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Air pollution policy in Canada

Improving on success

Ross McKitrick

Executive summary

Air quality in Canada has substantially improved since the 1970s and at least some of this improvement can be attributed to the detailed, extensive system of legislation currently in place to control air pollution. New initiatives in air pollution legislation, including the proposed *Clean Air Act*, should take into account the fact that air quality is already regulated and that pollution has already been substantially reduced. This chapter describes the evolution of Canadian air quality since the early 1970s and discusses the scientific question of whether current air pollution levels are a threat to human health. It then describes the existing structure of Canadian air-pollution policy, including the new focus on ultrafine particles and the introduction of Air Quality Indexes. I conclude by outlining some general principles that should guide policy-makers for developing future air-pollution legislation. I argue that policy-makers should begin by focusing on giving people access to objective, accurate, and up-to-date information on pollution levels and trends, as well as helping them to understand the existing structure of air-pollution regulations that affect their regions. I also argue for flexible, locally-tailored initiatives that give people more direct say in the level of environmental quality they enjoy, and for more exploration of the use of emission-pricing instruments.

Chapter 2

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False perceptions of air pollution

In the 1970s, people worried about inflation, which was often over 10% per year. We don't worry about it today, at least not very much, because inflation has fallen to low levels. Most types of air pollution are also much lower than they were in the 1970s (see figures 1–5 for some examples). But unlike inflation, people worry more about it now than they did back then.

Why the difference? Perhaps, it is because people are well informed about inflation. They notice when prices are going up, especially when their wages don't keep up. And the government regularly releases summary data about inflation, especially the Consumer Price Index, which is prominently published in an easily accessible form, so peoples' local experience of rising prices is mirrored in national-level statistics. As inflation fell in the early 1990s, people saw the official numbers dropping and it concurred with their own experience of stabilizing prices. Concern about inflation fell accordingly.

In the case of air pollution, people do not perceive it directly. People certainly notice extreme smog episodes but, on an annual basis, they are relatively rare occurrences—we expect to have a few each summer, lasting

1 I would like to thank four anonymous reviewers whose input greatly improved the final version of this chapter.

about a week each time. Otherwise, ordinary air pollution is not noticed. Do you know the level of suspended particulate matter, in micrograms per cubic metre, in the outdoor air in your city today? Do you know the concentration of sulphur dioxide (SO_2) or carbon monoxide (CO) in parts per million? Could you guess it to within plus or minus 100%? Not likely. Measuring such things requires highly specialized equipment. People would not directly perceive a change up or down, even a doubling or halving of typical daily concentrations.

For example: which city had higher monthly average SO_2 levels in 2002, Calgary or Ottawa? Answer: Ottawa, as it turns out. But, if you happened to make the trip from Ottawa to Calgary that year, did you stop and think how nice it was that the monthly average concentration of SO_2 was about one part per billion lower? Of course not. And if you were living in Calgary, did you experience more SO_2 in 1990 or 2002? Answer: 1990, by a small margin. But again, it is unlikely anybody noticed the change.

We could ask the same questions about other conventional air contaminants, like volatile organic compounds (VOC), ozone (O_3), total suspended particulates (TSP) or nitrogen oxides (NO_x). By and large, people have little or no idea what the current levels of air pollution are, how they compare across cities, whether they are higher this year than last year, and what the long-term trends are.

Without this kind of information, people are susceptible to unsubstantiated claims that air pollution is getting worse and worse or that we face a "crisis" over air quality. In light of the newly proposed federal *Clean Air Act*, Canadians are debating major new proposals for air-pollution policy in an information vacuum, making decisions on the basis of little more than slogans and propaganda. Yet Canada has an excellent system for monitoring air contaminant levels and the data are available via the Internet. Unfortunately, the data are published in an unprocessed form that makes it effectively inaccessible to most people. So this chapter starts by reviewing some broad trends in Canadian air pollution. If we are going to have a meaningful discussion about what kinds of policies ought to be pursued regarding air pollution, it has to start with an understanding of the facts of air pollution. This certainly includes the types, levels, and trends in air pollution but it is also necessary to dispense with some unfounded alarmist rhetoric about the health consequences of contemporary ambient levels of pollution. I will also explain some of the current policy mechanisms in place and the problem of using Air Quality Indexes to assess today's pollution levels. I conclude with some suggestions to guide those making policies to improve air quality in Canada.

Common air contaminants in Canada since 1974

Canada has measured air pollution levels in a widespread, systematic way since 1974. A large compilation of data is available at the Environment Canada "NAPS" web site of the National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>. Some provincial governments have more extensive data collections because they monitor in more locations than are included in the NAPS system. Ontario, for instance, has data for some monitoring sites going back to the early 1960s. Ontario publishes an annual report on air quality that makes use of NAPS and other monitoring data. The most recent edition, *Air Quality in Ontario: 2004 Report* (Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch, 2006) is an informative document of very high quality.

NAPS data are posted in large files in ASCII format showing the hourly readings of common air contaminants by station ID. If you have the time and programming skills, you might be able to find information about long-term air-quality trends in your city, but few people are likely to do so. The Fraser Institute published a compilation that makes the information more easily accessible (Brown et al., 2005). In this chapter, we are reproducing some trend graphs produced for The Fraser Institute in late 2004, using data up to the end of 2002 (where available), which was, at the time, the most up to date.

The following are the common types of air pollutants (also referred to as "criterion air contaminants") that have been systematically monitored since the 1970s: sulphur dioxide (SO_2); carbon monoxide (CO); particulate matter (PM); ground-level ozone (O_3); nitrogen oxides (NO_x); volatile organic compounds (VOC). Particulate matter smaller than 35 micrometers in diameter are called total suspended particulates (TSP). The TSP category is further broken down by particle size: PM_{10} refers to fine particles, smaller than 10 microns diameter; $PM_{2.5}$ refers to ultra-fine particles, smaller than 2.5 microns in size.

SO_2 was a focus of concern in the 1970s and 1980s, chiefly because of acid rain. When SO_2 mixes with oxidants and moisture in the atmosphere, it can make the rain acidic and this was flagged as a cause of stress on ecosystems through acidification of lakes and soils. Carbon monoxide is toxic to humans at high levels, and possibly has milder toxicity at low levels. O_3 is a lung irritant and, at high levels, makes breathing uncomfortable. It is not directly emitted to the atmosphere; instead it is formed as a result of a chemical reaction between NO_x and VOC under intense sunlight. NO_x, consisting of nitric oxide (NO) and nitrogen dioxide (NO_2), can be a lung irritant on its own at high-enough levels and is visible as the brown haze sometimes seen on summer days. VOC is a term that describes a long list of reactive gases, some of which are natural in origin and some of which result from personal and industrial emissions.

Canada has established National Ambient Air Quality Objectives (NAAQO) that prescribe standards for daily and annual exposure. The current standards are listed in Table 1.

Figures 1a–d and 2a–d (pp. 26 ff.) show trends in average monthly levels of SO_2 and TSP in Vancouver, Calgary, Toronto, and Montreal from 1974 to 2002 (except where data are unavailable after the late 1990s). Figures 3a–d, 4a–d, and 5a–d (pp. 30 ff.) show the comparable time series for CO, NO_2, and O_3. Comparable patterns are found in other large and mid-sized cities in Canada.[2] From these graphs, and the larger data sets from which they are drawn, we can draw several conclusions.

2 Canada-wide averages up to 1996 are shown on Environment Canada's website at <http://www.ec.gc.ca/soer-ree/English/Indicators/Issues/Urb_Air/Tech_Sup/uasup5_e.cfm>.

Table 1: Canadian National Ambient Air Quality Objectives (NAAQOs)

	Averaging time	Maximum desirable concentration	Maximum acceptable concentration	Maximum tolerable concentration
Sulfur dioxide (SO_2)				
	annual	11 ppb	23 ppb	—
	24-hour	57 ppb	115 ppb	306 ppb
	1-hour	172 ppb	344 ppb	—
Total suspended particulates (TSP)				
	annual	60 μg/m^3	70 μg/m^3	—
	24-hour	—	120 μg/m^3	400 μg/m^3
Ozone (O_3)				
	1-hour	50 ppb	82 ppb	153 ppb
Carbon monoxide (CO)				
	8-hour	5 ppm	13 ppm	17 ppm
	1-hour	13 ppm	31 ppm	—
Nitrogen dioxide (NO_2)				
	annual	32 ppb	53 ppb	—
	24-hour	—	106 ppb	160 ppb
	1-hour	—	213 ppb	532 ppb

Source: Environment Canada, 2005: table 9.

Sulphur dioxide (SO_2)

Monthly average levels of sulphur dioxide (SO_2) have fallen quite a bit since the 1970s. They were never a problem in cities on the Prairies. In eastern cities, including Toronto, Montreal, Ottawa, Hamilton, Windsor, Halifax, and London, monthly average levels frequently exceeded 20 or 30 parts per billion (ppb) up to the late 1970s but today levels are typically below 10 ppb, and the ordinary average is now about 5 ppb. The annual average desirable standard is 11 ppb and the maximum acceptable standard is 23 ppb.

Total suspended particulates (TSP)

Monthly average levels of Total Suspended Particulate (TSP) in Canadian cities were, on average, well over 120 micrograms per cubic metre (μg/m^3) in the 1970s. The annual average desirable standard is 60 μg/m^3 and the maximum acceptable standard is 70 μg/m^3. Since then, monthly average TSP levels have fallen in many places to near or below 60 μg/m^3. Vancouver has successfully achieved monthly average levels of 10 to 30 μg/m^3; Toronto and Montreal are slightly higher, usually having levels around 30 to 60 μg/m^3. (Note that there is a gap in records for Toronto from 1995 to 1998.) Saskatoon, Regina, Winnipeg, and Ottawa are similar to Toronto and Montreal. Calgary, Edmonton, Hamilton, and Windsor continue to have TSP levels between 50 and 100 μg/m^3. Halifax has always (back to 1974) had TSP readings below 50 μg/m^3, and currently they are below 30 μg/m^3.

Carbon Monoxide (CO)

In all Canadian cities, monthly average levels of carbon monoxide (CO) have been steady in recent decades at about 1 part per million (ppm). In some cities, the CO levels briefly rose in the 1970s to nearly 2 ppm but have been at or below 1 ppm for two decades or more. Environment Canada's 8-hour desirable standard is 5 ppm and the maximum acceptable standard is 13 ppm (there is no monthly or annual average standard).

Nitrogen dioxide (NO_2)

Environment Canada's annual average desirable standard for nitrogen dioxide (NO_2) is 32 ppb and the maximum acceptable level is 53 ppb. Most Canadian cities exceeded this standard for some months of the year up to the late 1980s, but since the mid-1990s they have monthly average levels between 20 and 30 ppb. Edmonton has a slight tendency to exceed the 32 ppb level in some months but during most of the year it too has levels at or below 30 ppb. Other than that, Canadian cities keep their monthly average NO_2 levels below 30 ppb.

Ozone (O_2)

All Canadian cities exhibit seasonal ozone patterns with monthly averages varying between 10 and 40 parts per billion (ppb). There has been little or no trend in ozone levels since the 1970s, with some evidence of an upward trend after 1990 in some cities. The Canada-wide desirable annual standard is 65 ppb. Compliance is determined by taking the 8-hour daily average for every day of the year, selecting the fourth-worst day of the year and averaging it with the same measure taken for the two previous years. If this average is less than 65 ppb, the city is said to have met the Canada-wide standard. All provinces except Quebec have agreed to meet this standard (Canadian Council of Ministers of the Environment, 2000: last, supernumerary, page). Since ozone episodes can involve spikes that last for four to eight days, the standard as currently written effectively requires a city not to have any summertime ozone episodes. It can be safely predicted that this standard will be very difficult to meet. In Ontario, the standard was violated at almost all monitoring locations over the 2002-to-2004 averaging interval, even though monthly averages are below 40 ppb (Ontario Ministry of the Environment, 2006).

Successes

We can say the following, in general, about Canadian urban air pollution.

- Carbon monoxide levels are not a problem.

- Sulphur dioxide levels were a problem in many areas in the 1970s and 1980s, but have been successfully controlled to the point that they are now well within the acceptable levels.

- Suspended particulates have been reduced to just below the acceptable level in most cities, though progress seems to have stalled since the 1980s.

- NO_2 levels are mostly at acceptable levels and have not changed much since the 1970s. The slight improvement has taken the form of eliminating the episodes of unacceptably high NO_2 levels but there has been no strong downward trend in average levels.

- Ozone levels have not gone down. Episodes of high ozone levels still occur, mainly in the summer, though the average annual levels in Canadian cities are low compared to the national standards.

- Atmospheric lead levels (not shown in the figures) fell dramatically in the late 1980s in response to the federal decision to ban lead in gasoline and paint. Since 1990, levels of lead in urban areas have been effectively zero in Canadian cities.

It is noteworthy that the type of air pollution that has been most resistant to change is ozone, which is not directly emitted by human activity. The process by which ozone is formed involves air pollution emissions but also depends on complex local atmospheric conditions. Ozone formation requires intense sunlight, a stable atmospheric boundary layer, and the right mix of precursor gases. Consequently, it is mainly associated with summertime conditions and high levels do not last more than a few days. For most of the year in Canada, ozone is not a problem. Reducing the summertime ozone spikes is very challenging since reductions in emissions of precursor gases do not guarantee reductions in current ground-level ozone concentrations.

Challenges

The overall picture we can take away from figures 1–5 is one of success at addressing some key challenges. Most cities, most months, have air quality that meets or exceeds Environment Canada's quality guidelines. The challenges that now confront us have the following features.

Different cities face different challenges

Calgary and Edmonton, for example, do not have problems with SO_2 but particulate levels are still a concern. Halifax has problems with neither. Hence, attempts to impose one-size-fits-all policies across the country will invariably misdirect resources for further air quality improvements.

Air-quality guidelines

Having met existing air-quality guidelines, we need to ask whether the guidelines themselves remain satisfactory or need to be revised further. As will be discussed below, while there is weak evidence of a statistical correlation between ambient air pollution and some health indicators, recent re-analyses and controlled laboratory experiments have provided persuasive evidence that today's air-quality standards do not need to be tightened.

Ground-level ozone

It is unlikely that major improvements in ground-level ozone can be achieved in the near future. This is not to say that improvements are impossible but, since ozone concentrations have been largely unresponsive to policies up to now, the difficulty in finding a "silver bullet" should not be underestimated. At present, the Canada-wide standards developed in June 2000 specifically required provinces to determine natural background levels of PM and ozone, so that they would not find themselves being held to standards that were cleaner than unpolluted air.

Air pollution and health

Toronto Public Health (Basrur, 2000) has claimed that thousands of people die of air pollution each year, a sound bite that was repeated by the federal Conservative government when launching their new *Clean Air Act*. If it is true, let's see the list of names, so the courts can certify a class action lawsuit on behalf of their survivors. But there is no list. These are not actual bodies; they are numbers generated by a computer. The computer model consists of a linear formula that takes current average levels of air pollution, multiplies them by some coefficients drawn from an unbalanced and uncritical survey of some epidemiological research, and yields a number that is supposed to tell us the fraction of actual deaths each year attributable to air pollution. It almost sounds plausible until you try entering the Toronto pollution levels from the mid-1960s. The model attributes about half the observed deaths from that period to air pollution and predicts more deaths in February 1965 due to air pollution than there were deaths from all causes (McKitrick, 2004). This is, to say the least, implausible.

The claim that ozone is killing Canadians was seriously challenged several years ago when British researchers Koop and Tole (2004) published a detailed statistical evaluation of air pollution and mortality in Toronto. Using the state-of-the-art Bayesian Model Averaging technique, they evaluated over 567 trillion model specifications and concluded that the data do not provide robust support for a correlation between ground-level ozone and mortality. They noted that some statistical specifications could appear to yield a positive relationship between air quality and premature death rates, but the models that fit the data best only attribute mortality effects to the weather variables. When they looked for possible interaction effects (that is, maybe pollution only matters in hot weather), they found nothing but a table "composed of zeroes (to three decimal places)" (Koop and Tole, 2004: 42).

This is not the first time that detailed re-analysis has overturned an apparent statistical correlation between pollution and mortality. In a widely-cited pair of studies, Schwartz (1993, 1994) examined data from Birmingham, Alabama, and concluded that a link exists between particulate matter and both hospital admissions and excess mortality. Smith et al. (2000) replicated these results on a new version of the Birmingham data but then showed they are not robust to minor changes in the statistical (regression) model. In other words, slight variations in the assumptions behind the analysis cause the result to disappear, which is an indicator that the underlying effect is not truly present in the data. Clyde (2000) also re-analyzed the data from Birmingham using Bayesian Model Averaging and found that Schwartz's method overstated the relative risk estimates and under-estimated the uncertainty. Upon re-analysis the results disappeared.

Dominici et al. (2002) estimated correlations between exposure to PM_{10} and risk of mortality in 88 American cities. While the nationally pooled results seemed to show a small positive effect, in all but seven cities the city-specific relative risk coefficients were insignificant and in 20 of the 88 cities the effect was negative: increased particulate pollution is associated with *reduced* mortality risk. The difficulty of identifying risks at low levels of air pollution also make it difficult to identify if there is a "safe lower limit" for air pollution, below which health concerns can be definitely ruled out. Epidemiological studies have not identified such a level but nonetheless there is evidence that contemporary urban air is not hazardous.

In 2000, the British government's Committee on the Medical Effects of Air Pollution (COMEAP) was asked to review claims that air pollution is a health hazard. After examining both epidemiological and clinical evidence they concluded that "[f]or the most part, people will not notice or suffer from any serious or lasting ill effects from levels of pollution that are commonly experienced in the UK, even when levels are described as 'high' or 'very high' according to the current criteria" (COMEAP, 2000: §3.1). Earlier, COMEAP issued a report on whether air pollution is a causal factor behind rising asthma incidence. They concluded:

> As regards the initiation of asthma, most of the available evidence does not support a causative role for outdoor air pollution. (This excludes possible effects of biological pollutants such as pollen and fungal spores.) … As regards worsening of symptoms or provocation of asthmatic attacks, most asthmatic patients should be unaffected by exposure to such levels of non-biological air pollutants as commonly occur in the UK. A small proportion of patients may experience clinically significant effects which may require an increase in medication or attention by a doctor. … Factors other than air pollution are

> influential with regard to the initiation and provocation of asthma and are much more important than air pollution in both respects … Asthma has increased in the UK over the past thirty years but this is unlikely to be the result of changes in air pollution. (COMEAP, 1995: §§1.16–1.19)

No clinical support for epidemiological findings

One reason that scientists have been reluctant to attribute health effects to air pollution is that experimental clinical studies do not provide a causal explanation for the correlation observed in some epidemiological findings. As Green et al. report (2002: 328), the implied risk-factor coefficients commonly used in epidemiological models to tie mortality to air pollution imply that ambient concentrations of sulphate aerosols are 1.7 times more carcinogenic than emissions from coke ovens, to which they add, rhetorically, "How plausible is that?" The 1999 Health Canada Science Assessment of then-proposed National Ambient Air Quality Objectives for particulate matter concluded:

> Despite the fact that the ranges of particle concentrations [in laboratory experiments] usually exceed those experienced by the general population, little evidence for a dose–response relationship has been documented in the clinical toxicological literature … Overall, the clinical data does not lend much support to the observations seen in the epidemiology studies, particularly to the observations that high ambient particulate concentrations are associated with mortality within hours or a few days at most. (CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, 1998: 14)

An updated assessment in 2004 (CCME, 2004) offered only cautious support for the small effects in epidemiological studies and also reported on a significant error discovered in a widely used statistical algorithm that added an upward bias to many of those published risk estimates. It restated the conflict between epidemiological and experimental results without resolution. Likewise, an updated review by COMEAP is underway in 2006, and a preliminary statement indicates that they are prepared, on prudential grounds, to view the epidemiological findings as indicative of causality. However, their updated review is focused on new epidemiological findings and does not refute the earlier clinical findings. They express caution about the ongoing uncertainty (COMEAP, 2006).

Current Canadian policy on air pollution

In discussing a policy on air pollution that fits the Canadian situation, it would be a mistake to think that we are starting in a vacuum. Canada already has a detailed regulatory system for managing air quality. While factors other than regulation (such as technological innovation, energy-efficiency gain, etc.; see McKitrick, 2006) may explain some of the post-1970 improvement in Canadian and American air quality, it is important to note that our assessment of current Canadian environmental policy starts from the observation that it is not obviously "broken" or in need of major overhaul.

Industrial air pollution

Provincial governments across Canada regulate industrial air pollution primarily through the issuing of approvals to firms that will be emitting to the atmosphere. The process of obtaining a Certificate of Approval (CoA) involves inspection of individual facilities and review of the specific equipment.[3] The standards applied under a CoA may include a combination of some technical requirements on the equipment, some prohibitions on emissions, and—principally—guidelines about allowable effects on the ground-level air at the "point of impingement" (POI), that is, the maximum estimated concentration at ground level where the contaminant leaves the site on which it is generated, or at another suitably defined external location. In Ontario's POI guidelines, there are 344 compounds listed, each with one or more standards associated with them (Ontario, Ministry of the Environment, Standards Development Branch, 2005). The standards take the form of acceptable concentrations at the point of impingement over different averaging times.

Some direct emission controls have been enacted for large point-source emitters. In Ontario, for example, the *Environmental Protection Act*, Regulation 194/05, lists a few large sources of SO_x and NO_x and their specific emission limits (Ontario, 2005). The Imperial Oil refinery at Sarnia is allowed to release 23,938 tonnes of SO_2 per year in 2006 and 2007 but must reduce those emissions to 9,200 by 2009 and thereafter. The same facility is allowed 3,164 tonnes of NO_x emissions, which must be reduced to 2,660 by 2009.

3 See, for examples, the following web sites: Alberta Environment, 2004; British Columbia, Ministry of Environment, 2005; Ontario, Ministry of Environment, 2006; Québec, Développement durable, Environnement et Parcs, 2002;

Tradable permits for SO_x and NO_x emissions

Regulation 194/05 also implements a system of tradable permits for SO_x and NO_x emissions in Ontario.[4] The system initially covered all generating plants with more than 25 Megawatts (MW) of installed capacity, or which generate more than 200,000 MW hours for sale in Ontario, and who emit NO_x and SO_x. It has since been expanded to cover all firms that sell electricity to the Ontario power grid. Firms that have been assigned emission limits are allowed to trade those limits among themselves and can bank their credits for use in future years. Credits are assigned based on a firm's share of electricity generation in the previous year. Allowing firms to trade their emission allowances rewards firms that exceed their emissions abatement targets, since they can sell their unused allowances and make money. It also helps firms that are finding it more costly than expected to meet their targets, since they can purchase allowances from other firms. Firms outside Ontario (limited to certain northeastern US states) can generate Emission Reduction Credits for sale to Ontario firms if they can show that they undertook emission reductions that would have a demonstrable benefit for Ontario's air quality. Overall, the targeted amount of pollution reduction is achieved at lower cost than under the old "command-and-control" system. Allowance trading does not set aside the POI requirements under each firm's Certificate of Approval.

Compulsory emission controls

The current structure of provincial air pollution law can give the impression that Canada does not have compulsory emission controls. In October 2006, when the federal Conservative government published a Notice of Intent to Regulate along with their proposed Canada Clean Air Act they stated, "Canada has historically relied on a variety of non-compulsory measures to reduce air emissions. However, these have not proved sufficient to reduce the health and environmental risks across the country" (CEPA Environmental Registry, 2006).

This is obviously untrue. The environmental risks associated with air pollution have, as noted above, been substantially reduced over the past 30 years. Emission caps and ambient air-quality standards do exist, as do emission controls on hundreds of compounds of concern. The certification process introduces considerable flexibility into the system for controlling air pollution, as it should, but the effectiveness of the outcome is obvious in the data.

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4 For more details, see Ontario, Ministry of Environment (no date), <http://www.ene.gov.on.ca/envision/env_reg/er/documents/2001/RA01E0020-C.pdf>.

Perhaps the reason so many people are confused on this point is that there is no one large, omnibus legislation that imposes a blanket emissions cap on all businesses. Instead, firms face regulations that are tailored to their specific operations. The basic principle, uniformly applied, is that, when the contaminant leaves the site it has to be diluted to the point where it is not a source of nuisance or injury to neighbours. Exceptions to this rule are associated with the high-profile, large-scale, firms like Inco in Sudbury, petrochemical operations in Sarnia, and power-generating stations at Lambton and Nanticoke, which are subject to further, specific regulations.

Motor vehicles

Canada has effectively followed the US federal motor-vehicle emission standards since they were first enacted in the 1960s. This is sensible since the Canadian motor-vehicle market is closely integrated with that in the United States and there is no need to redo all the research that lies behind the US federal regulatory system. The US regulations set limits for new vehicles in grams or pollution emitted per mile traveled.[5] There are three classes of regulation, covering Volatile Organic Compounds (VOC), Carbon Monoxide and NO_x (as of 1982, PM_{10} was also covered). Within each category, there are standards for both cars and light trucks (SUVs and pick-ups). Table 2 shows that the standards have become progressively more stringent since 1966. Each standard is scaled so it equals 100.0 in 1966. The actual 1966 values were 8 to 10 grams/mile for VOCs, 4 grams/mile for NO_x and 80 to 102 grams/mile for CO, where the range covers the car/light truck categories.

It is clear that new cars today are much cleaner than they were in the 1960s. New automobiles produce less than 5% of the CO emissions per mile than those on the road in 1966, and less than 2% of the NO_x. As for VOCs, a smog pre-cursor, a new car in 2006 would have to be driven for over 150 miles to produce the same quantity of VOC emissions as a new car did in one mile in 1966. PM_{10} levels have also fallen since 1982. For both new cars and new light trucks, the allowable emissions in grams per mile were cut by 87% between 1982 and 2007. The improvements also extend beyond new cars: market-driven quality improvements mean that new vehicle-emission characteristics last longer through the car's life cycle than was the case in the 1970s.

Early versions of these standards were applied in Canada in 1971 through the Motor Vehicle Safety Act. As standards in the United States tightened,

5 These are listed at United States, Department of Transportation, Federal Highway Administration, 2006, <http://www.fhwa.dot.gov/environment/aqfactbk/page14.htm>.

Table 2: Tightening motor-vehicle emission standards in the United States since 1966

	VOC		NO_x		CO	
	Autos	Light Trucks	Autos	Light Trucks	Autos	Light Trucks
1966	100.00	100.00	100.00	100.00	100.00	
1971	38.68	100.00	100.00	100.00	42.50	100.00
1981	3.87	21.25	24.39	63.89	4.25	17.65
2001	2.36	4.00	9.76	11.11	4.25	3.33
2006	0.66	0.88	1.71	1.94	4.25	3.33
2007	0.66	0.88	1.71	1.94	4.25	3.33

Note: Standards are scaled to start at 100; for actual quantities, see text.

Source: Ontario, Ministry of Environment (no date), <http://www.ene.gov.on.ca/envision/env_reg/er/documents/2001/RA01E0020-C.pdf>.

the federal government brought Canadian motor-vehicle manufacturers into compliance using voluntary agreements, or Memorandums of Understanding. Since the United States is such a large motor-vehicle market and automobile manufacturing is integrated across the border, Canada has harmonized engine and emission standards to those in the United States. This regulation was transferred in 1999 to the (federal) Canadian Environmental Protection Act (CEPA). CEPA prescribes a fleet average NO_x standard that is slightly tighter than the 2004 US standard but not as tight as the Tier II standards being phased in (Canada Gazette, 2003). CEPA also allows firms that go beyond the required standards in one model year to count that as a credit towards its fleet average in a subsequent year.

British Columbia and Ontario have enacted motor-vehicle Inspection and Maintenance (I/M) programs. These require an inspection of a car at the time of license renewal to determine if the vehicle achieves basic air-quality standards. The standards are less stringent for older vehicles and the vast majority of cars (over 90%) pass the test. Cars that fail the test have to undergo a tune-up or other maintenance, up to a specified dollar limit, then they are re-tested. If they do not pass the test the second time, but have reached the dollar limit for maintenance, they are given a temporary license renewal. Economists who have studied these programs have pointed out that they waste a lot of resources testing cars that have an extremely low probability of failing the standards and consequently any pollution reductions achieved come at a very high average cost (Harrington and McConnell, 1999; Harrington, McConnell, and Ando, 2000).

The federal role

In the United States, federal government has a prominent role in regulating air pollution through its administration of the *Clean Air Act* (1970) and Amendments (1977, 1990). Among other things, the *CAAA* sets out national ambient air-quality objectives that are binding on states and counties. If a county is deemed to be out of compliance with one or more federal air-quality standards, the State must file a remediation plan with the Environmental Protection Agency (EPA). Part of the remediation plan usually includes emission standards for specific sources or classes of sources. These standards have to be federally enforceable. The EPA, therefore, has the power to enforce these emission standards directly to ensure compliance.

By contrast, the Canadian federal government has tended to exercise less direct regulatory control. Up until passage of the CEPA in 1999, Ottawa mainly played a coordinating role through the Canadian Council of Ministers of the Environment (CCME). The CCME, for example, negotiated Canada-wide Standards for ozone and particulate matter in June 2000 (though Quebec did not agree to sign the resulting accord). To the extent that there are regulatory actions involved, they are undertaken by provincial governments, not the federal government. Because the federal government plays a coordinating role, there may be an impression that Canada has no clean air legislation. This is of course not true. Air pollution control is a provincial responsibility and is handled through the Certificate of Approval process, among other mechanisms.

The passage of CEPA introduced a new mechanism for federal regulation via the designation of substances as "toxic," which then allows the federal Minister of the Environment to enact emission controls. One controversial, and indeed nonsensical, application of this rule was in 2004 when the federal government designated carbon dioxide (CO_2) as a "toxic substance." CO_2 is not toxic in any reasonable meaning of the term, as it is an integral part of human and plant respiration. It is not covered by provincial air-pollution regulations. The federal government sought authority to regulate it in order to address greenhouse gas commitments made under the Kyoto Protocol. By using the CEPA "toxic" designation, it circumvented having to pass new and potentially unpopular legislation in Parliament.

The climate-change issue is discussed elsewhere in our forthcoming book, in a chapter by Indur Goklany. The fundamental problem with proposals for controlling carbon-dioxide emissions, as he explains, is that, even if conventional projections of global warming and their projected economic impacts are taken at face value, the best (implied) overall outcomes for long-term human prosperity and welfare are those in which CO_2 emissions are allowed to continue growing. Attempts to cap or reduce CO_2 emissions are much more difficult and expensive than attempts to reduce criterion air contaminants, mainly because CO_2 emissions are tightly coupled with average income levels and there is no economically viable way to filter or scrub large volumes of CO_2 from smoke. Consequently, even if emission-reduction targets have a small, long-term cooling effect on the climate, it is not sufficient to offset the economic hardship associated with the emission reductions.

Ultra-fine particles and air-quality indexes

In recent years, Canadian and American regulators have become increasingly concerned with a species of particulates called $PM_{2.5}$, or ultra-fine particles smaller than 2.5 microns; they are also called aerosols. Larger particles are less of a threat to health since our lungs can expel them. A concern about fine particles is that they embed themselves deep in the lungs and enter the bloodstream. Sulphate aerosols are formed by chemical reactions in the atmosphere involving sulphur dioxide and oxidizing precursors. SO_2 can be oxidized by the hydroxyl radical OH or hydrogen peroxide (H_2O_2) and form into sulfuric acid (H_2SO_4), or acid rain and other sulphates (SO_4). This dissociates into several molecules, including SO_4. NO_x can also help convert sulphur dioxide into sulphate (Stein and Lamb, 2000). Because of the complex nature of sulphate formation, the fact that SO_2 levels have fallen so much in recent years does not necessarily imply that sulphate levels have also dropped. What matters is whether the conditions that support the formation of sulphate aerosol have changed substantially.

Much attention has been focused on SO_4, or sulphate aerosol. Its ability to go deep into lung cavities makes it a useful compound for medicinal purposes. A common medicine in asthma inhalers is albuterol sulphate (Drugs.com: Drug Information Online, 2006). In this case, the active ingredient is attached to a sulphate aerosol to facilitate absorption, which raises the question of why doctors would prescribe it if it were a hazard to human health. For purposes of comparison, the European Union has issued ambient air standards of 40 $\mu g/m^3$ for aerosols ($PM_{2.5}$). A standard asthma inhaler delivers a medicinal sulphate dose of about 10,000 $\mu g/m^3$

(Green et al., 2002). Experimental evidence indicates that acid aerosols like sulphate or nitrate do not cause measurable cardiopulmonary responses at current ambient air levels, or even at concentrations much higher than are observed in North American cities, and there is ample experimental evidence that concentrations of aerosols experienced in contemporary outdoor urban air have no effect on the function of human lungs (Green et al., 2002, 2003).

Nonetheless, Ontario now counts SO_4 when calculating its Air Quality Index (AQI). This has led to a perception that Ontario is experiencing "more smog days" than ever before. The reality is different because the AQI has been revised. The Government of Ontario developed the AQI in the early 1990s. It is formed by measuring six air contaminants and translating each one onto an index scale, where numbers up to 15 mean Very Good air quality, 16 to 31 means Good, 50 to 99 means Poor, and so on. The highest reading of the six becomes the AQI value. Smog Advisories were first published in 1993. Regulators issue an advisory if they project, based on current air pollution readings and weather forecasts, that there is a high probability that at least one of the components will indicate Poor air quality over a wide area within the next 24 hours.

On hot, muggy days with a temperature inversion, all six categories may go up into the Poor or Very Poor (100+) categories, indicating a serious smog episode. But in the mid-autumn, it may be that five of the six categories are in the Good or Very Good category, while one goes up into the Poor category. Both would trigger a "smog alert."

In August 2002, the province added $PM_{2.5}$ to the list of AQI compounds, so sulphate aerosols can now trigger a smog alert. The next fall, two alerts were issued in October based on $PM_{2.5}$ levels, and, in February 2005, an alert was issued, again based on the new $PM_{2.5}$ criterion. Media coverage at the time noted how remarkable it was that these were the "first ever" smog alerts in the mid-fall or mid-winter. But that is because the AQI system had been re-defined. Had the AQI system been in place (including the $PM_{2.5}$ component) as far back as the late 1960s, fall and winter smog advisories would likely have been routine: today's smog advisories would seem few and far between by comparison.

Provinces use Air Quality Indexes for public information, to notify people about specific, short-term, smog episodes. However, the AQI is not a good way to measure trends in overall air quality, since the system is new and subject to revisions. Basic contaminant concentration data should be consulted for estimating trends in air quality.

Looking Ahead: Some "Do's" and "Don'ts" for the Canadian Air-Quality Agenda

Do we need a new set of air-quality regulations in Canada? Is the current system "broken" and in need of fixing? The difficulty in answering this question is that people have different things in mind when they think about air pollution. Some people might instinctively think of the air in mid-Toronto, near Highway 401, on a sweltering July day at rush hour. If we think that the aim of air-pollution policy is to ensure that, under those conditions, the air outside ought to be as clean as it is on an April morning in Muskoka, then clearly current regulations will seem inadequate. But this is obviously unrealistic. There are some times and places where we will always encounter deteriorations to air quality. The question is whether further improvements can be achieved at a low-enough cost to make the change worth pursuing.

As I write this (September 26, 2006), air quality across Ontario is either Good or Very Good, according to the Ontario AQI system, at every monitoring site around Ontario. There is nothing special about this day. Here in Southern Ontario it is sunny and mild, people have gone to work, businesses are running, the lights are on, and traffic is moving steadily on all the major routes. Does this imply bad air quality? No, the air quality is Good or Very Good as of 11 AM across all our urban areas, with no indication of problems developing. This is the typical situation for Canadian cities. The fact that air quality is good is, at least in part, attributable to the current suite of air pollution regulations, which allow people to pursue economic growth and development while still enjoying good air quality. The determinants of the AQI today are either ozone or fine particulates, the elements over which we have the least direct control. The contaminants we do control directly are at levels too low to affect the AQI reading, at least on this day, in southern Ontario. In this sense, the system we have is not broken and we should be reluctant to tinker with it.

On the other hand, there remain perceptions that air quality is not good, or is getting worse, and that we need to intervene with stronger measures. To that end I will suggest a number of Do's and Don'ts to guide policy formation.

1 *Do educate the public about the state of Canada's environment*

People need direct, objective information about the environment. Provincial and federal governments collect large amounts of basic data about the current state of the environment and past trends, yet little or none of it is made available to the public in a useable form. Instead, people pick up bits and pieces of information from agenda-driven sources. Environmental groups cite the increased number of AQI-based smog warnings in Ontario and tell people that air quality is getting worse and worse, without explaining the changes to the system that account for the increased frequency of smog advisories.

In recent years, the National Round Table on the Environment and the Economy proposed a set of "Sustainability Indicators," and produced a report on the subject (NRTEE, 2003). Unfortunately they were aiming in the wrong direction, trying to aggregate all environmental measures into one grand index. What is needed is an initiative in the opposite direction to provide disaggregated information on as many individual topics as possible.

Picture a web site where people can look at a map of the country and, by clicking a mouse, zoom in to provinces and regions and cities and neighborhoods. At each level, they would have access to long-term data as well as current conditions. This chapter has been concerned with air quality, and has emphasized taking a long-term view of the matter. Suppose that by going to this web site you could find your city, and even your neighborhood, within the city and instantly call up graphs of criterion air contaminants back to the early 1970s, or the 1960s, as well as recent averages and current up-to-the-hour readings. Suppose you could click on a contaminant's name and get a sidebar explaining what the chemical is, how it is formed, and what the major sources are. In some cases, the sidebar would be able to show time series of emissions. Then suppose that, with another click, you go to a page that describes the current regulatory system in your province and city for controlling that type of air contaminant. The data also exist to make long-term water pollution levels available in the same way, as well as forest cover, ground contamination, and many other topics of interest to the public.

Policy must be formed based on accurate understanding about the situations being addressed. At this point, there is a lot of misinformation being published about the state of the environment, leading to vague anxiety and in some cases unrealistic expectations about what needs to be done. For a relatively small investment in data dissemination, the discussion of environmental policy in Canada could move onto a much stronger, more objective foundation. This would help focus policy attention on real problems, not imaginary or obsolete ones.

2 *Don't impose a policy suitable for "downtown" problems on the whole country*

I don't mean to suggest that downtown Toronto, Montreal, or Vancouver have the "worst" air—depending on the contaminant, there can be worse places. Ozone, for example, forms just as readily over rural areas as in urban areas (in Ontario, Tiverton and Grand Bend have some of the highest ozone levels).

But a lot of people live and work in downtown areas and concerns about air quality tend to focus on those places where there is both elevated pollution and high population density.

It is tempting, when contemplating how to improve downtown air quality, to think about transportation policy initiatives, such as regulations on gasoline formulas, new standards for car emissions and subsidies for public transit. These types of regulation apply to all consumers, including those who live outside the city core, so a lot of costs will be borne by people who do not contribute to the problem. And even if the policies are effective, they primarily influence air contaminants that, these days, cannot be viewed as serious problems. Transportation tends to be associated with carbon monoxide and NO_x. At today's low levels, neither one is a problem in our cities, so imposing higher fuel costs or vehicle costs on broad strata of society will likely not generate sufficient payoff to make the new initiatives worthwhile.

3 Do maintain a decentralized approach to air emissions policy and give people a say in their own local policy framework

One-size-fits-all regulations on a national level do not do justice to the variation in preferences and priorities across the country; nor are they compatible with local democratic governance, particularly since a lot of air pollution depends on local meteorology or the local mix of pollutants. In addition, some communities place very high value on air quality, whereas others might view it as of lesser importance than promotion of local industry. To whatever extent possible, it is a good principle to tailor pollution policy to take account of these differing valuations.

In How to Repair the Air in Our Cities (McKitrick, 2003), I described a practical way of tailoring air-quality regulations on a city-by-city basis. The proposal involves replacing the current system of licensing motor vehicles by year with a system of licensing them by distance driven, where the cost per kilometer is adjusted by the emissions characteristic of the car and a local "clean air premium" parameter chosen by the people in a referendum or by their city council. This way, people who do not drive or who want to raise the cost associated with automobile air pollution will have a direct way of doing so, through a public vote. Presumably, some towns would vote to place a relatively low cost per kilometer on car licenses, while others would raise the price; and either way it would reflect local preferences rather than centralized commands.

The CoA system that governs industrial air emissions across Canada also allows for discretion and local flexibility both in the allowance of emissions and in the enforcement of regulation. Though it makes it hard to quantify and catalogue the full range of pollution-control mechanisms currently in place, it has proven to be an effective and flexible way to achieve tangible results in controlling air pollution. That flexibility should be preserved if the federal government moves to centralize air-emissions policy under a new *Clean Air Act*.

Having said that, there are circumstances in which variations in rules across the country increase costs. The United States currently has a patchwork of different requirements for gasoline formulation. This has created "boutique" markets that force refineries to produce small batches for individual regions, although differences in the formulations are minor compared to the cost burden created for consumers. In cases where there are economies of scale in compliance, it can be preferable to maintain consistent regulatory requirements everywhere.

4 Don't try to motivate policy by appealing to perceptions that are exaggerated or known to be false

We all agree that clean air is more desirable than dirty air and that worthwhile improvements to air quality can sometimes be achieved at manageable cost if priorities are set wisely and policy instruments are carefully devised and implemented. That is the basis for continuing to make progress on air quality. But all too often politicians try to justify new measures to combat air pollution on the basis of inaccurate claims that air quality is getting worse and worse; or that air pollution is causing children to get asthma; or that thousands of people die and tens of thousands get sick due to air pollution; or that billions of dollars in economic losses are incurred; and so on. Those sorts of claims do not stand up to close scrutiny.

Claims of a health crisis due to air pollution have been repeatedly shown to be overstated.[6] But if the alarmist claim gets debunked, does that mean we shouldn't try to improve air quality? No, it just means that we should make policy based on facts, not fears, and especially not on fears based on exaggerations and hyperbole. If there is a good rationale for a policy decision, it should not require falsehoods or fear mongering to get public support.

5 Do set realistic goals for ozone and aerosols, after critically assessing the evidence

Ozone and aerosols are difficult to deal with because of the complex processes that govern their formation. We can continue to try reducing the precursor compounds, namely sulphur, NO_x and VOCs. But the reductions in particulate

6 See McKitrick, Green, and Schwartz, 2005 for a more detailed critical review of the claimed health hazards of modern ambient urban air.

and NO_x emissions that have happened already have not translated into corresponding reductions in average ozone levels. They may have helped diminish the peak values during summertime ozone spikes. A sound strategy should begin with a recognition of what is feasible. There are atmospheric models that can be used to simulate the effectiveness of different policy strategies (see, e.g., DSS Consulting/RWDI Air Inc., 2005), and continued research into acid aerosol formation is needed to help identify the most effective strategies for reducing general ozone and aerosol levels, as well as attenuating the summertime peaks. There is some evidence that VOC emissions matter more than NO_x emissions for limiting ozone levels. But, until the matter is better understood, it would be unwise to promise major reductions in ground-level ozone levels. The Canada-wide Standard for ozone, discussed above, is a noble goal but we should not be too surprised if it is not readily achievable, especially since ozone is sensitive to the intensity of solar flux and we are near the start of a new solar cycle (NASA, Marshall Space Flight Center, Solar Physics Group, 2006).

6 Don't keep trying to solve yesterday's challenges

Sulpher dioxide reached high levels in urban air in the 1970s but has fallen to low levels today. Carbon monoxide is also at very low levels and motor-vehicle emission controls appear to be adequate for ensuring that increased driving does not translate into increased atmospheric CO loads.

Recognizing the progress that has been made up to the present does not mean that no further improvements need to be made but it does remind us that the lowest-cost reductions have already been exploited and further improvements will be costlier and more elusive than previous ones. For the purpose of setting priorities, governments should recognize where progress has been made and consider whether it would be better to devote attention and resources to other concerns that have not received adequate attention, and where greater reductions in risks can be obtained at lower costs.

7 Do steer towards using pricing mechanisms where possible

The United States and countries in Europe have shown, by example, that market mechanisms (emission taxes and tradable permits) can be effective methods for pollution control. For example, in the United States the permits market for sulphur dioxide has been a successful method for reducing SO_2 emissions while minimizing the cost of compliance for industry. Ontario has taken the lead in Canada by introducing NO_x and SO_x emission trading programs.

Tradable permits systems can reduce, but not eliminate, the social cost of emission-control policies. The question of whether emissions need to be reduced below current levels must be decided on its own merits. Many studies done by government agencies and activists claiming to "prove" that large potential economic benefits would arise from further air pollution reductions rely on the kind of exaggerated health-effects rhetoric criticized above. In general, cost-benefit analysis of environmental policy should be done by people who are not in a conflict of interest. Bureaucrats who work in the environmental regulation area are potential beneficiaries of a push to tighten pollution laws and extend the environmental regulatory bailiwick. At the very least, their cost-benefit analyses should not be taken at face value unless they have been independently reviewed by staff in other government branches and unless they openly present the evidence contradicting the claims that air pollution is a threat to life and health.

Here are two suggestions for situations where pricing mechanisms might be pursued.

7.1 NO_x and SO_x emissions trading in the eastern Canadian airshed

The federal government, through the CCME, should consider coordinating a large-scale pricing system to control SO_x and NO_x emissions in the eastern Canadian airshed. The American experience has shown that emissions trading is feasible and the introduction of limited trading in Ontario shows that Canadian firms and regulators are ready to take the next step. Implementing an emissions-trading system across provinces would require careful planning to deal with several thorny issues. First, it is clear from the environmental economics literature (e.g. Parry et al., 1999) that giving away permits rather than auctioning them increases the social costs of the tradable permits system. A tradable permits system with permits freely distributed based on existing output shares effectively creates an industrial cartel. Consumer prices go up and competition is diminished. By auctioning the permits instead, then using the revenue to pay for reductions in income or payroll taxes, the government minimizes the cartel power and the general social cost of the emission-control policy. In some cases, the emission goals can be reached at no overall macroeconomic costs.

Second, since eastern Canadian provinces all have emission policies in place already, it would be necessary to determine if a new emissions trading system made some earlier regulations redundant or counter-productive. This was not recognized in the United States when the acid rain allowance program was introduced. An older program called New Source Review was made redundant and its continuation actually undermined the intent of the emissions-control policy by delaying the changeover to new, less emissions-intensive industrial equipment (Gruenspecht and Stavins, 2002).

7.2 Ozone precursor management during urban smog episodes

Regarding NOx, VOCs, and other ozone precursors, the challenge right now is to manage episodes of very high pollution levels. One possibility is to implement temporary surcharges on motor fuels and stationary-source NO_x and VOC emissions in a city on days when the 8-hour average ground-level ozone reading goes above 50 ppb. The emissions tax should be targeted towards large emitters, such as plants with installed combustion capacity exceeding 25 GWh useful energy per year. The surcharge would not be large enough to seriously affect real income, but a level of 5¢ to 10¢ per litre would encourage drivers to economize on road use. The tax would have to have a specified phase-out time, such as 24 hours after the 8-hour O_3 average has dropped below 40 ppb.

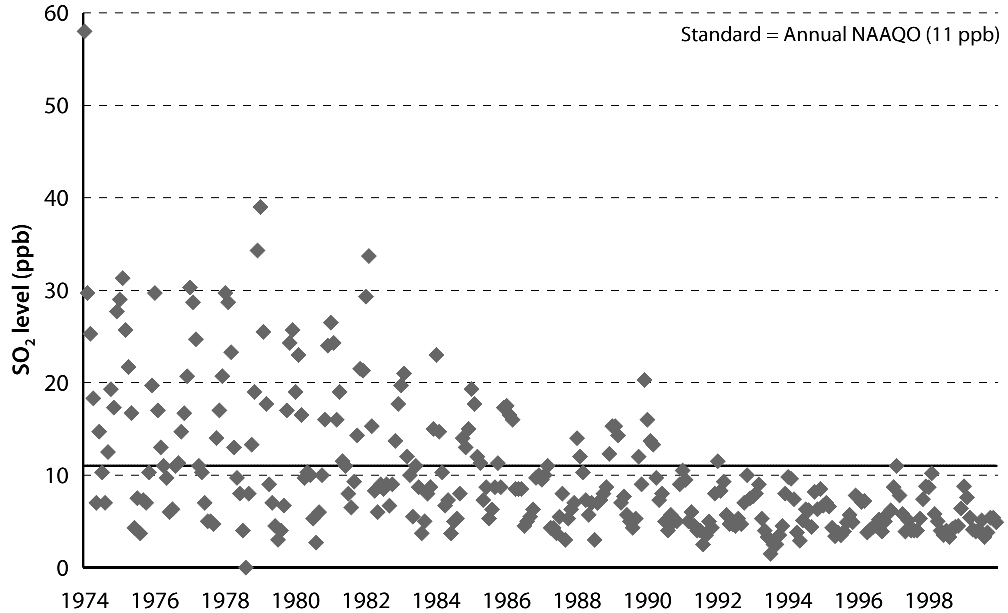
The Government of Canada should not keep the proceeds of the taxes. Instead, they should be aggregated by city and paid out at the end of the fiscal year as an equal lump-sum payment to all hospitals within the city. This kind of revenue-recycling does not assume compensation is needed for increased health-care costs due to the smog episode, since, on the grounds discussed above, we do not expect increased health-care costs due to ordinary variations in smog. But by maintaining local revenue neutrality the "smog surcharge" would be politically more feasible and, by agreeing ahead of time to the specific conditions for its implementation, there is less likelihood of governments distorting it into a net revenue source in the guise of a virtuous "green" tax.

Conclusion

Misunderstandings about Canadian environmental conditions and pollution policy abound. Many people seem to think air emissions in Canada are unregulated and that air quality is getting worse and worse. Neither claim is true. This chapter reviews recent evidence and shows that broad measures of air quality show real improvements since the 1970s. Most Canadians experience air quality, for most or all of the year, that is well within established air quality guidelines and is very unlikely to be deleterious to health. This chapter has also explained that Canada's decentralized regulatory system might have led to the impression that firms are not subject to emission controls when, in fact, they are carefully regulated. Consequently, there is no evidence that the system is "broken" or in need of major overhaul. Canada and the United States effectively decoupled air pollution from economic growth over the 1970s and 1980s. This is one of the greatest technological and social achievements of the twentieth century, yet it seems to have gone unnoticed and uncelebrated.

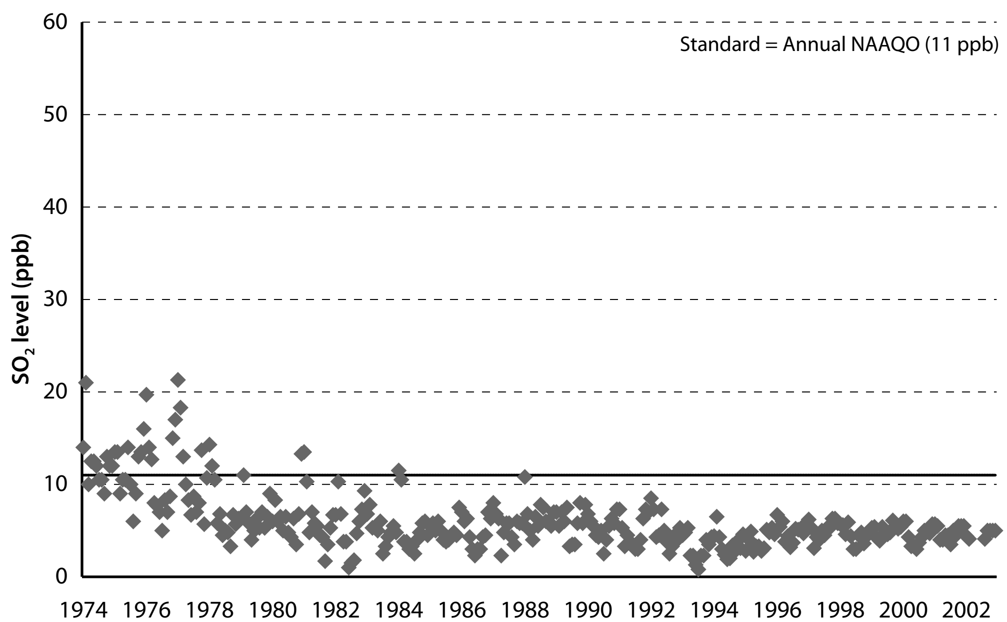
What is needed now, more than any new regulatory initiatives, is a comprehensive effort to put complete, objective, and detailed information about all aspects of environmental quality, including both current conditions and long-term trends, into the public sphere so that further discussion about the environment can take place in a context of facts and understanding, not rumours and rhetoric. Future environmental regulatory initiatives should be tailored to local needs, not aimed at ornate but misplaced national gestures. Future initiatives should be flexible and efficient, they should be responsive to local preferences and needs and they should work with, not against, our market economy. As we continue to improve the current Canadian environmental policy mix, it is important to be both realistic and optimistic, and to remember that we are building on success.

Figure 1a: Trend in ambient levels of SO_2 in Montreal, 1974–1999



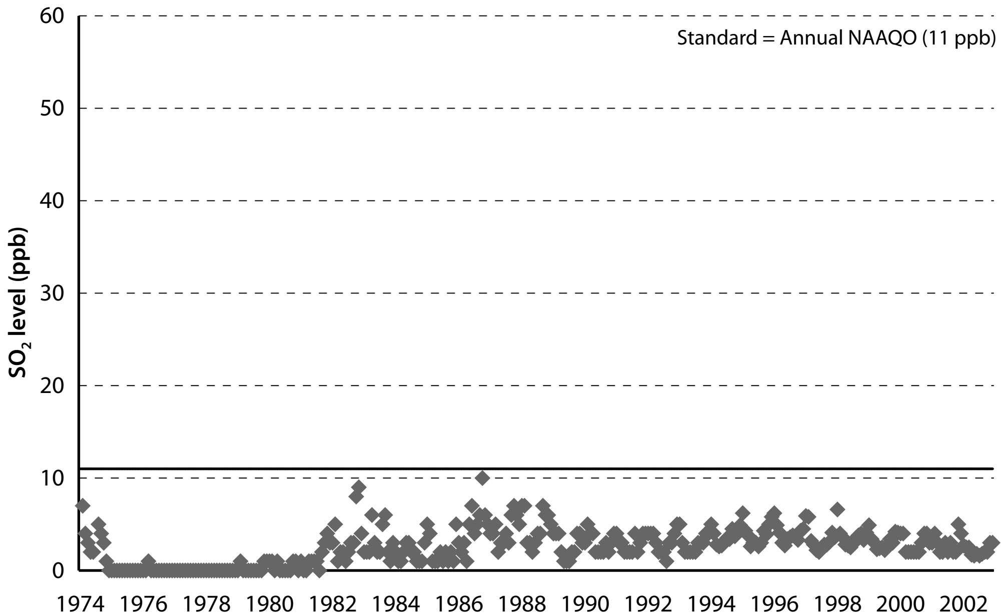
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 1b: Trend in ambient levels of SO_2 in Toronto, 1974–2002



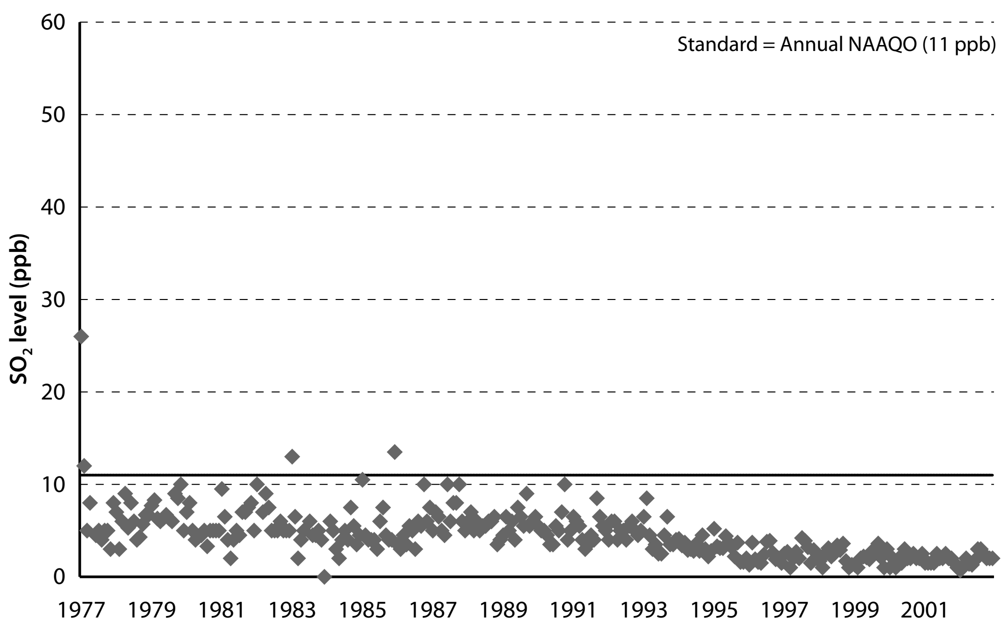
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 1c: Trend in ambient levels of SO_2 in Calgary, 1974–2002



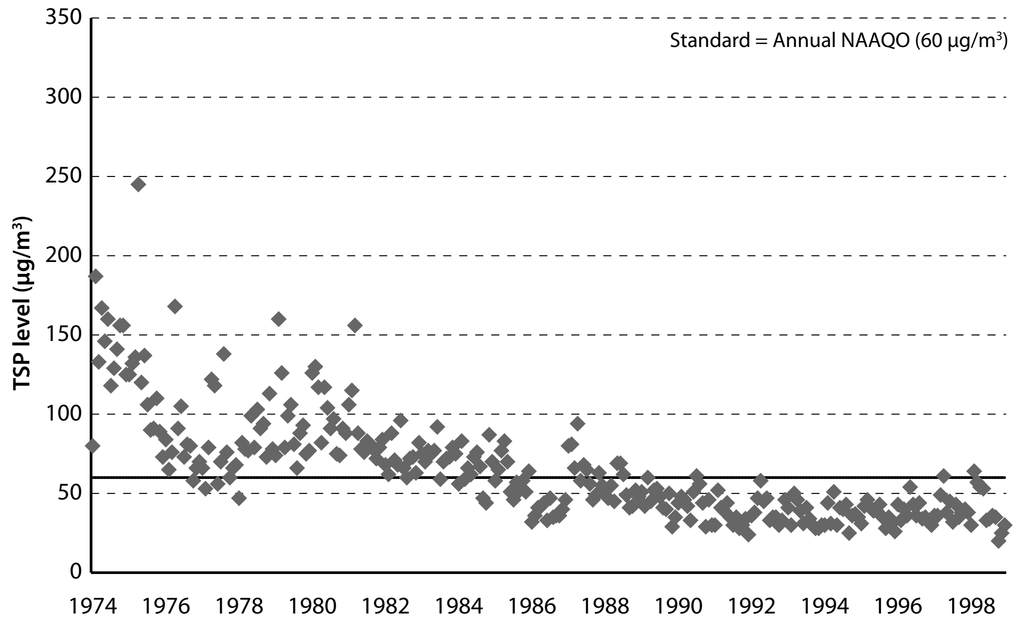
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 1d: Trend in ambient levels of SO_2 in Vancouver, 1977–2002



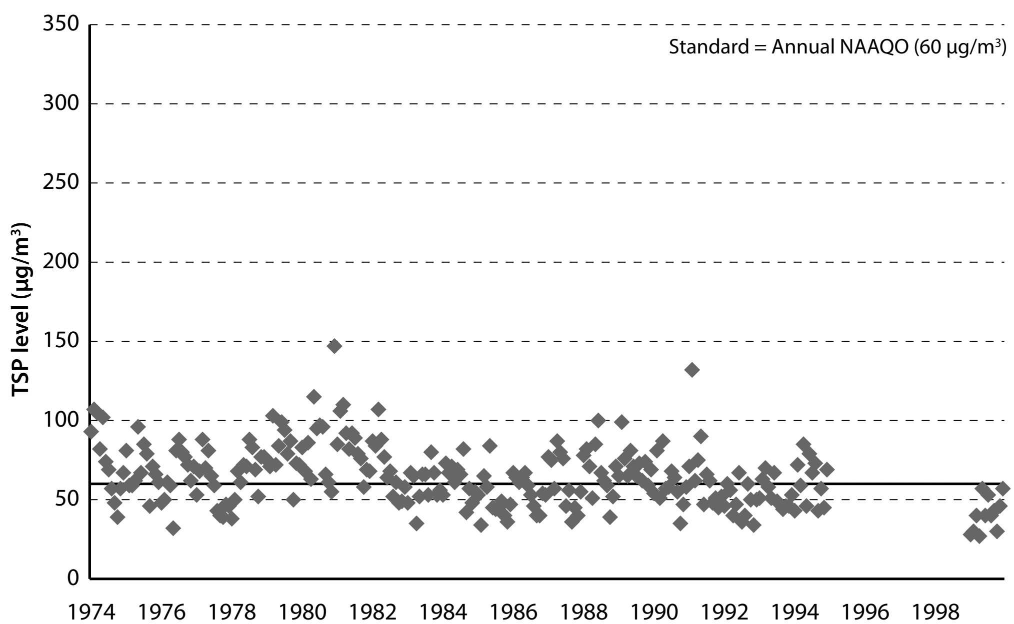
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 2a: Trend in ambient levels of TSP in Montreal, 1974–1998



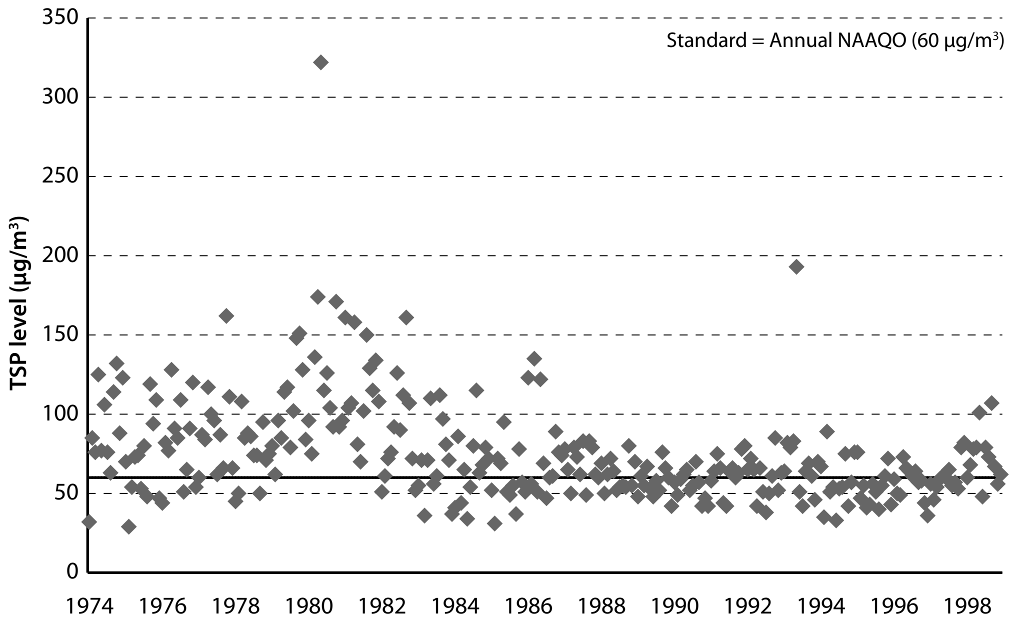
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 2b: Trend in ambient levels of TSP in Toronto, 1974–1999



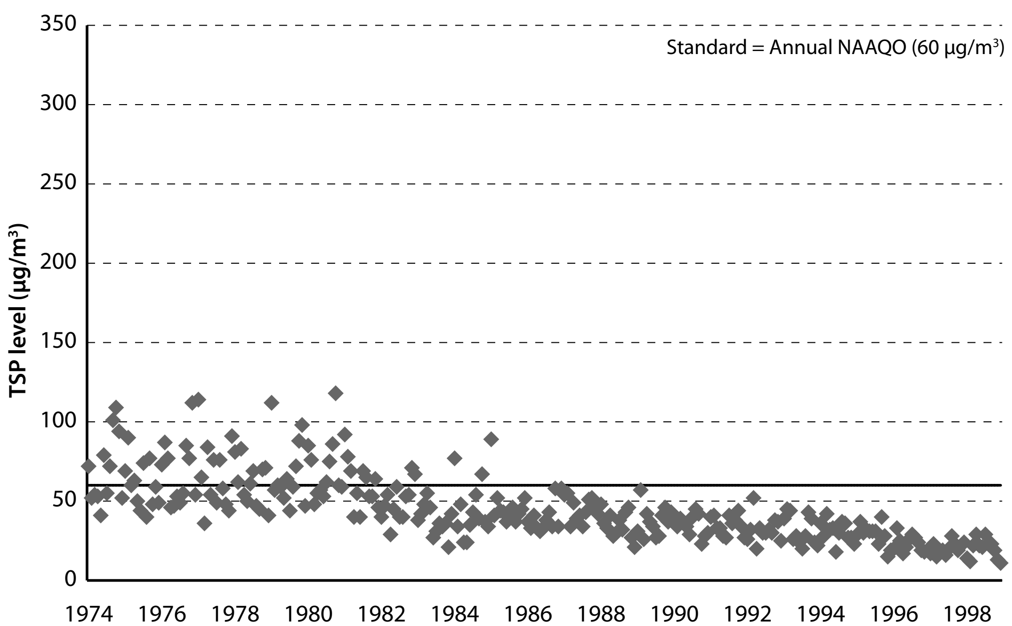
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 2c: Trend in ambient levels of TSP in Calgary, 1974–1998



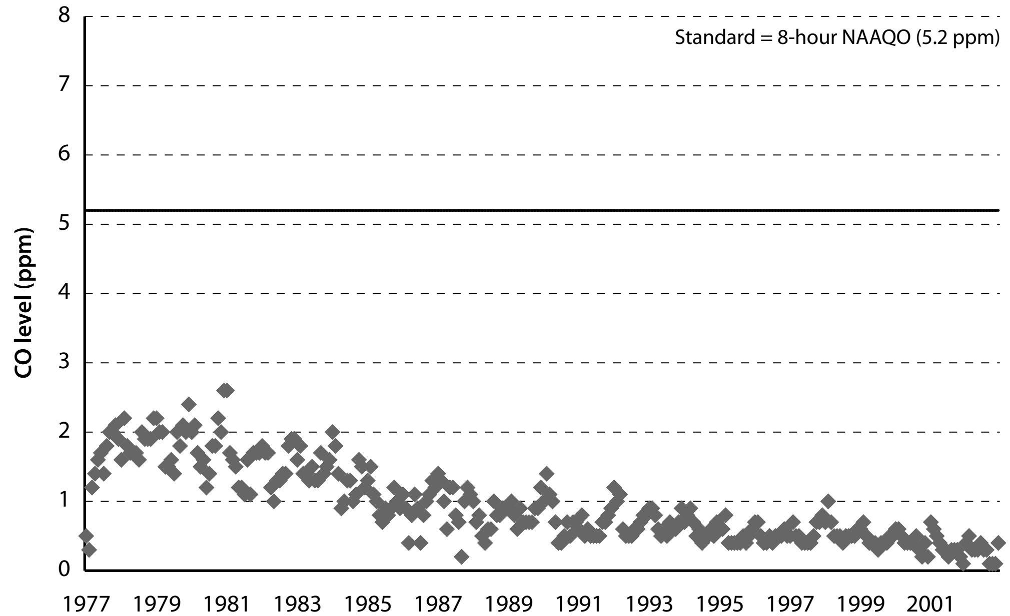
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 2d: Trend in ambient levels of TSP in Vancouver, 1974–1998



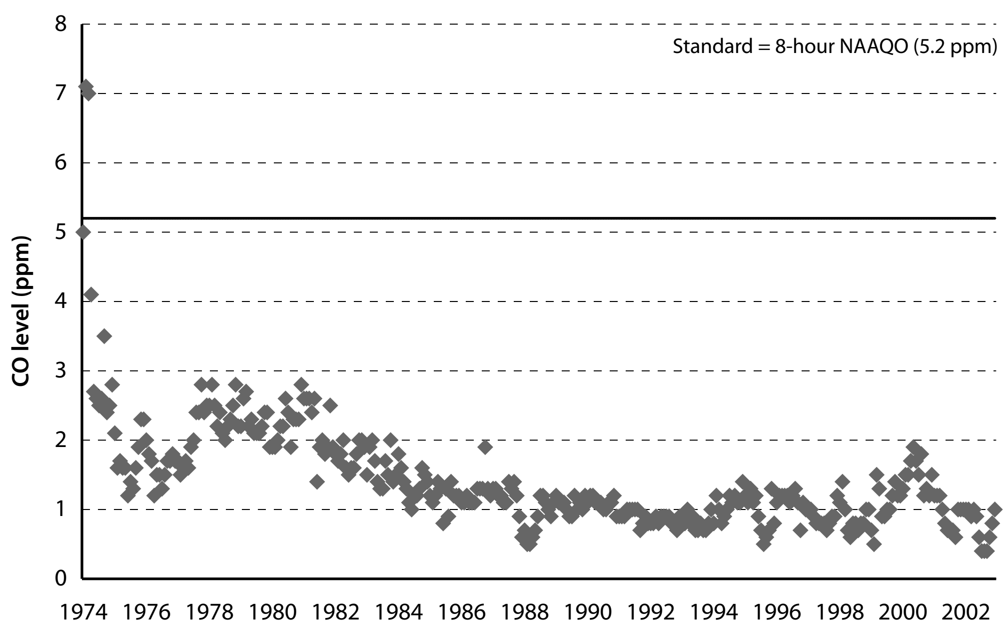
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 3a: Trend in ambient levels of CO in Montreal, 1977–2002



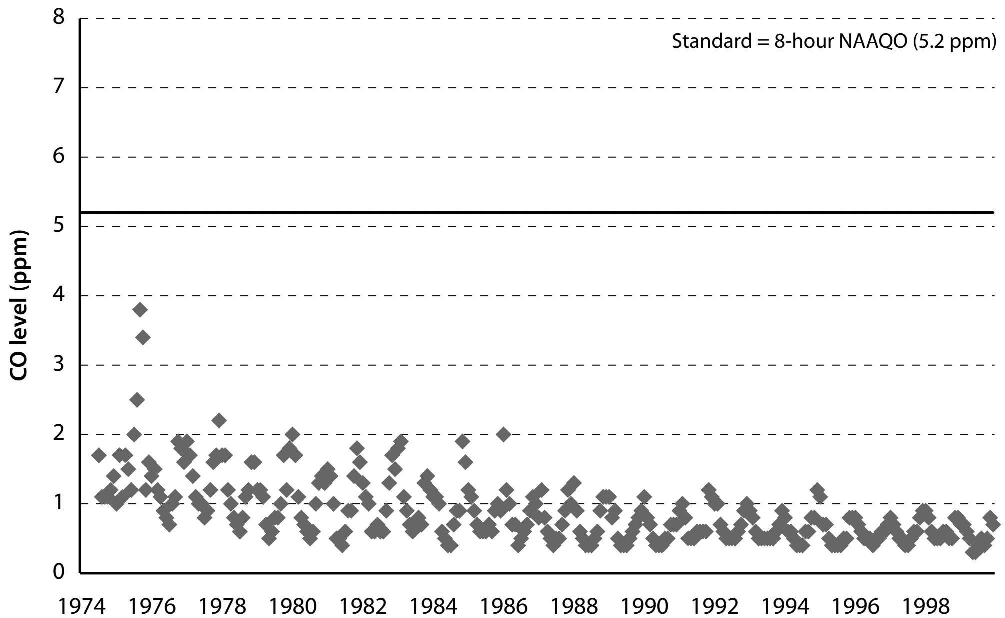
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 3b: Trend in ambient levels of CO in Toronto, 1974–2002



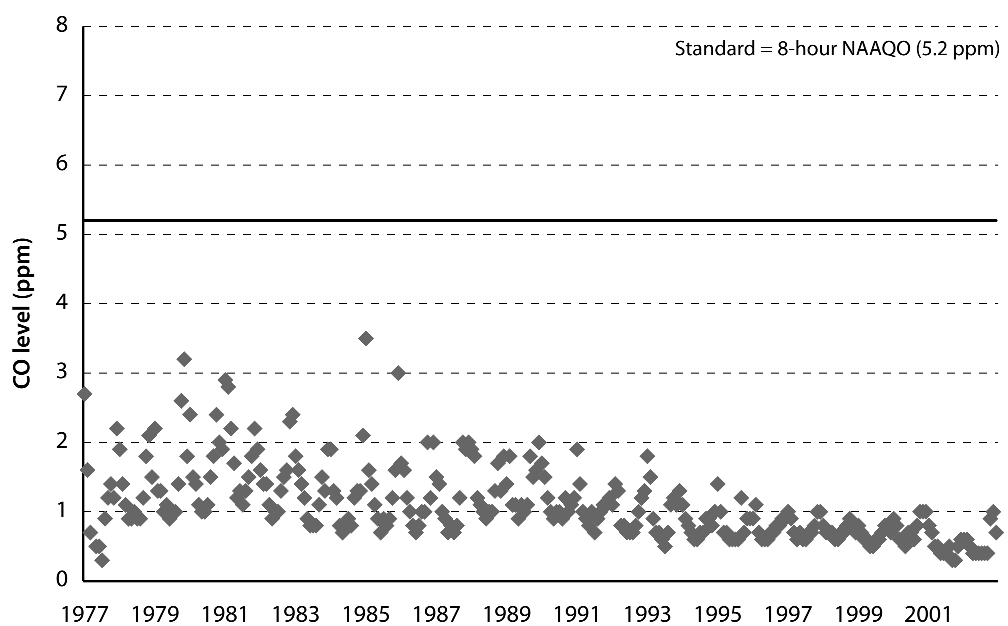
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 3c: Trend in ambient levels of CO in Calgary, 1974–1999



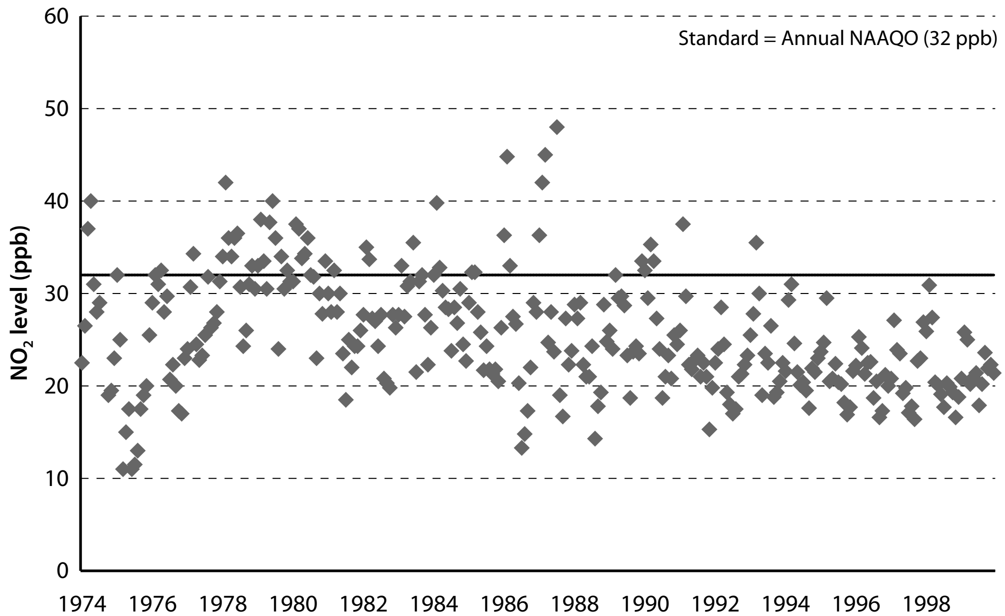
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 3d: Trend in ambient levels of CO in Vancouver, 1977–2002



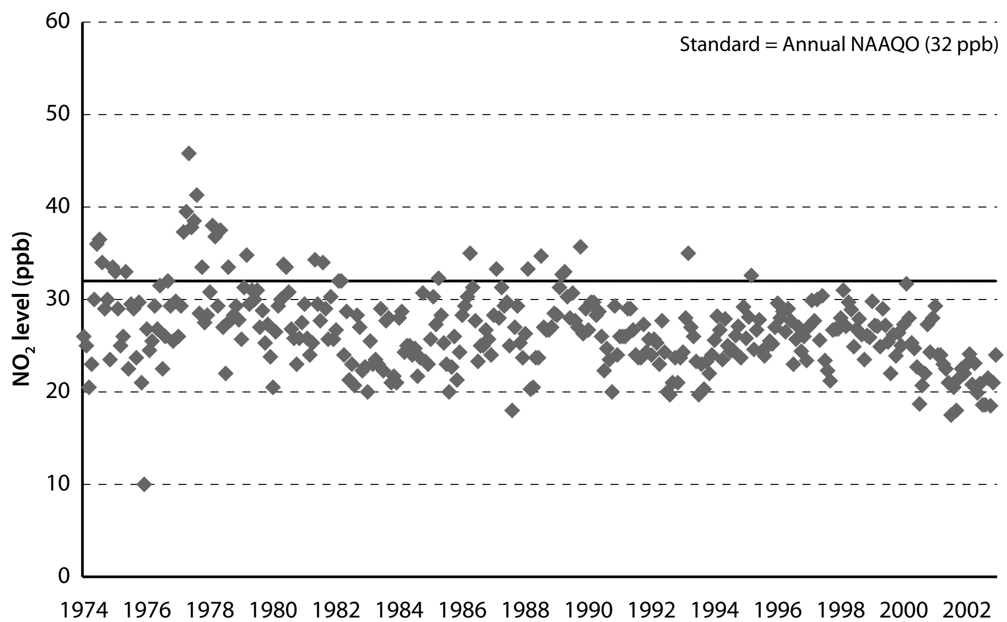
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 4a: Trend in ambient levels of NO_2 in Montreal, 1974–1999



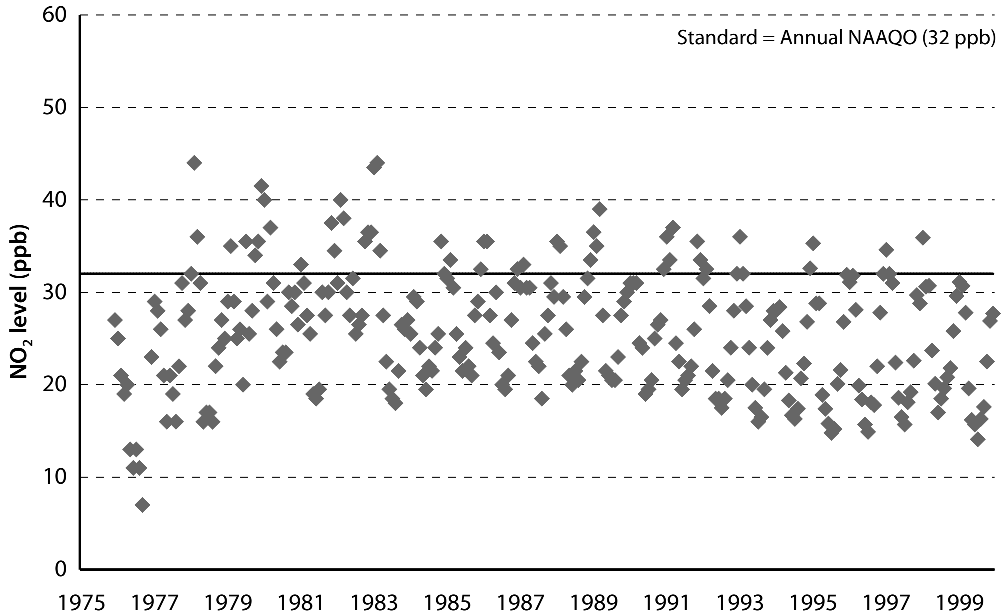
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 4b: Trend in ambient levels of NO_2 in Toronto, 1974–2002



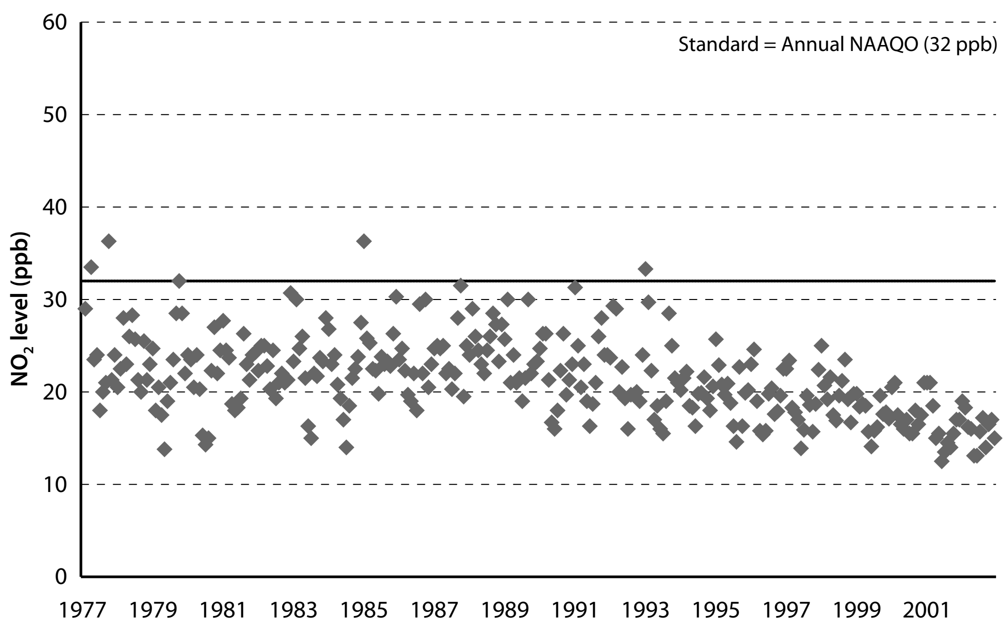
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 4c: Trend in ambient levels of NO_2 in Calgary, 1975–1999



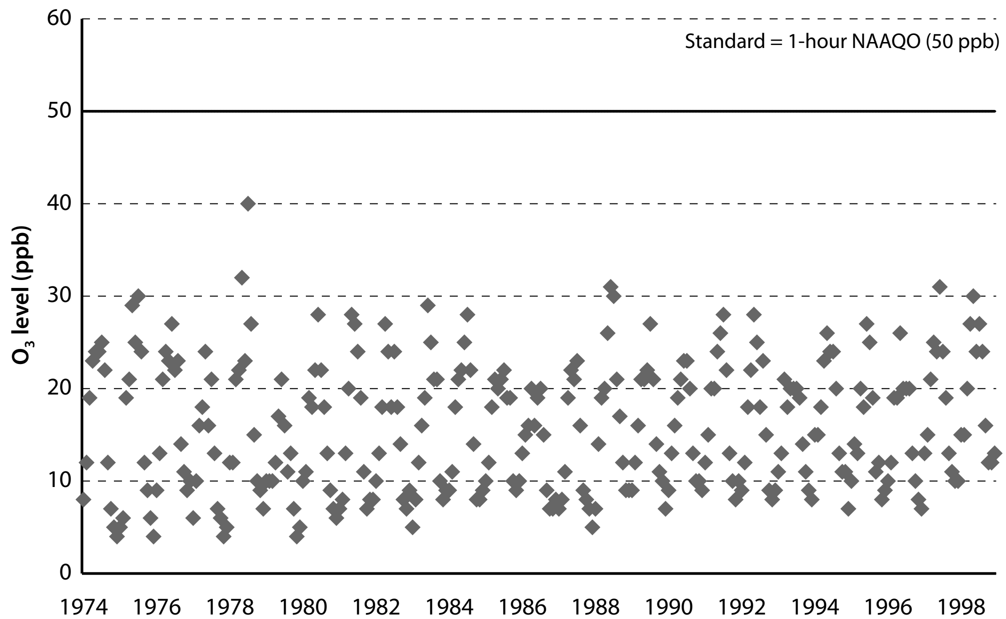
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 4d: Trend in ambient levels of NO_2 in Vancouver, 1977–2002



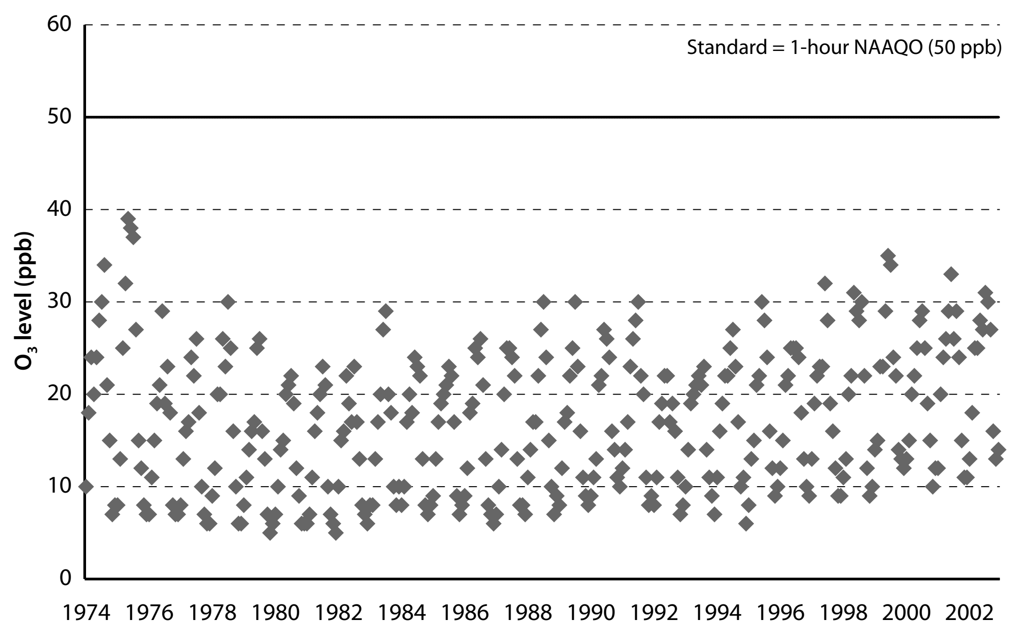
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 5a: Trend in ambient levels of O_3 in Montreal, 1974–1998



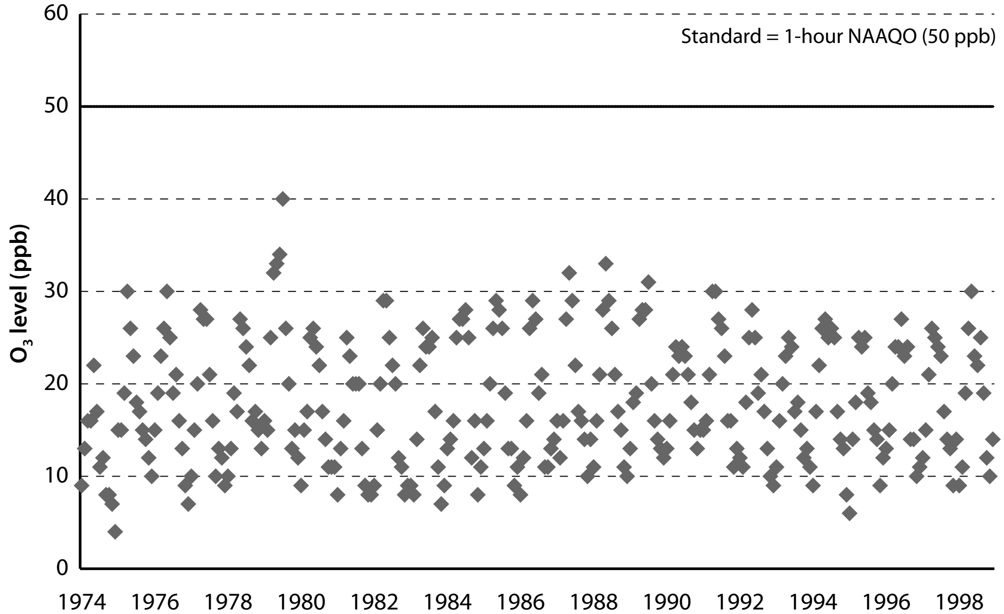
Note: The Canada-wide Standard for O_3 caps average peak episodes at 65 ppb. See text for details.
Source: Environment Canada, National Air Pollution Surveillance network,
<http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 5b: Trend in ambient levels of O_3 in Toronto, 1974–2002



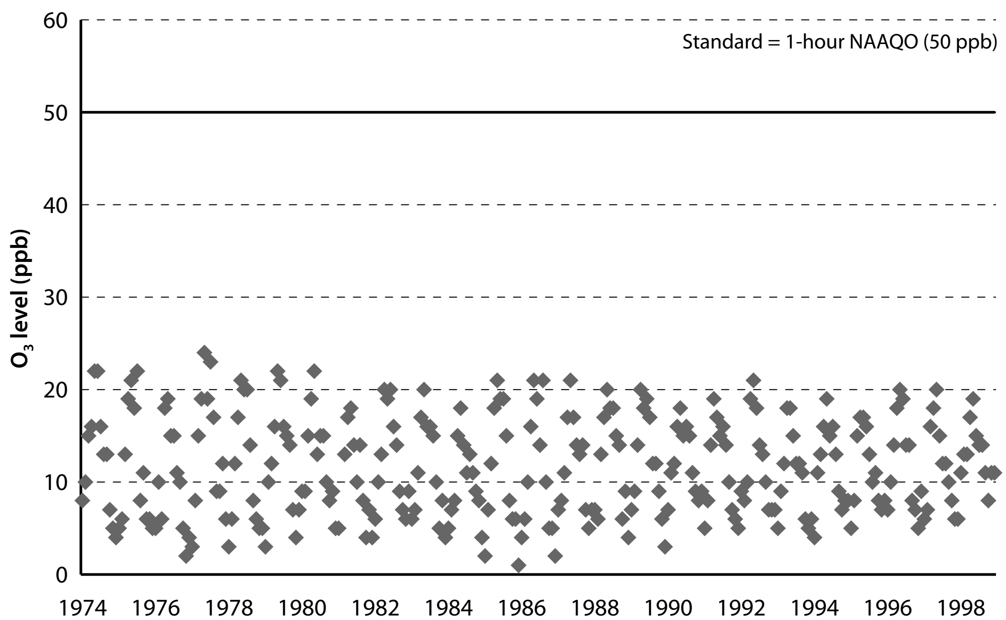
Note: The Canada-wide Standard for O_3 caps average peak episodes at 65 ppb. See text for details.
Source: Environment Canada, National Air Pollution Surveillance network,
<http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 5c: Trend in ambient levels of O_3 in Calgary, 1974–1998



Note: The Canada-wide Standard for O_3 caps average peak episodes at 65 ppb. See text for details.
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

Figure 5d: Trend in ambient levels of O_3 in Vancouver, 1974–1998



Note: The Canada-wide Standard for O_3 caps average peak episodes at 65 ppb. See text for details.
Source: Environment Canada, National Air Pollution Surveillance network, <http://www.etc-cte.ec.gc.ca/NAPSData/Default.aspx>.

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