CONCLUSIONS

A New State of the Art of Burden of Illness Estimation

Cheng and co-workers have developed a unique process to study the combined and independent impacts of extreme weather (hot/cold) and air pollution on human acute mortality under historical, current and future climates for four selected cities (Montreal, Ottawa, Toronto, Windsor) in south-central Canada. The process analysed North American and Canadian national archives and models of climatological, weather, air pollution and mortality data, making use of a suite of climatological, meteorological and statistical techniques. Using this process, scientific information suitable for public policy risk identification and assessment, as well as for improvement of the adaptive capacity of the health infrastructure in south-central Canada in response to projected human health impacts of climate change is now available for these specific cities, and the process shows great promise for application in many other urban areas. Specifically:

a method has been developed and verified which can quantify the *annual mean* burden of illness (in terms of elevated mortality) associated with extreme temperatures and air pollution using the method of synoptic classification of air masses in the four cities;

a model system has been developed that can be used (for each air-mass) to assess the changing meteorological and air pollution factors that contribute to the *day-to-day variability* in mortality, and to use the coefficients from this assessment to forecast daily mortality risk based on current or forecast daily weather and air pollution information; and

the daily model has been used in conjunction with existing Global Climate Models (GCMs), suitably adapted, to assess the *impact of climate change* in the future on public health associated with extreme weather and air pollution, in terms of elevated acute mortality and frequency of severe weather and air pollution episodes.

Toronto Mortality from Extreme Weather and Air Pollution.

For the City of Toronto, over the whole period of analysis, the mean annual elevated acute mortality associated with hot weather was 120; with cold weather 105; and with air pollution, 822. When data specific to 1999 were analysed, Cheng et al. found that air pollution- related elevated mortality was 705, agreeing well with the 695 premature deaths attributed to acute air pollution exposure in 1999 determined by Toronto Public Health in 2004.

Development of the Heat-Health Warning System for Toronto.

Annual mean occurrence of elevated mortality events forecast by the three hot-weather-type prediction models (HA1, HA2, HA3) and their agreement with observations were calculated for the whole period with combination of model development and validation data sets (Table 4). The number of identified days with elevated mortality events depends on the strength of the prediction models.

Table 4. Prediction of elevated mortality events for Toronto based on historical data. Can be used as basis of enhanced "Heat-Health Alert System".

Logistic probability	Predicted annual mean occurrence	Agreement with observations
$0.9	2.54	85%
0.8 - 0.9	2	85%
0.6 - 0.79	17.46	66%

The stronger the model, the greater the number of days with elevated mortality that are identified correctly. For 80 and 90% probability there was 85% agreement with observations, but with 60% probability only 66% agreement. For the purposes of development of alert systems for other cities, it is recommended that various cut-off probability thresholds be evaluated to balance the number of "advisories" or "warnings" given (and reduce the number of "false alarms").

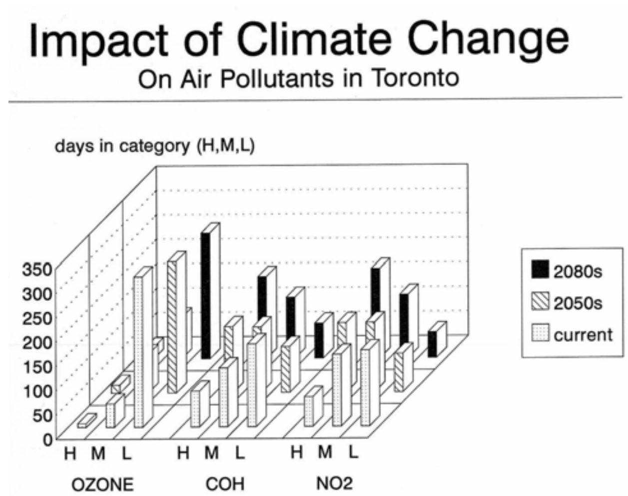
Climate Change, Extreme Temperature-related Weather Events and Air Pollution Episodes, and Associated Mortality in Toronto

Daily climate change scenarios for the 2050s and 2080s, when CO_2 is expected to double and triple relative to the 1975–1995 level, were used to estimate changes in the number of days within weather types. In addition, trends and changes in elevated mortality as a result of extreme temperature-related weather events and high air pollution episodes that might occur with projected global climatic warming were also assessed.

Air Pollution

Figure 15 shows the projected changes in air pollution levels according to the expected changes in CO2 levels during this century. This is the change expected according to air pollution emission policy Scenario III (air pollution emissions increased 32% by 2080), a reasonable assumption to be associated with the tripling of CO2 levels by that time. In all cases of the pollutants shown, by the 2080s days in the "low" categories are reduced: days in "moderate" and "High" categories are increased substantially.

Figure 15. Projected change in air quality for Toronto



Heat "alerts" and associated hot-weather mortality
The climate change models project a fourfold increase in the number of hot weather warnings by the 2080s, which if not responded to could lead to a tripling of heat-related deaths from 120 to 360 per year. On the other hand, cold related mortality could decrease from 105 to 35 per year.

Air pollution-related elevated mortality
Climate change models project from 25% (no change in pollutant emission) to 30% (32% increase in emission) increase in acute air pollution-related mortality by the 2080s for Toronto; going from current levels of 822 to 1070 per year.

Acute mortality by the 2080s due to extreme weather and air pollution
Summation of the numbers above would indicate elevated mortality from acute effects of severe weather and air pollution by the 2080s to be 1465 per year. It should be pointed out that these estimates have not taken into account either population growth or age structure changes that might be projected in the future for Toronto, and may well represent the lower bound of expected mortality.

IMPLICATIONS

This study was undertaken to investigate the combined and independent impacts of extreme weather (hot/cold) and air pollution on human acute mortality currently, and under future climates for four selected cities (Montreal, Ottawa, Toronto, Windsor) in south-central Canada, and to provide scientifically based information for policy development at all levels of government with respect to climate change, air quality and public health.

As outlined in the conclusions above, the study has succeeded in achieving all of its objectives. The information is now available. The task is to implement the changes in policy that must be carried out to protect public health. In 1998, in a monograph [11] on the health effects of air pollution and climate change, Last et al. concluded:

> *"To prevent further harm, and to promote immediate and long-term improvements in health, we must initiate and implement effective strategies to reduce the rate of fossil fuel combustion, greenhouse gas emissions, and air pollution. Implementing solutions today will reduce the burden of serious health problems tomorrow, especially the burden on our children and the generations to follow."*

At the time this was written we did not have the benefit of a unified methodological process which was capable of explicitly assessing this problem, or which could quantitatively estimate the associated burden of illness. Now there is no doubt, no need to speculate. The evidence is strong that the continuance of the industrialized world's dependency on fossil fuels will lead to increased death and disease for all the world, especially the urban areas which are increasingly becoming magnets for population growth. This dependency must, if not eliminated entirely, be reduced to a sustainable level which does not harm public health.

[11] Last, J.M., K. Trouton and L.D. Pengelly. Taking our Breath Away: The Health Effects of Air Pollution and Climate Change. 51 pp. David Suzuki Foundation, Vancouver, BC; October 1998.