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SMOG AND POPULATION HEALTH

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INTRODUCTION

Preventing sickness, as opposed to treating it, is widely seen as the most efficient means of achieving better public health. Reducing air pollution is one such proactive measure that can lead to better health, and it has been a government objective for decades. Most recently, the new Conservative government has suggested that it will introduce a Clean Air Act. According to a poll done for Natural Resources Canada in 2004-2005, air pollution and quality was the top environmental concern for Canadians.(1)

The following paper describes smog as an environmental determinant of public health and discusses some of the issues surrounding government efforts to combat this problem.

ENVIRONMENTAL DETERMINANTS AND POPULATION HEALTH

Since the 1970s, Canada has been a leader in developing the population health approach,(2) which views health as emerging from a combination of interrelated determinants, including the physical environment. Figure 1 outlines some of the many factors that determine health.

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(1) Ekos Research Associates Inc., "Public Perceptions of Climate Change: Annual Tracking Spring 2005," Final Report Submitted to Natural Resources Canada, Contract 23483-050297/CY/001, April 2005.

(2) For more information, see Odette Madore and Nancy Miller-Chenier, *Population Health: Concepts and Implications for Governments*, TIPS-23E, Parliamentary Information and Research Service, Library of Parliament, Ottawa, 7 February 2005; and the Public Health Agency of Canada's "Population Health Approach," http://www.phac-aspc.gc.ca/ph-sp/phdd/index.html, 14 April 2005.

Figure 1

Determinants of Health

Source: Health Canada, "Health and Environment: Critical Pathways," *Health Policy Research Bulletin*, Issue 04, October 2002, p. 3.

The Canadian Institute for Advanced Research has estimated that in Canada 25% of health is determined by the health care system, while 75% is due to other factors.(3) However, the vast majority of resources are funnelled into traditional medical and health care programs: according to the Organisation for Economic Co-operation and Development (OECD),(4) Canada designated 8% of its health expenditure to population-wide prevention and public health in 2003.(5)

The implications of air pollution for human health first gained widespread attention following the London smog event of 1952, which claimed between 3,000 and 12,000 lives.(6) Since that time, air quality in places such as Canada, the United States and the European Union has improved greatly. Nonetheless, scientific studies document continued, and costly, health effects of air pollution and smog, particularly in cities.

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(3) Standing Senate Committee on Social Affairs, Science and Technology, *The Health of Canadians – The Federal Role; Volume One – The Story So Far*, interim report on the state of the health care system in Canada, March 2001, http://dsp-psd.communication.gc.ca/Collection/YC17-371-1-01E.pdf.

(4) Organisation for Economic Co-operation and Development, "Health at a Glance – OECD Indicators 2005," 2005, www.oecd.org.

(5) This figure includes provincial, territorial and federal department administrative costs, and is thus far greater than the 3% average expenditure for population-wide prevention and public health by OECD countries (OECD (2005), p. 73).

(6) M. L. Bell, D. L. Davis, and T. Fletcher, "A retrospective assessment of mortality from the London smog episode of 1952: the role of influenza and pollution," *Environmental Health Perspectives*, Vol. 112, 2004, pp. 6-8.

THE ORIGINS OF SMOG

The main components of smog are ground-level ozone (O_3) and particulate matter (PM), which derive largely from industrial and vehicular combustion of fossil fuels and are able to travel over long distances. Peak smog areas in Canada are concentrated in the Quebec-Windsor Corridor, the Southern Atlantic Region, and the Lower Fraser Valley.

A. Ozone

Ground-level ozone is formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight. It is now believed to be harmful to humans at any level of exposure.(7) Levels of ozone tend to rise in the summer months as temperature and sunlight increase, and can become concentrated as a result of geography or meteorological conditions. Important sources of NO_x and VOCs are listed below.

Table 1

Natural and Human-made Sources of Major Smog-forming Pollutants

Pollutant	Sources, Both Natural and Human-made
Volatile organic compounds (VOC)	Tailpipe emissions, evaporation of gasoline at service stations, surface coatings such as oil paints, solvents such as barbecue starters, fuel combustion, vegetation
Nitrogen oxides such as nitric oxide (NO) and nitrogen dioxide (NO_2)	Tailpipe emissions, manufacturing industries, electricity generating stations, fossil fuel powered plants, oil refineries, pulp and paper plants, incinerators, bacterial action in soil, forest fires, volcanic action, lightning
Sulphur dioxide (SO_2)	Non-ferrous metal smelting, thermal electricity generating stations, oil refineries, pulp and paper plants, incinerators
Particulate Matter (PM)	Tailpipe emissions, fossil fuel powered plants, heating systems, industrial boilers, industrially produced chemicals in combination with naturally occurring chemicals, farmlands, roads, road salt, construction activities, volcanoes, wind erosion, forest fires, vegetation

(7) World Health Organization (WHO) Europe, *Health Aspects of Air Pollution: Results From the WHO Project "Systematic Review of Health Aspects of Air Pollution in Europe,"* June 2004, http://www.euro.who.int/document/E83080.pdf. For further technical background on smog and related government actions, see Alan Nixon, *Clean Air: The Breath of Life*, TIPS-68E, Parliamentary Information and Research Service, Library of Parliament, Ottawa, 8 October 2002.

B. Particulate Matter

Particulate matter is a complex combination of both solid and liquid particles including sulphates, nitrates, sand, dust, organic chemicals and metals.(8) Such precursors and primary particles also react to form new compounds, or pick up other substances and carry them through the air. Primary and secondary particles may be toxic, and their size, shape and other properties are highly variable.

Two main classes of PM – PM_{10} and $PM_{2.5}$(9) – are distinguished by their size and thus ability to penetrate the human respiratory system. PM_{10}, the larger of the two, is normally a product of physical processes, and tends to be filtered in the nasal passages. $PM_{2.5}$ tends to originate from combustion sources, and is able to penetrate into the lungs and possibly even the bloodstream. Studies show that both types, and particularly $PM_{2.5}$, are toxic to humans and correlate with observed health effects from air pollution. There is no level of exposure known to be safe to humans.(10)

HEALTH EFFECTS OF SMOG

Air pollution affects individuals differentially, depending on factors such as age, health status, activity levels, socio-economic status and exposure levels. Effects range from minor irritations of the respiratory tract and small biochemical or physiological changes, to breathing difficulties, coughing, reduced lung functioning, aggravation of existing respiratory and cardiovascular conditions, and possibly genetic mutation.

Studies demonstrate that incidents of elevated air pollution levels are associated with increased rates of doctor's visits, hospitalization and premature death, and the proportion of the population affected tends to decrease in correlation with the severity of air pollution impacts as illustrated in Figure 2.

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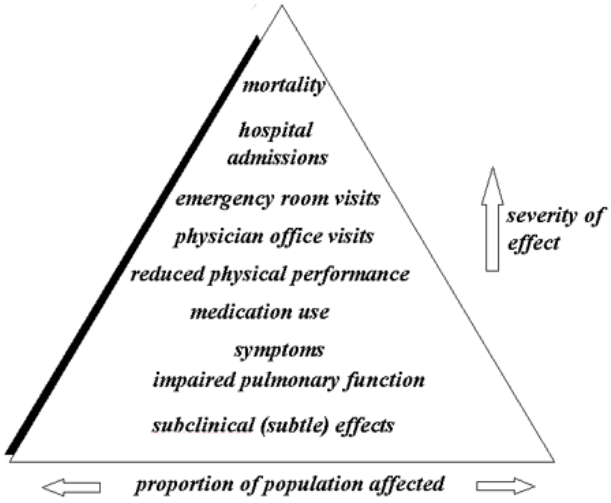
(8) United States Environmental Protection Agency (EPA), Web site, *Particulate Matter*, www.epa.gov/air/particlepollution/index.html (accessed 22 December 2005).

(9) $PM_{2.5}$ and PM_{10} refer to particulate matter having a diameter of $\leq$ 2.5 microns and $\leq$ 10 microns, respectively.

(10) WHO Europe (2004).

Figure 2

Air Pollution–Health Pyramid



Source: Health Canada, "Health Effects of Air Pollution," www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/health_effects-effets_sante_e.html.

Thus, while the impact of air pollution on any individual's health may be relatively minor, the fact that it affects a large proportion of the population makes this an important issue in population health. As for the most severe cases, Health Canada estimates that short-term exposure to air pollution contributes to 1,800 premature deaths in the country annually, while an additional 4,200 Canadians die prematurely each year due to the long-term effects of exposure to air pollution.(11)

THE SCIENCE OF AIR POLLUTION AND HEALTH

Understanding of the possible links between air pollution and health has advanced greatly over the past decades. Experts agree that both short- and long-term exposure to air pollution pose significant risks to human health.

The mechanisms by which these health effects occur are being revealed through ongoing research, but understanding is still incomplete. Ozone is known to affect lung functioning in a variety of ways, causing inflammation in the respiratory tract and damage to

(11) S. Judek, *et al.*, "Estimated Number of Excess Deaths in Canada Due to Air Pollution," Air Health Effects Division, Health Canada, and Meteorological Service of Canada, Environment Canada, Gatineau, Quebec, April 2005, http://www.hc-sc.gc.ca/ahc-asc/media/nr-cp/2005/2005_32bk2_e.html.

lung tissue and contributing to reduced inhalation capacity and lung functioning.(12) Particulate matter is also known to cause irritation and inflammation, and researchers have outlined a plausible mechanism linking PM to cardiovascular effects associated with air pollution exposure. PM triggers an inflammatory process in the lungs that has been shown to lead to accelerated atherosclerosis (plaque build-up), which raises the risk for heart attacks and strokes.(13)

Epidemiological studies have produced significant evidence linking elevated daily levels of ground-level ozone, particulate matter and sulphur dioxide to increased rates of hospitalization, respiratory illness and premature deaths in cities across North America and Europe.(14) Recent studies have drawn on large data sets spanning multiple urban areas and many years, providing increasingly convincing evidence of the short-term effects of air pollution on human health.

Likewise, studies have been highlighting the long-term effects of air pollution on human health, particularly since the 1990s. Following on two prominent studies in the previous decade,(15) a 2002 study covering 500,000 people in more than 100 cities for a period of 16 years again confirmed a positive correlation between long-term exposure to fine particulate air pollutants and the risk of lung cancer and cardiopulmonary mortality.(16)

A recent line of research concerns the potential for air pollution to trigger genetic, and therefore heritable, mutations in humans and wildlife. Researchers from McMaster University have published results indicating that exposure to urban and industrial pollution can

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(12) California Environmental Protection Agency, "Recent Research Findings: Health Effects of Particulate Matter and Ozone Air Pollution," Fact Sheet, January 2004, http://www.arb.ca.gov/research/health/fs/pm-03fs.pdf.

(13) S. F. Van Eeden, *et al.*, "Cytokines involved in the systemic inflammatory response induced by exposure to particulate matter air pollutants (PM10)," *American Journal of Respiratory and Critical Care*, Vol. 164, 2001, pp. 826-830; T. Suwa, *et al.*, "Particulate air pollution induces progression of atherosclerosis," *Journal of the American College of Cardiology*, Vol. 39, Issue 6, 2002, pp. 935-942.

(14) See the Selected Bibliography for a list of key studies on air pollution and health.

(15) D. W. Dockery, *et al.*, "An association between air pollution and mortality in six U.S. cities," *New England Journal of Medicine*, Vol. 329, 1993, pp. 1753-1759; C. A. Pope, *et al.*, "Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults," *American Journal of Respiratory Critical Care Medicine*, Vol. 151, 1995, pp. 669-674.

(16) C. A. Pope, *et al.*, "Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution," *Journal of the American Medical Association*, Vol. 287, 2002, pp. 1132-1141.

pose an increased risk of heritable mutations in rodents and birds, identifying particulate matter as a principal factor in the increased mutation rates.(17)

Particulate matter is still being vigorously researched; the focus of investigations has shifted away from whether there is a health impact, to what characteristics of PM determine toxicity and which sources of PM pose the greatest risk to human health.(18) Uncertainties regarding the human health effects of air pollution remain, as do sceptics;(19) however, taken as a whole the scientific evidence on the subject is striking enough to have motivated action by governments around the globe.

REGULATING AIR POLLUTION IN CANADA

A. *Canadian Environmental Protection Act, 1999*

The *Canadian Environmental Protection Act, 1999* (CEPA 1999) is the main federal environmental legislation. Under CEPA 1999, substances may be included on the Toxic Substances List, which allows the federal government to take action to control and reduce them through designated processes. Currently included are PM_{10}, O_3, and PM precursors (SO_2, ammonia (NH_3) gas, nitric oxide (NO), nitrogen dioxide (NO_2) and some VOCs).(20) CEPA 1999 also targets certain sources of air pollutants such as fuels and engine emissions.(21)

Smog reduction is being addressed through the development of Canada-Wide Standards (CWS) for particulate matter and ozone by the Canadian Council of Ministers of the Environment (CCME). CWS are intended to be "achievable targets that will reduce health and

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(17) C. M. Somers, *et al.*, "Reduction of Particulate Air Pollution Lowers the Risk of Heritable Mutations in Mice," *Science*, Vol. 304, No. 5673, 14 May 2004, pp. 1008-1010.

(18) J. Samet and D. Krewski, "Health Effects Associated With Exposure to Ambient Air Pollution: Discussion Paper," Background paper prepared for the 2003 NERAM/AirNet Conference, Rome, Italy, 5-7 November 2003.

(19) A recent debate, for example, was ignited as flaws were discovered in a modelling program commonly used to estimate health effects of particulate air pollution. This flaw tended to exaggerate the extent of negative effects based on given data sets; however, it was subsequently concluded that the underlying results of previous studies were still valid: K. A. Colburn, and P. R .S. Johnson, "Air Pollution Concerns Not Changed by S-PLUS Flaw," *Science*, Vol. 299, 31 January 2003, pp. 665-666.

(20) Environment Canada, "Toxic Substances List – Updated Schedule 1 as of 30 November 2005," www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm (accessed 30 January 2006).

(21) Environment Canada, "CEPA Environmental Registry," 1 February 2006, http://www.ec.gc.ca/CEPARegistry/default.cfm.

environmental risks within a specific timeframe,"[22] and are considered to be Environmental Quality Objectives under CEPA 1999. The process includes submission of implementation plans by signatories to the Canada-Wide Environmental Standards Sub-agreement.[23]

An alternate air quality tool under CEPA 1999, the National Ambient Air Quality Objectives (NAAQO), is used to set "effects-based long-term air quality goals" that may be adopted by jurisdictions at their discretion. While CWS are intended to supplant NAAQOs, several smog precursors do not have CWS and therefore continue to be listed in the NAAQO.[24] Ongoing research provides critical support to development of policy, standards and legislation.

B. Air Quality Index

A key tool in mitigating the human health effects of air pollution is the development of a more effective national Air Quality Index (AQI), which will be specifically health-based. This indicator will provide the public and decision-makers with an understandable measure that explicitly links health effects to air quality conditions, a tool that is not available for other environmental health issues. A pilot project for the health-based AQI was launched in September 2005, and the target date for implementation is spring 2007.[25]

C. International Efforts

Canada is also committed to various regional and international agreements on air pollution. The Canada-U.S. Air Quality Agreement and Ozone Annex is among the most significant, as cross-boundary pollutants contribute to some of the greatest air pollution problems in Canada.[26]

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(22) Health Canada, "Regulations Related to Health and Air Quality," 1 October 2004, www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg_e.html.

(23) The signatories are all the federal, provincial and territorial ministries, except Quebec.

(24) Health Canada (2004).

(25) Meteorological Service of Canada, "Canadian Air Quality Index," 6 September 2002, http://www.msc-smc.ec.gc.ca/CAQI/index_e.cfm.

(26) Environment Canada, "Canada-United States Air Quality Agreement," 14 September 2004, http://www.ec.gc.ca/cleanair-airpur/Pollution_Issues/Transboundary_Air/Canada_-_United_States_Air_Quality_Agreement-WS83930AC3-1_En.htm.

CANADA'S AIR QUALITY IN THE INTERNATIONAL CONTEXT

After decades of investment and research, Canada's record on air quality is mixed. Between 1990 and 2000, emissions of SO_2, NO_x and VOCs decreased 27%, 6% and 15% respectively,(27) but Canada's per capita emissions of VOCs were the highest among OECD countries as of 2003.(28) $PM_{2.5}$ levels have dropped relative to levels in the 1980s, but no significant decrease has occurred since the mid-1990s,(29) while human exposure to ground-level ozone in Canada actually increased 16% between 1990 and 2003.(30) Based on CWS monitoring, Environment Canada estimates that between 2001 and 2003, around half of Canadians lived in areas where O_3 levels were above the three-year standard, and one-third lived in areas where $PM_{2.5}$ or both O_3 and $PM_{2.5}$ were above the three-year standards.(31)

People in the United States also contend with serious regional smog problems, even as key emissions are declining. By 2003, overall emissions of ground-level ozone precursors VOCs and NO_x in the United States had decreased 54% and 25%, respectively, from 1970 levels.(32) Ground-level ozone in the United States has been decreasing since 1980 and was at its lowest level ever in 2003.(33) Likewise, PM_{10} concentrations have decreased an estimated 31% since 1988, and $PM_{2.5}$ concentrations have decreased 10% since 1999.(34)

Standards in the European Union and the United States are tightening as a growing body of scientific evidence suggests that there is no safe level of exposure to O_3 or PM.

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(27) Environment Canada, "Fine Particles and Ozone in Canada: A Canada-wide Standards Perspective, 2003 National Summary," October 2005, http://www.ccme.ca/assets/pdf/2003_pm_oz_ntnlsmryrpt_e.pdf.

(28) T. I. Gunton, *et al.*, "The Maple Leaf in the OECD: Comparing Progress Toward Sustainability," Report prepared for the David Suzuki Foundation by the Sustainable Planning Research Group, School of Research and Environmental Management, Simon Fraser University, Vancouver, 2005, http://www.davidsuzuki.org/files/WOL/OECD-English2-FINAL.pdf.

(29) Treasury Board of Canada, *Canada's Performance 2004: Annual Report to Parliament*, 2004, pp. 114-115, http://www.tbs-sct.gc.ca/report/govrev/04/dwnld/cp-rc_e.pdf.

(30) Statistics Canada, "Canadian Environmental Sustainability Indicators, 2005," *The Daily*, 14 December 2005.

(31) Environment Canada (2005). The three-year standards in question are determined based on "the 3-year average of the annual 98th percentile of the daily 24-hour average concentrations for $PM_{2.5}$, and the 3-year average of the annual 4th highest of the daily maximum 8-hour average concentrations for ozone" (Environment Canada (2005), p. i).

(32) EPA, *The Ozone Report – Measuring Progress through 2003*, April 2004, http://www.epa.gov/airtrends/aqtrnd04/ozone.html.

(33) *Ibid.*

(34) EPA, *The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003*, December 2004, http://www.epa.gov/airtrends/aqtrnd04/pm.html.

Current standards or guidelines are listed in Table 2 below, with proposed changes in parentheses. The United States recently proposed to lower target levels of PM,[35] while the WHO released new guidelines for air pollutants in 2005, recommending lower levels for O_3 and numerical targets for PM.[36] In Canada, air quality and the related science were reviewed for 2005, and the CWS will be reviewed by 2010.

Table 2
Air Quality Standards for Canada,[37] the United States,[38] and the European Union[39]

	Canada	United States	European Union*
Ozone, ppb			
• over an 8-hour period	--	--	51
• over a 24-hour period	60	80	--
$PM_{2.5}$, µg/m^3			
• over a 24-hour period	30	65 (35)	25
• annual	--	15	10
PM_{10}, µg/m^3			
• over a 24-hour period	--	150 ($PM_{2.5-10}$: 70)	50
• annual	--	50	20

* Note that for the EU, these are guidelines recommended by the WHO Regional Office for Europe; however, individual countries decide on individual standards and timelines, and air quality concerns differ greatly by region.

SETTING A VALUE ON AIR POLLUTION REDUCTION

In Canada, responsibility for addressing air pollution and its human health effects is shared between Health Canada and Environment Canada, and with provincial, territorial, regional and municipal governments, in cooperation with other stakeholders.[40]

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(35) EPA, *National Ambient Air Quality Standards for Particulate Matter*, http://www.epa.gov/air/particles/pdfs/rule20051220standards.pdf (accessed 20 December 2005).

(36) WHO Europe, "WHO Air Quality Guidelines Global Update 2005," Report on a working group meeting, Bonn, Germany, 18-20 October 2005, http://www.euro.who.int/Document/E87950.pdf.

(37) CCME, "Canada-Wide Standards for Particulate Matter (PM) and Ozone," endorsed by CCME, Quebec City, 5-6 June 2000.

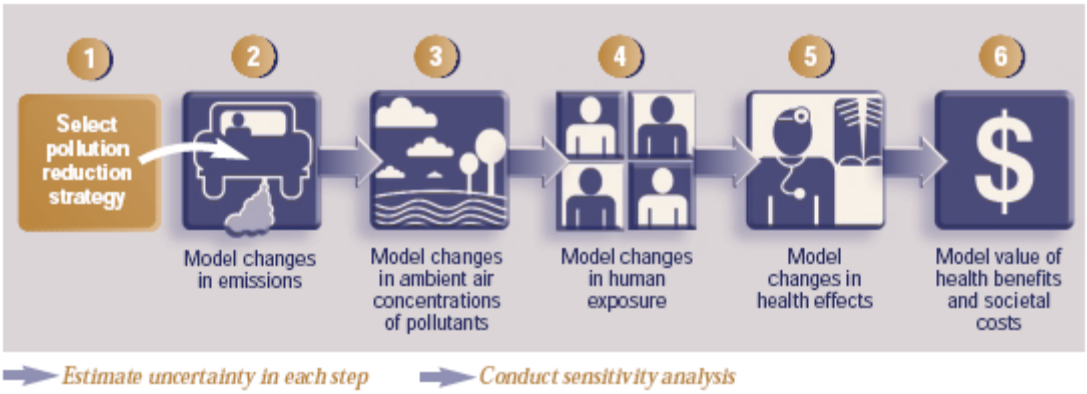
(38) EPA, "National Ambient Air Quality Standards (NAAQS)," http://www.epa.gov/air/criteria.html (accessed 20 December 2005).

(39) WHO Europe (2005).

(40) For further information, see: Health Canada Web sites, *Environmental & Workplace Health*, http://www.hc-sc.gc.ca/ewh-semt/index_e.html, and *Science & Research*, http://www.hc-sc.gc.ca/sr-sr/index_e.html (accessed 13 January 2006); and Environment Canada Web site, *Clean Air Online*, http://www.ec.gc.ca/cleanair-airpur/Home-WS8C3F7D55-0_En.htm (accessed 17 January 2006).

Air pollution policy development is a risk-management exercise that aims to balance health or environmental concerns with social values, economics and technology options. The general process is described in Figure 3.

Figure 3
Evaluation Process for Air Pollution and Health Policy Development



Source: B. Jessiman, R. Burnett, and P. de Civita, "Sulphur in Gasoline and Other Fuels: The case for action (and inaction)," in Health Canada, *Health Policy Research Bulletin*, No. 4, Ottawa, October 2002.

Each of the steps above is a complex modelling process that involves its own assumptions and degree of uncertainty. One problematic dimension is assigning monetary value to components such as health outcomes. What is the value of one more year of life? Of one day without an asthma attack? Moreover, "in a decision-making process, often what cannot be counted gets valued at zero and is therefore more likely to be omitted from the policy-setting process."(41)

Whenever possible, it is also important to try to incorporate coincidental environmental, agricultural and economic benefits and synergies with other policies when reviewing a given strategy. This was the case in developing regulations under CEPA 1999 on sulphur in gasoline, and was a key factor in reducing concentrations to levels comparable with standards in California and Japan and those proposed for the European Union and the United States.(42)

(41) CCME, "Economic Analysis: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone," June 2003, http://www.ccme.ca/assets/pdf/scrvw_execsmry_pm_oz_ecnmc_anlsis_e.pdf.

(42) B. Jessiman, R. Burnett, and P. de Civita, "Sulphur in Gasoline and Other Fuels: The case for action (and inaction)," in Health Canada, *Health Policy Research Bulletin*, No. 4, Ottawa, October 2002, pp. 19-22.

In 1999, the U.S. Environmental Protection Agency released an extensive study which estimated that by 2010, the economic value of the health and ecological benefits deriving from its 1990 Clean Air Act (CAA) amendments would approach US$110 billion, while the costs of these improvements would be approximately US$27 billion over the 20-year period.(43) More specifically, a 1995 study estimated that the targeted 40% reduction in SO_2 under the CAA would generate annual health benefits for the eastern United States and Canada of $12-80 billion (in 1994 US$).(44)

Similarly, the estimated health benefits of the sulphur in gasoline regulations in Canada were estimated to be over $6 billion for a 20-year period, while the costs (borne by industry) would be less than $3 billion over the same 20 years. Despite expressing initial concerns that this would necessarily result in plant closures, industry representatives have since indicated that there are no technological or economic impediments to achieving the standard, and no closures are expected.(45)

Recent studies by the Ontario Medical Association (OMA) and the Ontario government have attempted to assign a monetary value to the health, economic, agricultural and environmental impacts of air pollution in that province. For 2005, the OMA estimated direct health care costs at $506 million,(46) and indirect health costs (pain, suffering and loss of life) at almost $7 billion.(47) The Ontario Ministry of Environment looked at total health, environmental and associated industry costs of air pollution, estimated at $9.6 billion for 2005.(48) It also outlined the magnitude of the transboundary air pollution problem for the province, using

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(43) U.S. Environmental Protection Agency, News Release, "New report shows benefits of 1990 Clean Air Amendments outweigh costs by four-to-one margin," 16 November 1999, www.epa.gov/air/sect812/r-140.html.

(44) L. G. Chestnut, "Human Health Benefits from Sulfate Reductions under Title IV of the 1990 Clean Air Act Amendments," prepared for U.S. Environmental Protection Agency, Office of Air and Radiation, Washington, D.C., 1995.

(45) Jessiman, Burnett, and de Civita (2002).

(46) For comparison, Ontario's interim health and long-term care budget for 2004-2005 was $31 billion; see Ontario Ministry of Finance, *2005 Ontario Budget: Budget Paper A*, Toronto, May 2005, http://www.fin.gov.on.ca/english/budget/bud05/pdf/papera.pdf.

(47) Ontario Medical Association, "Illness Costs of Air Pollution (ICAP) 2005," www.oma.org/Health/Smog/report/icap05a.asp.

(48) David Yap, *et al.*, *Transboundary Air Pollution in Ontario*, Publication 5158e, Ontario Ministry of Environment, June 2005, http://www.ene.gov.on.ca/envision/techdocs/5158e_index.htm (accessed 16 June 2005).

30 years of data to estimate that 55% ($5.2 billion) of these costs were due to air pollution originating in the United States. This study was used to support the province's formal objections to proposed U.S. legislative changes that the Ontario government believes would relax controls on pollution emanating from coal-fired power plants located in the United States.(49)

CONCLUSION: AIR POLLUTION AND POPULATION HEALTH PERSPECTIVES

In the broader picture, air pollution reduction policies reflect environmental and population health concerns for Canadians. Any proposals to proceed further with implementing a population health approach that recognizes multiple determinants of health raise many important questions, such as:

- What priority should be placed on prevention, relative to treatment?
- At what point is evidence sufficient to act decisively to protect health?
- How important are well-functioning environmental processes for human health and well-being?
- How do social, economic, biological and environmental forces contribute to the overall health of Canadians?
- What does sustainable development imply for the health system in Canada?
- How do we value policies that have coincidental social, health, environmental or economic impacts, either positive or negative?

As explained by leading Canadian experts on air pollution and population health, there are many combinations of stresses that affect human health, the health of other organisms, and ecosystem functioning. Thus, if an air pollution reduction policy is cost-effective before considering these wider interrelated impacts, it is likely to be even more beneficial in a broader analysis.(50) Air pollution reduction policy must be part of a strategy that also addresses other determinants of health, most notably socio-economic status, in order to see the true benefits promised by a population health approach.

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(49) Robert Benzie, "Ontario Protests U.S. Pollution; Minister Opposes Plan to Relax Coal Plant Controls," *Toronto Star*, 18 February 2006.

(50) R. T. Burnett, *et al.*, "Population Health Issues in the Management of Air Quality," *Ecosystem Health*, Vol. 6, No. 1, 2000, pp. 68-78.

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B. Governmental Internet Resources

Environment Canada, *Clean Air Online*: http://www.ec.gc.ca/cleanair-airpur/.

Health Canada, *Environmental & Workplace Health*: http://www.hc-sc.gc.ca/ewh-semt/index_e.html.

Public Health Agency of Canada, *Population Health Approach*: http://www.phac-aspc.gc.ca/ph-sp/phdd/index.html.

United States Environmental Protection Agency, Office of Air and Radiation: http://www.epa.gov/oar/.

World Health Organization, Regional Office for Europe: http://www.euro.who.int/air.