TORONTO STAFF REPORT

May 27, 2005

To: Board of Health

From: Dr. David McKeown, Medical Officer of Health

Subject: Combined Impact of Extreme Heat and Air Pollution on Mortality

Purpose:

To provide highlights of a major study on the combined impacts of weather and air pollution on premature mortality.

Financial Implications and Impact Statement:

There are no financial implications arising from adoption of this report.

Recommendations:

It is recommended that the Board of Health request:

(1) that the federal Minister of the Environment, in collaboration with the federal Minister of Health, develop a national heat-health warning system that would enable major urban centres to implement appropriate heat response protocols to protect vulnerable populations during extreme heat events;

(2) that the federal Ministers of Environment and Health take into account the combined impacts of air pollution and heat during the development of a national heat-health warning system;

(3) that the federal Ministers of the Environment, Natural Resources and Health ensure that Canada's international obligations to meet the greenhouse gas reduction targets specified during ratification of the Kyoto Protocol are met as scheduled, and that greater consideration is given to mandatory rather than voluntary measures;

(4) that this report be forwarded to the Ontario Ministers of the Environment and Health and Long Term Care, other Ontario health units, the Ontario Public Health Association, the Association of Local Public Health Agencies, the Ontario Medical Association, and the GTA Clean Air Council for their consideration; and

(5) that the appropriate City Officials be authorized and directed to take the necessary action to give effect thereto.

Background:

In 2002, Toronto Public Health was awarded a multiyear grant from Health Canada's Health Policy Research Program to assess the combined impacts of air pollution and weather on human mortality. While many research studies have been conducted on the effects of air pollution on health, and the effects of extreme heat or cold on health, the current study is innovative because it assessed the combined effects of extreme heat/cold and air pollution on premature mortality.

This study, led by Toronto Public Health, was conducted in collaboration with leading scientists from: Environment Canada's Meteorological Service, Science Assessment and Integration Branch, and Adaptation and Impacts Research Group; Department of Medicine at McMaster University; and Health Canada's Surveillance and Risk Assessment Division. The study was overseen by a Project Advisory Committee comprised of health, environmental and policy experts. This report provides highlights of the full technical report (authored by Cheng et al, 2005). A summary report entitled "Influence of Weather and Air Pollution on Mortality" (authored by Pengelly et al.) is attached (Appendix 1).

The research findings are of interest to Health Canada's Climate Change and Health Office, as well as the Canadian Climate Impacts and Adaptation Research Network. The findings are also relevant to the City of Toronto in its efforts to better understand and take action on air pollution and extreme weather events, both now and in the future as global warming accelerates.This report focuses on the Toronto findings, and mainly as they relate to heat and air pollution impacts because these impacts increase with global warming.

Comments:

Health Concerns with Extreme Heat and Air Pollution:

Extreme heat events are associated with substantial premature mortality. For example, in Western Europe over 11,000 deaths were associated with the record-breaking heat wave of 2003. In the United States, an estimated 10,000 deaths were related to oppressive heat during the summer of 1980. Medical evidence shows that death can occur with a rise in core body temperature of 5^0C above normal. Seniors are at increased risk due to a decline in temperature regulation mechanisms with aging. Other factors that increase the risk of a heat-related death are underlying medical conditions (e.g. high blood pressure, abnormally rapid heart rate, obesity, lack of physical fitness, alcoholism and medication use).

Prolonged exposure to heat over several days without cooling intervals (such as typically occur at night) substantially increases heat impacts. Adaptive responses such as ensuring at-risk populations spend some time in cooler environments can greatly reduce the risk of premature mortality.

Air pollution has been conclusively linked to adverse health outcomes, particularly in vulnerable populations such as the elderly and those suffering from heart and breathing problems. Young children are also at increased risk. A 2004 study conducted by Toronto Public Health estimated that about 1,700 premature deaths each year in Toronto are attributable to acute and chronic exposures to five common air pollutants. Of these deaths, about 695 are attributable to acute exposures alone while the remainder are associated with longterm exposures to fine particulate matter.

Purpose of the Current Study:

The purpose of the current study was to improve understanding of the combined impacts of extreme temperatures (heat/cold) and air pollution on premature mortality currently and with future climate change. This information is of value in developing broad mitigative and adaptive policy responses. The four cities selected for study were Montreal, Ottawa, Toronto and Windsor.

Methods:

The findings of the current study are based on 46 years of mortality and hourly weather data (1954 to 2000) and 25 years of hourly air pollution data (1974 to 2000) for five common air pollutants (ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, and coefficient of haze as a measure of particulate matter). The study methodology (described in Appendix 1) is very complex and relies on techniques used by diverse disciplines. The study was carried out in three main steps.

The first step was development of a method to assign the annual mean burden of illness (in terms of elevated mortality) associated with extreme weather and air pollution using synoptic (i.e. synthesis of multiple variables that exist simultaneously) classification of air masses in the four cities. Synoptic classification makes it possible to link together measurements such as wind speed, wind direction, temperature, pressure and cloud cover into different types of air masses, which in turn can be linked statistically to daily mortality. The second step was to develop a model to assess the changing weather and air pollution factors that contribute to the day-to-day variability in mortality, and to use the relationships from this assessment to forecast daily mortality risk. The third step was to apply the daily model, in conjunction with internationally recognized Global Climate Models, to project the influence of climate change on the frequency of extreme weather and air pollution events, and thereby on mortality.

Combined Impacts of Air Pollution and Heat:

Table 1 summarizes the annual average elevated mortality attributable to heat alone, cold alone, air pollution alone, and heat/cold and air pollution acting together, for each of the four cities in the study. Toronto and Windsor had somewhat more heat-related than cold-related deaths, whereas the converse was true for Montreal and Ottawa.

Table 1. Average Annual Premature Mortality Attributable to Extreme Temperature and Air Pollution

City	Average Annual Mortality (based on 1954 – 2000 data)			
	Heat Related	Cold Related	Air Pollution Related	Temperature and Air Pollution Related
Toronto	120	105	822	1,047
Montreal	121	143	818	1,082
Ottawa	41	54	368	463
Windsor	37	32	258	327

The relative proportion of elevated mortality associated with extreme temperatures and air pollution was consistent across the four cities. Extreme weather (hot and cold) was associated with only about 20% of the total elevated mortality, whereas air pollution was associated with about 80% of the increased mortality. In Toronto, 120 deaths were heat-related, 105 cold-related, and 822 were related to acute exposure to five common air pollutants, based on the average annual number of deaths during the study period. On those relatively few days of the year with extreme heat, the average daily elevated mortality was about twice as high as when there were no temperature extremes but air pollution continued to be present. The study also showed that heat-related mortality was significantly higher for elderly people and those with cardiovascular illness than other individuals across the four cities.

When data specific to 1999 were analysed, air pollution-related elevated mortality was determined to be 705. This estimate is consistent with the 695 premature deaths attributed to acute air pollution exposure by Toronto Public Health in its prior air pollution burden of illness study using 1999 data. It is noteworthy that although the methods used in both studies are different, the air pollution-related mortality findings are similar. Based on historical analysis, the study also determined that premature mortality was higher in the past when air pollution levels were higher than in more recent times.

The study confirms the importance of air pollution as a significant risk factor leading to premature mortality. The study also confirms that extreme heat puts lives at risk. Protecting vulnerable populations from excess heat during extreme heat episodes would prevent premature mortality. Preventing premature mortality arising from air pollution is far more challenging because air pollution occurs year round, and is widespread across indoor and outdoor environments.

Projected Future Impacts of Air Pollution and Heat:

Using historical data from the last 46 years, the study was able to develop and validate a model for projecting the combined impacts of air pollution and global warming on premature mortality by 2050 and 2080. The study examined how weather and air pollution interacts to give rise to elevated mortality. For example, global warming is projected to increase ozone levels because ozone is created through photochemical reactions among nitrogen oxides and volatile organic compounds in the presence of sunlight. Even if air emissions stay the same in the future as now, increased sunny weather and warming will result in the formation of more air pollutants such as ozone. Exposure to ozone can result in many adverse effects on health, including increased hospitalization and mortality. Other adverse outcomes associated with climate change, such as increased mortality due to foodborne illnesses, water contamination, forest fires and flooding were not part of this analysis.

Two different methods were used to estimate future extreme temperature-related weather and air pollution-related mortality for five Global Climate Model scenarios. The results from both methods were very similar. Averaging the five Global Climate Model scenarios, and assuming that current air pollution emissions would remain relatively constant, the model projected the following changes in mortality rates:

(a) Heat related mortality would more than double by 2050 and triple by 2080 across the four cities;

(b) Air pollution-related mortality would increase across all four cities. In Toronto, it would increase by about 20% by 2050 and about 25% by 2080, in large part because of increases in ozone-associated elevated mortality.

Discussion:

There is strong consensus in the international scientific community that climate change is occurring, and that mean global temperatures are likely to increase by 1.4 to 5.8 ^{o}C in this century. As a result of warming and increases in the number of extreme hot weather events, the heat-related health risk is expected to increase significantly. The introduction of measures to reduce greenhouse gases is of primary importance in protecting the environment, human health, social and economic well being. However, despite measures that will be implemented this decade to reduce the rate of climate change, continued global warming is inevitable and requires adaptive policy responses.

One such adaptive response is the implementation of heat-health warning systems, as are currently in place in Toronto and major U.S. cities such as Philadelphia, Chicago and Cincinnati. An evaluation of Philadelphia's heat warning system has shown it to be effective. By assessing actual death rates during a four-year period when Philadelphia's warning system was in place, researchers were able to estimate that 117 lives were saved.

An example of an adaptive response to elevated air pollution levels is the Ontario Ministry of Environment's Smog Advisory program, which is based on public dissemination of information on current Air Quality Index readings.

The public health sector has an important role in advocating for progressive measures to reduce air pollution and greenhouse gas emissions. It also has a key role in warning the public of extreme heat/cold and air pollution events to lessen their adverse impact on vulnerable populations, especially the elderly and those with underlying medical conditions.

Mitigating Air Pollution and Climate Change:

The combustion of fossil fuels, such as coal in power plants, diesel in buses and trucks, natural gas and oil for space heating, and gasoline in cars, results in the release of air pollutants and greenhouse gases (such as carbon dioxide). Industrial point sources also contribute to both air pollution and climate change problems. Toronto Public Health has prepared numerous reports that have identified the need for concerted action to mitigate air pollution and greenhouse gases. In 2004, the Board of Health and City Council endorsed an "Action Agenda on Air and Health" that provided a comprehensive framework for action by the provincial government. City staff continue to work on a Comprehensive Air Quality Strategy that will focus priority attention on actions that can be taken by the City.

Central to any improvement in air quality is the progress that must be made by the federal government in ensuring implementation of the Kyoto Protocol. More than 160 countries have endorsed the Kyoto Protocol, requiring industrialized nations to collectively reduce emissions of six greenhouse gases by 5.2 percent below 1990 levels by 2012. Countries vary as to their commitment level. For example, the European Union must meet an 8% emissions reduction while Canada has ratified its commitment to reduce greenhouse gas emissions by 6% by 2012. Actions taken to meet our Kyoto targets will result in improvements in air quality, thereby reducing premature mortality associated with both climate change and smog.

At its meeting of May 9, 2005, the Board of Health adopted the recommendation that the Federal Minister of the Environment develop a comprehensive policy framework for aggressively reducing greenhouse gas emissions from all sources including each industrial sector and to establish clear implementation targets, timelines and a monitoring strategy to ensure that target reductions are achieved.

There is growing concern with the current direction of the federal government that relies increasingly on voluntary and educational mechanisms to achieve the Kyoto commitments. In light of the current research findings, this report recommends that the Federal Ministers of the Environment, Natural Resources and Health ensure that Canada's international obligations to meet the greenhouse gas reduction targets specified during ratification of the Kyoto Protocol are met as scheduled, and that greater consideration is given to mandatory rather than voluntary measures.

Adaptive Responses to Extreme Heat:

Toronto's Heat-Health Warning System was developed by researchers with the Centre for Climatic Research at the University of Delaware in the U.S. The system was based on an analysis of historical relationships between heat-related mortality and specific weather types to determine the most significant weather conditions (e.g. high heat and humidity) that lead to increases in heat-related mortality. Weather forecasts are used to identify those weather conditions that are predicted to lead to increased mortality over the next 48-hour period.

Environment Canada sends weather forecast data to the University of Delaware researchers, who in turn analyse the data and notify Toronto Public Health when a "heat alert" or "extreme heat alert" should be issued by the Medical Officer of Health. A heat alert is issued when there is a 65% or more chance that predicted weather conditions will result in premature death. An extreme heat alert is issued at 90% or greater chance of premature death.

The issuance of an extreme heat alert by the Medical Officer of Health triggers a co-ordinated response among key city agencies and community partners. This response includes media announcements, activation of a Heat Information Line, home visits, facilitating transfer to a hospital emergency department if warranted, opening up public cooling centres, outreach to homeless persons, and distribution of bottled water. Evaluation of heat warning systems has confirmed that they save lives during heat waves.

Toronto was the first Canadian city to establish a heat-health warning system, followed by Montreal. Many other municipalities have expressed interest in having similar systems in place in their regions. Given the widespread interest and health benefit of having warning systems and heat response protocols in place, it is timely to develop a national system.

The current study was based on a methodology similar to the one used to develop Toronto's heat warning system, however, it has taken into account additional weather variables and air pollution influences. Through their participation in this study, Environment Canada scientists have developed sufficient expertise to create a national heat-health warning system. Consequently, it is recommended that the federal Minister of the Environment, in collaboration with the federal Minister of Health, develop a national heat warning system that would enable major urban centres to implement appropriate heat response protocols to protect vulnerable populations during extreme heat events. Furthermore, it is recommended that the combined impacts of air pollution and heat be taken into account during the development of a national heat warning system. This would enable Toronto to operate its heat warning system based on Canadian expertise, and based on an improved method that takes into account air pollution influences.

Conclusions:

There is strong consensus in the scientific community that climate change is occurring and that global temperature will rise substantially during this century. Toronto Public Health, in partnership with government and university scientists, has completed a major study on the combined impacts of extreme weather and air pollution. This report highlights the combined effect of extreme heat and air pollution on Toronto residents over a 46-year time period (1954-2000) and makes projections on future impacts arising from global warming.

A much higher proportion of elevated mortality was associated with air pollution (80%) compared with extreme temperatures (20%). Air pollution levels and associated mortality were higher in the early years of the study than in more recent times. This study confirms the significance of air pollution as a major risk factor leading to premature mortality, in large part because air pollution is a year-round phenomenon. Heat was an even more serious health threat than air pollution on those days when temperatures were extreme. Heat-related health risk was significantly higher for elderly people and those with cardiovascular illness than others in the population.

The study projected premature mortality rates for 2050 and 2080, using the average of five climate change scenarios and assuming current air pollution emissions would remain relatively constant. As a result, the study projected that heat-related mortality would more than double by 2050 and triple by 2080. Air pollution-related mortality is projected to increase 25% by 2080 in Toronto, in large part because of increased ozone levels arising from global warming.

The implementation of heat-health warnings systems and heat response protocols saves lives. Toronto was the first Canadian city to establish a heat-health warning system, followed by Montreal. Many other municipalities have expressed an interest in having similar systems in place in their regions. Given the widespread interest and health benefit of having warning systems and heat response protocols in place, it is timely for Environment Canada, in collaboration with Health Canada, to develop a national heat warning system.

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List of Attachments:

Appendix 1. Influence of Weather and Air Pollution on Mortality in Toronto: Summary Report