Air Pollution Burden of Illness in Toronto:

2004 Summary

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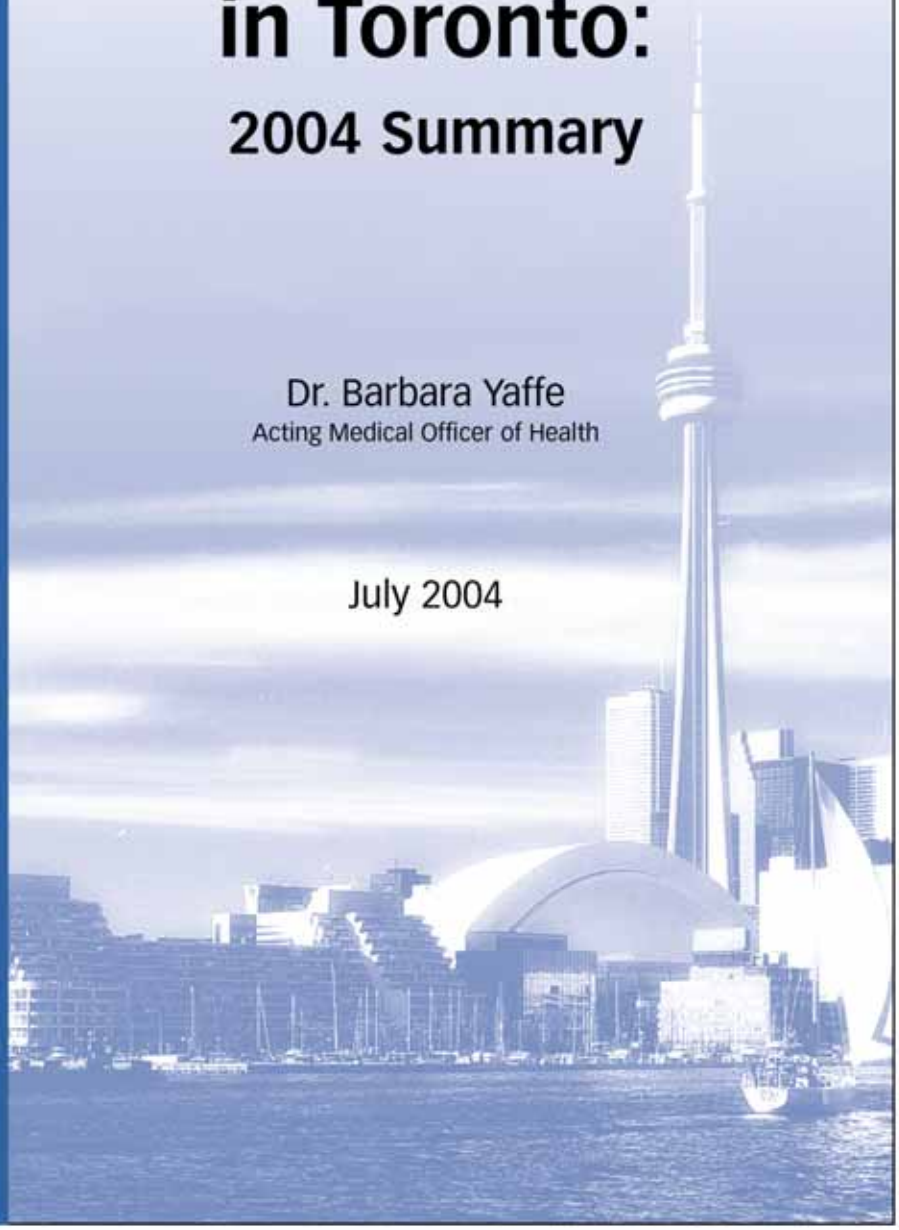

Toronto Public Health

Reference: Toronto Public Health. Air Pollution Burden of Illness in Toronto: 2004 Summary. Toronto: City of Toronto. 2004.

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Technical Basis: The new burden of illness estimates summarized in this report are derived from the technical study prepared for Toronto Public Health by L.D. Pengelly and J. Sommerfreund entitled *Air Pollution-Related Burden of Illness in Toronto: 2004 Update. Technical Report.* May 2004.

Distribution: Both the summary and technical reports are available on the website at: www.toronto.ca/health/hphe/air_and_health.htm

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Executive Summary

This report summarizes a new study by Toronto Public Health that determines the magnitude of the adverse health impact of outdoor air pollution on Toronto residents.

A previous study, released in May 2000, estimated that exposure to five common smog-related air pollutants contributed to 1,000 premature deaths and about 5,500 hospitalizations each year. That study based its risk estimates on information in the scientific literature regarding acute (short-term) exposures to air pollutants. When scientists track peak air pollution levels over time, they notice that more people experience health problems (such as severe heart and breathing difficulties that require admission to hospital) and early death right after pollution peaks than on days when pollution levels are much lower.

Since that time, there has been growing concern about the chronic effects of air pollution and how long-term exposure impacts on human health. Consequently, when Toronto Public Health conducted the current study, it took into account acute, and where possible, chronic effects. The method used to estimate the 'burden of illness' associated with air pollution was to apply risk coefficients from published studies to Toronto-specific data of the number of persons who died or were hospitalized, taking into account air pollution levels for each day throughout the year. The analysis was conducted for the base year 1999 because this was the most recent year for which complete health data on deaths and hospitalizations were available.

It is reasonable to expect that the new burden of illness estimate reflects the current state of health with respect to both short-term and chronic exposure to air pollution in Toronto. The annual average levels of the five key pollutants (ozone, particles, nitrogen dioxide, carbon monoxide and sulphur dioxide) examined in this study have not declined since 1999, and the absolute number of deaths and age structure of the population has been stable in recent years.

Based on the current burden of illness study, Toronto Public Health estimates that air pollution in our city contributes to about 1,700 premature deaths and 6,000 hospitalizations on an annual basis. The current mortality estimate is based on the health risk associated with acute exposures to ozone, nitrogen dioxide, carbon monoxide and sulphur dioxide, as well as the health risk associated with chronic exposure to fine particles ($PM_{2.5}$). Scientific studies by others have demonstrated that fine particles are associated with chronic endpoints such as cancer.

In addition to providing reliable estimates for the most serious health effects (hospitalization and premature mortality) associated with air pollution, the current study notes that less serious health outcomes (such as chronic bronchitis, emergency room visits and number of days that people experience asthma symptoms) affect tens of thousands of people in Toronto each year. Air pollution can aggravate pre-existing breathing and heart problems to such an extent that medical treatment is required. Of particular concern are people with asthma, which currently affects about 12% of children and 6% of adults in Canada. Toronto hospitalization data obtained during the current study reveal that children account for the largest number of asthma-related hospital admissions compared with other age groups, indicating their enhanced vulnerability. Poor air quality reduces the quality of life for Toronto's children and adults, and especially for those who face a lifetime of chronic respiratory problems that are made worse by air pollution.

Given the magnitude of health risk associated with air pollution in Toronto, it is of particular concern that pollutant trends reveal little improvement in air quality over the last two decades. This is in contrast to the provincial situation for which pollution reductions were larger and more consistent for the key pollutants that impact on health. For example, while nitrogen dioxide levels show a consistent decline across the province, levels have been increasing steadily in Toronto. Compared with other Ontario communities with air monitoring stations, Toronto had the highest summertime levels of fine particles and highest annual mean levels of nitrogen dioxide, based on the most recent data available (2002). Toronto's density, large numbers as residents, commuters and visitors, as well as its projected growth, add up to a very sizeable population exposed to these high pollution levels.

Burden of illness studies provide a reliable and cost-effective mechanism by which a local health unit can estimate the magnitude of health impact associated with air pollution in their region. These studies provide an important context for developing policies and programs that promote and protect the public's health. Given the size of the health risk associated with Toronto's air pollution, this study reinforces the importance of taking actions at all levels of government to ensure that the public and private sectors intensify air improvement initiatives. This study underscores the need to expand and sustain public transit infrastructure and to stimulate the shift to cleaner sources of energy, given that the major sources of the pollutants that give rise to the large burden of illness in Toronto are fossil fuel-based transportation and energy production.

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Introduction

In May 2000, Toronto Public Health released the report A*ir Pollution Burden of Illness in Toronto*[1]. Using 1995 as its base year, the study estimated that exposure to five common air pollutants contributed to about 1,000 premature deaths and 5,500 hospitalizations of Toronto residents each year. The recent discovery of an error in the application of a computer program used by most international researchers in estimating the health impacts of air pollution raised some concern about the continued validity of these estimates.

Toronto Public Health has since retained the lead scientist of the previous study to undertake a new assessment of the magnitude of the health risk associated with common air pollutants in Toronto. This report summarizes the new technical study based on more recent scientific literature regarding the health effects of pollutants, and took into account more current data regarding air pollution levels, mortality rates and hospitalizations for Toronto. The full technical study *Air Pollution-Related Burden of Illness in Toronto: 2004 Update*[2] is available on the City's website at www.toronto/health/hphe/pubs.htm.

Health Effects of Air Pollutants

Over the last decade, a large body of scientific evidence has accumulated that confirms that air pollution, even at the levels experienced in major urban centres such as Toronto, adversely affects the health of children and adults.[3-6] Effects are wide ranging and include increased incidence and duration of respiratory symptoms, reduced lung function, acute and chronic bronchitis, asthma attacks, emergency room visits, increased hospitalizations for respiratory and cardiac causes, elevated mortality rates, and reduced life expectancy.[4,7-13]

Newer studies link air pollution with lung cancer, heart attacks, strokes and high blood pressure.[14-17] One recent study suggests a link with congenital heart defects.[18] Many studies identify people with asthma, diabetes and those with congestive heart failure as being at particularly elevated risk from air pollution.[19] Furthermore, although the relationship between increased physical activity and adverse impacts arising from breathing polluted air is not fully understood, numerous studies have shown increased impacts with increased activity levels.[20-23] These effects tend to be most pronounced in people with underlying health conditions such as asthma.

Evidence is mounting that air pollution at levels known to occur in Toronto is harming its residents.

While the majority of studies focus on the relationship between differing levels of air pollution in various communities and their associated adverse health impacts, some studies known as 'intervention studies' provide unique insights into the health benefits associated with significant reductions in exposure to air pollutants. Research conducted during the Olympic Games in Atlanta, Georgia demonstrated a reduction in ozone levels, and significantly lower rates of childhood asthma events, for the period when traffic levels were greatly decreased.[24] A study conducted in the former East Germany following reunification and subsequent declines in particle and SO_2 levels showed improvements in children's lung function in a relatively short period of time.[10] An intervention study in Dublin, Ireland examined the impact of a ban on coal sales that resulted in significant reduction in black smoke levels. This study demonstrated that respiratory and cardiovascular death rates declined after the ban, suggesting that the control of particulate air pollution could substantially diminish daily deaths.[25] Studies such as these provide confirmatory evidence that policy interventions that improve air quality will contribute to health benefits.

Research shows that improving air quality will improve health.

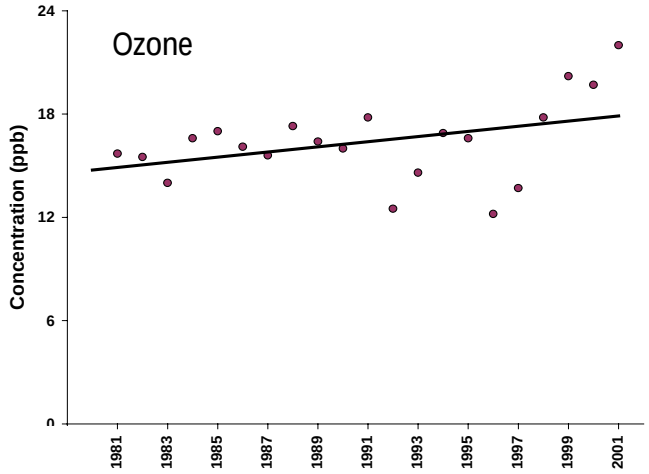
Air Pollution Trends in Toronto

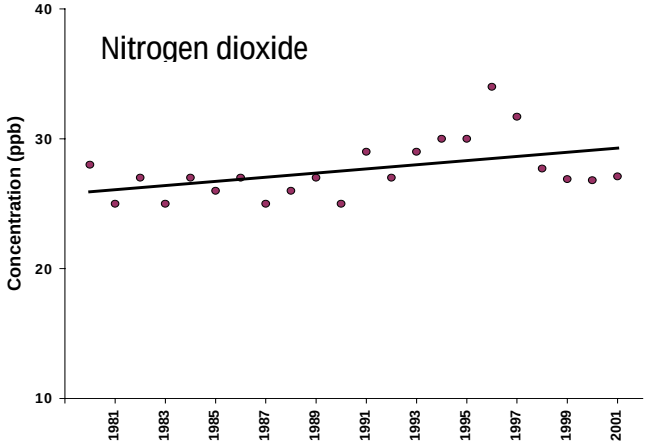
Air quality improvements in Toronto have stalled over the last two decades.

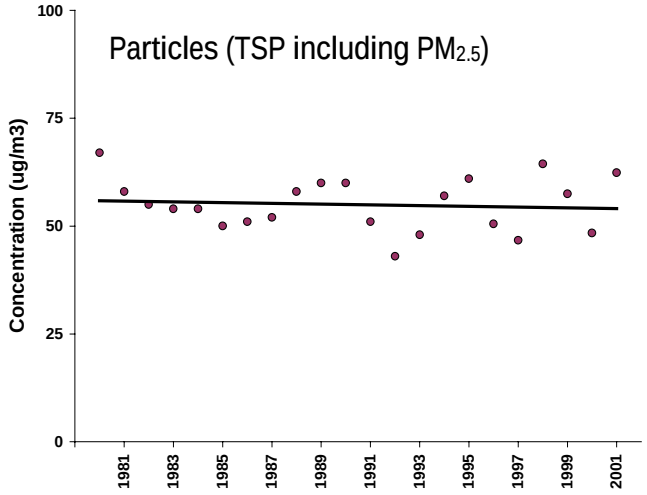
Trend data for key air pollutants with adverse health effects on the Toronto population reveal little improvement in air quality over the last two decades. Five common air pollutants of significant health concern are: ozone (O_3); nitrogen dioxide (NO_2); sulphur dioxide (SO_2); carbon monoxide (CO); and particles - measured as total suspended particles (TSP), or inhalable particles - particles of 10 micron diameter or less (PM_{10}), or respirable particles - particles of 2.5 micron diameter or less ($PM_{2.5}$). These pollutants all arise from the combustion of fossil fuels, such as during the operation of vehicles, heating of buildings, or generation of electricity from coal, oil or natural gas.

As shown in Figure 1 (based on data from the Ontario Ministry of the Environment[26]), the annual average levels of ozone and nitrogen dioxide have been increasing in Toronto since 1980, while total suspended particles have remained approximately the same. Sulphur dioxide and carbon monoxide levels show considerable variability from year to year, but overall are decreasing somewhat. The trend data reveal that despite many important air quality improvement initiatives by all levels of government, progress is slow and air quality has not improved significantly. It appears that gains in the transportation sector, such as the introduction of less polluting vehicles and gradual improvements in fuel quality, have been off-set by the increased volume and frequency of vehicle use and coal-based power production.

Figure 1: Trends in Annual Average Concentrations of Common Air Pollutants in Toronto





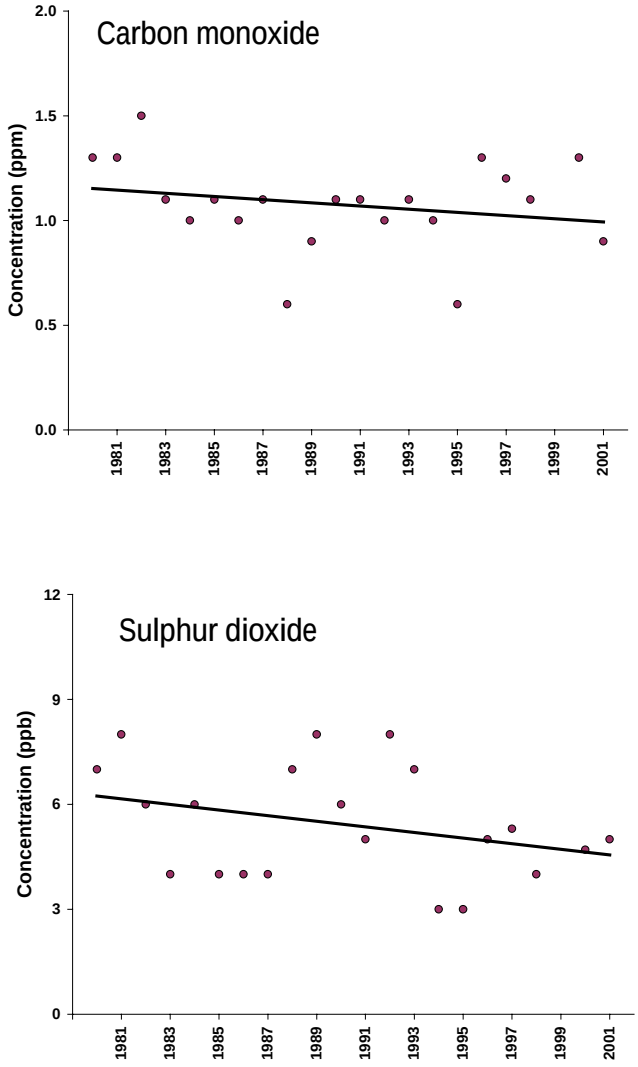


Key Pollutants:

$PM_{2.5}$ respirable particles
O_3 ozone
NO_2 nitrogen dioxide
CO carbon monoxide
SO_2 sulphur dioxide

Pollution Trends:
Over the last 20 years, average nitrogen dioxide and ozone levels are increasing, particle levels are the same, and carbon monoxide and sulfur dioxide levels show a slight decline.

Figure 1: Trends in Annual Average Concentrations of Common Air Pollutants in Toronto (Cont.)



Source: Based on data from Ontario Ministry of the Environment.[26]

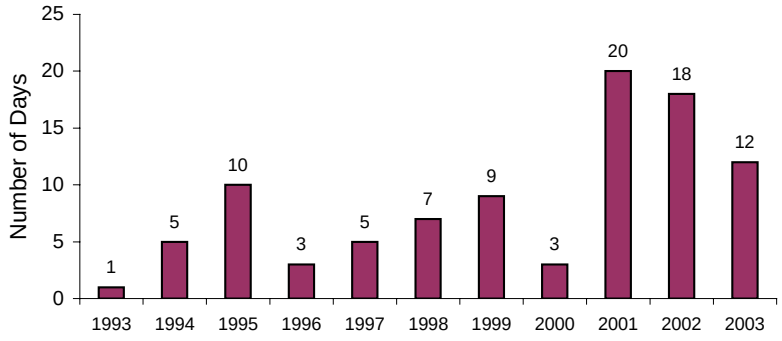
It is of concern that pollution trends for Toronto reveal little improvement in air quality over the last two decades. This is in contrast to the provincial situation for which pollution reductions were larger and more consistent for the key pollutants that impact on health. For example, while nitrogen dioxide levels show a consistent decline across the province, levels have been increasing steadily in Toronto. The transportation sector, and particularly emissions from cars, is the most significant source of nitrogen oxides (NOx), including nitrogen dioxide. Compared with other Ontario communities with air monitoring stations, Toronto had the highest summertime levels of fine particles and highest annual mean levels of nitrogen dioxide, based on the most recent data available (2002).[27]

When Toronto's air quality is compared to other large cities around the world, it comes out near the average for ozone and on the high side for nitrogen dioxide. When the 1-hour maximum ozone levels of 27 international cities were compared by the Ontario Ministry of the Environment over a 10-year period, Toronto ranked 16th out of the 27. Cities such as Los Angeles, Melbourne and Hong Kong had higher ozone levels, and cities such as Zurich, Helsinki and Vancouver had lower ozone levels. However, when the mean nitrogen dioxide levels in Toronto were compared over a 10-year period to the other 27 cities worldwide, Toronto came out 4th highest. Los Angeles, New York and Hong Kong had higher levels of nitrogen dioxide. Cities such as Boston, Chicago and Cleveland had similar levels, and cities such as Singapore, Miami and Melbourne had lower levels.[26]

Annual average pollution levels are a good indicator of chronic exposure levels and the state of progress in improving air quality in Toronto. In addition, the Ontario Ministry of the Environment's Air Quality Index (AQI) is a good indicator of the frequency of peak pollution levels of very high health concern. The Ontario Ministry of the Environment issues an air quality advisory (or 'Smog Advisory', also referred to as 'Smog Alert' by the Toronto Medical Officer of Health) when the AQI is expected to reach a value of 50 or higher on a widespread or persistent basis. Figure 2 suggests that the number of smog alert days in Toronto may be increasing. Although it is too early to tell, there is concern that climate change and the anticipated increase in hot sunny days may lead to even more smog alerts in the future. Hot sunny weather greatly enhances the formation of ozone, one of the key pollutants that triggers smog alerts.

Smog alerts may increase with climate change.

Figure 2: Number of 'Smog Alert' Days in Toronto



Importance of Burden of Illness Studies

The Ontario Ministry of Health and Long-term Care (MOHLTC), through its Mandatory Core Program, requires local health units to conduct health status studies on a regular basis. These studies compile health outcome data to enable the health unit to identify local illness rates and trends. This information is vital for planning public health programs, including setting priorities for service delivery and assessing program effectiveness in improving health. Typical indicators of health used in health status studies include measurable indicators such as birth weight, and rates of communicable diseases (such as TB) and chronic illnesses (such as stroke, heart attack and cancer).

In the case of communicable diseases, it is possible to have considerable assurance that a specific harmful agent is present (such as a specific virus or bacteria) and that this harmful agent is uniquely linked with the clinical symptoms observed in the affected individual. Such specificity and certainty is not possible for most exposures to environmental pollutants, and especially not for air pollutants.

Air pollutants typically increase the severity or frequency of common medical conditions or illnesses. However, because many factors give rise to the same medical condition, it is not possible to determine for an individual patient whether the adverse health outcome observed is due to air pollution or some other cause. Through population-based studies, however, such as those conducted by epidemiologists, it is possible to determine that groups of people exposed to higher levels of air pollution experience more adverse effects than those exposed to low levels. Given this situation, public health agencies are relying increasingly on "burden of illness" estimates as an indicator of the health impact of air pollution on the local community.

Air pollution-related burden of illness studies use risk coefficients from the peer-reviewed scientific literature that reliably link exposure to air pollutants with health outcomes. Risk coefficients are able to predict that exposure to a given quantity of a pollutant is likely to result in a health outcome of a specific magnitude. To illustrate one possible risk coefficient from the literature, exposure to each additional 10 ug/m^3 PM_{10} is anticipated to increase non-traumatic mortality in the exposed population by another 0.6%. The burden of illness studies apply risk coefficients for all pollutants of interest in the investigation to the actual data on pollutant levels and health outcomes (such as mortality and hospital admissions) available for the community under study.

Burden of illness studies are a cost-effective and reliable approach that enables public health officials to estimate the magnitude of the health impact associated with air pollution conditions in their local community, based on the most current health outcome and pollution data available. This methodology was used by Toronto Public Health in its 2000 study of air pollution-related premature mortality and hospitalizations. Environment Canada and Health Canada used a similar method and enhanced it further through development of the Air Quality Valuation Model. This model additionally assesses economic costs associated with health burdens in the population. The Ontario Medical Association used this methodology in its 2000 study that estimated that the illness costs of air pollution in Ontario were more than $1 billion a year in hospital admissions, emergency room visits and absenteeism. [28]

Burden of illness studies are a cost-effective and reliable way to determine the magnitude of health impact from air pollution in a given community.

Impact of the Previous Burden of Illness Study

The release of Toronto Public Health's Air Pollution-related Burden of Illness study in May 2000 generated considerable attention because it was the first time that information became available on the unexpected magnitude of the health risk from air pollution affecting Toronto residents. Discussion of the report by the Board of Health and later by Council resulted in a large number of recommendations for action by City staff and other levels of government, and set the stage for renewed attention on air quality improvement initiatives. Some highlights of the beneficial activities that resulted are:

- Gave rise to Toronto's first *Smog Summit* held in June 2000
- Enabled development of the education campaign *20/20 The Way to Clean Air*
- Focussed attention on 'low-sulfur' fuel purchases by the City
- Renewed attention on coal-burning at Lakeview Power Plant (which ends in 2005)
- Ensured further work on policy options to reduce emissions
- Gave rise to further research on health risks of diesel and problems with the AQI
- Enabled increased participation in policy discussions with other levels of government
- Facilitated local health and environmental groups in advocating for air improvements

Difficulty in Conducting Burden of Illness Studies

Burden of illness studies sometimes come under scrutiny with questions as to what proof there is that someone died prematurely or was hospitalized because of elevated pollution levels. Given the nature of these studies, it is not possible to point to a specific person who has been hospitalized due to a breathing or heart problem and determine that air pollution was the reason that this person was admitted to hospital. One of the reasons is that air pollution does not give rise to a single unique adverse health outcome or clinically observable illness, but rather contributes to many commonly-occurring conditions such as asthma attacks, chronic bronchitis and congestive heart failure.

Health studies clearly show that the number of people who die or are admitted to hospital because of lung and heart problems is higher in those groups exposed to more air pollution than those exposed to less air pollution.

Scientists have obtained evidence that air pollution can cause serious health problems by observing and comparing groups of people with different levels of exposure to pollution through epidemiological studies. Such studies frequently show that groups of people exposed to elevated levels of air pollution (compared to those with little exposure) have higher rates of hospital admissions or premature death. Cohort studies are particularly useful in understanding the health effects associated with chronic exposure to pollutants.

Another type of study common in air pollution research is the 'time series' study. Time series studies are based on the observation that when pollution levels increase suddenly, some people will experience adverse health effects one, two and sometimes three days after the peak exposure, but not later when the pollution levels return to a low level. This finding is consistent over many years. When scientists track the peak pollution levels over several years, they notice that more people experience adverse health outcomes (such as death, or cardiac and respiratory problems that require hospital admission) right after pollution peaks than on days when pollution levels are relatively low. Scientists use sophisticated statistical methods and computerized software programs to assist them in the analysis so that confounding factors, such as weather, are accounted for in the analysis.

In time-series studies of air pollution and mortality since 1995, generalized additive models (GAMs) were the most widely used method to adjust for effects of seasonality, trends and weather variables. It was common to use S-Plus software during the use of GAMs. The scientific community around the world was disturbed by the discovery that time-series studies using the GAMs methodology, when combined with the S-plus software in common use at that time, could result in incorrect estimates of the effects of air pollution on health.[29] In most cases, this methodological problem led to overestimates in the risk coefficients and hence an exaggerated assessment of health risks.

Consequently, when the burden of illness calculations were updated in the new study for Toronto Public Health, great care was taken to use only those risk coefficients that were calculated without the S-Plus problem. Fortunately, the international community of researchers was swift to re-analyse previous pivotal studies and provide corrected risk coefficients. While the re-assessed health risks associated with pollutants tended to be lower than previously reported, it is important to emphasize that the new studies reconfirmed that air pollution was associated with increased adverse health effects. The technical report by Pengelly & Sommerfreund[2] provides detailed information on the selection of risk coefficients for the current public health study.

Updated Estimate of Air Pollution Burden of Illness

This study looked at the number of premature deaths and hospital admissions attributable to short-term, and where possible, long-term exposure to air pollution in Toronto.

The method used to estimate the burden of illness associated with air pollution applies risk coefficients to Toronto-specific data of the number of persons who died or were hospitalized in 1999, taking into account air pollution levels for each day throughout the year. The current study examined the adverse impacts associated with short-term (acute), and where possible, long-term (chronic) exposure to air pollutants. Acute exposures typically involve peak pollution levels over a few days, whereas chronic exposure involves ongoing exposure over several years.

As seen in Table 1, health records indicate that a total of 6,072 people died from cardiovascular or respiratory causes in 1999. Of these 6,072 people, 695 are estimated to have died prematurely from acute exposure to five common air pollutants (Table 3).

As seen in Table 2, health records indicate that there were 45,715 hospitalizations of Toronto residents in 1999 for cardiac and respiratory problems. Based on Table 3, it can be seen that 6,264 of these hospitalizations are estimated to result from acute exposure to the five common air pollutants. Specific diagnoses with hospitalization include asthma, obstructive lung disease, respiratory infection, dysrhythmia, congestive heart failure and ischaemic heart disease.

Table 1: Total Deaths in Toronto by Cause – 1999

Cause of Death	Number of Deaths[a]
Cardiorespiratory:	
Cardiovascular	4,804
Respiratory	1,268
Total	6,072
All non-traumatic	13,246

[a] Excludes death counts with invalid or missing postal codes

Source: Derived from Provincial Health Planning Database, Ontario Ministry of Health and Longterm Care

Table 2: Total Hospitalizations in Toronto by Cause – 1999

Cause of Hospitalization	Number of Hospitalizations [a]
Cardiorespiratory:	
Cardiovascular	29,977
Respiratory	15,738
Total	45,715
All non-traumatic	177,632

[a] Excludes hospitalizations counts with invalid or missing postal codes

Source: Derived from Provincial Health Planning Database, Ontario Ministry of Health and Longterm Care

Table 3. Acute Air Pollution-Related Burden of Illness

An estimated 6,000 admissions to hospital occur each year in Toronto as a result of exposure to outdoor air pollution.

Pollutant	Annual Adverse Outcome		
	Acute Premature Mortality	Respiratory Hospital Admissions	Cardiovascular Hospital Admissions [a]
Particles:			
PM_{10}	177	597	421
Gases:			
CO	20	272	
NO_2	249	1461	2857
O_3	219	337	
$S0_2$	30	215	104
Gases: subtotal	518	2285	2961
Total	695	2882	3382

[a] Blank due to absence of specific risk coefficient, precluding burden of illness calculation

Source: Derived from Provincial Health Planning Database, Ontario Ministry of Health and Longterm Care

Our current estimate of premature mortality of 695 deaths attributable to the air pollution mixture in Toronto using 1999 data is based on recent studies and revisions of older published studies which examined the acute response to air pollution. Scientific understanding has advanced considerably since our first burden of illness study in 2000, and in addition has withstood challenges by industrial stakeholders.

To date, burden of illness studies have focussed on acute exposures (short-term or lasting for a few days) to pollutants and their association with increased risk of various adverse health outcomes. Although much of the recent epidemiological research has focused on the effects of short-term exposures, several studies suggest that long-term exposure (on the order of years) may be more important in terms of overall public health.[30] Fine particulate ($PM_{2.5}$) air pollution is associated with elevated risk of all-cause, lung cancer and cardiopulmonary mortality.[30] Relatively small differences in long-term exposure to airborne particles can have substantial effects on life expectancy.[8] The U.S. Environmental Protection Agency[31] reports on a calculation for the 1969-71 life table for American white males that indicates that a chronic exposure increase of 10 ug/m^3 of particulate matter was associated with a reduction of 1.3 years for the entire population's life expectancy at age 25.

Chronic exposure to air pollution reduces life expectancy.

Given the growing concern and interest in chronic effects, the current study for Toronto Public Health used risk coefficients for chronic exposure to particles obtained from the re-analysis by the Health Effects Institute[7] of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. These two major studies of chronic exposure to fine particles have been carefully validated by the Health Effects Institute. Their original conclusions are supported and strengthened by the re-analysis. The risk coefficients developed were based on chronic exposure to particles over 5 to 7 years.

Based on 1999 Toronto air pollution and mortality data, we estimated that 447 premature deaths were associated with chronic sulphate exposure, and 1,236 premature deaths with chronic $PM_{2.5}$ exposure, as shown in Table 4. However, we caution that these two estimates should not be summed because in theory, the sulphate measure is part of the $PM_{2.5}$ measure, given that sulphate particles are usually less than 1 micron in diameter.

Table 4: Chronic Air Pollution-Related Burden of Illness - Toronto 1999

Pollutant	Annual Chronic Premature Mortality [a]
SO_4	447
$PM_{2.5}$	1,236

[a] Deaths attributable to $PM_{2.5}$, which includes SO_4

Source: Derived from Provincial Health Planning Database, Ontario Ministry of Health and Longterm Care

Given the growing evidence about greater health risks with chronic exposure to fine particles compared with short-term exposure, Toronto Public Health views it as appropriate to base its burden of illness estimates on chronic exposure to $PM_{2.5.}$ Unlike the gaseous pollutants (CO, NO_2, O_3 and SO_2), fine particles are known from the toxicological literature to be associated with chronic endpoints such as cancer. It is possible, however, that future research will reveal that even gaseous pollutants are associated with greater health risks with chronic exposure compared with short-term exposure, however, at this time reliable risk coefficients for long-term exposure are not available for the gaseous pollutants.

An estimated 1,700 Toronto residents die prematurely each year from exposure to outdoor air pollution in the city.

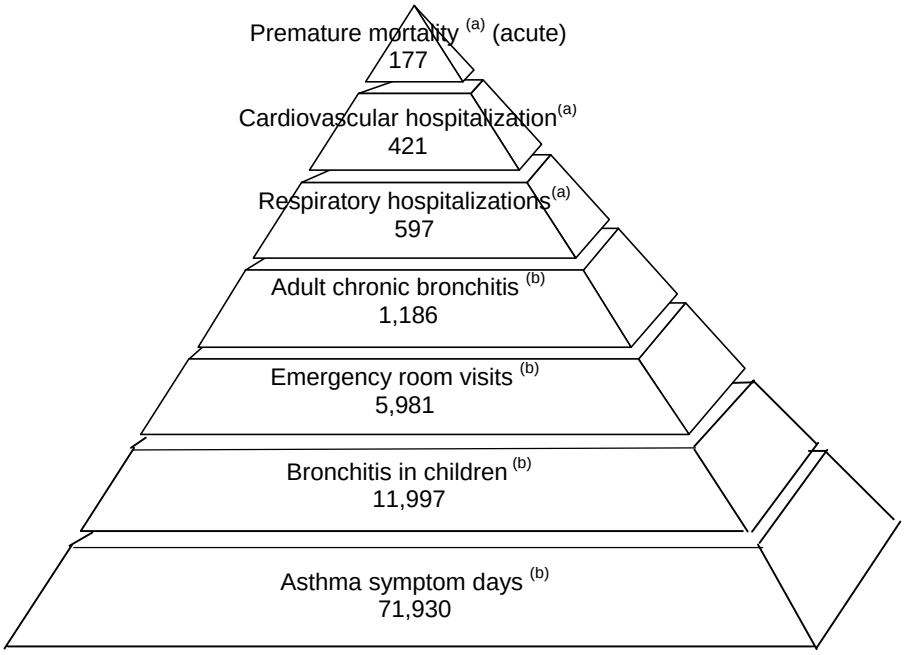
Toronto Public Health has determined that the best estimate of premature mortality is about 1,700 deaths during 1999 attributable to five common smog pollutants. This number is based on an estimated 518 premature deaths attributable to short-term exposure to gaseous pollutants (CO, NO_2, O_3 and SO_2) and 1,236 premature deaths attributable to chronic exposure to $PM_{2.5.}$ Compared with Toronto Public Health's previous study released in 2000 (which examined only acute effects), the current assessment (which begins to include chronic effects) is reflective of the progress in scientific thinking and new published results by other researchers since our earlier study.

Although the 2004 report is based on 1999 data, this study provides a reasonable estimate of the number of deaths in a "typical" year that occur prematurely attributed to air pollution exposures. While Toronto's population continues to increase slightly, the age-standardized mortality rates have decreased slightly, resulting in stability in the absolute number of deaths. For example, between 1994 and 1999, the change in the absolute death rate in Toronto was less than 1%.

The current estimate of burden of illness represents only the most serious health effects resulting from air pollution. Scientists have long recognized that air pollution results in a 'pyramid' of health effects, with the least common but most serious health outcome (such as premature death) appearing at the peak of the pyramid, and the less serious but more numerous health outcomes (such as asthma symptom days and respiratory infections) appearing in progressive

levels below that peak. Figure 3 illustrates for one key pollutant (inhalable particles – PM_{10}) the increasing prevalence of less serious health outcomes that affect a larger portion of the population. The pyramid of health effects is demonstrated using PM_{10} (rather than $PM_{2.5}$ or other pollutant) because it was the only one for which information on exposure-effect mathematical relationships were available. The numbers in the pyramid are calculated for the Toronto population using 1999 as the base year.

Figure 3: Pyramid of Health Effects – Toronto
Annual Estimate for Inhalable Particulates (PM_{10})



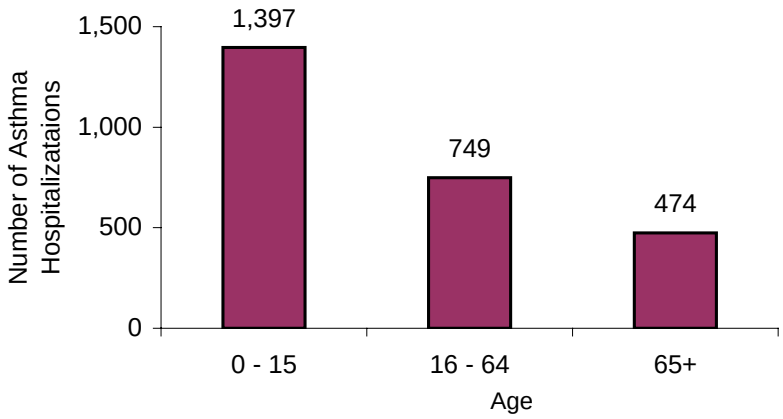
(a) From Table 3
(b) Calculated from exposure-effect relationships for PM_{10}.[32]

Air pollution can aggravate pre-existing breathing and heart problems to such an extent that medical treatment is required. It can also diminish the quality of life for sensitive populations. Of particular concern are people with asthma. Asthma affects a significant portion of the Canadian population. In 1997, it was estimated that about 12% of Canadian children (ages 0 to 19) and 6.3% of adults had been previously diagnosed with asthma.[33]

Air pollution reduces the quality of life for those people with breathing and heart problems, and makes their symptoms worse.

Asthma rates have been increasing. In Ontario, the prevalence of asthma in children under 14 has risen dramatically from 2.5% in 1983 to 11.2% in 1995.[34] This suggests that a greater proportion of children may be at increased risk from air pollution today than two decades ago. Toronto hospitalization data obtained during the current study reveal that children account for the largest number of asthma-related hospital admissions compared with other age groups (Figure 4).

Figure 4: Annual Asthma-Related Hospital Admissions – Toronto 1999 [(a)]



[(a)] Excludes hospitalizations with invalid or missing postal codes

Poor air quality in the city can reduce the quality of life for Toronto's children and adults, and especially for those who face a lifetime of chronic respiratory problems that are made worse by air pollution.

Conclusion

Burden of illness studies provide the most reliable and cost-effective mechanism to date by which a local health unit can estimate the magnitude of health impact associated with air pollution in the community. Based on the current burden of illness study, Toronto Public Health estimates that air pollution in our city of 2.5 million residents contributes to about 1,700 premature deaths and 6,000 hospitalizations on an annual basis.

The current mortality estimate is based on the health risk associated with acute exposures to ozone, nitrogen dioxide, carbon monoxide and sulphur dioxide, as well as the health risk associated with chronic exposure to fine particles ($PM_{2.5}$). Scientific studies by others have demonstrated that fine particles are associated with chronic endpoints such as cancer. Even though the current study was done for the base year 1999 (the year when the most recent health outcome data was available), this burden of illness estimate is anticipated to reflect the state of health today. This is a reasonable expectation given that average air pollution levels are similar now to those in 1999, and given that the total number of people dying each year and the age structure of the population has been stable in recent years.

The current study also notes that less serious health outcomes attributable to air pollution, such as increased rates of chronic bronchitis, emergency room visits and asthma symptoms, affect tens of thousands of people in Toronto each year. Air pollution can aggravate pre-existing breathing and heart problems to such an extent that medical treatment is required. Poor air quality reduces the quality of life for Toronto's children and adults, and especially for those who face a lifetime of chronic respiratory problems made worse by air pollution.

Burden of illness studies provide an important context for developing policies and programs that promote and protect the public's health. Given the magnitude of health risk associated with Toronto's air pollution, this study reinforces the importance of taking actions at all levels of government to ensure that the private and public sectors intensify air improvement initiatives. The major sources of pollutants that give rise to the large burden of illness in Toronto are fossil fuel-based transportation and energy production. This study underscores the need to expand and sustain the public transit infrastructure and to stimulate the shift to cleaner sources of energy.

Toronto Public Health estimates that outdoor air pollution in our city contributes to about 1,700 premature deaths and 6,000 hospitalizations each year.

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