TORONTO
Public Health

Condition Critical

Fixing Our Smog Warning System

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The views presented in *Condition Critical* are solely the views of the authors and Toronto Public Health. However, our views have benefited from discussions by the Project Advisory Committee for the *Toronto Air Quality Index Health Links Analysis* study. This Project Advisory Committee included representatives from: the Ontario Ministry of the Environment; Environment Canada; Ontario Ministry of Health and Long Term Care; Office of the Chief Administrative Officer for the City of Toronto; Toronto Works and Emergency Services; Pollution Probe Foundation; Toronto Environmental Alliance; Ontario Association of Family Physicians and the Ontario Medical Association.

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EXECUTIVE SUMMARY

In a previous study released in May 2000, Toronto Public Health determined that each year about 1,000 Toronto residents die prematurely and another 5,500 are admitted to hospital because of six smog-related pollutants. At the same time, the provincial Air Quality Index (AQI) system described air quality as "good" or "very good" about 95% of the time. These observations present a dichotomy to the public since on the one hand, they are informed that air quality is good or very good almost all the time, but on the other hand, they are informed that it is harming the health of thousands of people in Toronto. Given concerns that the AQI communications tool might not accurately reflect health risk, Toronto Public Health undertook a new study to determine whether provincial air quality classifications incorporated into the AQI (i.e., very good, good, moderate, poor and very poor air quality) appropriately reflect the burden of illness associated with these air quality classifications.

Building on the methodology applied in Toronto Public Health's previous Air Pollution Burden of Illness study, the new study calculated the number of hospitalizations and premature deaths that occurred for each air pollutant category in the AQI. The results show that 92% of the premature deaths and hospitalizations attributable to air pollution in Toronto occur when air quality has been classified as good or very good by the provincial AQI. An estimated 8% of adverse health outcomes occur when the air quality is in the moderate or poor range.

This does not mean that poor air quality has little adverse impact on health. On those days when the air quality is poor and smog alerts are called, air pollution *is* a serious problem, however, the research suggests that air pollution is a health problem on other days as well. The AQI classifications for good and very good air quality inadvertently misrepresent the quality of the air relative to health impacts because they do not take into account the many more hours/days of somewhat lower levels of air pollution that contribute to the large burden of premature mortality and ill health.

The AQI has the potential to be an extremely important communications tool that can let the public know when air pollution levels are high enough to produce health problems. Given the widespread media attention that the AQI receives, it can communicate the need for the public to take steps to protect personal health during elevated pollution levels, as well as to the need to adopt less polluting practices year round.

This study notes several reasons why the AQI needs to be improved. It will take many years before air quality can be improved substantially, even with concerted action by all levels of government, industry and the public. Pollution trends in Toronto do not provide reason for optimism since smog-related pollution levels have not improved in the last 15 years. In addition to taking strong steps to improve air quality, there is a need to ensure that the public has accurate information about air pollution levels so that individuals can take steps to protect themselves and their families. This is especially important for sensitive populations such as seniors, young children and those with cardiac and respiratory illnesses. The size of vulnerable populations in Toronto is very large. For example, in 1998, there were 48,000 hospitalizations of Toronto residents due to breathing and heart problems. People with respiratory and cardiac conditions are at greater risk from the adverse impacts of air pollution than the general population. Consequently it is important that the AQI system indicates pollution levels that adversely impact these people by incorporating a special notification system directed at vulnerable populations.

It is of concern that the size of some vulnerable populations in Toronto is increasing. For example, seniors over 65 represent a growing population in Toronto and they are also the population that is most frequently hospitalized for respiratory and heart problems. The population of seniors (over 65) has almost doubled between 1971 and 1996 while the overall population in Toronto increased only 14% over the same time period. The same trend has been observed for children with asthma, who are also at increased risk from air pollution compared with other children. The prevalence of asthma in children under 14 years has risen dramatically in Ontario from 2.5% in 1983 to 11.2% in 1995. Consequently, a greater proportion of children are at increased risk from air pollution today than two decades ago.

This study identifies several reasons why the current AQI communications system misrepresents the health risk associated with air pollution levels. One reason is that the AQI does not include fine particulates (e.g., PM_{10} and/or $PM_{2.5}$), which are known to contribute significantly to the harmful effects of air pollution. A second reason is that the air quality standards for several pollutants (carbon monoxide, sulphur dioxide and nitrogen oxides) that make up the AQI are seriously out-of-date. Another reason is that the AQI public reporting mechanism is based on a single “driver” pollutant and does not take into account the cumulative contributions of the smog-related air pollutants that make up the AQI. The result is that the AQI values do not correlate well with air-related health risks, and therefore are incapable of accurately predicting when air pollution levels will or are adversely impacting the health of the public, including sensitive populations.

The study culminates in a Five-Point Action Plan for consideration by provincial and federal agencies in improving the AQI public communication tool. Components of the Action Plan are: (1) add fine particulates (PM_{10} and/or $PM_{2.5}$) to the AQI; (2) replace existing AQI categories (very good, good, moderate, poor, very poor) with more appropriate classifications (background, low, medium, high, smog alert); (3) include more accurate health effects information and develop a special messaging system for vulnerable populations; (4) update regulatory standards for pollutants in the AQI to ensure they better reflect health effects and (5) revise the AQI formula to reflect cumulative health impacts associated with simultaneous exposure to the multiple pollutants that comprise the AQI.

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1. MIXED MESSAGES – GOOD AIR BUT BAD HEALTH

In May 2000, Toronto Public Health released the report *Air Pollution Burden of Illness in Toronto*[1]. Using 1995 as its base year, the study determined that each year about 1,000 Toronto residents die prematurely and another 5,000 are admitted to hospital because of six smog-related pollutants. In addition to these severe effects, air pollutants are associated with thousands of preventable visits to hospital emergency rooms, increased symptoms of chronic bronchitis and asthma. Air pollution is also adding significant cost to the health care system. The Ontario Medical Association has estimated that air pollution costs Ontario residents more than one billion dollars each year in hospital admissions, emergency room visits and absenteeism[2].

The six pollutants examined in the Toronto *Air Pollution Burden of Illness* study all have one thing in common. They are emitted when fossil fuels such as coal, oil, gasoline and diesel are burned as fuels in cars, trucks, furnaces and industrial processes. Within Toronto, the transportation sector is the largest contributor of air pollutants, however significant pollution levels also come from beyond Toronto, including power plants in Ontario and the United States[3].

Scarcely a week goes by in the summer without a media story about air pollution and its impact on human health. The public is regularly informed of the latest research that shows the health impacts of air pollutants at increasingly lower levels. While health effects research has advanced at a rapid rate, the ability of governments to establish up-to-date health-based air quality standards has not kept pace.

In interactions with the community, it is apparent that a dichotomy exists regarding air quality messaging to the public. On the one hand, studies by air quality experts around the world provide evidence that communities with the highest air pollution levels also experience the highest rates of air-pollution related ill health. Furthermore, most highly populated urban centres, such as Toronto, are known to have levels of air pollutants high enough to affect even healthy people, not just the vulnerable such as seniors, children and those with pre-existing respiratory and cardiac problems[3].

On the other hand, public communication tools such as the provincial Air Quality Index (AQI) describe air quality as “good” or “very good” about 95% of the time. Air quality is described as “poor” only on those rare days when there is a severe pollution episode that results in an “air quality advisory”, also known as a “smog alert”. In Toronto, there were only 8 days in 1995 designated as “smog alert” days based on the provincial AQI, yet this was the same year for which Toronto Public Health determined that air pollution led to 1,000 premature deaths and 5,500 hospitalizations.

The provincial Air Quality Index (AQI) has the potential to be an extremely important communications tool that can let people know when air pollution levels are high enough to produce significant health problems. Given the widespread media attention that the AQI receives, it can be an excellent vehicle for communicating the need for the public to take steps to protect its health during elevated pollution levels, such as by staying indoors and not exercising vigorously outdoors.

But what is the consequence of an air quality messaging system that perhaps misrepresents the health risks associated with its AQI values? Might it not fail to warn vulnerable segments of the population to take action to protect themselves during days with increased pollution levels? Furthermore, if the dominant message of the AQI system is that air quality is "good" or "very good" most days of the year, might this not hinder an otherwise engaged public from shifting its behaviour to adopting less polluting practices all year long?

Given the significant consequences that might arise from an AQI communications tool that does not correlate well with health risk, Toronto Public Health undertook a new study to determine whether the provincial air quality classifications (e.g., very good, good, moderate, poor and very poor) based on AQI values appropriately reflect the state of air quality and the associated burden of illness for Toronto residents. This report summarizes Toronto Public Health's new technical study entitled *Toronto Air Quality Index Health Links Analysis*[4] and makes recommendations for improving the AQI.

2. THE AIR QUALITY INDEX – WHAT IT IS AND HOW IT WORKS

The Air Quality Index (AQI) is primarily a communication tool to provide the public with information about the quality of the air and what this means in terms of probable human health effects. The AQI has the potential to influence members of the public to modify their behaviour, either to protect their own health or that of family members, or to reduce air pollution emissions by, for example, reducing vehicle use. It is also used by many agencies as an indicator of air quality trends.

The federal government, through Environment Canada, first developed its *Index of the Quality of Air (IQUA)* in 1976 and last revised it in 1991. Efforts are underway to launch a Canadian Air Quality Index in 2002 based on a "common index and appropriate health messages". Development of a national index will require agreement with the provincial and territorial governments.

Some provinces, such as British Columbia, New Brunswick and Ontario already have well-developed AQI systems. There are some differences among them, but all of these indices use the same basic structure in which an AQI value of 50 coincides with one or more pollutants exceeding a set threshold such as a regulatory standard or guideline. Jurisdictions vary somewhat as to which pollutants they include. Pollutants commonly included are ozone, nitrogen dioxide, carbon monoxide and sulphur dioxide. Among Canadian provinces, only New Brunswick uses its air quality index to trigger regulatory controls to restrict pollution sources when a specific AQI value is exceeded.

The U.S. Environmental Protection Agency's (U.S. EPA) AQI has a structure similar to the Canadian one. However, it includes fine particulate matter (PM_{10} and $PM_{2.5}$) that are strongly associated with human health effects, whereas the indices in most Canadian jurisdictions use particulate indicators such as "coefficients of haze" that are not as accurate indicators of human health effects.

Ontario's Air Quality Index

Ontario's AQI is comprised of measurements of sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), total reduced sulphur (TRS) and coefficient of haze or total suspended particulate (TSP). Fine particulates (PM_{10} or $PM_{2.5}$) are not part of the Ontario AQI.

The AQI is divided into five categories that correspond to a concentration range for each pollutant. After each hour of sampling, the concentration of each pollutant at each monitoring station is converted into a number that corresponds to the AQI scale. AQI values are classified as follows:

AQI Scale	*Category*
0 – 15	***Very good***
16-31	***Good***
32-49	***Moderate***
50-99	***Poor***
100+	***Very poor***

Table 1 shows the AQI category and "break points" for several pollutants of health concern in Toronto. The "breakpoints" indicate the concentration range of each pollutant that is used within the AQI. The shaded boxes in Table 1 indicate where pollutant concentrations exceed the Ontario ambient air quality criteria (AAQC).

While the public may assume that adverse health effects start when the AQI says the air is "poor", this is not the case. In the case of ozone and carbon monoxide, the AQI value of "50" and its corresponding designation of "poor" occurs only when either of these air pollutants exceed their regulatory guidelines. For sulphur dioxide and nitrogen dioxide, air quality is deemed "moderate" when they are present at levels that exceed their regulatory guidelines.

Table 1. AQI Category and Breakpoints

AQI Category	Break Points Based on 1-Hour Pollutant Concentration (ppb)			
	CO	**Ozone**	**SO_2**	**NO_2**
Very good	< 12,000	< 23	< 164	< 104
Good	12,000 – 22,000	23 – 50	164 – 250	104 – 204
Moderate	23,000 – 30,000	51 – 80	251 – 340	205 – 254
Poor	31,000 – 49,000	81 – 149	341 – 1,999	255 – 524
Very poor	> 49,000	> 149	> 1,999	> 524

Source: OMOE, 2001[5] (shaded boxes show concentration ranges above the AAQC)

Abbreviations	
CO	*carbon monoxide*
NO_2	*nitrogen dioxide*
O_3	*ozone*
SO_2	*sulphur dioxide*
TSP	*total suspended particulates*
PM_{10}	*fine particulates smaller than 10 microns*
$PM_{2.5}$	*fine particulates smaller than 2.5 microns*

Table 2 provides the current provincial description of health impacts associated with each AQI category. It is notable that for AQI values less than 32 (that is air quality described as "good" or "very good"), the table states that there are "no known harmful effects.

Table 2. Provincial Description of Health Impacts Associated with AQI Category

AQI Index	Category	CO	NO_2	O_3	SO_2	SP
0 – 15	Very Good	No known harmful effects.	No known harmful effects.	No known harmful effects.	No known harmful effects.	No known harmful effects.
16 – 31	Good	No known harmful effects.	Slight odour.	No known harmful effects.	Damages some vegetation in combination with ozone.	No known harmful effects.
32 – 49	Moderate	Blood chemistry changes but no noticeable impairment.	Odour.	Respiratory irritation in sensitive people during vigorous exercise; people with heart/lung disorders at some risk; damages very sensitive plants.	Damages some vegetation.	Some decrease in visibility.
50 – 99	Poor	Increased symptoms in smokers with heart disease.	Air smells and looks brown. Some increase in bronchial reactivity in people with asthma.	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/lung disorders at greater risk; damage to some plants.	Odour; increasing vegetation damage.	Decreased visibility; soiling evident.

Source: OMOE, 2001[5]

Table 3 summarizes Ontario's Ambient Air Quality Criteria and identifies the scientific basis used to set each criterion [5,6]. The criterion for total suspended particulates (TSP) is based on visibility, not on health effects. The criterion for carbon monoxide (CO) is based on the levels considered to be "background". The criteria for the ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and fine particulates (PM_{10}) are supposed to be based on adverse human health effects.

Although the AQI was established with the best available understanding at the time, scientific knowledge has changed since then. Health effects have now been documented at levels below existing standards, and it is now believed for many smog-related pollutants that there is no threshold below which adverse health effects do not occur. Standards for carbon monoxide, nitrogen dioxide, and sulphur dioxide are especially out of date[1]. Although the regulatory criterion for ozone has been revised more recently, it is still set at a level above those associated with significant adverse health effects due to economic factors. It has also been demonstrated that adverse human health effects are more consistently linked to air levels of fine particulates (PM_{10} and $PM_{2.5}$) than to total suspended particulates.

Table 3. Ontario Ambient Air Quality Criteria (AAQC)

Contaminant	AAQC (units)	Averaging Period	Basis
CO	30,000 (ppb)	1-hour	Background
O_3	80 (ppb)	1-hour	Health
NO_2	200 (ppb)	1-hour	Health
SO_2	250 (ppb)	1-hour	Health
TSP*	120 (ug/m3)	24-hour	Visibility
PM_{10} **	50 (ug/m3)	24-hour	Health

* TSP is < 44um aerodynamic diameter.
** PM_{10} is < 10 um aerodynamic diameter (shows interim standard).
Source: OMOE, 2001[5] and 1999[6]

Using the AQI to Forecast Serious Air Pollution Episodes

One of the greatest benefits of the AQI is that it can be used to *predict* when serious air pollution is expected, as well as what the current pollution levels are around a particular location. The OMOE makes continuously updated AQI data available throughout Ontario. Computed AQI values and air quality forecasts are released to the news media and public several times each day.

In addition, the OMOE informs all Medical Officers of Health and their respective health units when a "Smog Watch" or "Air Quality Advisory" is called. An "air quality advisory" is called by the OMOE when there is a high probability that the AQI will exceed 50 on the AQI scale within the next 24 hours.

In the City of Toronto, the Medical Officer of Health issues a "Smog Alert" when informed by the OMOE of an "Air Quality Advisory". Both terms refer to the same thing: air quality is expected to be or is currently classified as "poor" based on the AQI reaching a value of 50 or greater. Table 4 summarizes the number of "smog alerts" in Toronto since 1993.

Table 4. Smog Alerts in Toronto

Year	Number of "Smog Alert" Episodes	Total Number of "Smog Alert" Days
1993	1	1
1994	2	5
1995	5	8
1996	2	3
1997	2	5
1998	3	7
1999	5	9
2000	3	3
2001	7	20

In 2000, the OMOE added the "Smog Watch" feature to provide a longer forecast period of when poor air quality is anticipated. A "Smog Watch" is called when there is a 50% chance that air quality will be "poor" (that is the AQI will exceed 50) within the next 3 days. The purpose of the smog forecast system is to enable people to better plan how to avoid increased exposure to pollutants, as well as minimize their pollution emissions during air pollution episodes.

Each year we can expect between 5 to 10 "smog alert" or "air quality advisory" days in Toronto based on the current AQI system. Because ozone is the pollutant that almost always triggers smog alerts in Toronto, there is considerable variation in the number of smog alerts each year since ozone's creation is dependent upon the weather. Ozone is created from a reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight. Consequently, when the weather is very hot and sunny, the amount of ozone that builds up is much greater than when the weather is cool, cloudy and rainy. Given that mean global temperatures are increasing, it is reasonable to expect the number of smog alerts to increase as well. The summer of 2001 resulted in a record number of "smog alert" days that coincided with unusually hot and dry weather. It is possible that fine particulates (PM_{10} and $PM_{2.5}$) were present in Toronto's air at excessive levels as well as ozone, but we do not currently have access to the data to substantiate that. In general, the levels of smog-related air pollutants that contribute to health impacts in Toronto have not decreased over the last 15 years.

To obtain the latest AQI values, call the OMOE's automated telephone dialling system at 1 800 387-7768 (or in Toronto call 416 246-0411). A French recording is available at 1 800 221-8852).

The AQI can also be obtained from the OMOE's website at www.ene.gov.on.ca.

In Toronto, Public Health operates a Smog Alert Information telephone line at 416 392-0808 and provides general information on smog and how to reduce it on its website at www.city.toronto.on.ca/health/smog/index.htm.

What's The Difference?

Smog Watch - *50% probability that air quality will be "poor" within the next 3 days.*

Air Quality Advisory - *high probability that air quality will be "poor" within 24 hours or that it is currently "poor".*

Smog Alert - *same thing as Air Quality Advisory.*

3. THE AQI AND HEALTH IMPACTS – WHAT THE TORONTO STUDY SHOWS

Air Pollution Levels Rated "Good" Most of the Time

In May 2000, when Toronto Public Health released its study *Air Pollution Burden of Illness in Toronto*, concerns were expressed about the adequacy of the province's Air Quality Index (AQI). Toronto Public Health staff have conducted a follow-up study entitled *Toronto Air Quality Index Health Links Analysis (2001)* to determine whether the provincial classifications (i.e. very good, good, moderate, poor and very poor) based on AQI values appropriately reflect the state of air quality and the associated burden of illness for Toronto. This section of the report summarizes the new technical study.

The AQI indicates that air quality in Toronto is "good" or "very good" more than 95% of the time when Toronto Public Health has estimated that air quality leads to about 1,000 premature deaths and 5,500 hospitalizations each year. To better understand how this can be, it is necessary to look at the levels of pollution in the city in relation to the AQI "break points".

Except for ozone, pollutant levels in Toronto rarely reach the "poor" or "moderate" AQI category. Table 5 summarizes the pollution levels for carbon monoxide, ozone, nitrogen dioxide, and sulphur dioxide in Toronto in 1995. By comparing average and maximum pollutant levels, it becomes apparent that, other than ozone, average pollutant levels are almost always in the concentration zone that the AQI classifies as "very good". In contrast, maximum levels for ozone reached the "poor" classification category at all six air monitoring sites in the city.

Table 5. Levels of Gaseous Air Pollutants in Toronto (1995)

Monitoring Site	Average and Maximum 1-Hour Pollutant Levels (ppb) *							
	CO		O_3		NO_2		SO_2	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.
Toronto (31103)	700	6,000	16.6	107	30	120	3	80
Scarborough (33003)	1,000	9,000	19.3	111	25	130	4	80
North York (34020)	500	9,000	18.6	108	18	100	2	60
Etobicoke West (35003)	800	10,000	16.3	96	25	110	3	210
Etobicoke South (35033)	900	9,000	16.5	117	30	120	5	90
York (36030)	1,000	8,000	17.8	98	30	180	3	60
AAQC (1-hour)		30,000		80		200		250

AQI break-points	CO	O_3	NO_2	SO_2
Very good	0 - 12,999	0- 23	0-104	0-164
Good	13,000 – 22,999	24 – 50	105– 204	165 – 250
Moderate	23,000 – 30,999	51 – 80	205 – 254	251 – 340
Poor	31,000 – 49,000	81 –149	255 – 524	341 – 1,999

* "Average" = annual arithmetic mean of 1-hour samples collected continuously.
"Maximum" = highest 1-hour reading in 1995.
Source: OMOE, 1996[7]

Method

The methodology for the *Toronto Air Quality Index Health Links Analysis* study upon which this report is based is described in detail in the technical report. The new study uses the 1995 air quality and health effects data compiled for the *Air Pollution Burden of Illness in Toronto* study. In both studies, the mortality and hospitalization estimates were calculated using air quality data for four of the six criteria pollutants in the AQI (O_3, NO_2, CO and SO_2), and for the particulate pollutants represented by PM_{10} and sulphates (SO_4). These air pollutants were selected because their adverse health effects have been clearly documented and quantified in the scientific literature. For each air pollutant, health impacts were estimated using a "unit incremental heath risk" that represents the increase in health impacts expected for each unit increase in air pollution. The "unit incremental health risk" numbers used for each air pollutant in the *Toronto Air Quality Index Health Links Analysis*[4] are the same numbers calculated for, and used in the original *Air Pollution Burden of Illness in Toronto* study.

In addition to the individual pollutant data that was compiled for the previous study, the new study obtained hourly data for the numeric value of the AQI from the OMOE for 1995. When the OMOE reports its hourly AQI data, the final AQI value is based on the pollutant that results in the highest AQI value. This pollutant is referred to in our study as the "driver" pollutant since it determines the AQI value reported.

A year has 8,760 hours (24 hours x 365 days). Accordingly, all AQI hourly values available from the OMOE for each of the six Toronto monitoring sites were used in the analysis. Due to a few missing values, there were some minor data gaps, but overall, about 8,500 hours of valid AQI data were available for analysis from each monitoring station. It needs to be noted that while continuous hourly levels of CO, NO_2, SO_2 and O_3 were available from the OMOE, PM_{10} data were available only on the basis of a 6-day rotation of daily 24-hour values.

Using the methodology applied in the original *Air Pollution Burden of Illness* study, the number of hospitalizations and premature deaths were calculated for each air pollutant for each category in the AQI. Consistent with the approach applied in the original study, health impacts for ozone and PM_{10} were calculated only for those daily concentrations that exceed the background levels (i.e., 30 ppb for ozone and 5 ug/m^3 for PM_{10}). In this way, the burden of illness was estimated only for that portion of ozone and PM_{10} air levels that can be prevented by emission reductions.

Summary of Results

Tables 6, 7, 8 and 9 summarize the results of this study and are described in greater detail in the technical report *Toronto Air Quality Index Health Links Analysis*[4]. Tables 6, 7, 8 and 9 also show the number of air-pollution related adverse health outcomes first calculated in the previous *Air Pollution Burden of Illness* study[1]. Each table also shows the relative distribution in a specific health outcome for each pollutant across the four air quality classifications – very good, good, moderate and poor.

Table 6. Summary of Distribution of Adverse Health Outcomes by AQI Category

Health Outcome	Estimated Number of Cases	% of Health Outcomes			
		Very Good	Good	Moderate	Poor
Premature Death	1,317	64	32	3	<1
Respiratory Hospitalization	2,083	61	35	3	<1
Cardiac Hospitalization	4,426	47	35	14	4
All outcomes		58	34	7	1

Table 7. Air Pollution Related Premature Mortality for Each AQI Category (Toronto – 1995)

Pollutant	Estimated Number of Premature Deaths	Relative Distribution in Premature Deaths per Pollutant Across AQI Categories (%)			
		Very Good	Good	Moderate	Poor
O_3	59	17	77	5	0
NO_2	485	70	27	3	<1
CO	431	66	28	4	<1
SO_2	117	63	30	6	0
PM_{10} (Includes SO_4)	226	58	42	0	0
SO_4	120	55	45	0	0
All pollutants	1,317	64	32	3	<1

Source: Toronto Public Health, *Toronto Air Quality Index Health Links Analysis*, Toronto: City of Toronto, October 2001.

Table 8. Air Pollution Related Respiratory Hospitalizations for Each AQI Category (Toronto – 1995)

Pollutant	Estimated Number of Respiratory Hospitalizations	Relative Distribution in Respiratory Hospitalizations per Pollutant Across AQI Categories (%)			
		Very Good	Good	Moderate	Poor
O_3	197	17	77	6	0
NO_2	1161	70	26	4	<1
CO	0	0	0	0	0
SO_2	168	63	30	7	<1
PM_{10} (Includes SO_4)	556	58	42	0	0
SO_4	171	54	46	0	0
All pollutants	2085	61	35	3	<1

Source: Toronto Public Health, *Toronto Air Quality Index Health Links Analysis*, Toronto: City of Toronto, October 2001.

Table 9. Air Pollution Related Cardiac Hospitalizations for Each AQI Category (Toronto – 1995)

Pollutant	Estimated Number of Cardiac Hospitalizations	Relative Distribution in Cardiac Hospitalizations Per Pollutant Across AQI Categories (%)			
		Very Good	Good	Moderate	Poor
O_3	880	<1	34	49	17
NO_2	2184	70	27	4	<1
CO	552	18	59	20	3
SO_2	0	0	0	0	0
PM_{10} (Includes SO_4)	810	57	43	0	0
SO_4	171	54	46	0	0
All pollutants	4426	47	35	14	4

Source: Toronto Public Health, *Toronto Air Quality Index Health Links Analysis*, Toronto: City of Toronto, October 2001.

Significant Burden of Illness Occurs when Air Quality is "Good"

The results show that 92% of the premature deaths and hospitalizations attributable to air pollution in Toronto occur when air quality has been classified as "good" or "very good" by Ontario's AQI. An estimated 8% of the adverse health outcomes occur when the air quality is in the "moderate" or "poor" range (see Table 6).

This does not mean that "poor" air quality has little adverse impact on health. It shows, rather, that the "poor" air quality designation does not capture the many hours and days when air pollution is actually adversely affecting health. In other words, air quality that is currently classified by the AQI as "very good" or "good" is responsible for a significant portion the adverse health effects attributed to air quality.

The statistical illusion that the least health burden occurs when the levels are the highest arises from the fact that there are many more "good" air quality days than there are "poor." On any specific day when pollution levels are high, the overall number of adverse effects is greater than on any specific day when pollution levels are low. However, there are many more hours/days of "very good" or "good" air quality than there are "moderate" or "poor" air quality. It is the many hours/days of somewhat lower levels of air pollutants that contribute to the large burden of ill health and premature mortality that has been observed in Toronto.

Most Health Effects Occur Below Regulatory Limits

The study demonstrates that most of the adverse health effects seen in the Toronto population associated with each of the six air pollutants occur when pollution levels are below the respective air standards. For ozone and carbon monoxide, about 80% of the health effects occur when the air quality is rated as "very good" or "good" by the AQI. For nitrogen dioxide and sulphur dioxide, about 95% of the adverse health effects occur at levels rated as "very good" or "good" by the AQI. In the case of particulates, 100% of adverse health effects in Toronto residents occur when air quality is described as "good" or "very good".

As indicated earlier in the report (see Table 1), when the pollutants that make up the AQI are rated as "good" or "very good", they are present at levels well within their respective air quality standards. Were the air quality criteria for carbon monoxide, nitrogen dioxide, and sulphur dioxide revised to better reflect current health effects research, it is reasonable to predict that more days would be designated as "poor" air quality days in the city (based on the assumption that exceedances of air standards would coincide with a "poor" designation). And because these three air pollutants tend to be present at higher levels in the winter months[1], it is likely that this could result in "smog alerts" being issued in the winter as well as in the summer months.

Cold weather "smog alerts" could have a beneficial impact on public education and policy development related to air quality. They could reinforce the need to develop long-term, year round emission reduction behaviours, practices and programs at both the individual and institutional level.

Significant Burden of Illness Associated with Fine Particulates

Particulates is the term used to refer to tiny particles in the air. These particles can include road dust, acid mists, metal fumes and organic chemicals. In the past, particulate levels were measured based on total suspended particulates (TSP) averaged over 24-hour periods. Total suspended particulates (TSP) includes all particles with a diameter less than 44 microns, which means that they can include dust associated with construction projects.

While the OMOE had introduced an interim 24-hour criterion for fine particulates (PM_{10}) of 50 ug/m^3 in 1997 that better reflects health concerns than total suspended particulates (TSP), PM_{10} has not yet been added to Ontario's AQI.

Scientific research conducted in recent years has demonstrated that adverse human health effects are more closely associated with the inhalable particulates (PM_{10}) that are less than 10 microns in diameter and the respirable particulates ($PM_{2.5}$) that are less than 2.5 microns in diameter, than with the total suspended particulates (TSP). These fine particulates (PM_{10} and $PM_{2.5}$) include less inert dust and can penetrate deeper into the lungs to affect the more sensitive tissues.

The results of this study reinforce the importance of incorporating fine particulates (PM_{10} or $PM_{2.5}$) into Ontario's AQI. Tables 7, 8 and 9 indicate that fine particulates (PM_{10}) are responsible for about 27% of premature deaths, 44% of respiratory hospitalizations, and 35% of cardiac hospitalizations attributed to air pollution in the City of Toronto each year. This is too significant a burden of illness to be excluded from an air quality rating system. In order for the AQI to function as an effective public warning system, it must include fine particulates so that people can be notified when fine particulates are present at air levels that could be harmful to health. This is particularly important for those people with pre-existing conditions such as heart problems who are at greatest risk.

If fine particulates (PM_{10} or $PM_{2.5}$) were added to the AQI, it is expected that there would be a modest increase in the number of "smog alerts" issued each year. Using 1998 monitoring data, the OMOE has estimated that the interim standard for PM_{10} is exceeded about 5% of the time at the monitoring stations in downtown Toronto. As these exceedances occur in both the winter and summer months, it is expected that fine particulates would result in smog alerts being issued in the winter months as well.

By 1998, the OMOE had established 24-hour PM_{10} monitoring stations at 26 urban locations in Ontario[5]. This monitoring system is based on a 6-day sampling cycle, which means that data are available for a given site once every six days. This means that currently, the OMOE measures air levels of fine particulates when they occur on one of the six days in which monitoring is conducted. This differs

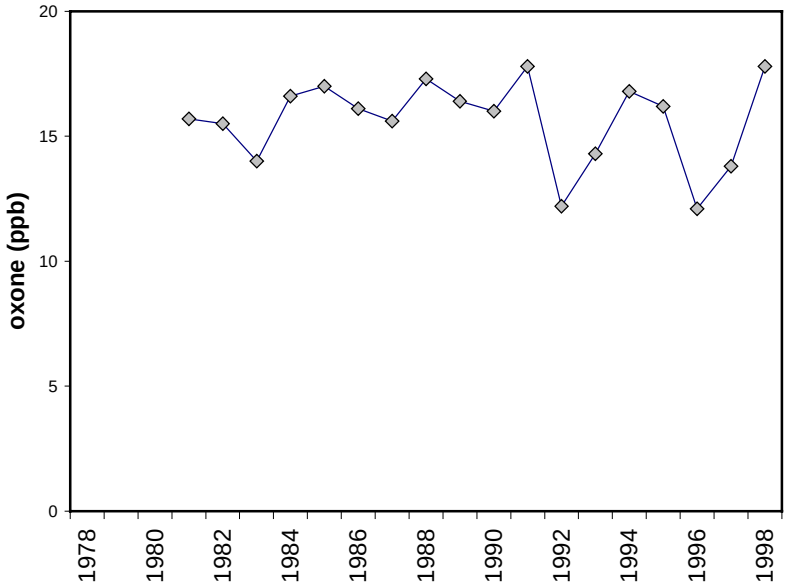
substantially from the continuous hourly air quality data that is collected every day for the other pollutants that are included in the AQI system. This point reinforces the need to accelerate the implementation of the state-of-the-art continuous $PM_{10}/PM_{2.5}$ monitoring network across the province. The technology, known as TEOM, is commercially available and starting to be used by the OMOE.

4. WHY WE NEED AN IMPROVED SMOG WARNING SYSTEM

Air Quality Will Not Improve Quickly

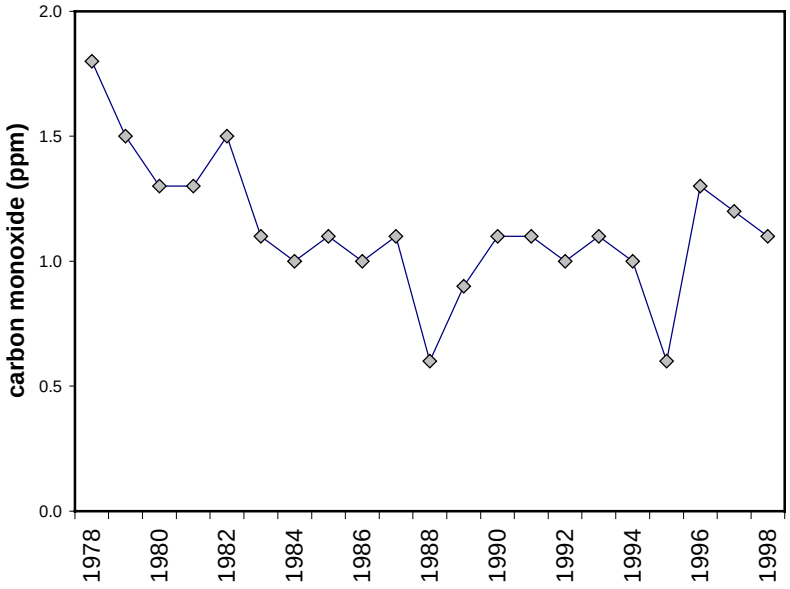
Unfortunately, smog is here to stay for quite a while. It will take many years before air quality improves substantially in Ontario, even with concerted action by all levels of government, industry and individuals. Pollution trends in Toronto over the last 15 years do not provide reason for optimism. Figures 1 to 5 show that the yearly average levels of ozone, carbon monoxide, sulphur dioxide, suspended particulates and nitrogen dioxide have not improved substantially in the 15-year span between 1983 and 1998.

Figure 1. Yearly Average Levels of Ozone in Toronto 1978-1998



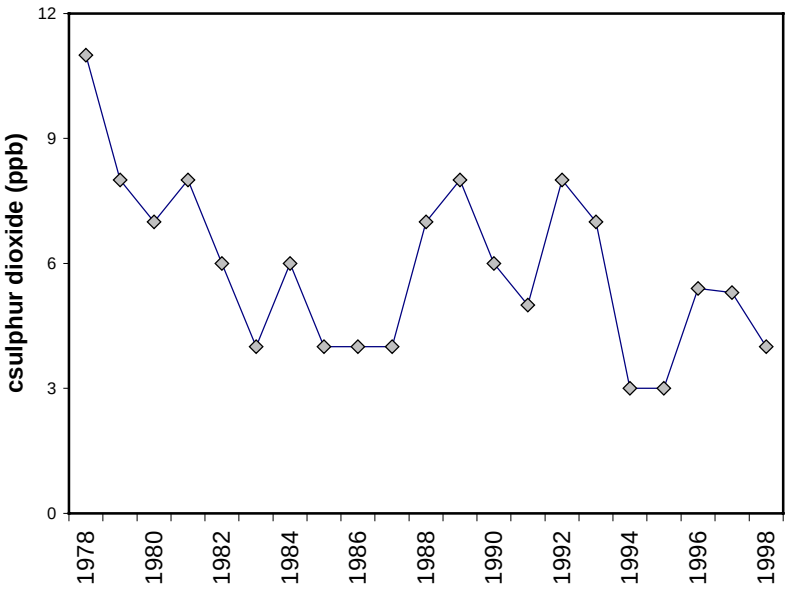
Source: Based on OMOE data.

Figure 2. Yearly Average Levels of Carbon Monoxide in Toronto 1978-1998



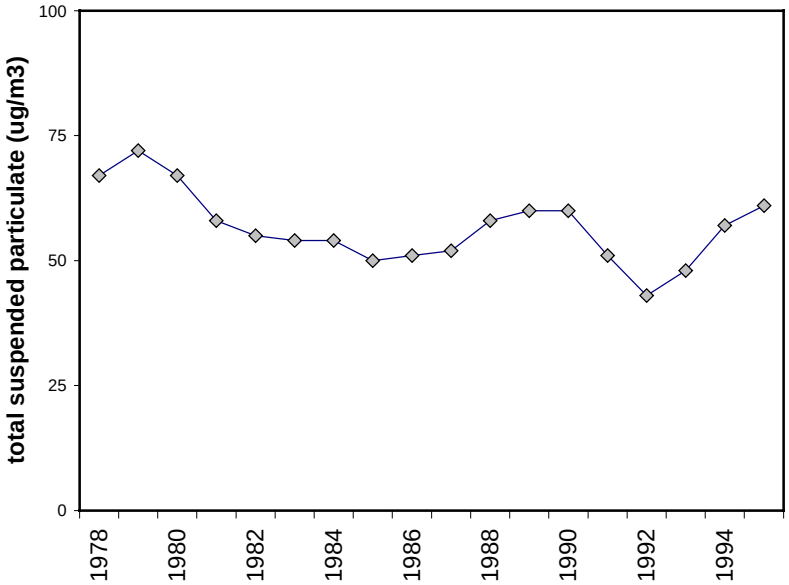
Source: Based on OMOE data

Figure 3. Yearly Average Levels of Sulphur Dioxide in Toronto 1978-1998



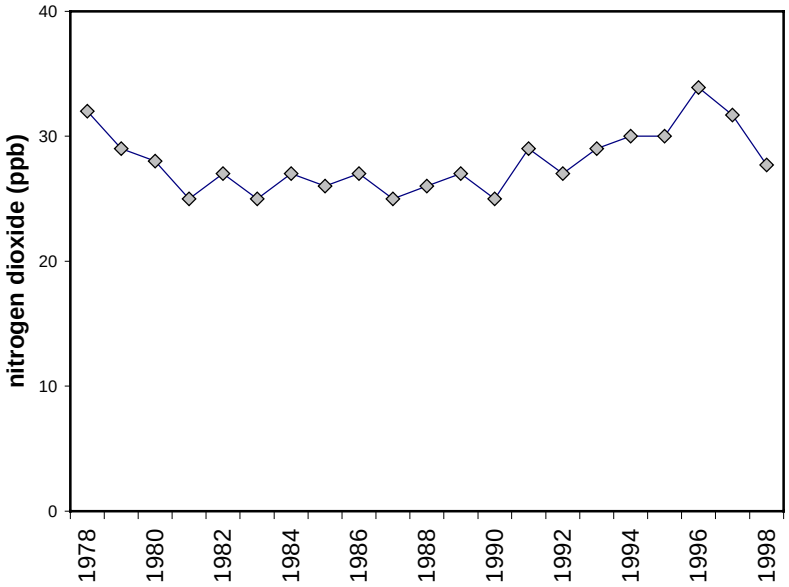
Source: Based on OMOE data.

Figure 4. Yearly Geometric Mean Levels of Total Suspended Particulate in Toronto 1978-1998



Source: Based on OMOE data.

Figure 5. Yearly Average Levels of Nitrogen Dioxide in Toronto 1978-1998



Source: Based on OMOE data.

The Population at Risk is Significant and Growing

Research has consistently demonstrated that seniors, young children and those with pre-existing respiratory and cardiac conditions are more sensitive and more vulnerable to air pollution than the general population [1,3].

A significant number of Toronto residents experience respiratory and cardiac conditions that may put them at increased risk when air quality is poor. Figure 6 indicates that there were 48,000 hospitalizations of Toronto residents in 1998 due to "breathing or heart problems". "Heart problems" include conditions such as dysrythmia, ischaemic heart disease and heart failure. "Breathing problems" include conditions such as respiratory infections, obstructive lung disease and asthma. The hospitalization data in Figure 6 suggest that both seniors and children experience high rates of hospitalization for respiratory illness compared with the rest of the population.

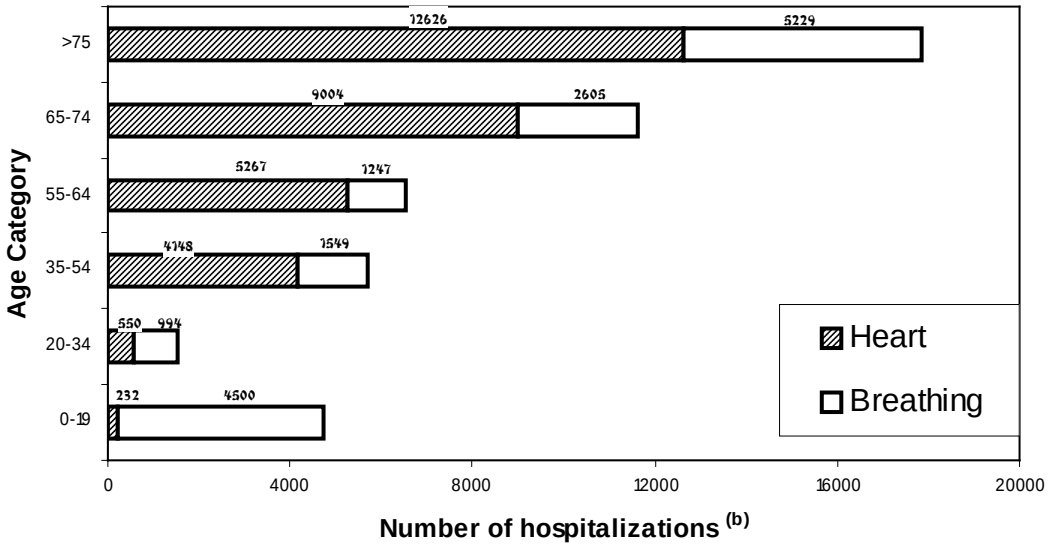
Asthma affects a significant portion of the Canadian population. The 1996-97 National Population Health Survey indicates that more than 2.2 million Canadians have been diagnosed with asthma by a physician at some time in their lives. It also indicates that more than 12% of Canadian children ages 0 – 19 years and 6.3% of adults have been diagnosed with asthma[9].

At the same time as air quality improvements have stalled, the size of some sensitive populations has increased. A number of studies suggest that asthma rates are increasing in Canada. For example, Ontario's Chief Medical Officer of Health has reported that the prevalence of asthma in children under 14 years has risen dramatically from 2.5% in 1983 to 11.2% in 1995 [10]. This suggests that a greater proportion of children are at increased risk from air pollution today than twenty years ago.

In addition, seniors, who are known to be at greater risk from air pollution, represent a growing population within Toronto. The population of seniors in Toronto is increasing at a rate that outstrips growth of the overall population. Figure 7 demonstrates that the population of seniors in Toronto almost doubled between 1971 and 1996 while the overall population increased by only 14% over the same time period. This suggests that a greater number of Toronto's seniors are at increased risk from air pollution today than 20 years ago. With increasing life expectancy, we can expect this trend to continue.

An effective smog warning system is one that provides sensitive populations – seniors, children, and those with pre-existing medical conditions – with accurate and up-to-date information about the adverse health effects that may be associated with different pollution levels. Given that sensitive populations are at increased risk at lower air pollution levels than the general population, they would benefit from accurate air quality and health effects information so that they can undertake personal protection measures.

Figure 6. Toronto Hospitalizations Due to Breathing and Heart Problems – 1998/99[(a)]

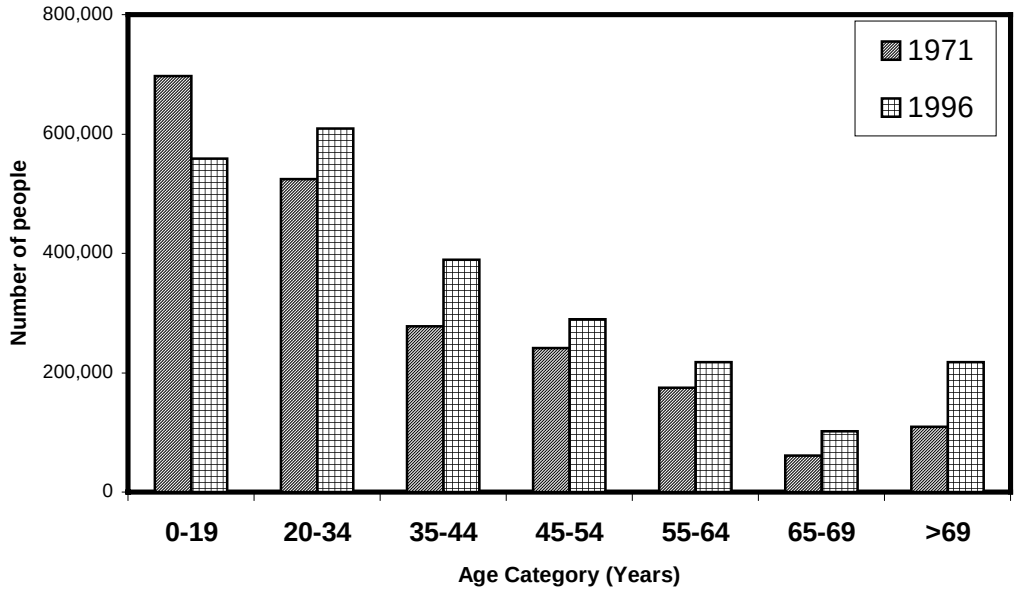


Source: OMHLTC, 2001[8]

(a) "Heart problems" refer to cardiovascular hospitalizations for conditions including dysrythmia, ischaemic heart disease and heart failure.
"Breathing problems" refer to respiratory hospitalizations for conditions including respiratory infection, obstructive lung disease and asthma.
Total population in Toronto in 1998 is estimated to be 2,508,948 (MOHLTC, 2001. 1998 data).

(b) In 1998, there were 47,951 hospitalizations of Toronto residents due to cardiac and respiratory problems.

Figure 7. Population Distribution by Age in Toronto, 1971 vs 1996



Source: Statistics Canada, 1999.

The Absence of a Threshold

There is a growing body of evidence that demonstrates that there may be no threshold of exposure to air pollution that is without some health risk. In other words, it may be more accurate overall to say that for some people living in a large urban centre, many days may be a "bad" air day, but that some times of the day have better air quality than others. In light of this reality, it is important to reconsider the structure of the AQI messaging system. It may be helpful to move away from discrete descriptive categories such as "good" and "poor" towards less value-laden classifications that emphasize the continuous nature of the AQI scale, much like is done for the UV Index.

By emphasizing the continuous nature of the AQI scale, it would be easier to convey that all levels of air pollution entail some hazard for some populations. The greater the number on the AQI scale, the greater the hazard. With such a system, the public would be encouraged to pay attention to the AQI value itself, rather than to an AQI classification that suggests that air quality is "good" or "very good" when it is not. We suggest adding the descriptors "background", "low", "medium", "high" and "smog alert" to help the public understand the numeric AQI scale.

In essence, the continuous scale feature of a revised AQI system could be used to enable the public, and especially sensitive populations, to take action to protect their health at levels well below the regulatory limits. For example, persons with asthma or chronic obstructive lung disease may need to take precautionary measures at AQI values that pose little health threat to the general population.

A continuous scale could continue to forecast and trigger "air quality advisories" or "smog alerts". It may be reasonable to trigger "smog alerts" when any one pollutant exceeds its respective regulatory standards. With this approach, "smog alerts" would still be reserved for more serious pollution episodes. Of course, in order for "smog alerts" to be triggered under appropriate circumstances, it is essential that regulatory standards reflect the current scientific knowledge respecting health effects.

Air Pollutants Can Have a Cumulative Effect

Tables 7, 8, and 9 reinforce that human health is affected by the levels of several different pollutants that are commonly present in the air. All six of the air pollutants examined in this study contribute to the premature deaths and hospitalizations attributed to air pollution in Toronto.

The current AQI system has not been designed to reflect this reality. The AQI value reported to the news media and the public is based on a single pollutant (i.e., the 'driver") that gives rise to the highest calculated AQI for a given hour at a given monitoring station. The current AQI system does not indicate those times when more than one air pollutant is present at higher levels.

Depending on their sources, the various pollutants that make up the AQI will not necessarily increase or decrease together at the same time. For example, ozone levels typically build up in the afternoon but nitrogen dioxide levels show peaks with rush hour traffic. Monitoring data reveal that on some "smog alert" days ozone levels are high but other pollutants are not, and conversely that on low ozone days, particulate levels may be very high. These observations suggest that it may be useful to consider developing a new formula for calculating AQI values so that they take into account the sum of pollutant contributions for a given hour. In this way, the AQI may provide a more accurate reflection of actual pollutant exposures, and consequently, provide a better predictor of health risk.

5. AN AGENDA FOR ACTION

This investigation of the Air Quality Index (AQI) and its relationship to air pollution-related illness and premature death in Toronto gives rise to the following observations and conclusions:

The Need to Revamp the AQI System

- Toronto Public Health's research shows that about 92% of the premature mortality and hospitalizations attributable to air pollution occurs when air quality is in the "good" or "very good" range, as classified by the Ontario Ministry of the Environment. An estimated 8% of adverse health outcomes occur when the air quality is in the "moderate" or "poor" range. This suggests that the current AQI messaging system does not accurately reflect the potential health risks associated with lower levels of air pollutants.

  While not intentionally, the current AQI system conveys the impression to the public that air pollution is without health risk, and therefore not a concern until AQI values reach the "poor" classification. Less effort needs to be spent on informing the public that air quality is "good" or "very good" most of the time, and more effort is needed to inform the public about the overall health impacts of air pollution as well as the probable effects of lower levels of air pollution that are of concern to vulnerable subpopulations.

- The *no threshold* concept is a very important one to consider in the development of a good AQI communications tool. A growing body of scientific evidence is challenging the notion that a threshold level exists below which smog-related pollutants do not harm human health. It is therefore important to reconsider the structure of the AQI messaging system to get away from discrete categories (i.e., "good" and "poor") and move towards emphasis of a continuous AQI scale similar to that used for the UV Index. A continuous scale could more easily convey that all levels of smog entail some hazard. The greater the AQI number, the greater the health hazard, and vice versa.

- The formula used to calculate the AQI values should be re-examined. The current system is based on the concept of a "driver" pollutant. The AQI values reported to the news media and public are based on the single pollutant (the "driver") that gives rise to the highest calculated AQI for a given hour at a given monitoring site.

The health impact, however, is likely the *sum* of the effects of the various pollutants that a person is exposed to at that time. By calculating the hourly AQI values in a way that takes into account the *sum* of pollutant contributions for a given hour, the AQI could better predict health risk and therefore function as a better warning system.

- There is an urgent need to add fine particulates (PM_{10} and/or $PM_{2.5}$) to the mix of pollutants included in the AQI. The current use of the "coefficient of haze" (COH) does not provide an accurate indicator of those fine particulates that have been most clearly associated with adverse health effects. The addition of fine particulates to the AQI will likely result in a modest increase in the number of "smog alerts", some of which are anticipated to happen in the winter months.

- If "smog alerts" occur in both summer and winter, it would reinforce the need to implement long term year round shifts in individual behaviours as well as corporate emission reduction practices. In this way, an improved smog warning system would be of benefit to both public education and policy development.

Improved Messaging Around Health Effects

- Overall, smog-related pollution levels in Toronto have remained relatively constant in the last 15 years and show no signs of significant improvement. At the same time as air quality improvements have stalled, the size of some populations at risk has increased considerably. For example, the population over the age of 65 has almost doubled between 1971 and 1996, even though Toronto's population has increased only 14% (from 2.1 to 2.4 million) over that time period. Seniors are at particular risk from air pollution since they have more respiratory and heart problems than the general population.

  Children with pre-existing respiratory problems are also at increased risk from air pollution. This is particularly true for children with asthma. There are reports that the prevalence of asthma in Canadian children has increased dramatically from 2.5% in 1983 to 11.2% in 1995.

- Given the very large number of people in Toronto (and Ontario) who have breathing and heart problems, it is important that the AQI communications tool develop special messaging for vulnerable populations. By shifting the emphasis towards the continuous nature of the AQI scale, it would be possible to deliver health messages to sensitive populations for AQI values lower than those of concern to the general population.

- There is a need to update the health effects information that is provided to the media and public in explaining the health implications of the AQI values. The current information provided is seriously out-of-date. As such, it is very misleading because it suggests "no known health effects" for pollution levels known to impact on human health. Scientists at Health Canada need to assist the Ontario Ministry of Environment and Environment Canada in developing more appropriate health messaging.

Improved Smog-related Air Pollution Standards

- In Toronto, over 95% of smog-related illness and death takes place when pollution levels are within the regulatory limits. The provincial standards (i.e. AAQC values) for nitrogen dioxide, sulphur dioxide and carbon monoxide are particularly out of date and need to be revised, taking into account the latest health-effects research.

- In addition to a renewed emphasis on the continuous nature of the AQI scale, the OMOE should maintain an AQI value that continues to forecast and trigger "air quality advisory" or "smog alert" days. It may be reasonable to trigger "smog alerts" at the AQI level that occurs when any one pollutant exceeds the regulatory standard (i.e. AAQC).

Provision of State-of-the-Art Pollution Monitoring System

- The AQI communications tool is dependent on the quality and quantity of air pollution monitoring data that is collected across Ontario (and Canada). This data must be available on a continuous basis so that hourly pollution levels can be converted to hourly AQI values.

  Pollution levels fluctuate considerably throughout the day. By having continuous up-to-date AQI information available, members of the public can plan their activities so that periods of high pollution can be avoided, especially with respect to vigorous outdoor activities.

- The OMOE is moving towards implementation of state-of-the-art continuous monitoring of PM_{10} and/or $PM_{2.5}$. The technology, known as TEOM, is commercially available. Use of this technology could provide hourly fine particulate data that in turn could be incorporated into the AQI.

Sufficient resources need to be made available to the OMOE to enable it to implement continuous monitoring of fine particulates across the province. It is also important to supplement this monitoring with the capability to identify the chemical composition of fine particulates to better understand how particulates affect health.

Five Point Action Plan: Fixing Our Smog Warning System

1. *Implement province-wide continuous monitoring of fine particulates (PM_{10} and/or $PM_{2.5}$) and add fine particulates to the AQI.*

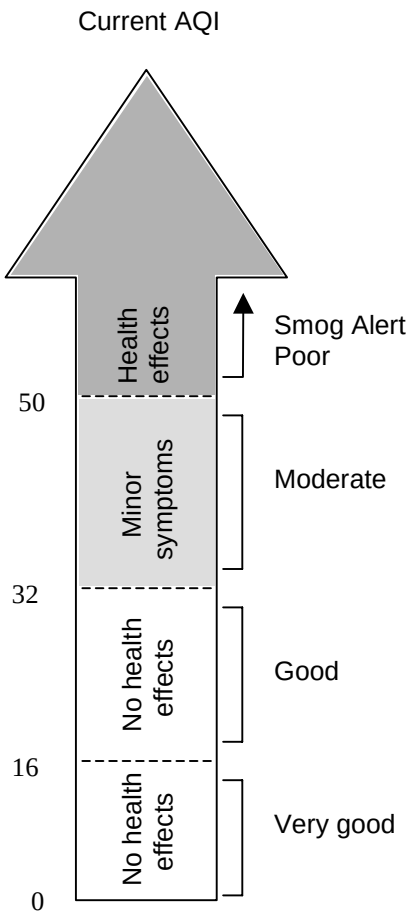
2. *Replace the existing AQI categories (very good, good, moderate, poor, very poor) with more appropriate classifications (background, low, medium, high, smog alert) to emphasize that adverse health impacts increase with increasing AQI values..*

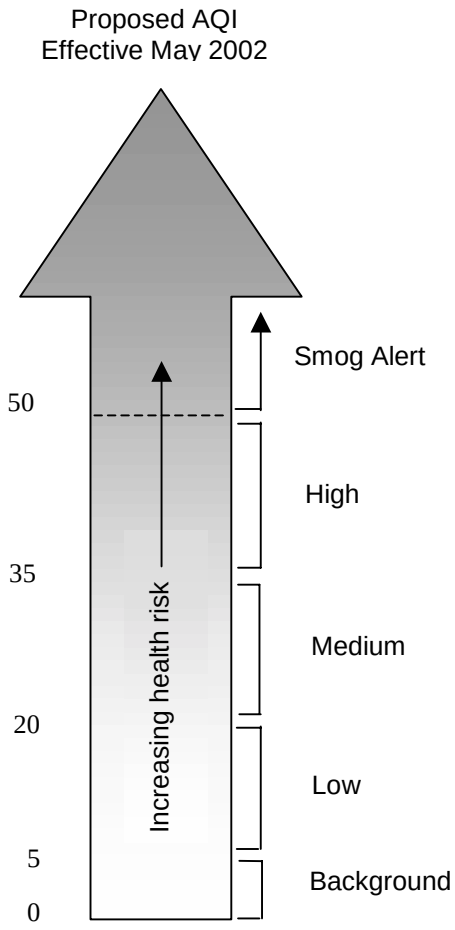
3. *Use the latest scientific research to describe health effects expected at all pollution levels and develop a special messaging system that alerts sensitive populations to the health risks that they may encounter at lower pollution levels.*

4. *Update the regulatory standards for air pollutants included in the AQI to ensure that they better reflect adverse health effects.*

5. *Revise the AQI formula to reflect the cumulative health impacts associated with simultaneous exposures to more than one air pollutant, and establish an AQI value that triggers "smog alerts" (e.g., at exceedance of regulatory standards).*

The first three points of this Action Plan are urgently needed and relatively easy to do. They should be implemented before May 2002 when next summer's smog season begins and the public begins to pay attention to smog alerts. The fourth and fifth points will take longer to accomplish because of the intensive nature of the research and consultation involved in standard setting and assessing cumulative impacts, however, they are essential components in the ongoing improvement of the AQI.





The current AQI misrepresents health risk by conveying to the public that there is no health risk when the AQI is less than 32 and in the "good" or "very good" range. It is not until the AQI reaches 50 that health risks are publicized. This puts vulnerable populations at risk who experience adverse health impacts at AQI levels below 50. It also undermines public education efforts to encourage the public to reduce household emissions because they are led to believe that air quality is good or very good most of the time.

To ensure a smooth transition to an improved AQI in 2002, it is proposed that the current number scale for the AQI be maintained but that the descriptive labels are changed. It is also essential that fine particulates be added to the AQI formula so that smog alerts are triggered when PM_{10} exceeds its provincial standard. As a result, a slight increase in the number of Smog Alerts would be expected in 2002 compared with 'typical' years.

In the new system, Smog Alerts would still be triggered once the AQI reaches 50. This would happen when any one AQI pollutant exceeds its regulatory standard. In addition, the new system would emphasize increasing health risk as the AQI number gets larger. Special messages would need to be developed for vulnerable populations that alerts them to increased health risks as the AQI values increase to the "medium" and "high" range.

6. RECOMMENDATIONS

It is recommended:

1. That the Ontario Minister of the Environment improve the Air Quality Index (AQI) and smog advisory notification system as set out in this report by:

   (a) Lowering the Ambient Air Quality Criteria (AAQC) for nitrogen dioxide, carbon monoxide and sulphur dioxide to reflect current research on the human health effects of these air pollutants;

   (b) Restructuring the AQI system to make it a more accurate indicator of health concerns by:

      (i) Adding fine particulates (PM_{10} and/or $PM_{2.5}$) to the mix of pollutants used to calculate the AQI;

      (ii) Developing a new formula to calculate AQI values that takes into account the total pollutant contributions for each given hour;

   (c) Restructuring the AQI messaging system by:

      (i) Emphasizing that the AQI is a continuous scale in which health risk increases as the AQI number increases;

      (ii) Re-naming "Air Quality Advisories" as "Smog Alerts" to increase public understanding that serious air pollution episodes are occurring;

      (iii) Discontinuing to describe air quality as "good" or "very good" when the AQI is less than 32;

      (iv) Replacing the current AQI classifications (very good, good, moderate, poor, very poor) with more appropriate classifications (background, low, medium, high and smog alert) by May 2002;

      (iv) Continuing to forecast and trigger "air quality advisories" and "smog alerts" when some predetermined AQI value (such as a regulatory standard) is exceeded; and

      (v) Developing a special messaging system that alerts sensitive populations (such as the elderly, children and those with respiratory and cardiac problems) to AQI values that pose increased health risks;

   (d) Accelerating the implementation of province-wide continuous monitoring of fine particulates (PM_{10} and/or $PM_{2.5}$);

2. That the Government of Ontario ensure that sufficient resources are made available to the Ministry of the Environment to implement continuous monitoring of fine particulates across the province, and to improve the Air Quality Index (AQI) as advised in Recommendation 1;

3. That the federal and provincial Ministers of Health provide the federal and provincial Ministers of the Environment with updated information on the adverse health effects anticipated at different Air Quality Index (AQI) values based on the latest international health studies;

4. That the federal Minister of the Environment ensure that the proposed new national Air Quality Index (AQI) for Canada includes fine particulates and encompasses a health effects warning system that accurately conveys the health risk associated with AQI values for both the general population and more sensitive subpopulations;

5. That the Toronto Medical Officer of Health and her staff offer to assist in the review of improved health messaging associated with the current provincial and proposed federal Air Quality Index; and

6. That this report be forwarded to: the GTA Clean Air Council; all health units in Ontario; the Ontario Public Health Association, the Canadian Public Health Association; the Canadian, Ontario and New Brunswick Lung Associations; the Association of Municipalities Organizations; and the Federation of Canadian Municipalities, for their information and action as appropriate.

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