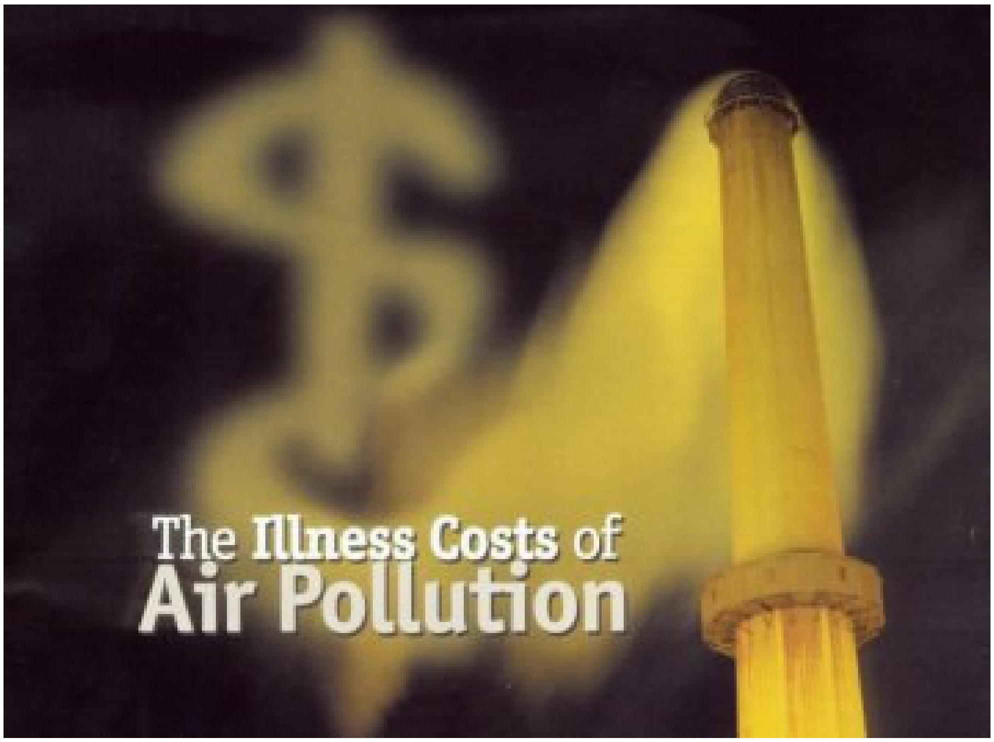

Ontario Medical Association

2005-2026 Health & Economic Damage Estimates

June 2005

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Acknowledgements

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Introduction

In June 2000, the OMA presented the first version of our Illness Costs of Air Pollution software model and detailed findings on the health effects and economic costs of air pollution in Ontario. It was apparent that over time, a rapidly improving scientific understanding of smog's health effects would require the OMA to update this model. In 2000 the science would not support the information that we are now able to present. Due to our improved understanding, we have found that some of our previous estimates have been decreased, but the science now compels us to attribute more serious illness and premature deaths to smog.

Included in the new OMA determinations of smog's toll are new health studies on the chronic effects of exposure, new air pollution and demographic data and extensive analysis of the principle studies on the health effects of air pollution.

Improved as it is, there are still gaps in scientific understanding and thus further improvements to ICAP will be possible in the future. Of most concern to the OMA is the lack of credible studies on doctors' office visits due to smog related illness. We have not included a value for this important and expensive impact, thus still underestimating smog's overall cost.

Damage Estimates

The updated version of ICAP has been used to generate revised estimates of provincial health and related economic damages associated with air pollution exposure. The following damage estimates relate primarily to the risks of exposure to fine particulate matter (i.e., $PM_{2.5}$) and ozone.

Health Effects

ICAP provides estimates of health effects according to four major health endpoints, namely,

- Premature Death
- Hospital Admissions
- Emergency Room Visits
- Minor Illnesses

Damages for each of these major health endpoints may be further broken down by more specific illness categories, age groups and geographic locations. Following is a summary of the latest damage estimates for Ontario.

Premature Death

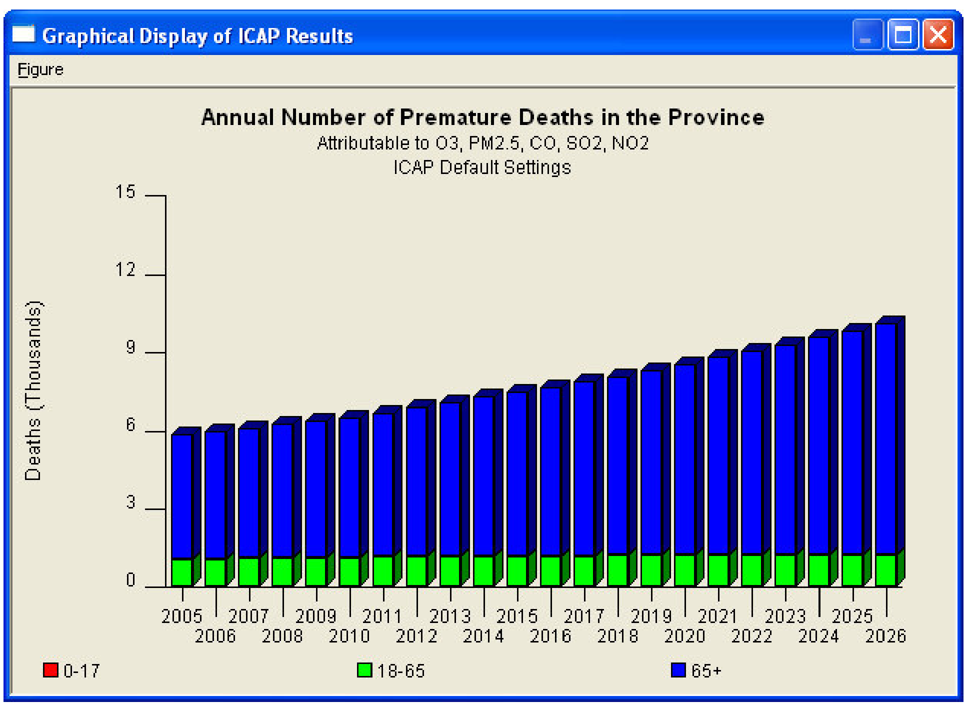
The revised version of ICAP includes concentration-response functions based on time-series and cohort epidemiological studies. Where available, the cohort-based relative risks, which show the long-term, cumulative impacts of air pollution, are preferred for policy analysis since they present a more complete picture of health risks associated with air pollution. Previous ICAP estimates of premature death were based on time-series studies, which only identified the immediate impacts of pollution.

Figure 1 shows the expected number of premature deaths by age group over the next 20 years.

The great majority of the premature deaths will be suffered by the elderly. It is our belief that children and infants with compromised health conditions are also at risk of premature death, but there is not sufficient scientific documentation for this age group, so the risk of these deaths has not been included in our calculations.

The OMA's new cumulative estimate for smog-related premature mortality is 5,800 deaths annually. This is considerably greater than the 1,900 estimated in ICAP 2000 and there are a number of reasons for this. The 2000 estimate was based strictly on time-series studies and included risks for course smog particles (PM_{10}) only. We now have clear scientific evidence of premature deaths for a number of other pollutants (i.e., ozone (O_3) sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO)) and have included these time-series findings. The most significant change though is that we now have reliable cohort-based studies for $PM_{2.5}$ which show the premature deaths that result from the long-term effects of exposure. Although for the purposes of presentation we have added the short-term and long-term smog deaths together, they are quite different. The approximately 4,000 additional deaths for which smog is a factor are the result of a lifetime of exposure and the cumulative effects of smog on our bodies. Whereas short-term effects could be mitigated by eliminating the pollution exposure or providing medication to counteract a health response, a physician cannot cure someone whose tissue has accumulated the effects of smog over time. All that we can do then is try to manage the illness.

Figure 1 – Premature Deaths Broken Down By Age Group



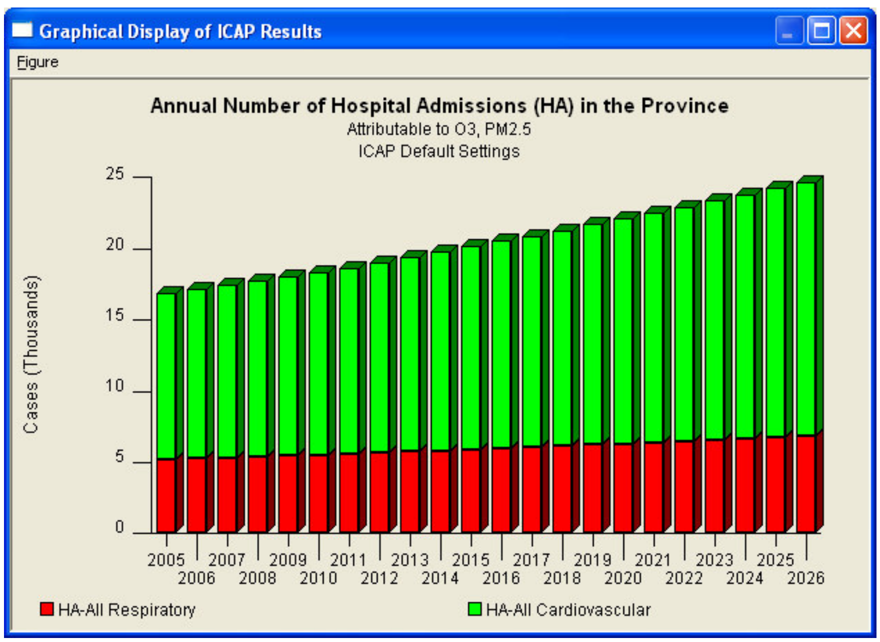
Similar to the 2000 premature death estimate, most of the deaths are related to respiratory and cardiovascular illnesses. The cohort-based studies found also an increased risk of death due to lung cancer. This finding relates not to an increased risk of contracting lung cancer (although this may be the case as well) but to an increased chance of premature death for those that do contract lung cancer from whatever cause.

Hospital Admissions

Comprehensive cohort-based epidemiological studies are available only for premature death. The risks for all other health endpoints are based on time-series studies. Likewise, all morbidity (illness) risks include only risks associated with exposure to particulate matter and ozone.

Figure 2 shows the expected number of hospital admissions associated with respiratory and cardiovascular illnesses.

Figure 2 – Hospital Admissions Broken Down By Illness Type



In ICAP 2005, the total hospital admissions associated with air pollution exposure is estimated at over 16,000. Most of these cases will be associated with cardiovascular illnesses. The increase in estimated hospital admissions compared to the ICAP 2000 estimate is associated with changes in the provincial population, improved and more comprehensive risk estimates and the inclusion of all cardiovascular and respiratory illness types that are treated at hospitals. The 2000 hospital admissions estimates were based only on six specific cardiovascular and respiratory illness types.

Figure 3 shows the total hospital admissions broken down by age group. Most of the estimated hospital admissions are associated with two adult age categories. As with other illness risk estimates, the proportion of elderly cases is forecast to increase substantially as the "baby boomers" age and move into the oldest age class.

Emergency Room Visits

Less severe respiratory and cardiovascular illnesses are often treated by unscheduled emergency room visits. Figure 4 shows the expected number of emergency room visits associated with respiratory and cardiovascular illnesses. For the purposes of this determination, Emergency Room Visits that result in admission due to the more severe nature of the illness, have been factored out to avoid double counting.

In 2005, the emergency room visits associated with air pollution exposure is estimated at almost 60,000 cases. As with hospital admissions, most of these cases will be associated with cardiovascular illnesses.

Figure 3 - Hospital Admissions Broken Down By Age Group

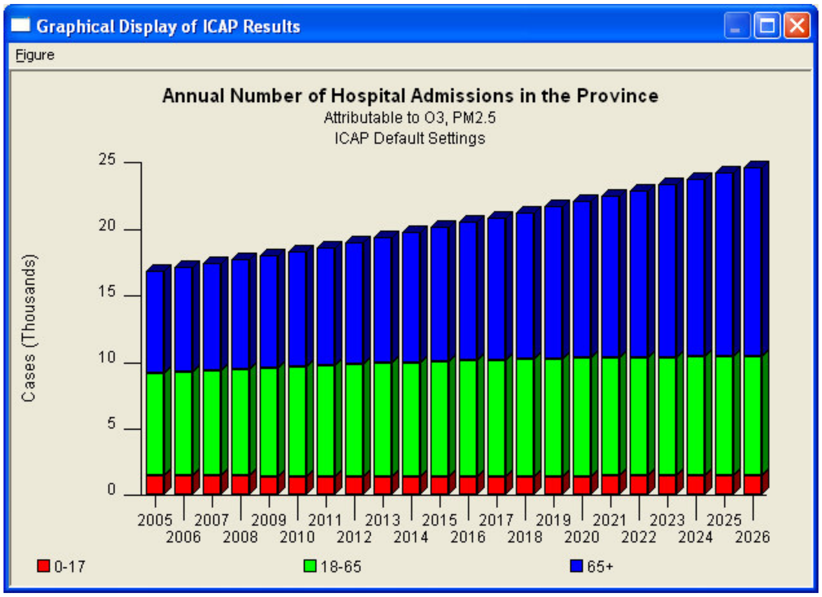
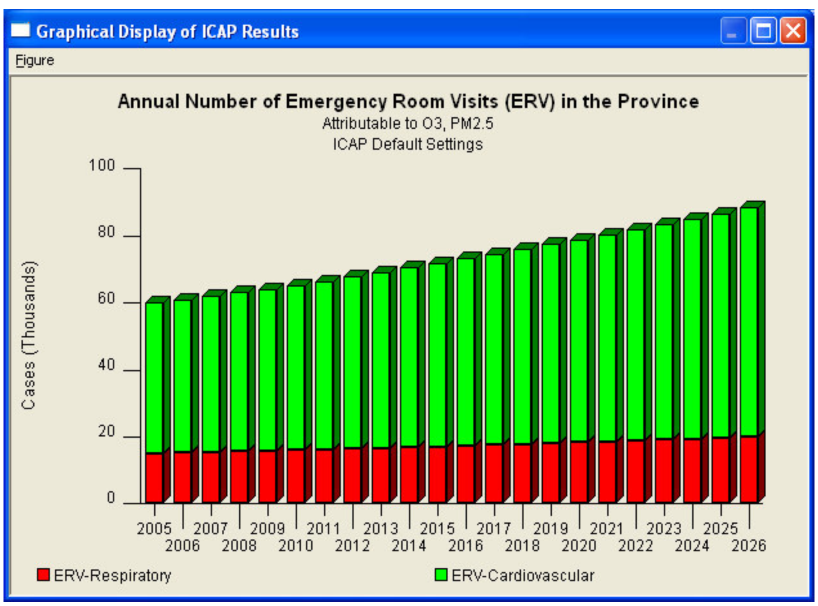


Figure 4 – Emergency Room Visits Broken Down By Illness Type

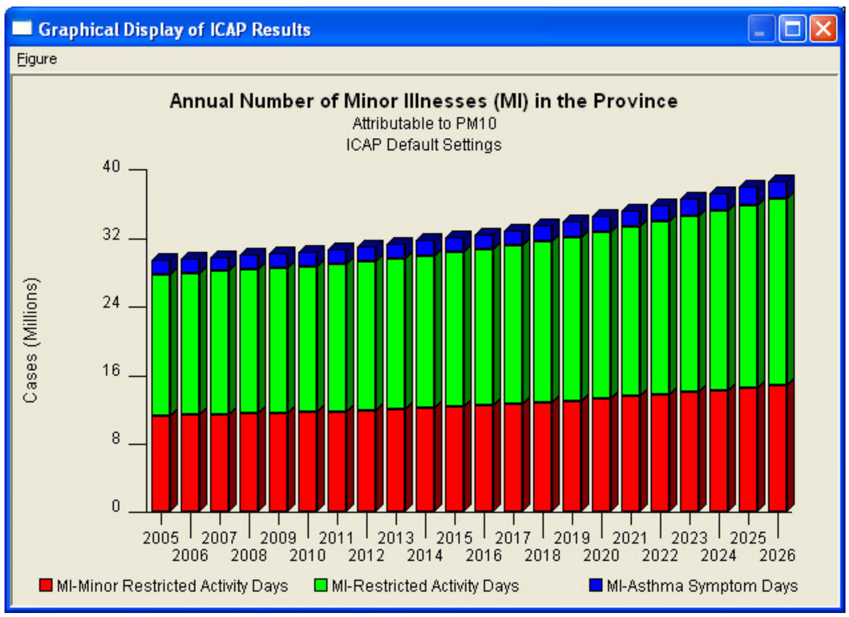


The increase in estimated emergency room visits is the result of additional risk estimates being added for fine particulate matter. The 2000 estimates were based primarily on ozone exposure. The distribution of these emergency room visits by age group is similar to that associated with hospital admissions. Likewise, the distribution is expected to be strongly skewed toward the elderly age group in the future.

Minor Illnesses

Minor illnesses are the least severe health endpoint associated with air pollution exposure but by far, the most common. Figure 5 shows the expected number of minor illnesses associated with exposure to particulate matter (i.e., PM_{10}) broken down by three general minor illness types.

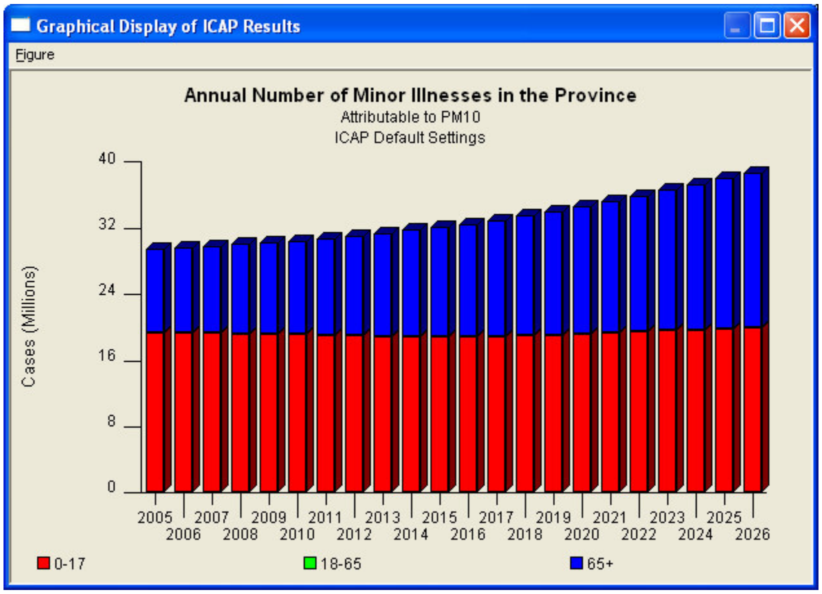
Figure 5 – Minor Illnesses Broken Down By Illness Type



Minor illness risk factors for exposure to fine particulate matter (i.e., $PM_{2.5}$) are not currently available. Likewise, there are a significant number of studies about respiratory clinical symptoms caused by ozone exposure but minor illness risk factors for ozone exposure have not been included in the revised version of ICAP due to the dearth of suitable epidemiological studies on minor illness risks. Finally, minor illness risks are included only for the youngest and oldest age groups, similar to the configuration of the 2000 version of ICAP. Undoubtedly, adults also suffer from minor illnesses associated with air pollution exposure but suitable risk factors are not currently available. For these reasons, the estimates of minor illness cases are likely underestimates.

In 2005, a total of over 29 million minor illnesses are expected to be associated with air pollution exposure. Most of these cases will be minor restricted activity days and restricted activity days. As shown in Figure 6, these minor illnesses are associated only with the youngest and oldest age groups. Children under 18 account for the majority of the minor illness cases.

Figure 6 – Minor Illnesses Broken Down By Age Group



Summary

Table 1 provides a summary of estimated health cases associated with air pollution for four example years. These results show changes that occurred as the result of recent improvements to ICAP 2005, but also demonstrates the substantial increase in health damages that can be expected in Ontario over the next 20 years if air quality does not improve. For example, premature deaths are expected to climb from 5,800 in 2005 to 10,000 in 2026. Similar trends are evident with all of the other health endpoints included in ICAP.

Table 1 – Provincial Health Damage Summary for Four Example Years

	Example Years			
	2000*	2005	2015	2026
Premature Deaths	1,925	5,829	7,436	10,061
Hospital Admissions	9,807	16,807	20,067	24,587
Emergency Room Visits	45,250	59,696	71,548	87,963
Minor Illnesses	46,445,663	29,292,100	31,962,200	38,549,300

*** Estimates from the original OMA ICAP model are included here for the purpose of comparison.**

- **Premature death estimates were significantly lower in 2000 because the previous model relied solely on time-series studies which only identified smog's immediate health effects. The science now makes it possible to estimate the health implications of long-term exposure and deaths due to smog-related chronic illness.**
- **Hospital admission estimates have increased as a result of changes to risk coefficients and more illnesses being included in the analysis.**
- **Emergency room visit estimates have increased because of new risk coefficients and the inclusion of more smog pollutants in our determination.**
- **Minor illness estimates have decreased as the result of changes to the risk coefficients, but were also significantly influenced by improved air pollution data and an increase in background level of air pollution.**

Economic Damages

ICAP provides estimates of economic damages according to four major categories, namely,

- Lost productivity
- Healthcare costs
- Pain and suffering
- Loss of life

Table 2 presents a summary of the economic damages for 2005, 2015 and 2026 in constant 2004 dollars. Following is a discussion of these revised economic damage estimates for Ontario.

Table 2 – Economic Damages for Three Example Years

	Example Years		
	2005	2015	2026
Lost Productivity	$374,342,400	$402,883,900	$466,508,500
Healthcare Costs	$506,612,700	$571,089,400	$701,988,500
Pain and Suffering	$536,546,600	$593,149,400	$718,341,300
Loss of Life	$6,391,700,000	$8,279,400,000	$11,027,400,000
Total	$7,809,201,700	$9,846,522,700	$12,914,238,300

Lost Productivity

Lost productivity includes the time lost due to treatment and recovery from air pollution-related illnesses. Lost productivity includes time lost by patients and caregivers. Lost time is valued at the going wage rate for the corresponding age of the person affected.

In 2005, economic damages due to lost time from air pollution-associated illness are expected to be in the order of $374 million. This total is expected to increase to over $466 million by 2026.

Healthcare Costs

Healthcare costs include the costs of institutional care plus medication.

In 2005, economic damages due to healthcare costs from air pollution-associated illness are expected to be in the order of $507 million. This total is expected to increase to nearly $702 million by 2026.

Pain and Suffering

Economic damages associated with pain and suffering relate to the amount that people are willing to pay to avoid illnesses causing pain and suffering. The original version of ICAP was based on a preliminary Canadian study of the willingness to pay of patients suffering from various types of symptoms. The results of that study have been refined and these refined pain and suffering estimates were used for these economic damages.

In 2005, economic losses associated with pain and suffering from air pollution-related illness are expected to be in the order of $537 million. This total is expected to increase to more than $718 million by 2026.

Loss of Life

The value of premature death is estimated based on the willingness of people to pay to reduce this risk. The value of reducing the risk of premature death has been revised based on a recent Canadian study (Krupnick et al, 2002). The value varies with age. Overall, the default values in ICAP are considerably less than what have been used in other air pollution damage studies.

In 2005, economic losses involving premature death associated with air pollution exposure are expected to be in the order of $6.4 billion. This total is expected to increase to over $11 billion by 2026.

Total Damages

Combining these four economic damage categories produces an estimate of the total provincial economic damages associated with exposure to air pollution.

In 2005, overall economic losses associated with air pollution exposure are expected to be in the order of $7.8 billion. This total is expected to increase to over $12.9 billion by 2026.

Regional Distribution of Damages

The ICAP model has the capacity to produce quite detailed estimates of damages that can be broken down by various combinations of pollutants, locations, illness types and age groups. The OMA will soon release a summary of health and economic damages for various locations throughout the province. Further breakdowns can also be produced using the ICAP software, which the OMA will make available on its website.

Revisions to ICAP

ICAP relies on four principal information elements, namely, 1) the size and characteristics of the exposed population, 2) the type and concentration of air pollution to which the population is being exposed, 3) the expected health responses of the population to air pollution exposure, and 4) the economic consequences of adverse health effects caused by air pollution. All of these elements have been updated in the new version of ICAP.

Population Data

In Canada, a new population census is conducted every five years. The last census occurred in 2001, and so was not available for ICAP 2000, which relied on 1996 census data. These census statistics were obtained for each census division (CD) in Ontario and used to update the ICAP population data.

Air Quality Data

Comprehensive air quality monitoring data available for the most recent years (i.e., for 2000 to 2002) have been obtained. ICAP 2000 used air quality data from 1991 to 1993. The geographic interpolation of this data to census divisions was undertaken using a mathematical procedure known as kriging.

The focus of ICAP relates to health damages associated with exposure to air pollutants arising from anthropogenic emissions. Some pollutants originate from natural causes (e.g., forest fires) and some originate from far outside our geographical region (e.g., global transport, stratospheric contributions, etc). For this reason, natural background concentrations are often deducted to obtain estimates of damages caused by human emissions of air pollutants. The estimates of background concentrations in this version of ICAP have been refined using data from the Ontario Ministry of the Environment.

Base Incidence Rates

Health damages associated with air pollution are dependent on:

- The size and health characteristics of the exposed population.
- The relative risk of exposure to a certain air pollutant at a certain concentration

Base incidence rates (BIRs) for various illnesses in the population have been updated. Death and illness statistics were obtained from various sources for the Ontario population. Separate statistics were obtained where available for each of the three age groups in ICAP.

Concentration-response Functions

Several recent major reports were used to derive the new ICAP pollution concentration-health response functions (CRFs). The discovery of a mathematical problem with the S-Plus statistical software on which many epidemiologists had relied for their analyses necessitated an extensive re-investigation. The data was re-analysed and revised relative risk estimates were published (HEI, 2003). The results of this re-analysis have been incorporated in this new version of ICAP.

Part of the reason for the urgent need to have the HEI re-analysis performed was the impending finalization of the U.S. Environmental Protection Agency (EPA) particulate matter criteria document. Once the HEI results were available, the criteria document was finalised and released to the public (US EPA, 2004). This document provides an exhaustive analysis covering studies from all parts of the world that relate to the epidemiological and clinical findings on the risk of exposure to particulate matter. This document and its interpretation by the US EPA were carefully considered in developing the particulate matter CRFs.

A third major source of information was the Review of the California Ambient Air Quality Standard by the California Air Resources Board (CARB, 2005). This document is similar in scope and detail to the US EPA particulate matter criteria document. The ozone review document was a primary reference for the revised ozone concentration-response functions.

All three documents are current and provide a strong technical basis on which to derive the ICAP concentration-response functions. Primary epidemiological studies were consulted as required.

Another major development in the air pollution epidemiological literature has been the increasing attention being given to the results of relative risk estimates derived from long-term cohort studies. ICAP has been modified to include premature death concentration-response functions based on cohort studies.

Economic Damage Coefficients

The economic damage coefficients in ICAP have been adjusted to 2004 dollars. Some factors have been updated with readily available statistics (e.g., wage rates).

Two major adjustments to the economic coefficients have been made, namely, the estimates of the losses associated with premature death and those relating to pain and suffering. These changes are in response to new studies published since the last version of ICAP was released.

ICAP Operation

Revisions have been made to the ICAP software to make it more user-friendly and transparent. Changes have been made to 1) the variables that the user can modify, 2) to the Monte Carlo simulation routine used for uncertainty analysis and 3) to the operation of the system when designing and reviewing the results of an ICAP run.

Concluding Comments

This summary report provides an overview of the revisions that have been made to ICAP and the effects of these revisions on provincial health and economic damage estimates. Following are some concluding comments arising from these results.

Improved Damage Estimates

These revised damage estimates represent a significant improvement over the previous damage estimates. Major improvements include:

- Updated population, air quality and base illness data.
- Refined and expanded concentration-response functions based on the latest scientific literature.
- Refined economic coefficients based on the latest health economics literature.

Gaps and Uncertainties

While the revised damage estimates are an improvement over the previous estimates, many gaps and uncertainties still remain. In most cases, these gaps tend to result in underestimates of the true damages. One such gap is the lack of a complete set of concentration-response functions for each of the air pollutants. As additional concentration-response functions are added, the damage estimates will improve further.

In general, the variability of the damage estimates increases as the severity of the health endpoint decreases. This trend is due to several factors. First, the more severe health endpoints are more likely to result in accurate diagnoses and reporting. Second, the number of studies declines as the severity of the health endpoint declines. There are various reasons for this.

Many of the ICAP default values include error ranges for the mean estimates. ICAP includes a Monte Carlo simulation routine designed to examine the effects of these error ranges on damages estimates. These uncertainty bounds are an important consideration when specific air quality improvement polices are being analysed.

Enhanced Software

A revised version of the ICAP software has been produced and is being released to the public, similar to what was done with the first version of ICAP. The new software has some significant improvements that make use of the model easier and more transparent. This new software should be used rather than the previous version of ICAP for analyzing the health consequences of air pollution.

Future Revisions

Undoubtedly, understanding of air pollution effects on human health will continue to expand in the future. The latest version of the ICAP software is a reasonable tool for analyzing and understanding the consequences of air pollution. However, users should recognize that ongoing refinements are essential. Given the increased user access to the ICAP default values, skilled and knowledgeable users will be better able to update their system as new information and understanding emerge. Nonetheless, refinements to the core software will likely continue to be required in the future. User feedback has been helpful in shaping the new version of ICAP and comments on the new version are welcomed.

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