891	Chilliwack Airport	Airport Road	Chilliwack
E223756	Hope Airport	62715 Airport Road	Hope
E231866	Victoria Topaz	923 Topaz	Victoria
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232245	Maple Ridge Golden Ears Elementary School	23124 118th Avenue	Maple Ridge
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E238212	Abbotsford Central	32995 Bevan Avenue	Abbotsford
E242892	Coquitlam Douglas College	1250 Pinetree Way	Coquitlam

Table D5 Sulphur Dioxide (SO_2) Monitoring Sites in British Columbia

STATION ID	STATION NAME	STREET ADDRESS	CITY
0220204	Powell River Cranberry Lake	Wildlife Sanctuary	Powell River
0220205	Powell River Wildwood	Wildwood Motors	Powell River
0250009	Trail Butler Park	Butler Park	Trail
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310172	Squamish	38075 2nd Avenue	Squamish
0310174	Vancouver Robson Square	Robson and Hornby	Vancouver
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0450322	Prince George Jail	775 E Highway 16	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
0605008	Kamloops Federal Building	317 Seymour Street	Kamloops
0770703	Pine River Gas Plant	Gas Plant Site	Chetwynd
0770705	Fort Nelson Townsite	Village Site	Fort Nelson
0770708	Taylor Townsite	McMahon Complex, Alaska Highway	Taylor
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207417	Richmond South	Williams and Aragon Road	Richmond
E207418	Burnaby South	5455 Rumble Street	Burnaby
E207879	Robson	3113 Charleston Road	Robson
E209177	North Vancouver Mahon Park	16th Street & Jones Avenue	North Vancouver
E209178	Langley Central	23752 52nd Avenue	Langley
E209179	Prince George CBC Transmitter		Prince George
E220891	Chilliwack Airport	Airport Road	Chilliwack
E221821	Rumble Beach Hospital	1090 Marine Drive	Port Alice
E221822	Port Alice Lake Road	Lake Road	Port Alice
E222778	Langdale Elementary	Forres Road	Langdale
E223615	Kitimat Whitesail	1332 Lahakas Blvd. N.	Kitimat
E223616	Kitimat Haul Road	Haulage Road	Kitimat
E223827	Kitimat Rail	CN Rail Yard	Kitimat
E231866	Victoria Topaz	923 Topaz	Victoria
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E234230	Taylor South Hill	Pingle Creek Road	Taylor
E237631	Pine River Hasler	Pine River Gas Plant	Chetwynd
E238212	Abbotsford Central	32995 Bevan Avenue	Abbotsford
E239298	Fort Nelson Brucker Ranch	Block A of District Lot 1676	Fort Nelson
E244516	North Burnaby Capitol Hill	Grosvenor Cresent	North Burnaby
E244517	Burnaby North Eton	North Eton and Madison Avenue	Burnaby
E249492	Vernon Science Centre	2704 Highway #6	Vernon

Table D6 Nitrogen Dioxide (NO_2) Monitoring Sites in British Columbia

STATION ID	STATION NAME	STREET ADDRESS	CITY
0110031	Victoria Royal Roads University	2005 Sooke Road	Victoria
0220204	Powell River Cranberry Lake	Wildlife Sanctuary	Powell River
0310162	Port Moody Rocky Point Park	Moody Street and Esplanade	Port Moody
0310174	Vancouver Robson Square	Robson and Hornby	Vancouver
0310175	Vancouver Kitsilano	2550 West 10th Avenue	Vancouver
0310177	Burnaby Kensington Park	6400 E. Hastings	Burnaby
0450307	Prince George Plaza 400	1011 4th Avenue	Prince George
0500886	Kelowna College	3333 College Way	Kelowna
E206270	Burnaby Mountain	Ring Road, SFU	Burnaby
E206271	Surrey East	19000 72nd Avenue	Surrey
E206589	Smithers St Josephs	4020 Broadway Avenue	Smithers
E206898	Kamloops Brocklehurst	Mayfair Street	Kamloops
E207417	Richmond South	Williams and Aragon Road	Richmond
E207418	Burnaby South	5455 Rumble Street	Burnaby
E207723	North Delta	8544 116th Street	Delta
E208096	Quesnel Senior Secondary	585 Callanan Street	Quesnel
E209177	North Vancouver Mahon Park	16th Street & Jones Avenue	North Vancouver
E209178	Langley Central	23752 52nd Avenue	Langley
E220891	Chilliwack Airport	Airport Road	Chilliwack
E222520	Elk Falls Dogwood	Adjacent to 660 Westmere	Campbell River
E222778	Langdale Elementary	Forres Road	Langdale
E223756	Hope Airport	62715 Airport Road	Hope
E223827	Kitimat Rail	CN Rail Yard	Kitimat
E227431	Whistler Meadow Park	Meadow Park Sport Centre	Whistler
E231866	Victoria Topaz	923 Topaz	Victoria
E232244	Pitt Meadows Meadowlands Elementary School	18477 Dewdney Trunk Road	Pitt Meadows
E232245	Maple Ridge Golden Ears Elementary School	23124 118th Avenue	Maple Ridge
E232246	Vancouver International Airport #2	3153 Templeton Street	Richmond
E238212	Abbotsford Central	32995 Bevan Avenue	Abbotsford
E242892	Coquitlam Douglas College	1250 Pinetree Way	Coquitlam
E246240	Abbotsford Airport - Aldergrove Walmsley Road	31790 Walmsley Road	Aldergrove
E249492	Vernon Science Centre	2704 Highway #6	Vernon

Appendix E
Summary of National and Provincial Air Quality Objectives For Common Air Contaminants

(units in µg/m^3 unless otherwise noted)

			National Ambient AQ Objectives			Provincial Objectives[1]		
Contaminant	Averaging Period	CWS	Maximum Desirable	Maximum Acceptable	Maximum Tolerable	Level A	Level B	Level C
$PM_{2.5}$	24-hour	30[2]						
PM_{10}							50	
O_3	1-hour		100	160	300			
	8-hour	65 ppb[3]						
	1-year			30				
NO_2	1-hour			400	1000			
	24-hour			200	300			
	1-year		60	100				
SO_2	1-hour		450	900		450	900	900
	24-hour		150	300	800	160	260	360
	1-year		30	60		25	50-80	
CO	1-hour		15 mg/m^3	35 mg/m^3		14.3 mg/m^3	28.0 mg/m^3	35.0 mg/m^3
	8-hour		6 mg/m^3	15 mg/m^3	20 mg/m^3	5.5 mg/m^3	11.0 mg/m^3	14.3 mg/m^3

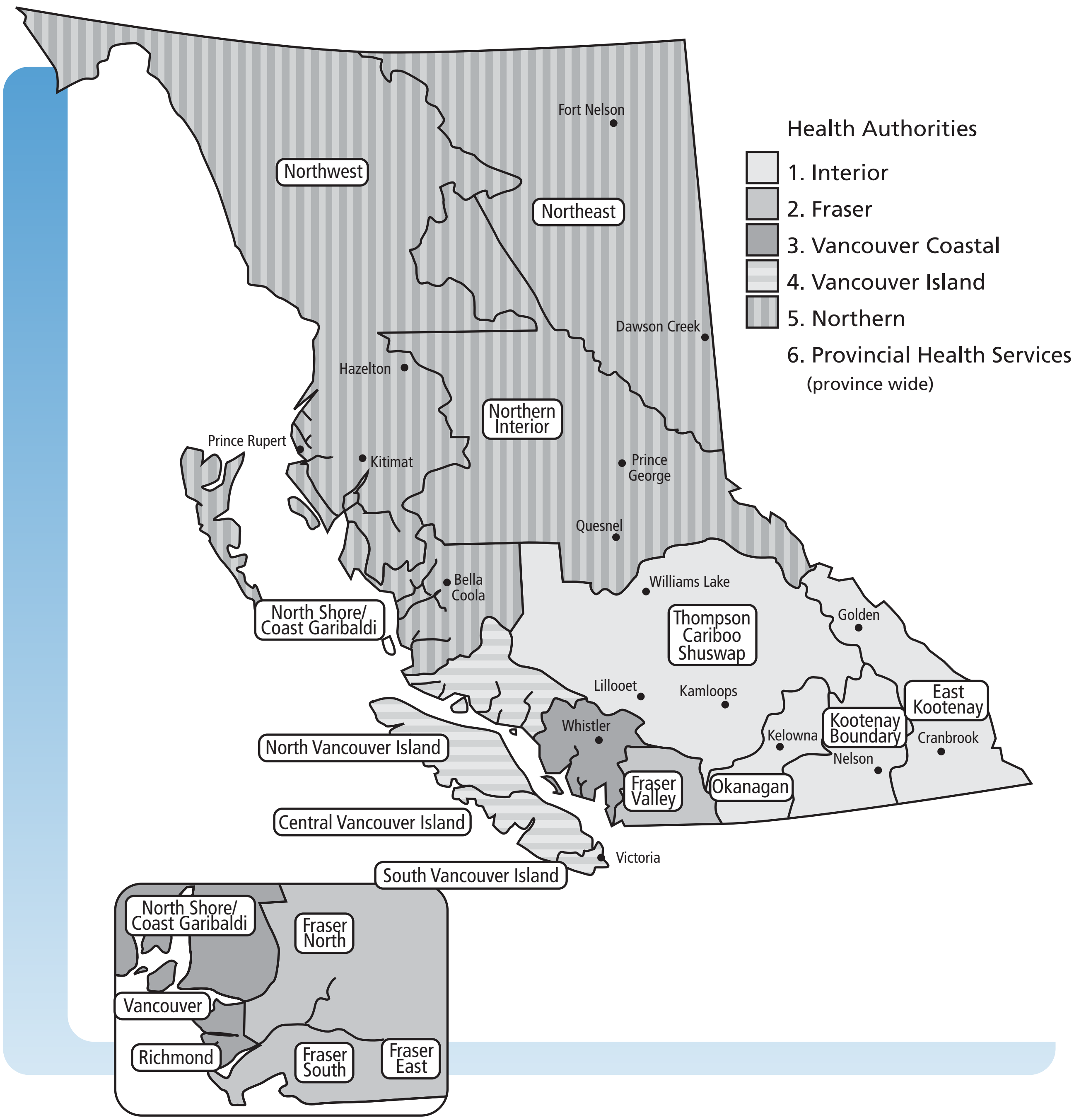
[1] Provincial objectives include collection of industry-specific Pollution Control Objectives. For PM_{10}, a single objective was developed that most closely aligns with a Level B objective.

[2] Based on annual 98th percentile value averaged over 3 consecutive years.

[3] Based on annual 4th highest value averaged over 3 consecutive years.

Appendix F
Map of Health Authorities and Health Service Delivery Areas in British Columbia

Map of Health Authorities and Health Service Delivery Areas in British Columbia



BRITISH COLUMBIA

Ministry of Health Services
Office of the
Provincial Health Officer