Brief Report:
Estimate of Mortality Burden of Air Pollution in Northern and Interior British Columbia, 2001-2005

Catherine Elliott and Ray Copes,
Division of Environmental Health Services, BCCDC

Introduction

Air pollution is responsible for over 2.4 million deaths worldwide each year (Ezzati et al 2002) and is estimated to cause three to six percent of total mortality in the developed world. More deaths are attributable to air pollution than any other environmental or occupational toxin (Mokdad et al 2004). In the US, air pollution is estimated to cause 60% of deaths attributable to environmental or occupational toxins and 1 to 2% of total mortality. The mortality attributable to air pollution is similar to that attributable to motor vehicles (1%), and greater than that attributable to illicit drug use (<1%) (Mokdad et al. 2004).

In his 2003 report, British Columbia's Provincial Health Officer highlighted the need to improve estimates of mortality attributable to air pollution in Interior and Northern communities (BCPHO 2004; p.88). Since residents of these regions are exposed to higher concentrations of particulate matter than those in the rest of the province, they may suffer greater health impacts. New information has come to light since the Provincial Health Officer's Report on air quality that will improve estimates of the burden of disease from air pollution. In particular, reanalysis of the major air pollution studies suggests that exposure to PM over the long-term may have greater impact on mortality than previously thought (Laden et al 2006). Furthermore air quality monitoring has now been conducted for a longer period and across a greater number of sites in Interior and Northern BC. We are now able to estimate the mortality burden of *long-term* exposure to air pollution in Northern and Interior BC.

There has been considerable discourse on the uncertainties involved in this type of risk analysis. First, there is some concern that correlations between particulate matter and death do not correspond to a causal relationship. However, given the consistency of observations over a range of geographical scales and timeframes, the dose-response relationship and the biological plausibility, we believe that the weight of evidence does represent a causal association. For a more detailed discussion of this issue, we refer readers to Pope and Dockery (2006) and the Committee on the Medical Effects of Air Pollutants (2006). Second, this type of risk analysis involves the application of a dose-response relationship observed in one region (US cities), to another (Northern and Interior BC). Given the differences in the constituents of particulate matter, and the population differences, our calculations can only be seen as estimates. It is not our intention to suggest that this risk analysis provides an exact death count, but rather that it provides a 'best estimate' given the current state of knowledge. Quantifying the health impacts of air pollution in Northern and Interior BC communities can serve as a basis for assigning appropriate priority to air pollution by placing it in context with other public health concerns.

Scope of this Report

This study adds to current knowledge about the impact of air pollution in Northern and Interior BC by:
(1) using the most current evidence to estimate the burden of illness attributable to long-term exposure to outdoor and indoor air pollution in the Northern and Interior Health Authorities and,
(2) comparing the mortality attributable to air pollution to other causes of death in these regions.
Our objective is to contribute to the information that Medical Health Officers can use to assess the potential health impacts of air pollution *in their regions*, and thereby assist in setting air pollution into context with other risks.

Methods

We used the methods of Bates and colleagues to estimate mortality attributable to particulate matter (2003).

We used annual mean PM 2.5 (particulate matter smaller than 2.5 um) as the basis for our estimation of outdoor air pollution because of the close associations of annual mean PM 2.5 with mortality in several large cohort studies (Abbey et al 1999, Dockery et al 1993, Krewski et al 2000, Laden et al 2006, Millar et al 2004, Pope et al 1995, 2002, 2004). We chose to estimate impact from exposure to air pollution over the long term because it corresponds to the actual exposure of the population more than short-term exposure. Furthermore, recent air pollution research has demonstrated that the mortality burden of long-term exposure to air pollution is an order of magnitude greater than that previously estimated for short-term exposure (Krewski et al 2000, Laden et al 2006, Pope et al 2002 and 2004).

For a sensitivity analysis, we used high, central and low values of concentration response functions (CRFs), to represent the range of likely estimates as suggested in the method of Bates et al (2003). CRFs were derived from recently published studies on long-term exposure to PM 2.5. The low, central and high values used were: 1.6, 10.5, 26 % increase in mortality per 10 ug/m^3 rise in PM 2.5 (Table 1). Sources for the low CRF are work by Pope et al (2002 and 2004). The central CRF is the mean of the central estimates in the six major papers from the ACS and Six Cities studies (Dockery et al 1993, Krewski et al 2000, Laden et al 2006, Pope et al 1995, 2002, 2004). The high CRF is from Laden and colleagues (2006).

Ambient PM measurements were obtained from BC Ministry of Environment continuous samplers for 2001 to 2005. The sampler closest to the major population concentration was used as an exposure estimate for each local health area (LHA). PM 2.5 concentration for LHAs without monitors was estimated as the median PM 2.5 concentration for all monitored LHAs in that Health Authority. The mean PM concentration at each monitor was calculated for all years with at least 11 months of data between 2001 and 2005. Mortality data for 2001 to 2005 was obtained from BC Vital Statistics Agency.

This method assumes a linear relationship between PM 2.5 concentration and mortality count for all measured levels of PM 2.5. There is no known low threshold for this relationship, despite measurements in regions with low PM 2.5 concentrations (Figure 1, Bates et al. 2003, Kunzli et al. 2000).

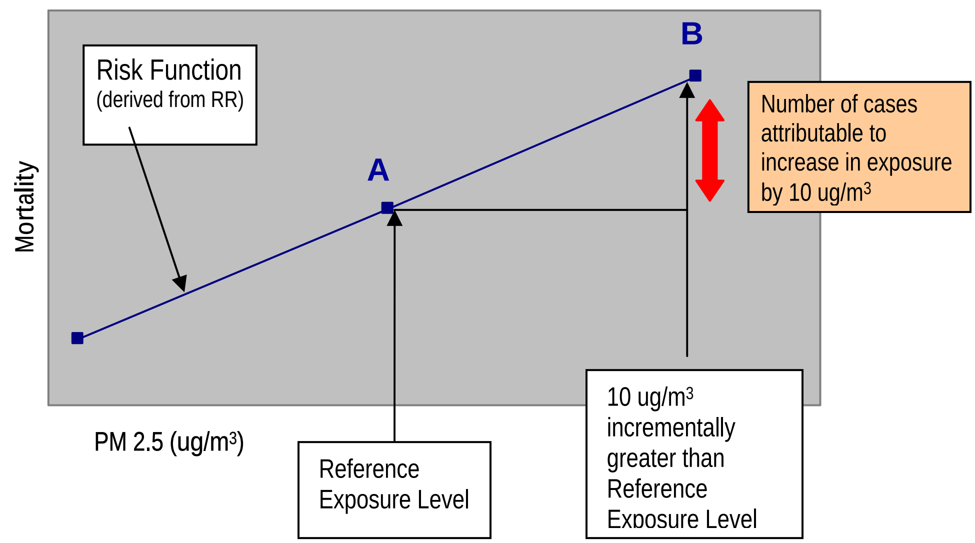

Figure 1. Linear relationship between mortality and PM 2.5 concentration used to calculate attributable mortality (adapted from Kunzli et al. 2000).

The following equation was used to calculate attributable mortality:

Attributable mortality = CRF x PM 2.5 increment x all cause mortality

Where *CRF* is the concentration response function: the factor by which mortality count increases per 10 ug/m^3 rise in the concentration of particulate matter. *PM 2.5 increment* is the difference between the observed annual mean PM 2.5 and a low concentration determined *a priori* in units of 10 ug/m^3. The low concentration represents a 'base case' which can be set to the lowest achievable PM 2.5 concentration, a concentration that is anticipated with changes in emissions or some other meaningful level. If the increment is less than zero, then the number of attributable deaths is estimated at zero. This calculation was performed for each LHA.

We chose to use two reference values for PM 2.5 concentration. One reference concentration was the lowest mean annual concentration in the province between 2001 and 2005 which occurred in Terrace (3.39 ug/m^3). The estimate based on this reference concentration is the mortality attributable to the lowest measured background concentration of PM 2.5. A second reference concentration is mean annual PM 2.5 at the Vancouver International Airport (5.79 ug/m^3). This estimate allows for comparison with a region that has been a major focus for air pollution research and programming in British Columbia. In addition, this is similar to the concentration that the PHO report deemed the "best attainable result" for the province outside the coastal communities, Vancouver Island, parts of the GVRD, and the Fraser Valley (6.0 ug/m^3; BCPHO 2004, p.56).

Mortality burden of exposure to environmental tobacco was calculated using a Health Canada estimate for attributable mortality for BC pro-rated on a population basis to the Health Authorities. Mortality burden of indoor smoke from solid fuel use was based on the WHO estimate for attributable mortality in the US, Canada and Cuba.

Key Findings

Ambient outdoor and indoor pollution combined are estimated to cause 198 deaths per year in the Interior and 61 deaths per year in the North (central estimates). We estimate that between 62 and 600 deaths per year are attributable to air pollution in Interior and Northern BC combined (Table 2).

This is the first estimate of the mortality burden of long-term exposure to air pollution specific to Interior and Northern British Columbia.

The mortality burden of air pollution is unevenly distributed among Northern and Interior communities. The communities with the highest number of deaths attributed to outdoor air pollution have the combination of a high PM 2.5 concentration and a larger population (Table 3). In the North, Prince George has a high mortality burden with estimated 165 deaths attributed to ambient air pollution during the five year period between 2001 and 2005. Prince George also has the highest annual mean PM 2.5 concentration of any measured community at 9.6 ug/m^3, a notable 1.2 ug/m^3 higher than the next highest community. In the Interior, Kelowna, Kamloops and Vernon are all estimated to have a high mortality burden at 194, 108, and 106 deaths respectively during the five-year period between 2001 and 2005.

Comparison with previous estimates

The first estimate of mortality attributable to air pollution in BC was calculated by Vedal using similar methodology to this study (1995). He used the concentration response function for short-term increments in annual mean PM 10 above 20 ug/m^3 and the CRF for short-term exposure from the Six Cities study, which was the best information at the time (1% per 10ug/m^3 increment of PM10, Dockery 1993). He estimated that 82 deaths in BC each year were caused by PM 10 levels above this threshold (Vedal 1995). We now know that this was an under-estimate because it did not take long-term exposures into account.

Vedal also estimated that 69 of these 82 deaths (64%) occurred outside the Lower Mainland, Capital Regional District and Nanaimo Regional District. He was the first to demonstrate the proportionally large mortality burden of air pollution which exists outside the province's major population centres.

Subsequently Brauer and colleagues used sophisticated modeling to estimate the mortality burden of air pollution in the Lower Mainland. They took a novel approach which provided a range of estimates based on the number of days when air pollution was assumed to affect mortality, taking all pollutants into consideration. They estimated that air pollution caused 0 to 600 deaths per year in the Lower Mainland, based on air quality data between 1994 and 1998 (Brauer et al 2000). The Medical Health Officers from the Lower Mainland indicated that 15 to 150 deaths per year was a ‘more likely’ range (Fraser Health Authority nd, BCPHO 2004). Extrapolating these numbers on a population basis to the NHA and IHA would result in an estimate of 0 to 269, based on Brauer’s numbers, and a ‘more likely’ estimate of 7 to 67 based on the MHOs’ numbers.

The third estimate was presented in BC’s Provincial Health Officer’s Report. Once again, the concentration response function for short-term exposure to PM 2.5 was used to calculate incremental mortality in BC (BCPHO 2004). This was compared to estimates extrapolated on a population basis from other studies in Ontario and Internationally. This report estimated that between 25 and 250 deaths each year in BC were due to outdoor air pollution. Furthermore, air pollution from indoor and outdoor sources combined was estimated to cause between 138 and 403 deaths per year in BC.

The PHO’s Report also provided an estimate of the air pollution mortality in Interior BC. They estimated that 71 deaths in the Interior of the province were attributable to PM 2.5 above 6.0 ug/m^3. This estimate was based on PM 2.5 in 2003, and the suggested high CRFs for short-term exposure to PM 2.5 from Bates et al 2003. The PHO’s estimate is greater than our estimate (using Vancouver as the reference concentration) because: (1) it was based on a year with poor air quality, and (2) the PM 2.5 concentration applied to unmonitored communities was greater. Our examination of the trend in PM 2.5 demonstrates that many communities experienced higher particulate matter pollution in that year than in the previous and subsequent years. In addition, the PHO estimate applied the median concentration of 8.5 ug/m^3 to the population in unmonitored sites. Since the release of the PHO’s report, monitoring has begun in several new sites, and those with lower PM such as Fort St. John, Kitimat and Terrace. The median annual mean PM 2.5 concentrations in the Interior and North are now considerably lower, at 6.2 and 5.1 ug/m^3 respectively. Since this median concentration is applied to a substantial portion of the population who live in unmonitored communities, this decrease in estimated exposure considerably lowers the mortality estimate.

We estimate that between 35 and 573 deaths each year in the Interior and the North are attributable to PM 2.5 increments above the lowest concentration in the province (Terrace PM 2.5 = 3.4 ug/m^3; Table 4). Whereas using the PM concentration at Vancouver Airport as the reference (PM 2.5 = 5.79 ug/m^3), we estimate that the Interior and the North have between 9 and 142 deaths annually attributable to PM 2.5 (Table 4). This sensitivity analysis highlights two characteristics of these estimates: first, rather than providing a point estimate, they provide a wide range of potential mortality burden and second, they are sensitive to the reference PM 2.5 concentration.

Our estimates of mortality are larger than most previous estimates, because (1) they are based on both the higher PM in Interior and Northern BC whereas most previous estimates were based on estimates for the Lower Mainland extrapolated on a population basis to the Interior and the North and (2) our estimates are based on the recently published effects of air pollution over the long-term, which are an order of magnitude greater than the short-term effects used in previous estimates (Table 5).

Air pollution has a significant impact when compared with other factors that contribute to mortality (Tables 6, 7). Using the lowest pollution levels in the province as the reference concentration, we estimate that annual mortality attributable to air pollution 179 deaths in the Interior and 53 deaths in the North. This places air pollution as a significant contributor to mortality, with attributable mortality about one-sixth that of smoking attributable mortality and one-third to one-half that of alcohol-related mortality.

Comparison of these estimates with direct causes of death must take into consideration that air pollution is a contributory cause of death, and that deaths attributed to air pollution are 'counted' in the direct causes (e.g. cardiovascular deaths). Nevertheless, it does demonstrate that the mortality attributable to air pollution is substantial, and an important modifiable cause of death in these regions.

Air-pollution attributable mortality was under-estimated by previous researchers because the effects of exposure to air pollution *over the long term* was not as well understood at the time of these estimates (c.f. Brauer, Brumm and Ebelt 2000).

Limitations

This study applies concentration response functions (CRFs) that were derived in urban centres throughout the United States to the North and Interior of BC. The true relationship between air pollution and mortality in the North and Interior is only approximated by these CRFs. Furthermore Northern and Interior communities have PM 2.5 concentrations that are lower than the communities where the CRFs were derived. Since there are no studies specific to this region, these are the best currently available approximations of the relationship between particulate matter and mortality.

It is reassuring that the concentration response functions derived in different cities throughout North America are surprisingly consistent across locations and populations. However the research also demonstrates that both particulate matter composition (Laden et al 2000) and population socioeconomic status (Pope and Dockery 2006, HEI 2000) may influence the relationship between PM and mortality. These factors may be particularly important in Northern and Interior BC.

Particulate Matter Composition

PM fractions represent complex mixtures of particles and gases from various emission sources. However, it is becoming apparent that health effects likely depend on particle composition and co-pollutant mixtures. Recent studies in the Netherlands (Roemer et al 2001) have demonstrated that distance to a major road is an important factor in the magnitude of health impact: living closer to a major road was associated with higher risk of mortality. Other studies have found associations between health effects and truck counts on adjacent roadways (Brunekreef et al 1997, Duhme et al 1998). Laden et al studied relationship between mortality and portions of particulate matter, representing crustal sources, vehicle exhaust and coal combustion (2000). Each 10 ug/m^3 increase in PM 2.5 concentration was associated by increased mortality by: 3.4% for mobile sources, 1.1% for coal combustion and no association was found for crustal sources. These studies support the hypothesis that particles from combustion, particularly mobile sources, are the most harmful.

In BC communities, particulate matter composition varies with season. Spring PM peaks may be associated with dust from roads (crustal) whereas mid-winter peaks are often associated with inversion trapping residential woodsmoke, transportation and industrial emissions. Although considerable emissions data exist, little is known about the actual composition of ambient PM in Northern and Interior communities. Health impacts of PM in Northern and Interior BC would likely vary with local sources of PM, and differ to some extent from the concentration response functions that were used in this study which were generated in the United States.

Socioeconomic Status

Health effects of air pollution appear to be greater amongst those with lower socio-economic status. A reanalysis of the major studies of health impacts of particulate matter explained some of the reasons why the Six Cities Study (SCS) estimates for concentration response factors were nearly twice as high as American Cancer Society Study (ACS) estimates. Part of this difference was thought to be caused by the over-representation of well-educated individuals in ACS relative the SCS (Pope and Dockery 2006). This was borne out in sensitivity analysis by the Health Effects Institute, which looked for effects of demographic factors, income, poverty, unemployment, education access to health services, climate, physical environment and gaseous co-pollutants (HEI 2000). Interestingly, education was the only covariate found to modify the effect of air pollution on mortality. Those with higher educational attainment had lower relative risk of mortality. The authors felt that education may represent socio-economic status, thus lending further support to the concept that air pollution impacts are highest for those of low socio-economic status.

Interior and Northern BC communities have lower socio-economic status than the rest of the province. BC Statistics has developed a comprehensive set of over 80 indicators describing the socio-economic status throughout the province. On a six category ranking of overall socioeconomic status, most of the BC Interior and Northern regions are ranked in the lower two categories whereas most of the Lower Mainland regions are ranked in the upper two categories (BC Statistics 2006). Furthermore the SES in Interior and Northern BC is lower than in the communities where the CRFs were derived. This would suggest that the impact of PM on mortality may be greater in Northern and Interior BC communities than that which we estimated in this study.

Environmental Tobacco Smoke

Our estimate of mortality from ETS is based on Health Canada estimates for the country, pro-rated based on population. However, BC's North in particular has one of the highest smoking rates in the country at 31.2% compared to a provincial average of 20% (Ipsos-Reid 2003) and the national rate of 21% (Health Canada 2003). Not only do more Northerners smoke, but more permit smoking in their homes. An astonishing 37% of Northern homes allow smoking compared with 23% in the Interior and the provincial average of 21% (Ipsos-Reid 2003). Due to high exposure to second hand smoke in the Interior and especially the North, our estimate based on the national rates, likely underestimates the true mortality burden from ETS.

Important Air Pollutants Not Adequately Represented in these Estimates

Detailed estimates of mortality burden due to residential wood combustion (RWC) and radon were beyond the scope of this report.

We estimated mortality from RWC based on the World Health Organization estimates for on mortality in the Americas – which is that RWC causes no mortality in the region. However, studies from the developed world demonstrate that wood smoke exposure is related to increasing respiratory symptoms and lower respiratory tract infections among children (Butterfield et al 1989, Liu et al 2003, Honicky et al 1985, Morris et al 1990, Robin et al 1996, Zelikoff 2006) and increased COPD exacerbations among adults (Orozco-Levi 2006). Furthermore, the central monitors used in this study do not capture individual and neighborhood exposures to particulate matter from wood smoke which may be substantial. Therefore RWC may contribute to mortality in the Interior and the North, however we were unable to capture this in our estimates.

Radon is an important indoor air pollutant which is present in Northern and Interior homes at levels sufficient to cause health effects such as lung cancer with long-term exposure (IARC 1988). However, estimation of the mortality burden of radon was beyond the scope of our analysis.

Summary

This study re-emphasizes the importance of air pollution to public health by demonstrating that air pollution is associated with a substantial mortality burden in Northern and Interior BC, with a substantial mortality burden. We estimate that 61 deaths per year in the North and 198 deaths per year in the Interior are attributable to indoor and outdoor air pollution. These estimates are greater than previous estimates, because they take into consideration recent findings that demonstrate a ten-fold greater impact of long-term exposure to outdoor air pollution compared with short-term exposure. Our estimates place air pollution among the important modifiable public health concerns in the Interior and the North.

Recommendations

This study provides evidence to support:

- Actions to reduce ambient particulate matter, particularly in the communities with the greatest mortality burdens: Prince George, Kelowna, Kamloops and Vernon. Such actions would include identifying the sources of air pollution and using education, enforcement and engineering to decrease pollution.
- Identification of the constituents of ambient particulate matter in BC's Interior and North, and focusing efforts on mitigating the components with the greatest health effects (e.g. from combustion sources).
- Ongoing support of efforts to reduce exposure to environmental tobacco smoke, which is an important cause of mortality.
- Research into health effects of other air pollutants such as residential wood combustion and radon.

Table 1. Concentration response functions for mortality attributable to long-term exposure to PM 2.5 (percentage increase in mortality per 10 ug/m^3 increase in annual mean PM 2.5 (adapted from Pope and Dockery 2006).

Study	Concentration Response Function (95% CI)	Source
Six Cities Study, original	13 (4.2,23)	Dockery et al 1993
Six Cities Study, HEI reanalysis	14 (5.4,23)	Krewski et al 2000
Six Cities Study, extended reanalysis	16 (7,26)	Laden et al 2006
ACS, original	6.6 (3.5,9.8)	Pope et al 1995
ACS, HEI reanalysis	7.0 (3.9,10)	Krewski et al 2000
ACS, extended reanalysis	6.2(1.6,11)	Pope et al 2002, 2004
ACS adjusted for education	8-11	Dockery et al 1993 Pope et al 2002 Krewski et al 2000
ACS, Los Angeles, fine spatial analysis	17 (5,30)	Jerrett et al. 2005*
AHSMOG*	1.1 (-2.3,4.6)	Abbey et al 1999
AHSMOG, males AHSMOG, females	8.5 (-2.3, 21) CV mortality only: 42 (6,90)	McDonnell et al 2000 Chen et al 2005
Women's Health Initiative	CV mortality only: 32 (1,73)	Miller et al 2004
11 CA counties, elderly	1 (-0.6,2.6)	Enstrom 2005
Veterans**	15 (5,26)	Lipfert et al 2006
Values used in this analysis	*Low 1.6* *Central 10.5* *High 26*	*Pope et al 2002, 2004* *Mean value of six major studies**** *Laden et al 2006*

* Seventh Day Adventist community, non-smokers.
** Middle aged, hypertensive male Veterans' Associate patients; 81% current or former smokers, 35% African Americans
*** The six major studies from the Six Cities Study and the Amercian Cancer Society study, which are the first six studies listed in this table.

Table 2. Estimated annual mortality attributable to particulate matter, environmental tobacco smoke and residential wood smoke. Central mortality estimates are listed, with high and low estimates in brackets.

Factor	Interior	North
Long-term exposure to ambient PM 2.5[a]	179 (27,443)	53 (8,130)
Environmental tobacco smoke [b]	*19*	*8*
Residential woodsmoke [c]	*0*	*0*
Annual mortality attributable to indoor and outdoor air pollution	198 (46,462)	61 (16,138)

a Annual mortality attributable to PM 2.5 incremental to the lowest concentration in the province (Terrace, 5.39ug/m^3)
b Health Canada estimate of 108 deaths in BC in 1998, extrapolated on a population basis to Interior and North and for population 2001-2005. The five-year average is used for annual mortality (nd).
c WHO estimate for developed world, estimate of death from biomass burning in US, Canada and Cuba is zero (world region AMR-A; WHO nd).

Table 3. Mortality attributable to annual mean PM 2.5 increment above the lowest in the province (Terrace 3.39 ug/m3) for 2001 to 2005 inclusive. Central mortality estimates are listed, with high and low estimates in brackets.

Location	PM 2.5	Five-Year Mortality Central (High,Low) Estimate
Northern Health Authority		
Fort Nelson	4.2	1 (0,2)
Fort Saint John	3.8	3 (0,7)
Kitimat	3.8	1 (0,3)
Terrace	3.4	+
Smithers	6.0	5 (1,13)*
Houston	6.5	6 (1,16)*
Prince George	9.6	165 (25,409)
Quesnel	8.3	41 (6,101)
Rest of NHA (median PM 2.5)	5.1	41 (6,102)
Total NHA	-	*263 (40,652)*
Interior Health Authority		
Williams Lake	6.2	24 (4,58)
Kamloops	6.1	108 (17,268)
Vernon	7.0	106 (16,262)
Kelowna	6.1	194 (30,481)
Golden	8.4	9 (1,22)
Rest of IHA (median PM 2.5)	6.2	453 (69,1121)
Total IHA	-	*894 (136,2214)*

C (H, L) are central, low and high values used for sensitivity analysis.
+ Terrace had the lowest PM 2.5 in the province, and was used as the reference concentration.
* Houston and Smithers are in the same LHA, so the mortality burden was calculated using the mean PM 2.5 concentration of the two cities.

Table 4. Estimated annual mortality attributable to PM 2.5 increment above Vancouver International Airport (5.79 ug/m3) and Terrace (3.39 ug/m3) for 2001 to 2005 inclusive. Central mortality estimates are listed, with high and low estimates in brackets.

Location	Estimated mortality attributable to PM 2.5 concentration incremental to Vancouver Central (High,Low) Estimate	Estimated mortality attributable to PM 2.5 concentration incremental to the lowest concentration in BC Central (High,Low) Estimate
Northern Health Authority	25 (4,63)	53 (8,130)
Interior Health Authority	32 (5,79)	179 (27,443)
Annual mortality Interior and North combined	57 (9,142)	232 (35,573)

Table 5. Range of estimates for annual attributable mortality for outdoor air pollution in Northern and Interior BC.

Source of the Estimate	Annual Mortality
Brauer's estimate for the Lower Mainland pro-rated to Northern and Interior BC*	0 – 269
MHO's 'more likely' estimate pro-rated to Northern and Interior BC*	7 – 67
PHO Report estimate for the province pro-rated to Northern and Interior BC*	6 – 60
Vedal's estimate for outside Lower Mainland and CRD/NRD	69
PHOs Report for PM >6.0 ug/m^3 in the Interior	71
Our estimate for Interior and Northern BC combined based on annual mean PM 2.5 in excess of Vancouver concentration**	57 (9,142)
Our estimate for Interior and Northern BC combined based on annual mean PM 2.5 in excess of the lowest concentration measured in BC**	232 (35,573)

* IHA and NHA contain 24% of the population during the years 2001 to 2005
** Mortality is presented as Central (Low, High) estimates.

Table 6. Mean annual mortality in the Northern Health Authority attributable to ambient air pollution compared to other attributable deaths and to causes of death. Mortality due to ambient air pollution is estimated for PM 2.5 concentration incremental to the lowest concentration in BC and population for 2001-2005.

Cause of Death	Annual Mortality
Air pollution	53 (8,130)
Smoking attributable mortality*	319
Alcohol related mortality	168
Cardiovascular disease	297
Stroke/CVA	82
Chronic Pulmonary Disease	73
Diabetes	61
Drug Induced	57
Influenza and Pneumonia	51

* Smoking attributable mortality does not include environmental tobacco smoke (second-hand smoke).

Table 7. Mean annual mortality in the Interior Health Authority attributable to ambient air pollution compared to other attributable deaths and to causes of death. Mortality due to ambient air pollution is estimated for PM 2.5 concentration incremental to the lowest concentration in BC and population for 2001-2005.

Cause of Death	Annual Mortality
Air pollution	179 (27,443)
Smoking attributable mortality*	1271
Alcohol related mortality	463
Cardiovascular disease	1415
Stroke/CVA	437
COPD	283
Influenza and Pneumonia	228
Diabetes	187
Drug Induced	173

* Smoking attributable mortality does not include environmental tobacco smoke (second-hand smoke).

References

Abbey DE, Nishino N, McDonnell WF, et al. Long-term inhalable particles and other air pollutants related to mortality in non-smokers. Am. J. Respir. Crit. Care Med. 1999;159:373-382.

Bates DV, Koenig J, Brauer M. 2003. Health and air quality 2002-phase I. Methods for estimating and applying relationships between air pollution and health effects. [RWDI Project: W02-304].British Columbia: British Columbia Lung Association.

Brauer M, Brumm J, Ebelt S. Evaluation of ambient air pollution in the Lower Mainland of British Columbia: public health impacts, spatial variability, and temporal patterns. Final Report to the Administrative Council of Lower Mainland Medical Health Officers. UBC School of Occupational and Environmental Hygeine and Department of Statistics. July 17, 2000.

British Columbia Provincial Health Officer. 2004. Every Breath You Take…Provincial Health Officer's Annual Report, 2003. Air Quality in British Columbia, a Public Health Perspective. Victoria BC. Ministry of Health Services.

British Columbia Statistics. 2006. British Columbia Regional Socioeconomic Indicators Methodology. http://www.bcstats.gov.bc.ca/data/sep/method.pdf Accessed Aug 27, 2006.

Brunekreef B and Holgate ST. Air pollution and health. Lancet 2002;360:1223-1242.

Butterfield P, LaCava G, Edumunston E, Penner J. Woodstoves and indoor air: the effects on preschooler's upper respiratory symptoms. J Environ Health 1989;52:172-3.

Chen LH, Knutsen SF, Shavlik K, et al. The association between fatal coronary heart disease and ambient particulate air pollution: are females at greater risk? Environ, Health Perspect. 2005;113:1723-1729.

Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FA. An association between air pollution and mortality in six US cities. NEJM 1993;329:1753-9.

Duhme H. Weiland SK. Keil U. Epidemiological analyses of the relationship between environmental pollution and asthma. Toxicology Letters 1998;102-103:307-16.

Enstrom JE. Fine particulate air pollution and total mortality among elderly Californians, 1973-2002. Inhal. Toxicol. 2005;17:803-816.

Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJL, Comparative Risk Assessment Collaborating Group. 2002. Selected major risk factors and global and regional burden of disease. Lancet 2002:360:1347-60.

Fraser Health Authority. Nd. http://www.fraserhealth.ca/HealthInfo/PublicHealth/AirQuality.htm#Conclusions. Accessed October 20th, 2006.

Health Canada.2003. Smoking in Canada, An Overview. http://www.hc-sc.gc.ca/hl-vs/tobac-tabac/research-recherche/stat/ctums-esutc/fs-if/2003/2003-smok-fum_e.html. Accessed August 27, 2006.

Health Effects Institute. Special Report: Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Cambridge MA: 2000; Health Effects Institute.

Honnicky RE, Osborne JS 3rd, Akpom CA. Symptoms of respiratory illness in young children and the use of wood-burning stoves for indoor health. Pediatrics 1985; 75(3):587-593.

International Agency for Research on Cancer. 1988. Radon. Summaries and Evaluations Volume 43: 173. http://www.inchem.org/documents/iarc/vol43/43-02.html

Ipsos Reid.2003. Smoking Prevalence in British Columbia, Final Report. http://www.preventionsource.org/ipsossurvey.pdf#search=%22smoking%20prevalence%20in%20british%20columbia%20final%20report%20ipsos-reid%22. Accessed August 10th, 2006.

Jerrett M, Burnett RT, Ma R, Pope CA III, Krewski D, Newbold KB, Thruston G, Shi Y, Finkelstein N, Calle EE, Thun MJ. 2005. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiol. 16:727-736.

Krewski D, Burnett RT, Goldberg MS, Hoover K, Siemiatycki J, Jarret M, Abrahamowicz M, White WH. 2000. *Reanalysis of the Harvard Six Cities Sutdy and the American Cancer Society Study of particulate air pollution and mortality. Special Report.* Health Effects Institute: Cambridge MA.

Kunzli N, Kaiser R, Medina S, Studnicka M, Chanel O, Filliger P, Herry M, Horak F Jr, Puybonnieux-Texier V, Quenel P, Schneider J, Seethaler R, Vergnaud J-C, Sommer H. 2000. Public-health impact of outdoor and traffic-related air pollution: a European assessment. Lancet 2000: 356:795-801.

Laden F, Schwartz J, Speizer FE, Dockery DW. Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities Study. Am J Respir Crit Care Med 2006;173:667-672.

Lipfert FW, Wyzga RE, Baty JD et al. Traffic density as a surrogate measure of environmental exposures in studies of air pollution health effects : long-term mortality in a cohort of US veterans. Atmos. Environ. 2006;40:154-169.

Liu SL-J, Box M, Kalman D, Kaufman J, Koenig J, Larson T, Lumley T, Sheppard L, Wallace L. Exposure assessment of particulate matter for susceptible populations in Seattle. Environ Health Perspect. 2003; 111:909-918.

McDonnell WF, Nishino-Ishikawa N, Petersen FF, Chen LH, Abbey DE. Relationships of mortality with fine and coarse fraction of long-term ambient PM10 conentrations in nonsmokers. J. Expo. Anal. Environ. Epidemiol. 2000;10:427-436.

Miller KA, Siscovick DS, Sheppard L, et al. Air pollution and cardiovascular disease events in the Women's Health Initiative Observational (WHI-OS) Study. Circulation 2004;109:e71 (Abstract from the American Heart Association Conference on Cardiovascular Disease Epidemiology and Prevention. Full report currently in review). [cannot find report on OVID Medline]

Mokdad AH, Marks JS, Stroup DF, Gerberding JL. 2004. Actual causes of death in the United States, 2000. JAMA 2004:291(10):1238-45.

Morris K, Morgenlander M, Coulehan JL, Gahagen S, Arena VC. Wood-burning stoves and lower respiratory tract infection in American Indian children. Am J Dis Child 1990; 144(1):105-108.

Orozco-Levi M, Garcia-Aymerich J, Villar J, Ramirez-Sarmiento A, Anto JM, Gea J. Wood smoke exposure and risk of chronic obstructive pulmonary disease. Eur Respir J 2006; 542-546.

Ostro B, Broadwin R, Green S, Feng W-Y, Lipsett M. 2006. Fine particulate air pollution and mortality in nine California counties: results from CALFLINE. Environ. Health Perspect. 114:29-33.

Pope CA III, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath JCW. Particulate air pollution as a predictor of mortality in a prospective study of US adults. Am. J. Respir. Crit. Care. Med. 1995; 151:669-674.

Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Long-term exposure to fine particulate air pollution. J. Am. Med. Assoc. 2002; 287:1132-1141.

Pope CA III, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, Godlewski JJ. Cardiopulmonary mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 2004; 109:71-77.

Pope CA, Dockery DW. Health effects of fine particulate air pollution: lines that connect. J. Air & Waste Manage. Assoc. 2006; 56:709-42.

Robin LF, Lees PSJ, Winget M, Steinhoff M, Moulton LH, Santosham M, Correa A. Wood-burning stoves and lower respiratory illness in Navajo children. Pediatric Infectious Disease Journal 1996; 15:859-865.

Roemer WH, van Wijnen JH. Daily mortality and air pollution along busy streets in Amsterdam, 1987-1998. Epidemiology 2001; 12:649-53.

Vedal S. 1995. Health effects of inhalable particles: implications for British Columbia. British Columbia: University of British Columbia.

World Health organization. Global estimates of burden of disease caused by the environment and occupational risks. http://www.who.int/quantifying_ehimpacts/global/globalair/en/index.html. Accessed August 24th, 2006.

Zelikoff JT, Chen LC, Cohen MD, Schlesinger RB. The toxicology of inhaled woodsmoke. Journal of the Toxicology and Environmental Health, Part B, 2002; 5:269-282.