Section 1

Introduction

Since 1979, the Index of the Quality of the Air (IQUA) has been published for Canadian cities as a single value derived from the measurement of several air pollutants that are averaged from 1 to 24 hours. While first used in Saint John, New Brunswick, its design has been accepted from coast to coast. Cities and towns continue to adopt it, usually with the assistance of provincial and federal departments of the environment.

The index is designed to help agencies better inform the public about the general or prevailing air quality in their community. The single number describes ambient air in terms of both the measured levels of pollution and the public perception of the quality of the air at a certain time and location.

The IQUA has the following attributes, it:

- has been scientifically designed;
- includes the major pollutants;
- relates the effects of air pollutants on the environment to a common scale;
- is a uniform index, thereby allowing different locations to be compared;
- is designed so that other pollutants or combinations thereof, can be included;
- is a stringent index as it communicates the worst effect;
- represents the air quality in the vicinity of a monitoring station; and
- is consistent with publicly perceived air quality.

The IQUA is based on the National Ambient Air Quality Objectives (NAAQOs) (Tables 1 and 2), which have been defined under the *Canadian Environmental Protection Act* (CEPA) and which provide a uniform scale for assessing the quality of the air in all parts of Canada. These objectives are set for three levels: **desirable, acceptable,** and **tolerable**. Objectives have been set for the following pollutants: sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and total suspended particulate (TSP). An objective has recently been proposed for total reduced sulphides (TRS).

The **maximum desirable objectives** are long-term goals for air quality generally; they also provide a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology.

The **maximum acceptable objectives** are intended to provide adequate protection against adverse effects on humans, animals, vegetation, soil, water, materials, and visibility.

The **maximum tolerable objectives** denote time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population.

Levels greater than maximum tolerable require immediate attention to bring about

Table 1 National Ambient Air Quality Objectives* (Environment Canada, 1990)

Pollutant	Averaging Time	Maximum Desirable Concentration**	Maximum Acceptable Concentration**	Maximum Tolerable Concentration**
Sulphur Dioxide	annual	0.01	0.02	
	24-hour	0.06	0.11	0.31
	1-hour	0.17	0.34	
Suspended Particulate	annual	60 $\mu g/m^3$	70 $\mu g/m^3$	
	24-hour		120 $\mu g/m^3$	400 $\mu g/m^3$
Ozone	annual		0.015	
	1-hour	0.05	0.08	0.15
Carbon Monoxide	8-hour	5	13	17
	1-hour	13	31	
Nitrogen Dioxide	annual	0.03	0.05	
	1-hour		0.21	0.53

* Conditions of 25°C and 101.32 kPa are used as the basis for conversion from $\mu g/m^3$ to ppm or ppb.
** Units are in ppm unless otherwise indicated.

improved air quality for the protection of the public. Consultation with health experts in such situations would be advisable so that better advice to the public can be provided.

The following assumptions have been made in the design and use of this index.

- The index will be based on valid air quality data obtained from monitoring stations that are situated so as to represent the general air quality of a community.
- At the defined objective levels (desirable, acceptable, and tolerable), the effects of all pollutants have equal importance with respect to the quality of the air.
- The index can be calculated for each hour of the day and consideration is given to the last 1-hour average and the last 8-hour and 24-hour running average concentrations.
- The air quality objectives for TSP cannot be fairly represented by IQUA due to the lack of employment of real time particulate monitoring equipment in Canada. However because of the importance of particulate to an air quality index, the following may be considered as interim surrogates for continuous TSP measurements:
  - daily 24 hour TSP (HiVol) measurements,

Table 2 Examples of Types of Effects Used as Break Points [a,b]

National Ambient Air Quality Objectives Averaging Time	Carbon Monoxide[c] CO (1-hour, 8-hour)	Nitrogen Dioxide NO_2 (1-hour)	Ozone O_3 (1-hour)	Sulphur Dioxide SO_2 (1-hour, 24-hour)	Suspended Particulate[d] (24-hour)
Beyond Tolerable (Very Poor Range)	Physiological stress on individuals with cardiovascular and respiratory disease; possibly increased mortality.	Increasing sensitivity of patients with asthma and bronchitis.	Impairment of respiratory function; increased respiratory symptoms.	Hypersensitive individuals may experience breathing difficulties; increased morbidity.	Increasing sensitivity in patients with asthma and bronchitis.
Maximum Tolerable (Poor Range)	Increasing cardiovascular symptoms in nonsmokers with heart disease. Some visual impairment.	Increased rate of respiratory illness from long-term exposure. Odour and atmospheric discoloration.	Decreasing performance by some athletes exercising heavily.	Increasing sensitivity in patients with asthma and bronchitis. Odorous. Increasing vegetation damage and sensitivity.	Visibility decreased. Soiling evident. Increased frequency and severity of lower respiratory disease in children.
Maximum Acceptable (Fair Range)	Increasing cardiovascular symptoms in smokers with heart disease. Blood chemistry changing.	No known human health effects.	Increasing injury to some species of vegetation.	Increasing (foliar) injury to species of vegetation.	Decreasing visibility.
Maximum Desirable (Good Range)	No effects.	No objective.	Materials are affected by ambient air levels of oxidants.	No effects.	No objective.

a Examples extracted from the National Air Quality Objectives published from 1974 to 1978.
b Health Canada and environment Canada advise that the matrix is provided as an example only and does not represent the full nature or extent of the health and environment effects.
c In order to protect all sensitive groups of the population, ambiant concentrations of CO should be such that COHb levels do not exceed 5% saturation in nonsmokers.
d The levels do not apply to chemically active particles.

- COH**/visibility sub-index, and
- COH/inhalable particulate sub-index.

Some jurisdictions have developed visibility and inhalable particulate sub-indices based on 1-hour and 2-hour COH measurements. The committee found these not to be as good as real time measurements of inhalable particulate. Consistent with the IQUA philosophy, only pollutant sub-indices based on NAAQOs published under CEPA should be included in the report. To date, an objective for inhalable particulate (PM_{10})

** COH = Coefficient of Haze

has not been developed and the proposed objective for Total Reduced Sulphur (TRS) is currently under evaluation. However, these have been included in this report, with the appropriate cautionary statements, as an appendix. Any agency (jurisdiction) adopting these sub-indices should carefully consider these limitations.

Protecting against the potential adverse effects of certain pollutants on humans, animals, vegetation, soil, water, materials and visibility is the rationale for establishing up to three levels of National Ambient Air Quality Objectives (NAAQOS). Table 2 is an example of an effects matrix showing the types of effects used as breakpoints in the establishment of NAAQOs. The breakpoints set the boundaries for the IQUA ranges of Good to Very Poor. These types of matrices can be used by air pollution agencies in conjunction with appropriate health department consultation to issue cautionary health statements to the public about the potential effects of air quality as reported by the IQUA.

Section 2

Determination of the Index

To determine the Index, the concentrations of individual pollutants are converted to a common scale (the pollutant sub-index scale). The scale is designed so that a value of 0 corresponds to 0 concentration, 25 corresponds to maximum desirable, 50 corresponds to maximum acceptable, and 100 corresponds to maximum tolerable. The convention is that the index increases with deteriorating air quality.

As shown in Figures 1 to 6, the breakpoints for the segmented linear function are obtained from the Ambient Air Quality Objectives. Where objectives were not specified for a particular pollutant and/or averaging time, the pollutant index was determined by linear interpolation or extrapolation, or by acceptance of breakpoints established by other jurisdictions, as shown in the pollutant sub-index figures. For example, a level of 2 ppm SO_2 has been recommended as the appropriate maximum tolerable level (1-hour), but has not been adopted as a National Ambient Air Quality Objective (Figure 2).

Using the figures (graphs) in this report directly or by solving the equations using breakpoints provided in Table 3 (with computer assistance), each individual pollutant concentration can be converted to a pollutant sub-index.

After each pollutant sub-index has been determined, the maximum sub-index value is selected as the numerical value of the Index of the Quality of the Air.

The air quality can then be described verbally according to the following scale:

Descriptor	Numerical Values
Good	0 to 25
Fair	26 to 50
Poor	51 to 100
Very poor	101+

For example, at 0800h today in the downtown area, the following concentrations of pollutants were observed:

- average sulphur dioxide (SO_2) over the last hour = 0.14 ppm
- average sulphur dioxide (SO_2) over the last 24 hours = 0.05 ppm
- average carbon monoxide (CO) over the last hour = 21 ppm
- average carbon monoxide (CO) over the last 8 hours = 2 ppm
- average nitrogen dioxide (NO_2) over the last hour = 0.10 ppm
- average ozone (O_3) over the last hour = 0.07 ppm

Using Figures 1 through 6, the pollutant sub-indices in Table 4 were determined:

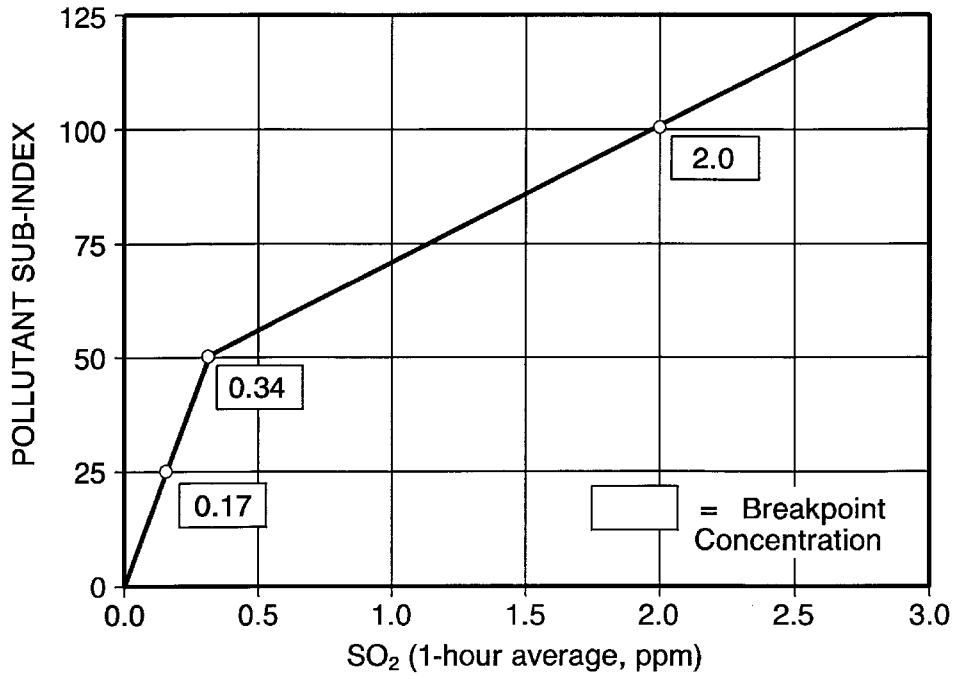

Figure 1 **Sub-index for 1-hour Average Sulphur Dioxide Concentration**

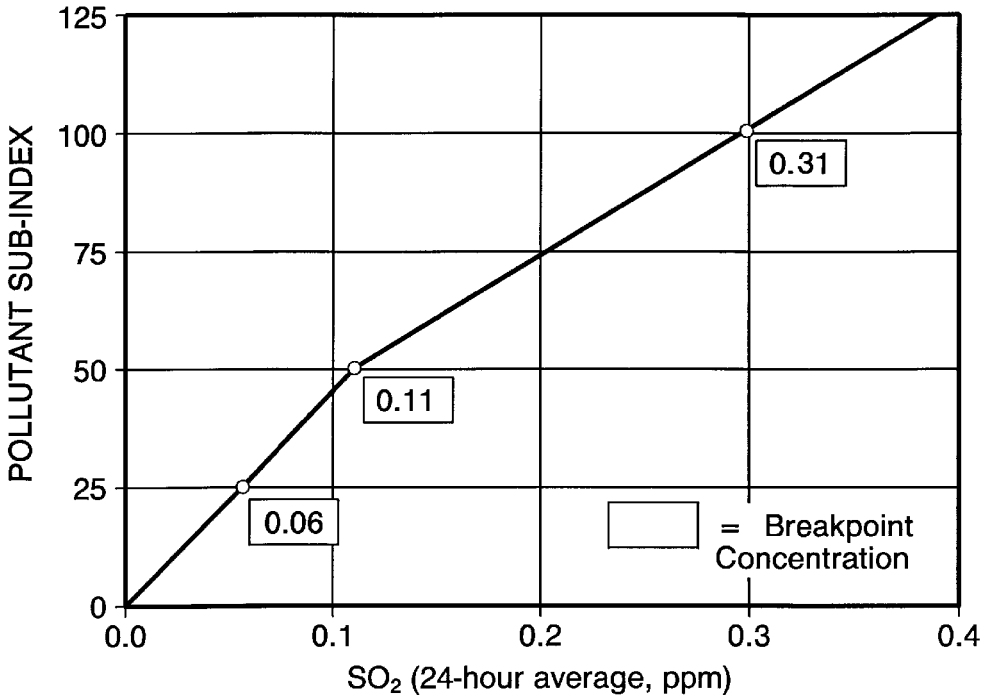

Figure 2 **Sub-index for 24-hour Average Sulphur Dioxide Concentration**

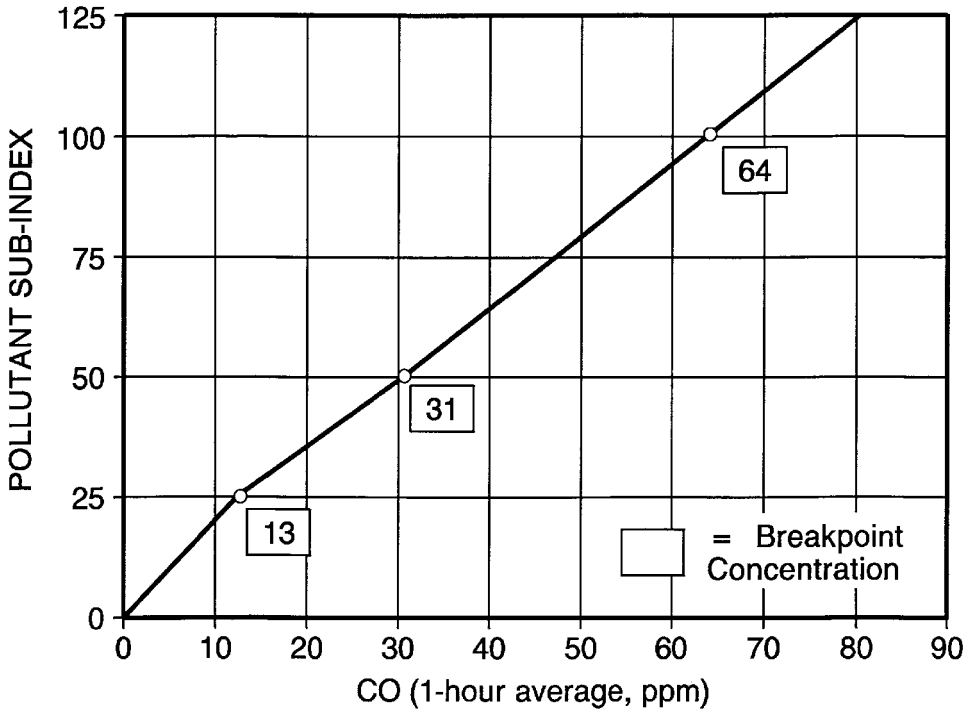

Figure 3 **Sub-index for 1-hour Average Carbon Monoxide Concentration**

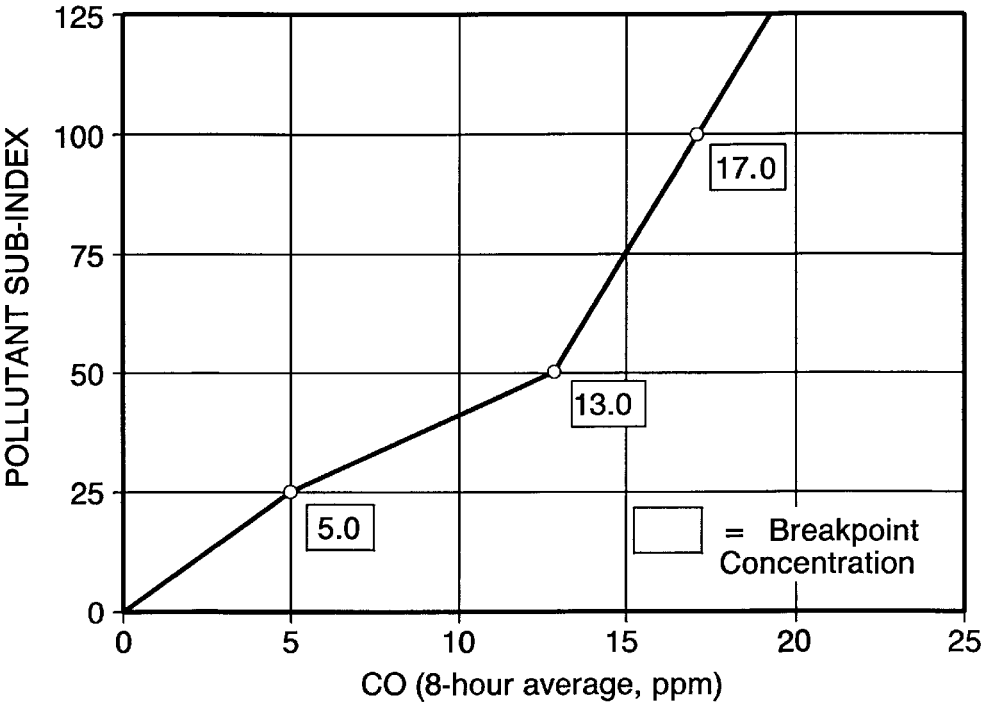

Figure 4 **Sub-index for 8-hour Average Carbon Monoxide Concentration**

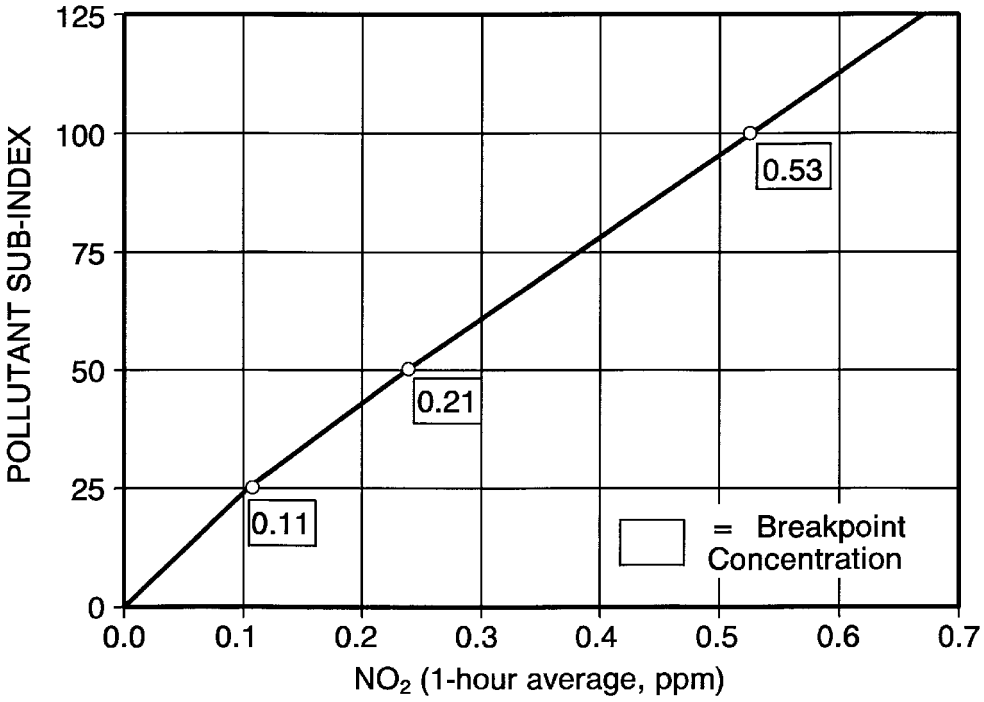

Figure 5 **Sub-index for 1-hour Average Nitrogen Dioxide Concentration**

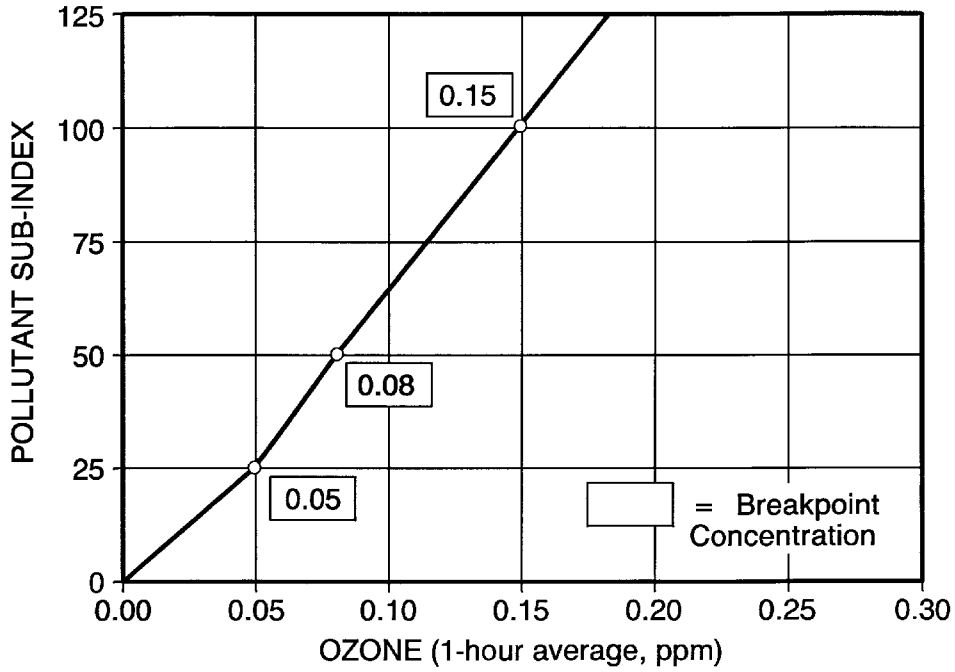

Figure 6 **Sub-index for 1-hour Average Ozone Concentration**

Table 3 Breakpoint Concentrations (parts per million)

	SO_2		CO		NO_2	O_3
	1-h	24-h	1-h	8-h	1-h	1-h
Good (25)	0.17	0.06	13	5.0	0.11*	0.05
Fair (50)	0.34	0.11	31	13.0	0.21	0.08
Poor (100)	2.0**	0.31	64**	17.0	0.53	0.15

* Interpolated value for breakpoint.
** Extrapolated value for breakpoint.

The maximum pollutant sub-index value was determined by the 1-hour carbon monoxide concentration, which has a numerical sub-index value of 36. The IQUA has a value of 36, which corresponds to the air quality descriptor fair.

Table 4 Pollutant Sub-indices Determined from Figures 1 through 6

Pollutant	Measured Value (ppm)	Averaging Time (hours)	Pollutant Sub-index
TSP	59 $\mu g/m^3$	24	25
SO_2	0.14	1	21
SO_2	0.05	24	23
CO	21	1	36
CO	2	8	10
NO_2	0.10	1	23
O_3	0.07	1	35

Section 3

Use of the Index

The IQUA should be calculated routinely and released with the corresponding air quality descriptor at least twice a day so that it can be carried by various media.

The committee recommends that when the IQUA exceeds a value of 50, it should be released hourly until the value is less than 50. In such instances, the issuing agency may wish to identify the pollutant that is driving the index, advise the public of any precautions that should be taken, and inform the public of any control actions that are being taken.

Different monitoring locations in a city may show large differences in measured pollutant levels, resulting in varying air quality. It is therefore not advisable to issue an average index for a city using readings from two or more monitoring stations.

3.1 Index Prediction

The release of the IQUA may be enhanced by the inclusion of the maximum value of the index over the previous 24 hours. While this is of interest to the public, the forecast of air quality for the remainder of the day or longer may be more useful. Some jurisdictions may therefore provide a forecast with the release of IQUA information.

To enable accurate predictions to be made, current air quality data must be examined and related to local source strengths, background levels, and meteorological conditions. Special circumstances, such as the scavenging of ozone in urban areas, must also be considered.

Before an agency considers issuing IQUA forecasts, the following conditions should be met:

- strong relationships between ambient pollutant levels, source strengths, and meteorological conditions should be available;
- seasonal and diurnal emission characteristics for locally produced pollutants should be established;
- important meteorological predictors should be identified;
- methods of forecasting meteorological predictors should be available; and
- the public should be advised of the expected accuracy of such forecasts and the effect of changing weather conditions on verification.

Using the preceding example and considering weather conditions and emissions to be similar for the next day, the following statement and forecast could be issued:

‘‘The IQUA for downtown at 1400 h today is Fair with a reading of 36. The pollutant causing this decline in air quality is carbon monoxide. The IQUA is expected to rise during rush hour this evening and improve to the Good range overnight. Tomorrow is expected to be similar to today with readings in or near the Fair range during the daylight hours.’’

References

Environment Canada, ‘‘National Urban Air Quality Trends-1981 to 1990’’ Ottawa, Ontario, EPS 7/UP/4 October, 1994).

Environment Canada, ‘‘National Urban Air Quality Trends-1978 to 1987’’ Ottawa, Ontario, EPS 7/UP/3 (May, 1990).

Environment Canada, ‘‘Standard Reference Method for the Measurement of Suspended Particulate in the Atmosphere (High Volume Method)’’ Ottawa, Ontario, EPS 1-AP-73-2 (1973).

Bibliography

Dann, T., ‘‘PM_{10} and PM_{25} - Concentrations at Urban Sites: 1984-1993’’ Environment Canada (November, 1994).

Environment Canada, ‘‘Review of NAAQOs for Sulphur Dioxide,’’ A Report by the Federal- Provincial Advisory Committee on Air Quality, Environment Canada (April, 1987).

Environment Canada, ‘‘Review of NAAQOs for Carbon Monoxide,’’ A Report by the Federal- Provincial Advisory Committee on Air Quality, Environment Canada (April, 1987).

Environment Canada,‘‘Guidelines for a Short-term Air Quality Index’’, A Report by the Federal- Provincial Committee on Air Pollution, Environment Canada (March, 1980).

Environment Canada, ‘‘Annual Index of the Quality of Air’’, A Report by the Federal-Provincial Committee on Air Pollution (August, 1980).

Environment Canada, ‘‘Criteria for National Air Quality Objectives,’’ A Report by the Federal-Provincial Committee on Air Pollution (November, 1976).

Government of Canada, ‘‘Recommended NAAQOs for Reduced Sulphur Compounds (draft),’’ A Report by the Federal-Provincial Advisory Committee on Air Quality (June, 1989).

Shenfeld, L. and D. Yap, ‘‘Ontario New Air Quality Index’’, Paper presented at: *The 8th World Clean Air Congress,* The Hague, Netherlands (September, 1989).

Thom, G.C. and W.R. Ott, ‘‘Air Pollution Indices Council on Environmental Quality,’’ U.S. Environmental Protection Agency (December, 1975).

Appendix

Particulate Sub-indices

The Coefficient of Haze (COH) has been measured at many stations in Canada as a surrogate for real time measurement of particulate. Some jurisdictions have developed their own IQUA sub-indices based on this measurement. The breakpoints for the sub-index are shown in Table A.1. The IQUA criteria for breakpoint concentration are shown in Table A.2. The following cautions regarding this practice should be noted.

1. The COH and inhalable particulate (PM_{10}) are not included in the National Ambient Air Quality Objectives.

2. There is no consistent general (country-wide) relationship between COH and TSP, COH and visibility, COH and inhalable particulate (PM_{10}), or COH and respirable particulate ($PM_{2.5}$).

3. Real time monitors are available for TSP, PM_{10}, $PM_{2.5}$, and visibility. There is a National Air Ambient Quality Objective for 24-hour for TSP (see Figure A.4). There is a continuous monitor for particulates (24-hour), it can be used if the sampling results are equivalent to the High Volume Method (Environment Canada, 1973).

4. The visibility sub-index measured as COH is not based on National Ambient Air Quality Objectives. It is the traditional surrogate for fine suspended particulate matter because the latter measurement was not available on a real-time basis. The measurement is intended to represent perceived changes in visibility due to fine particulate (see Figure A.1.).

5. National Ambient Air Quality Objectives have not as yet been set for inhalable particulate. As the direct method of measurement is not amenable for real-time reporting, the 24-hour COH is substituted as an estimate of the inhalable particulate. The conversion for national average conditions (Figure A.2) is described by the formula $PM_{10} = 60\ [COH]^{0.5}$. If COH = 0.69, then $PM_{10} = 50\ \mu g/m^3$ and the sub-index = 25. This formula may be further refined to reflect the particular conditions of each monitoring site in order to improve the correlation with the mass measurement. Agencies that own or are about to buy U.S. EPA certified inhalable particulate monitors can use the sub-index shown in Figure A.3.

Table A.1 Coefficient of Haze Breakpoint Concentrations

	Visibility 1-h	Inhalable Particulate PM_{10}** 24-h	24-h	TSP* 24-h	TRS+ 1-h (ppm)
Good (25)	1.7	0.25	30 $\mu g/m^3$	60 $\mu g/m^3$	0.005***
Fair (50)	4.0	0.84	55 $\mu g/m^3$	120 $\mu g/m^3$	0.010****
Poor (100)	6.0	2.5	95 $\mu g/m^3$	400 $\mu g/m^3$	0.100****

* TSP - breakpoints reflect NAAQOs.
** PM_{10} - proposed breakpoints based on conversion of TSP objectives to their PM_{10} equivalents.
*** Interpolated value for breakpoint.
**** Recommended new objective.
\+ These breakpoints are provisional, solely for the development of an air quality sub-index, pending the adoption of an ambiant Air Quality Objective. This does not preclude agencies fromusing their existing standards and objectives.

Table A.2 Criteria for Breakpoint Concentrations

Parameter	Total Suspended Particulate	Sulphur Dioxide		Carbon Monoxide		Nitrogen Dioxide	Ozone
Figure		1	2	3	4	5	6
Monitor	SP	SO_2	SO_2	CO	CO	NO_2	O_3
Averaging Time	24-h	1-h	24-h	1-h	8-h	1-h	1-h
Units	$\mu g/m^3$	ppm	ppm	ppm	ppm	ppm	ppm
Breakpoints:							
Good = 25	60*	0.17	0.06	13	5	0.11*	0.05
Fair = 50	120	0.34	0.11	31	13	0.21	0.08
Poor = 100	400	2.0**	0.31	64**	17	0.53	0.15

* Interpolated value for breakpoint.
** Extrapolated value for breakpoint.

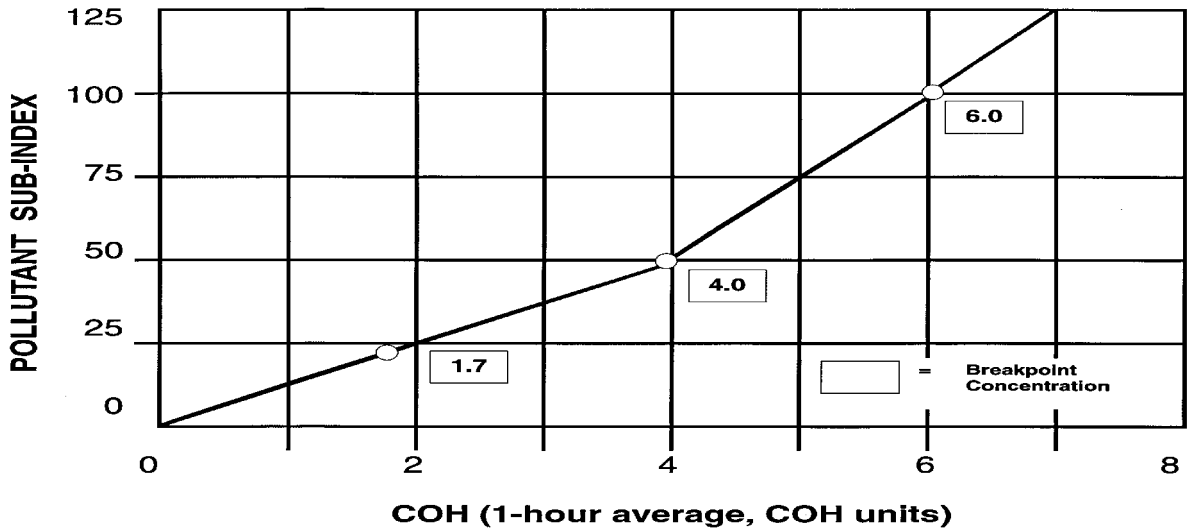

Figure A.1 Sub-index for Visibility

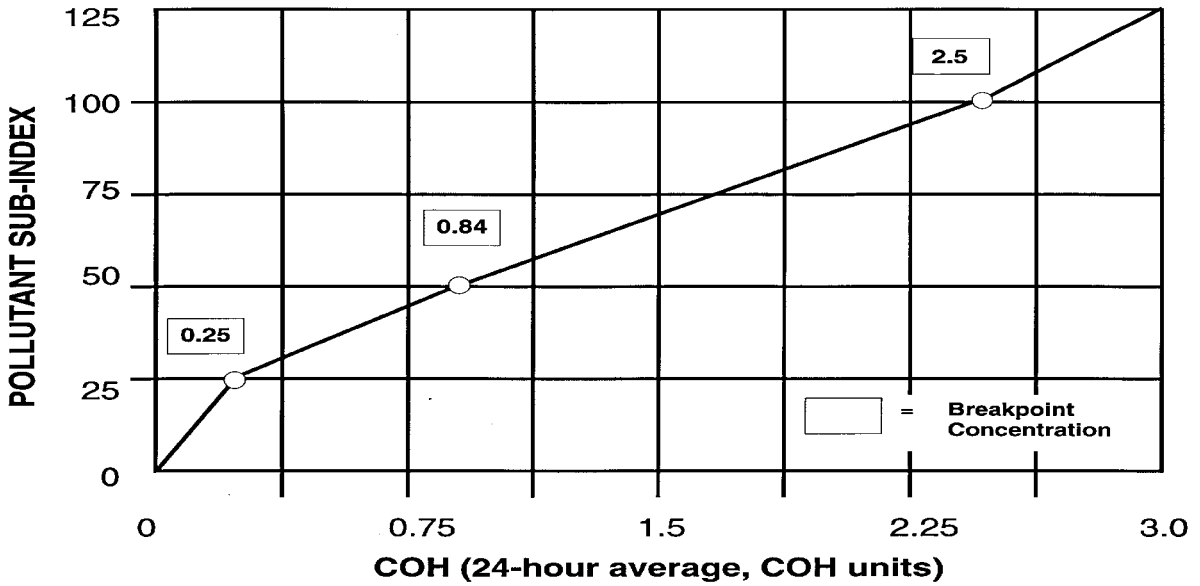

Figure A.2 Sub-index for 24-hour Average Inhalable Particulate Concentration

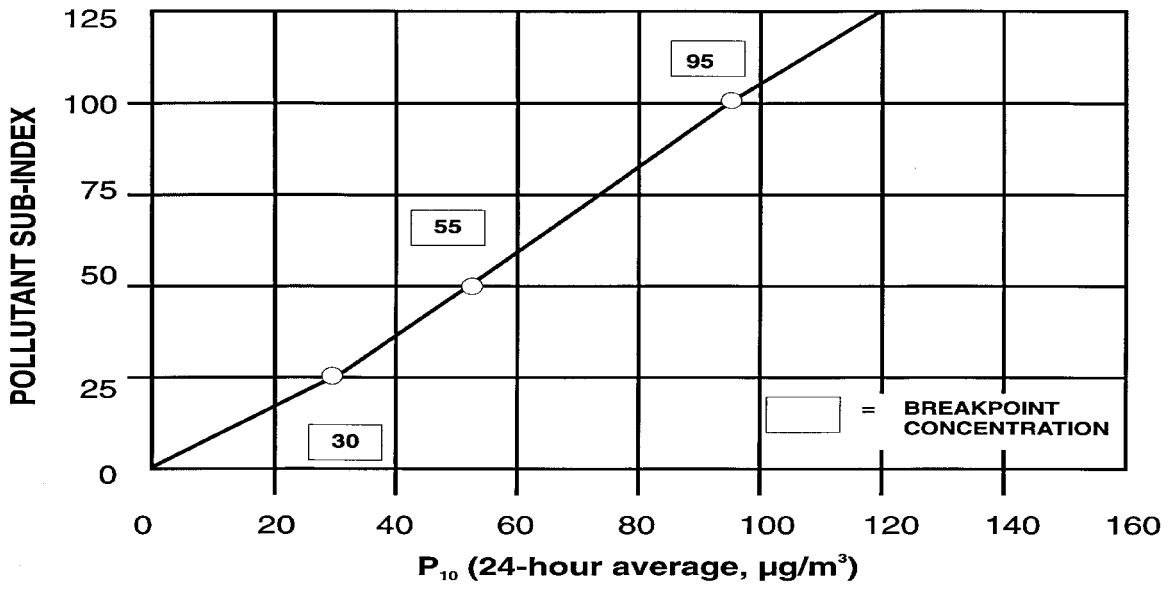

Figure A.3 Inhalable Particulate PM_{10} Sub-index

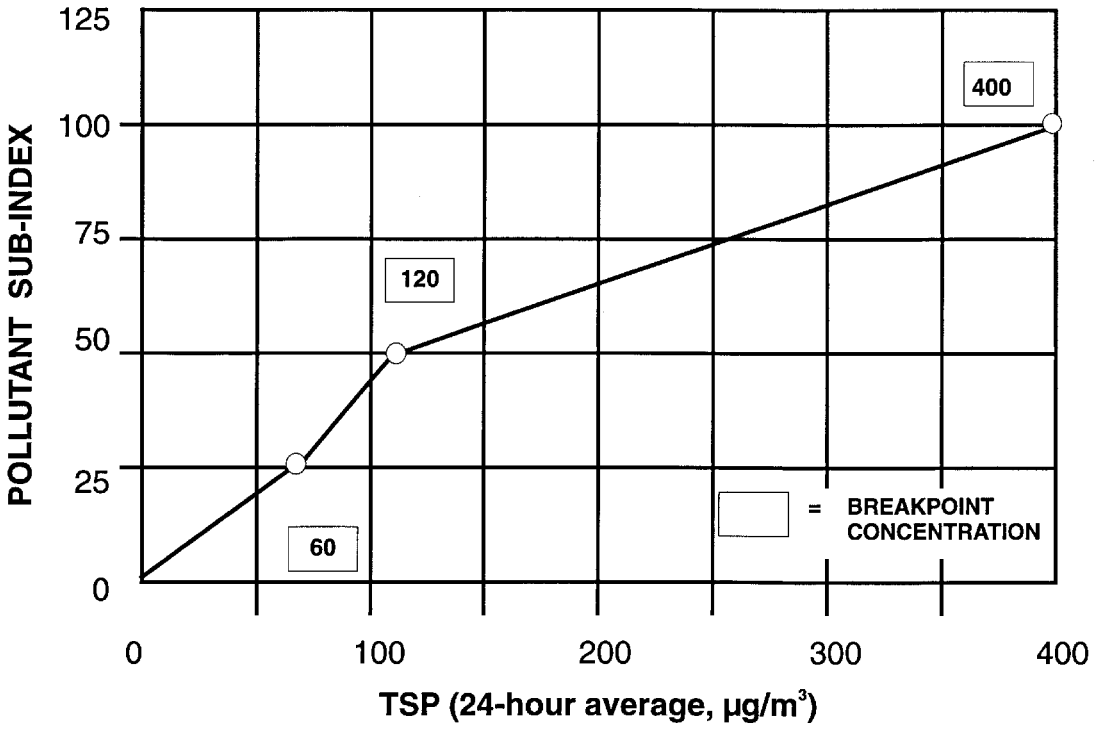

Figure A.4 24-Hour Total Suspended Particulate Pollutant Sub-index

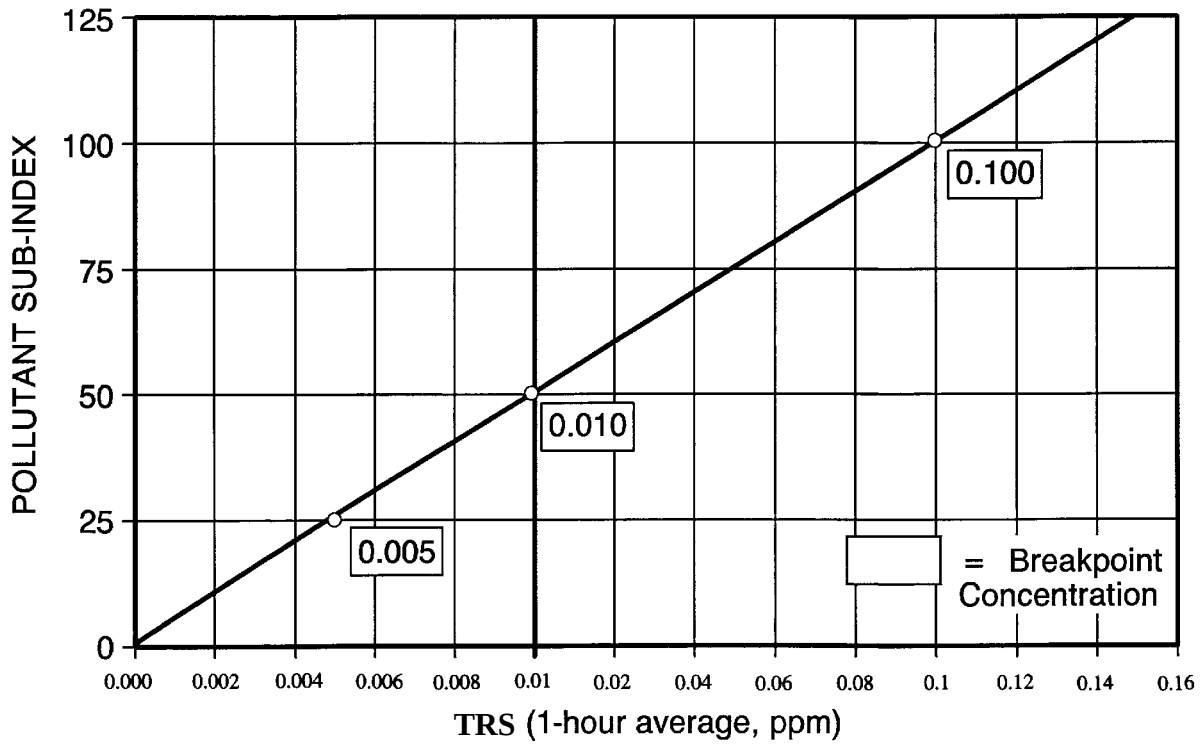

Figure A.5 Sub-index 1-hour Average Reduced Sulphur Concentration