Hamilton-Wentworth Air Quality Initiative

H A Q I

Ambient Air Quality & Effects on the Environment in Hamilton-Wentworth

Environment Work Group Final Report

DECEMBER 1997

ACKNOWLEDGEMENTS

The Hamilton-Wentworth Air Quality Initiative (HAQI) is a cooperative initiative to assess and report on air quality in the regional municipality of Hamilton-Wentworth. Partners include government, industry, the community, and academia.

Numerous parties have contributed to this summary report, either directly or indirectly, and are hereby acknowledged. Without the contribution of the chairs and members of the working groups, the writing of this report would not have been possible. Special thanks is extended to Dr. Brian McCarry, Dr. Bill Booty and Mr. Robert Barlow-Cash for their contributions toward the HAQI and guidance in preparing the report. The Workgroup also thanks Dr. Denis Corr for chairing the group.

Many government staff members participated in the preparation of this report, including Mike Shackleton, Frank Dobroff, Bill Gizyn, Gary Bowen, Simon Wong and Eric Loi of the Ontario Ministry of the Environment, and Anita Wong from Environment Canada. Oskar Resler of Environment Canada and Gary Bowen provided valuable assistance in preparing all the geo-referenced data and maps.

The Environment Workgroup report is one of four Workgroup reports prepared for the HAQI. The other three reports cover human health, aesthetics, odours and economics, and transportation issues. In addition, a Summary Report integrates the findings of all four technical reports.

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1 INTRODUCTION

The mandate of the Environment Workgroup of the Hamilton-Wentworth Air Quality Initiative (HAQI) is to summarize ambient air quality data and sources, to identify air quality issues of public concern, and to identify environmental impacts that have a measurable effect within the Hamilton-Wentworth Region. This mandate was achieved by:

- assembling existing monitoring, inventory, and modelling data for use by the various workgroups,
- conducting modelling where possible to estimate how the emissions from different sources contribute to poor air quality, and
- evaluating the impacts of air quality on the ecosystem, including vegetation, wildlife, aquatic systems, soils, and agriculture.

Information on each of these points will be described in this report under the headings 'Ambient Air Monitoring', 'Emissions and Modelling' and 'Environmental Effects'.

The majority of the work done by the Environment Workgroup was to assemble air-related data and provide support to other workgroups, particularly the Human Health Workgroup. As part of this effort, lists of priority pollutants were developed, both for human health and environmental effects. Furthermore, existing data were put in an electronic format together with a geographic information system (GIS) so it can be used in the future.

1.1 Environment Workgroup Activities

The focus of the workgroup's work and the activities are summarized below.

i) A large amount of air quality data is available, most of it related to human health outcomes. Relatively little information is directly related to the environmental impacts of air pollutants within the region of Hamilton-Wentworth. For the purpose of this report, environmental impacts are defined as any measurable effect not related to human health, odour or transportation. These other effects are dealt with in separate reports (HAQI, 1991a, HAQI, 1997b and Pengelly et. al., 1997).

ii) The environmental effects addressed in the present report are:

a) soiling and aesthetic impairment
b) reduced visibility
c) vegetation injury and impairment
d) materials damage/aging and corrosion and property damage
e) bioaccumulation and biotoxicity

ii) A variety of data are used in this report. Ambient conditions are summarized using the following measurements of air quality:

Particulate	TSP (Total Suspended Particulate), PM_{10} (Inhalable Particulate Matter equal to and less than 10 microns in diameter), Black Fallout, Dustfall, COH (Coefficient of Haze)
Oxidants	Ozone, NO_x (Nitrogen Oxides), VOCs (Volatile Organic Compounds)
Metals	Pb (lead), Mn (manganese)
VOC's	benzene, 1,3 butadiene, naphthalene and isoprene.

Some parameters are included because their environmental effects are of particular importance: acid rain [sulphur dioxide/sulphate (SO_2/SO_4^{2-}), nitrogen oxides/nitrate (NOx/NO_3^-)] as it is a provincial, national, and international issue; and fluoride (F^-) for its historical concerns in the Hamilton-Wentworth Region.

Available inventory and modelling data (SO_2, NO_x, TSP and selected toxics e.g., benzene and benzo[a]pyrene (B[a]P)) were collected so as to identify major emission sources and their contributions in Hamilton-Wentworth[1].

iii) Lists of priority pollutants were developed both for health and environmental effects (see Table 1.1). Table 1.2 outlines the environmental effects the workgroups were concerned with and the air related environmental data in Hamilton-Wentworth.

iv) Data collected by the Environment Workgroup were also used by the other working groups of the HAQI. This was one of the main functions of the Environment Workgroup. For example, ambient air monitoring data for emissions affecting human health are discussed in the Human Health Workgroup's report (Pengelly et. al., 1997).

v) A number of compounds for which little or no data are available in Hamilton-Wentworth are listed below. The Environmental Workgroup believes these may be of importance because of public concern or possible environmental impacts.

ammonia	chlorine
peroxyacetyl nitrate	formaldehyde
hexachlorobutadiene	ethylene
mercury	zinc

vi) An extensive electronic database of air quality data linked to a geographic information system has been developed and resides at the Environment Canada Centre for Inland Waters (CCIW). This system can be used for trend analysis, geographic analysis and

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[1] Total reduced Sulphur (TRS) data are used to illustrate the use of back-trajectory analysis to identify sources.

other types of data interpretation. This database can be made publicly available if there is sufficient public interest. The data will require regular updating to stay current.

Table 1.1: HAQI List of Priority Pollutants By Workgroup

Airborne Pollutant	Human Health Workgroup	Environmental Workgroup[1]
Particulate Matter (PM_{10} and $PM_{2.5}$) and Sulphates (SO_4^{2-})	✔	✔
Ground Level Ozone (O_3)	✔	✔
Sulphur Dioxide (SO_2) and Acid Aerosols	✔	✔
Carbon Monoxide (CO)	✔	
Nitric Oxide (NO) and Nitrogen Dioxide (NO_2)	✔	✔
Air Toxics*	✔	
Black Particulate Fallout and Total Reduced Sulphur Compounds (TRS)	✔	✔
Fluoride (F^-)		✔

* Air toxics include benzene, 1,3-butadiene, cadmium, hexavalent chromium, lead, manganese and benzo[a]pyrene

[1] includes environmental and nuisance factors

Table 1.2: Environmental Effects/Air Priority Contaminants in Hamilton-Wentworth.

Contaminants	Environmental Effects	Available Data
Particulate Black Fallout TSP (Total Suspended Particulate) Dustfall COH (Coefficient of Haze) PM_{10} (Particulate Matter with diameter equal to or less than 10 microns) Acid aerosols	Soiling Aesthetic impairment Reduced visibility Smog	Meteorology Emission inventory Ambient air measurements
Oxidants Ozone Isoprene NO_x (Nitrogen Oxides) VOCs (Volatile Organic Compounds)	Smog Visible vegetation injury	Meteorology Vegetation injury observations Emission inventory Ambient air measurements
Fluoride	Visible vegetation injury	Meteorology Vegetation injury observations Ambient air measurements Foliar concentrations
Acid Rain SO_4^{2-} (Sulphate) NO_x (Nitrogen oxide and Nitrate) SO_2 (Sulphur Dioxide)	Property damage Vegetation impairment	Emission inventory Ambient air measurements
Metals/Toxics Pb (Lead) Mn (Manganese) PCDD/F (Dioxins/Furans) BaP (Benzo[a]Pyrene)	Biotoxicity Bioaccumulation	Meteorology Emission inventory (partial) Ambient air measurements Foliar concentrations
VOCs Benzene 1,3-butadiene Isoprene Naphthalene	No known direct effects	Ambient air measurements

2 DESCRIPTION OF THE STUDY AREA

Hamilton-Wentworth is situated at the west end of Lake Ontario, on a sheltered natural harbour. The enclosed harbour is surrounded by the Niagara Escarpment, about one hundred meters high, which provides views over the entire area and, together with the lake, shelters the harbour basin from temperature extremes. Hamilton-Wentworth is also the gateway to the Niagara Peninsula and on the main route between Southern Ontario and the U.S.

Hamilton-Wentworth is a thriving commercial centre of 457,000 people. The region is home to a major university, two of the largest steel companies in Canada and other diversified industries, and a centre for medical research. Hamilton-Wentworth includes the City of Hamilton (population 318,000) and five neighbouring suburban towns which are primarily agricultural and residential.

The Niagara Escarpment bisects the centre of the city and region adding to the distinctive character of the area and also acting as a major wildlife corridor. The escarpment separates the upper and lower city of Hamilton, and has given rise to separate communities such as Dundas, Ancaster and Stoney Creek. The area on top of the escarpment, predominantly residential in nature, is commonly referred to as the "mountain whereas the area at the base of the escarpment is referred to as "downtown". Most of the heavy industry is located in the northeast end of the downtown area adjacent to Hamilton Harbour.

The same features which give the region its natural beauty have also led to the intensification of environmental impacts as the city and region have grown. The enclosed nature of Hamilton Harbour and surrounding inlets allowed the buildup of aquatic pollutants from both industry and other development. The protective effect of the escarpment sometimes allows the buildup of airborne pollutants during temperature inversion conditions. These effects can be exacerbated by high volumes of traffic and the dense concentrations of industry. The Ministry of the Environment has monitored air quality in Hamilton since 1970. Data show that air pollution readings tend to be highest near the northeast industrial area.

3 METEOROLOGY

Hamilton's climate is fairly typical of Southern Ontario with temperatures that can range from a high of 35 °C in summer to a low of -25 °C in winter. Annual precipitation amounts are approximately 75 cm of rain and 150 cm of snow. The primary winds in the Region are from the southwest and west, as shown in Figure 3.1[2]. These winds may bring with them pollution from the United States, but they also move locally generated industrial and downtown air pollution away from the city and out over the lake. The other prominent wind direction is from the northeast quadrant over Lake Ontario. Sometimes this is a result of a lake breeze effect (see Figure 3.2). Winds from three sectors--the southeast--almost never occur in the lower city due to the geographic influence of the Niagara Escarpment.

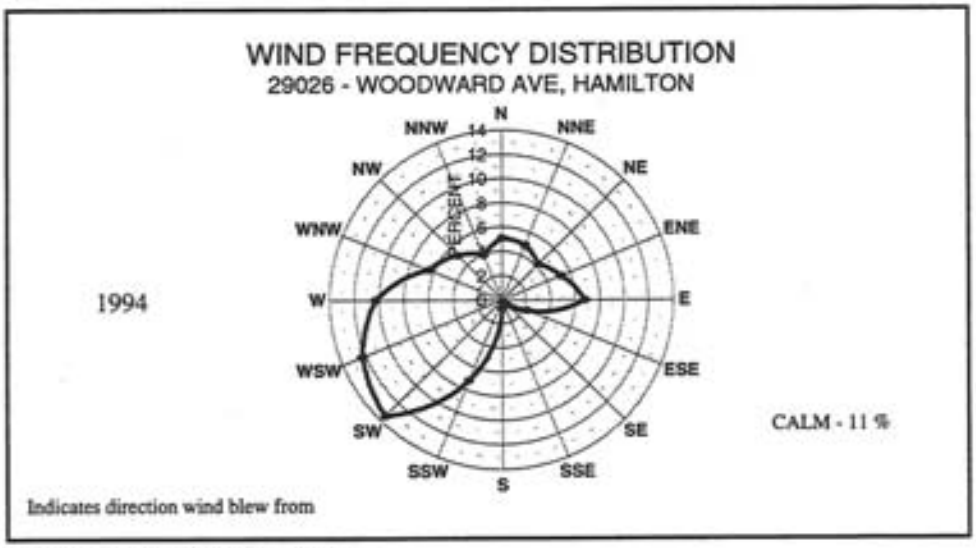

Figure 3.1: Wind Directions

3.1 Inversions

Temperature inversions (where warm air sits above a layer of cooler air) occur routinely year round on cloudless nights when the ground cools rapidly, in turn quickly cooling the air near the ground. Heat from the sun breaks this inversion up by mid-morning.

Another fairly common scenario is the lake-breeze effect during the spring and autumn (Figure 3.2). During the morning, the ground is heated by the sun; and combined with the heat given off by vehicles, office buildings, and industries; creates an "urban heat island" effect, which is characterized by warmer air over the centre of the city. The warm air rises. This draws in cooler

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[2] Data taken from Woodward Ave. This site may not be representative of the entire Hamilton area, but historically, the data have been used to assess wind directions.

air from Lake Ontario bringing pollutants from the northeast end of Hamilton into the downtown core. Warmer southerly winds blowing over top of the escarpment create an inversion layer over the city. This effectively traps pollutants in the downtown core.

The polluted air may spread over the escarpment depending on the height of the inversion layer. As this warm air and its pollutants rise above the escarpment, they often are met with the prevailing southwesterly winds and are swept out over Lake Ontario. If the lake breeze still exists, these pollutants can be recirculated over the city once again.

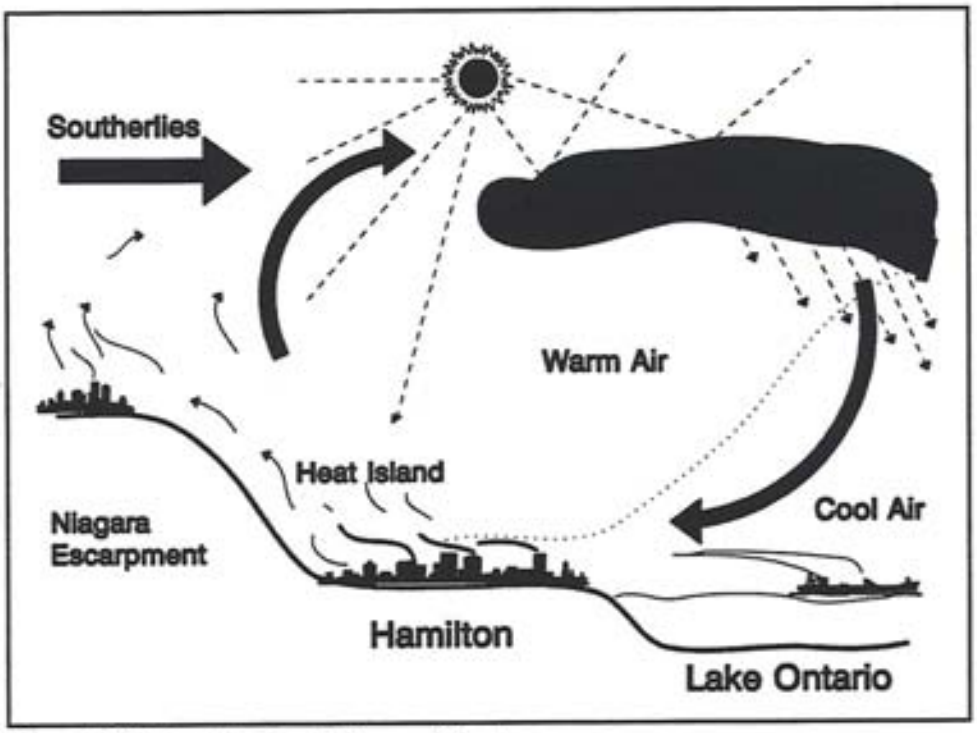

Figure 3.2: Hamilton Lake Breeze Effect

3.2 Measurements

The Ministry operates meteorological station 29026 at the Hamilton Sewage Treatment Plant on Woodward Avenue; it is a tower with wind and temperature sensors at three levels, with the highest at 100 metres. Supplementary information is available from the Environment Canada Mount Hope Airport and Royal Botanical Gardens weather stations. Since 1995, smaller wind towers have monitored winds at other locations in the industrial zone and more recently on the Escarpment in Flamborough at Redland Quarries. These meteorological data are used for determining pollutant sources and preparing pollution wind roses, in modelling, in regional abatement and assessment activities and in preparing the annual regional air quality reports.

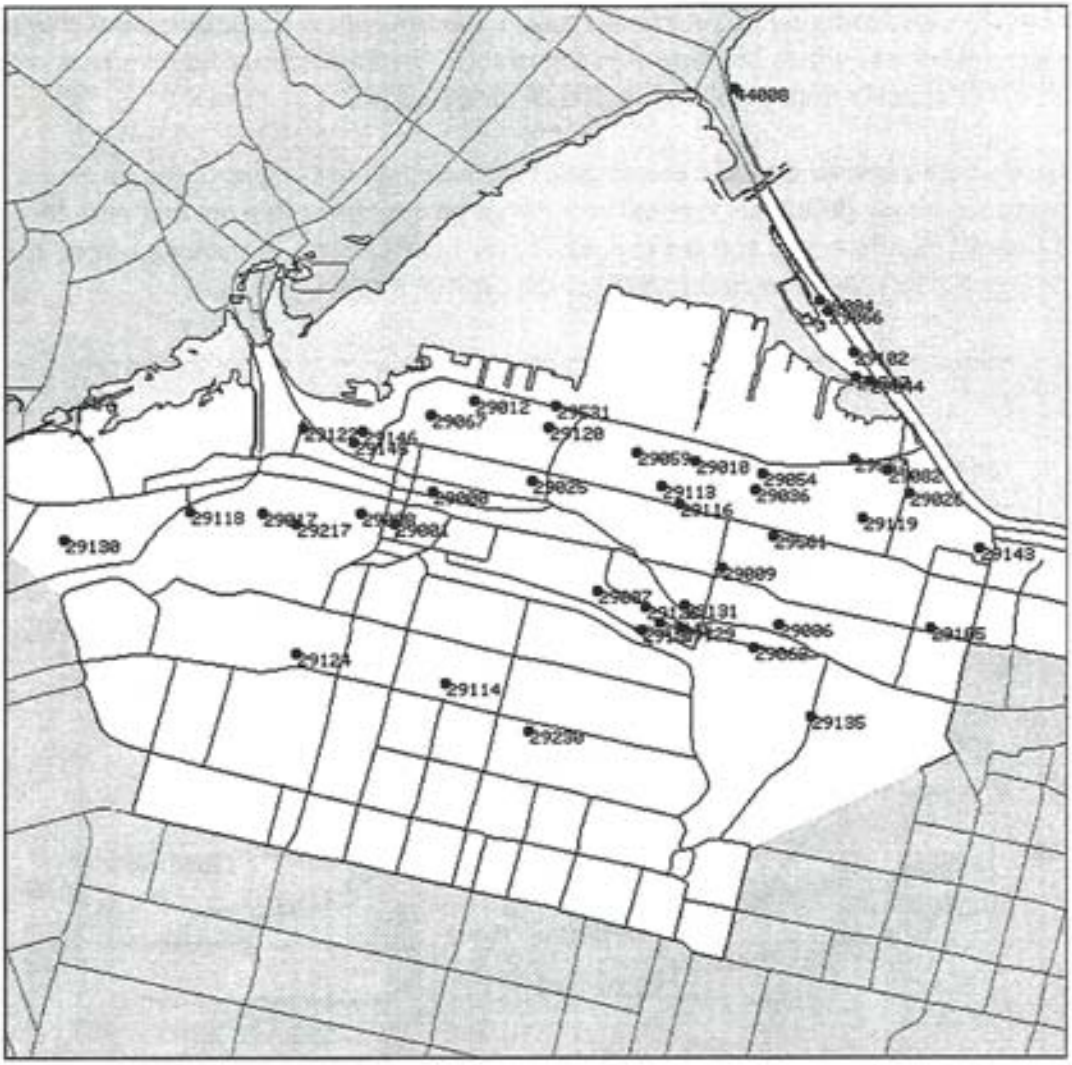

Figure 3.3: Location of MOE Monitoring Sites in Hamilton-Wentworth

The Ministry of the Environment has conducted air monitoring in Hamilton since 1970. An extensive network of air monitors shows that air pollution levels tend to be highest near Hamilton's northeast industrial zone, including Beach Boulevard. A map of more recent monitoring sites is shown in Figure 3.3.[3] Most fixed monitoring stations are located in the lower city, within a 5 km zone of Hamilton's industrial section. For more detailed information on station locations and parameters monitored, refer to the annual regional air quality data reports produced by the Ministry of the Environment and Energy (MOEE, 1997)[4].

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3 Not all parameters are monitored at every station.

4 The Ministry of the Environment and Energy is the former name of the Ministry of the Environment. The name changed in 1997.

4 AIRBORNE PARTICLES

Airborne particles come in many different sizes; are made up of numerous different materials; and are measured in a number of different ways. The most common way to classify them is by their size.

Heavier, larger particles tend to fall quickly from the atmosphere and are referred to as dust or dustfall. These particles are usually greater than 100 microns in diameter (a micron is one millionth of a metre). These large-size particles are easily visible on surfaces when deposited. They can be lifted by the wind, thrown up by vehicle wheels, or generated by industrial processes such as grinding or aggregate handling. Due to their relatively large size, these particles tend to travel relatively short distances before they fall to the ground.

The intermediate range of particle sizes vary from 10 to 50 microns in diameter and are referred to as Total Suspended Particulate (TSP). TSP is generated from road and ground dust, and from industrial and vehicle emissions.

Particles of special significance to human health are those which are inhalable and respirable. Inhalable particles are commonly defined as those with diameters of no greater than 10 microns (PM_{10}). Respirable particles are those with diameters of no greater than 2.5 microns ($PM_{2.5}$). All of these particles can breach the defence mechanisms of the mouth and throat and penetrate into the lung. The smaller the particle, the further it can penetrate into the lung, and presumably the more damage it can do.[5] Inhalable and respirable particles come from a variety of sources, including industrial and vehicle emissions, and from road dust.

4.1 Ambient Air Monitoring

Historically, Hamilton has tended to have high levels of airborne particulate, relative to other urban areas in Ontario. Measurements taken by the Ministry of the Environment indicate levels of particulate frequently exceed government objectives[6]. Particulate measurements are collected by a network of instruments including up to 20 dustfall jars, 20 high volume samplers (TSP), 4 inhalable (PM_{10}) samplers, 7 COH tape samplers, and more recently, 4 TEOM continuous inhalable particulate monitors.

Large particles are measured by dustfall jar, which is an open-ended tube containing a bag into which particles settle by gravity. The settled amount is measured by weighing the amount of

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5 For more information please refer to Pengelly et. al., (1997).

6 Refers to MOE Ambient Air Quality Criteria (AAQC) for dustfall, COH and TSP as described in Reg.337 under the Environmental Protection Act. Ontario criteria for dustfall are 7 g/m^2/30 days (30 days and 4.6 g/m^2/30 days (1 year arithmetic mean), for TSP are 120 $\mu g/m^3$ (24 hours) and 60 $\mu g/m^3$ (1 year geometric mean), and for COH are 1 COH unit (24 hours) and 0.5 COH unit (1 year).

material falling into the bag. TSP is measured by drawing air through a filter. The filter is weighed before and after collection and can be analyzed for the chemical composition of the particles. PM_{10} and smaller particles are measured after collection on a specially designed air particulate collector or by newer real-time particulate monitoring devices. COH (Co-efficient of Haze) is another method by which particulate is measured. This method involves a moving filter tape which samples particles for one hour then shines a light through the darkened spot on the filter. The darkness of the spot affects the amount of light transmitted, which is related to the amount of particulate collected. COH has been used extensively in Ontario to provide real-time measurements of particles in air. More recently, the TEOM (Tapered Element Oscillating Microbalance) has become the preferred method by which such particles are measured in Ontario.

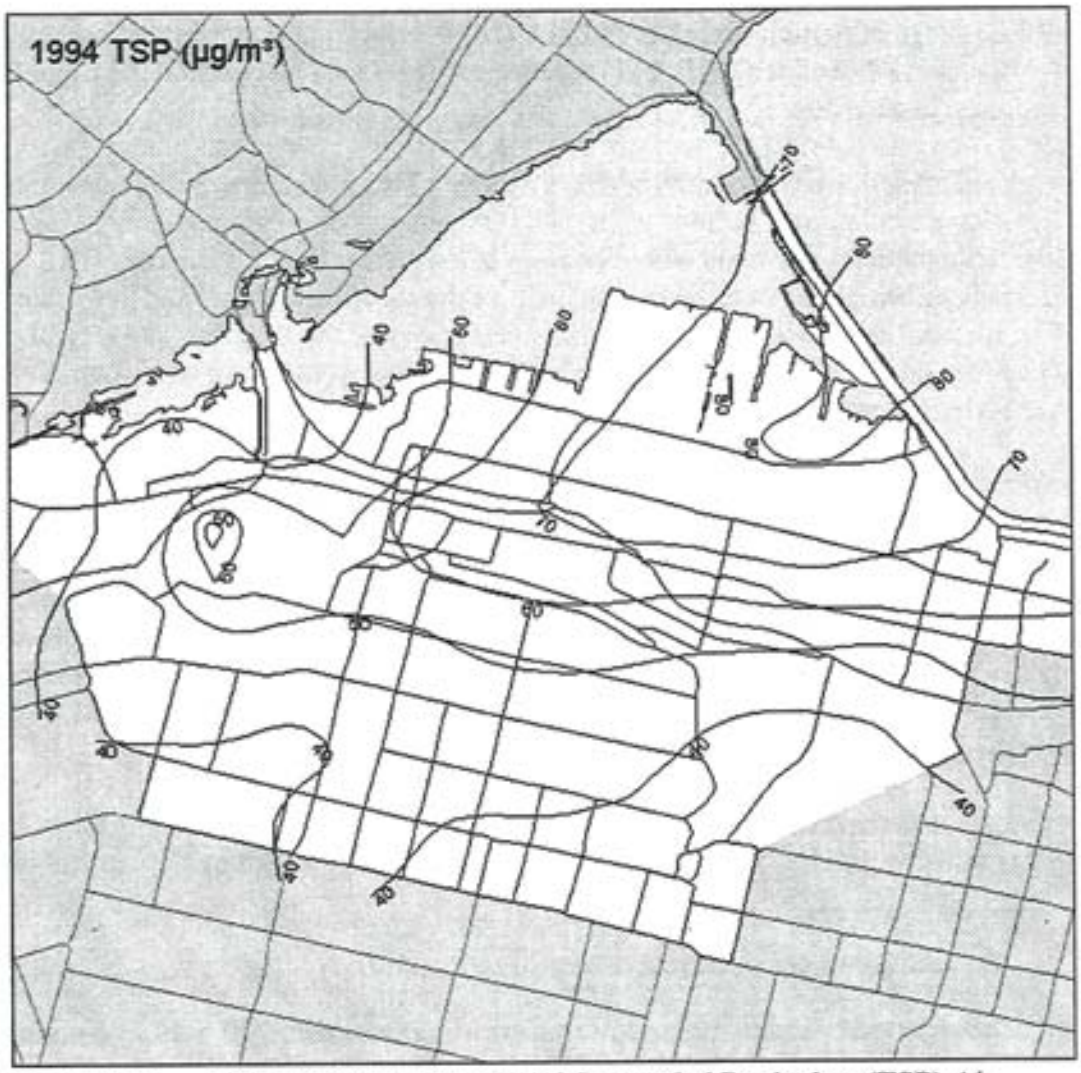

Figure 4.1: 1994 Annual Average Total Suspended Particulate (TSP) Air Concentration Isopleths (µg/m³)

Relatively elevated concentrations of all sizes of particulate are found close to the industrial zone. Figures 4.1 and 4.2 show the distribution of TSP concentrations and dustfall as measured during 1994. The annual AAQC of TSP and dustfall are exceeded in the industrial zone. The annual AAQC for COH is also exceeded in this area. Most particulate annual objectives are not exceeded beyond 2-5 km from this zone.

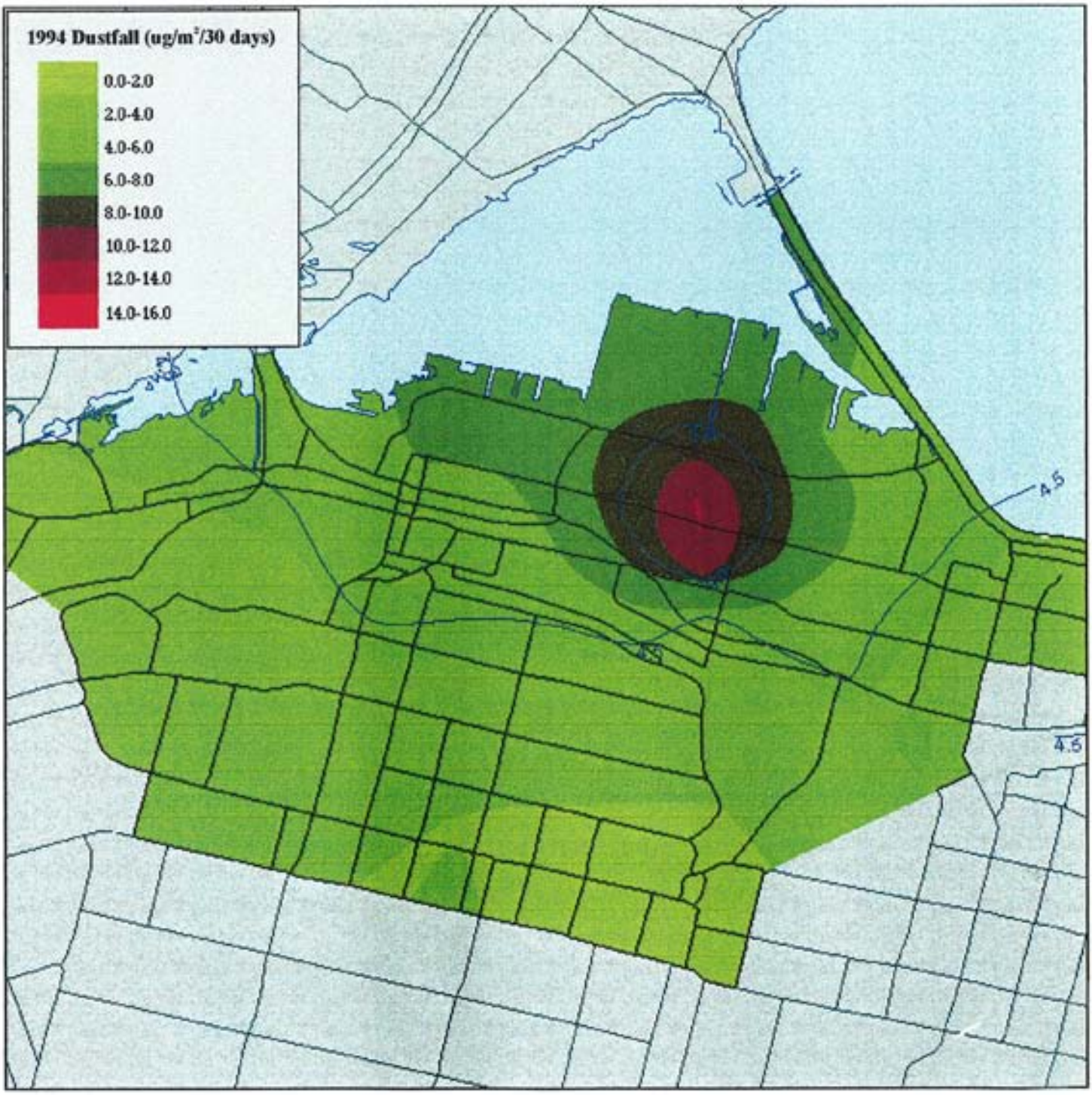

Figure 4.2: 1994 Annual Average Dustfall Deposition Levels (ug/m²/30 days)

Exceedances of the 24 hour objectives for TSP and PM_{10}, on days with light winds or when winds are from the northeast, are common. Industrial and vehicle emissions are poorly dispersed on these days leading to exceedances of daily objectives in Hamilton. TSP and PM_{10} concentrations in Hamilton under these conditions are illustrated in figures 4.3 and 4.4.

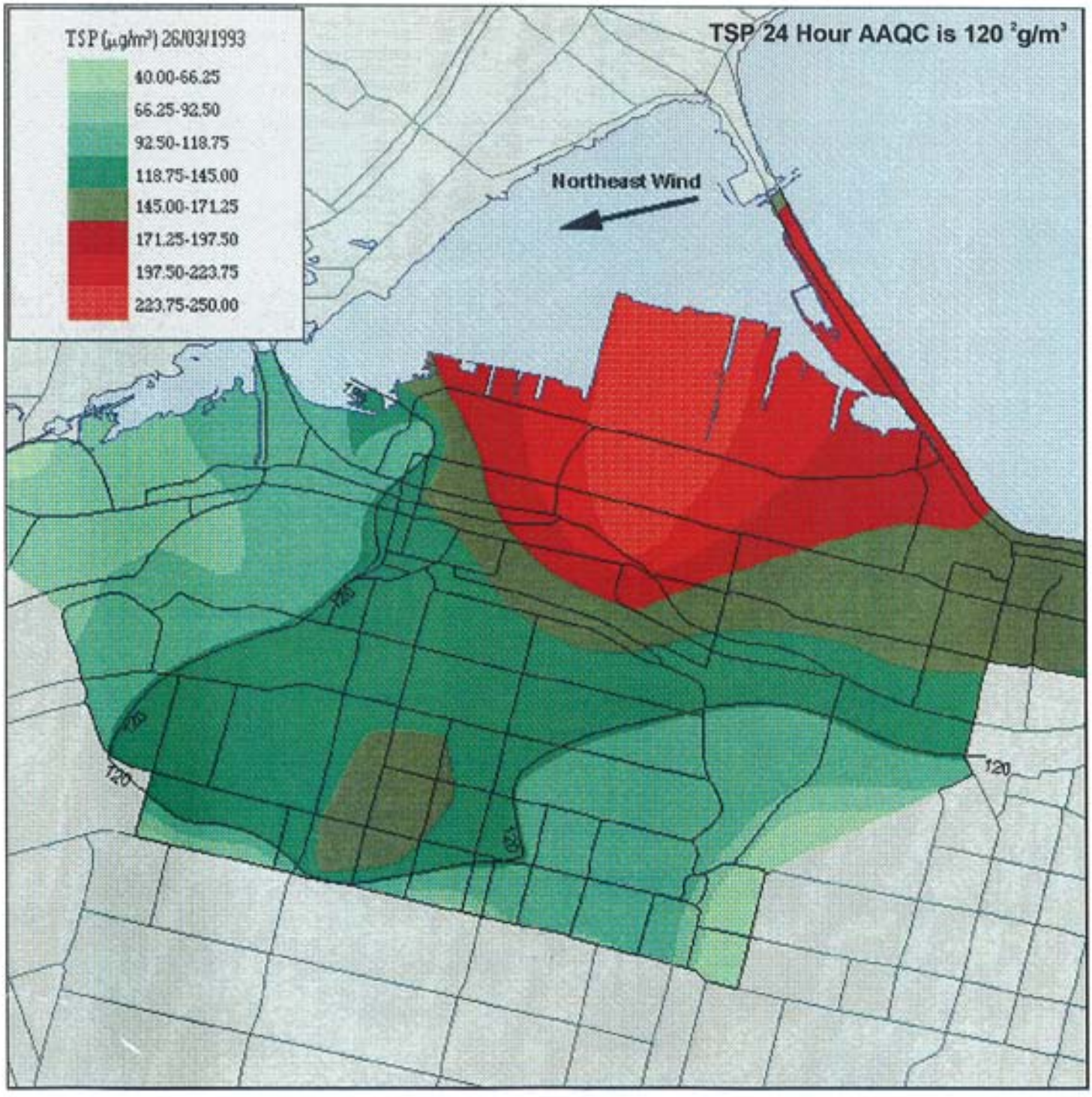

Figure 4.3: Daily Air Concentration Isopleths of total Suspended Particulate (TSP) when Wind is from the Northeast (March 26, 1993)

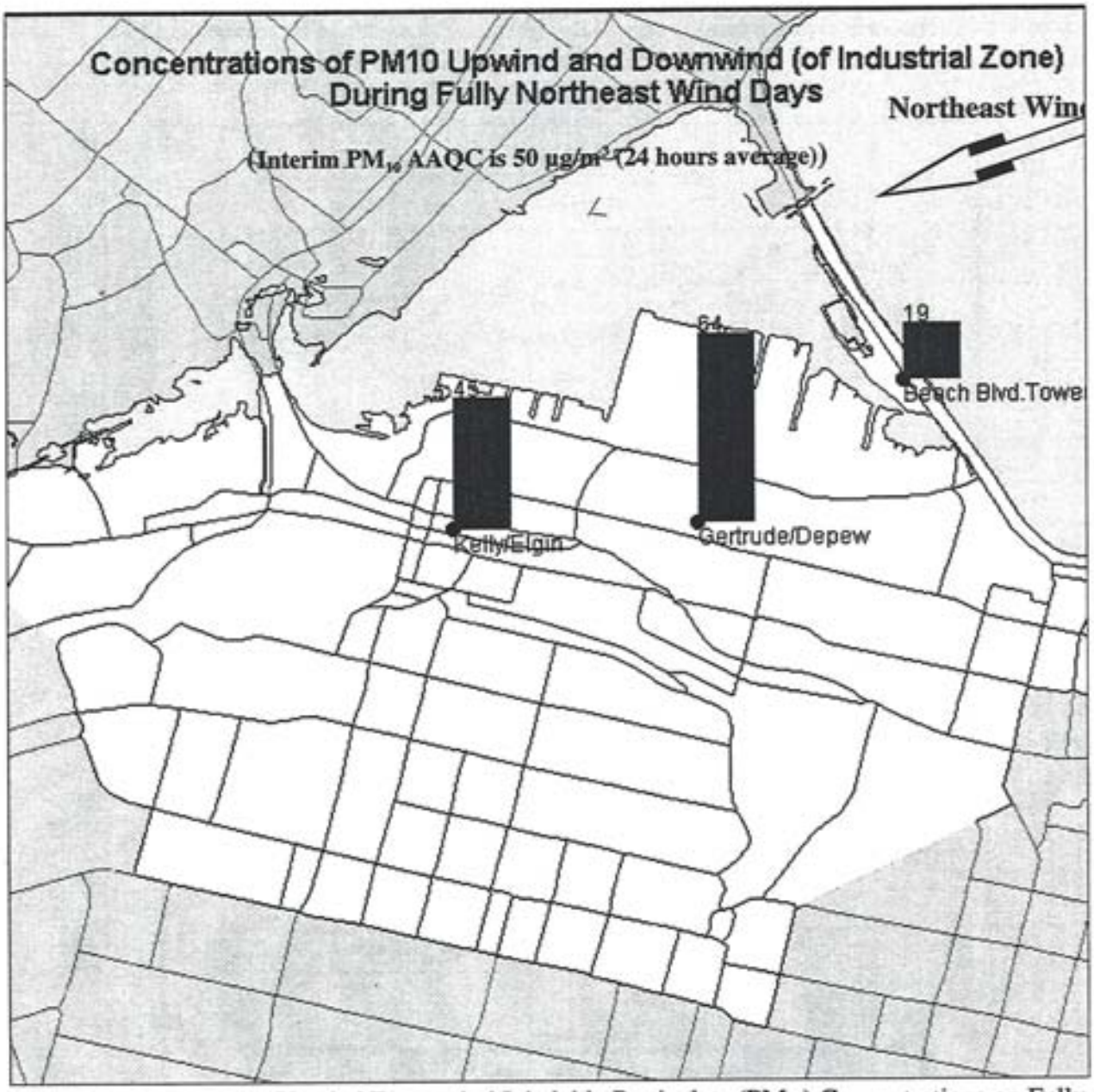

Figure 4.4: Average Upwind/Downwind Inhalable Particulate (PM_{10}) Concentrations on Fully Northeast Wind Days During 1993-1995 ($\mu g/m^3$)

Particulate emissions have declined significantly since the late 1960s and early 1970s. The greatest emission reductions for TSP occurred in the 1970s due to the abatement efforts of the major industries (MOEE, 1997). Reductions in dustfall did not occur until the 1980's. The pace of emissions reductions has been much more gradual since the early 1980's, as it has been more difficult to achieve substantive reductions at the major pollution sources. These trends are shown

in figure 4.5. The emission reductions shown in Figure 4.5 relate to point sources at major industries. Fugitive and non-industrial sources are not included due to lack of data.

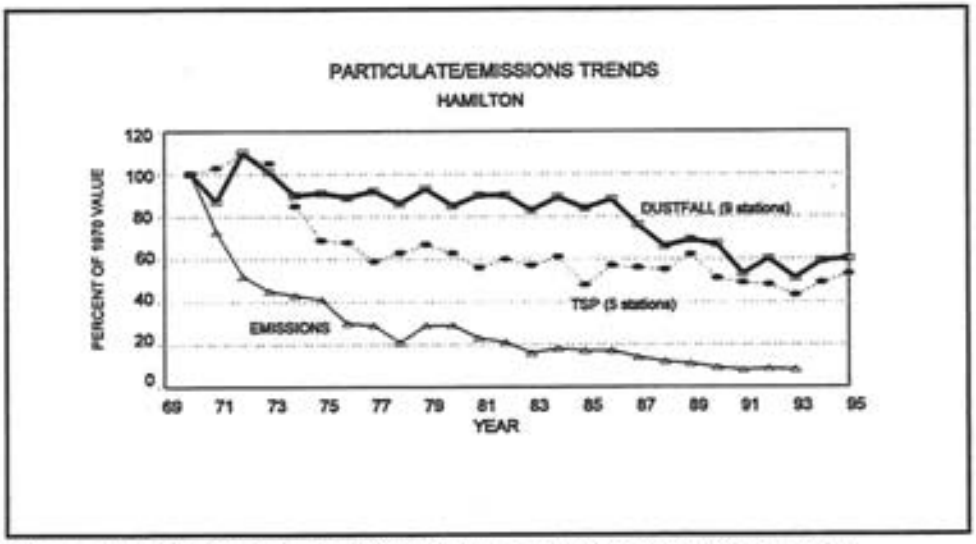

Figure 4.5: Particulate/Emissions Trends in Hamilton-Wentworth

Current levels of particulate in Hamilton are compared to other Ontario cities such as Windsor and Toronto in Figure 4.6. Ambient particulate levels near the industrial area are higher than levels in the downtown area and exceed the AAQC. Particulate levels in downtown Hamilton and on the mountain are below the AAQC, and are comparable to other cities in Ontario.

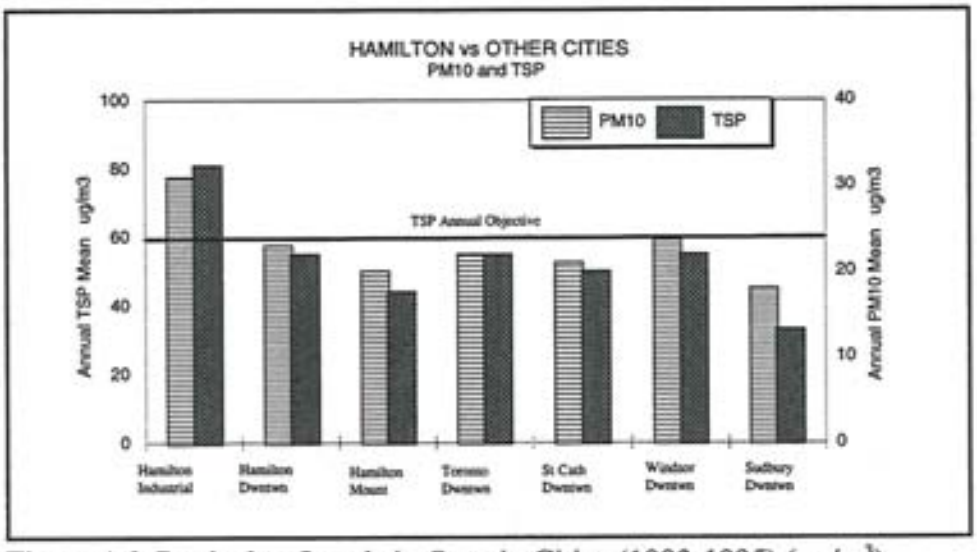

Figure 4.6: Particulate Levels in Ontario Cities (1993-1995) ($\mu g/m^3$)

4.2 Emissions and Modelling

Little direct emissions data exists for inhalable particulate. Ambient monitoring and meteorology data were used to determine the relative contributions from industry and other sources (such as vehicle emissions and road dust) to airborne particulate. Techniques included pollution rose analyses, contour plots of data, upwind/downwind observations and dispersion modelling. One such study is discussed below (Case Study 4.1: Summer 1995 McMaster University Air Particulate Sampling Program).

4.2.1 Contributions to PM_{10} Ambient Levels

Since PM_{10} is the most important pollutant in Hamilton-Wentworth from a health effects standpoint, it is essential to estimate the relative contributions from different sources. There are two main ways to do this.

(A) Analyze PM_{10} levels and examine average differences at monitoring stations across the city .

(B) Use estimated emissions from industrial sources (back calculated from monitoring data) and then mathematically model the concentrations across the city.

Method A Estimates

Method A uses the spatial difference in ambient air concentrations across Hamilton to estimate the contribution from different sources. Table 4.1 shows the 24 hour PM_{10} values measured for 25 days in 1992 to 1996 where readings were close to the average levels for downtown Hamilton. Based on Method A, the contributions to PM_{10} at the downtown stations are estimated to be 16% due to industry, 16% due to urban activities and 68% due to long range transport. In the industrial zone, the contributions to PM_{10} are estimated to be 40% due to industry, 11% due to urban activities and 49% due to long range transport. On the mountain, contributions are estimated to be 10% due to industry, 10% due to urban activities and 80% due to long range transport.

Method B Estimates

Method B uses a combination of dispersion modelling results and annual ambient air concentration data to estimate the contributions from the different sources. The dispersion modelling is based on emissions data generated from the back calculations discussed in Section 11.3 of this report.

Table 4.1: Selected Inhalable Particulate (PM_{10}) Typical Ambient Air Concentration Days in Hamilton ($\mu g/m^3$)

(Average PM_{10} = 22-27 µg/m3 @ 29000-Elgin/Kelly - No precipitation days)

Date	PM_{10} Concentrations at Monitoring Stations (micrograms per cubic metre)					
	29000	29324	29313	29302	22304	WIND
	Downtown	Mountain	Industrial	Beach	Nanticoke	
92/03/13	24		29	42		W
92/04/06	25		31	47		SW
93/01/07	26	23	31	39	18	SW
93/01/19	22	13	18	52	10	WSW
93/02/18	25	15	22	46	11	SW
93/03/08	25	22		37		WSW
93/11/09	26	27	26	130	21	WSW
93/12/09	22	14		65	17	SW
94/04/14	23	16	22	34		SW
94/04/20	23	15	43	44		W
94/07/13	24		43	28	16	SW
95/05/21	27		36	50	21	WSW
95/09/30	24	25		30	30	SSW
96/01/22	24	19	26	36	16	SW
96/08/25	26	24			15	SW
AVG	**24**	**19**	**30**	**49**	**18**	
92/04/18	27		40	12		NE
92/10/21	24		30	17	13	NE,W
94/08/06	27			23	15	E
94/09/05	23		31	14	15	ENE
94/09/23	24		16	11	14	E
94/12/04	26	39	36	26	29	ENE,SW
95/02/02	23	22	73	13	16	NNE
95/12/05	24	15		24	10	E-W
96/02/21	26	26	67	14	10	N,C
96/04/09	24	20	46	19		NE,SW
AVG	**25**	**24**	**42**	**17**	**15**	
Overall Avg.	**25**	**21**	**35**	**36**	**17**	

The estimated contribution (using method B)[7] from the various sources are presented in Figure 4.7. Contributions to the PM_{10} at the downtown stations are estimated to be 15% due to industry, 30% due to urban activities and 55% due to long range transport. In the industrial zone, the contributions to PM_{10} are estimated to be 45% due to industry, 15% due to urban activities and 40% due to long range transport. On the mountain, contributions are estimated to be 10% due to industry, 20% due to urban activities and 70% due to long range transport.

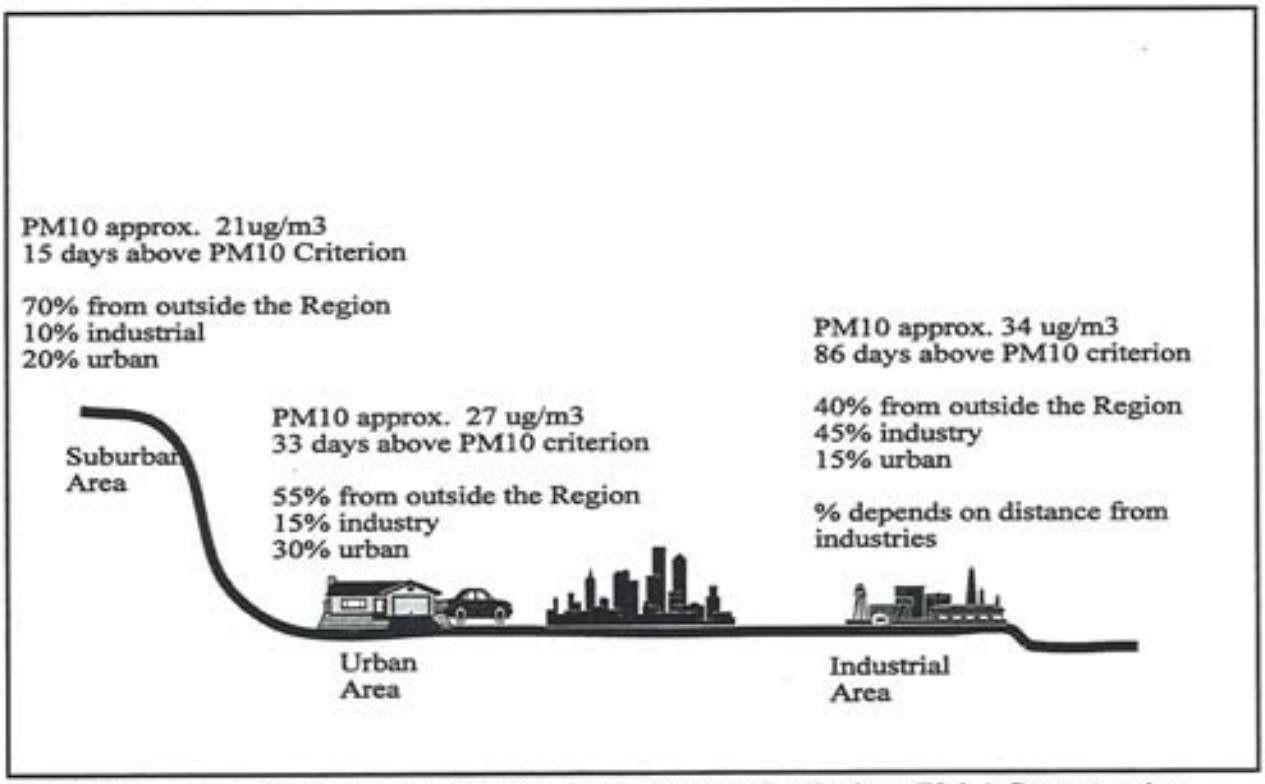

Figure 4.7: Contributions to Average Annual Inhalable Particulate (PM_{10}) Concentration (Method B)

Given the uncertainties in these two types of calculations, there is remarkably good agreement between the results of the methods. It should be stressed that these are the contributions on average days, not the worst days. However, because of the much greater number of average days in a year, most health effects can be assigned to the average conditions rather than the extreme.

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7 The contribution of industrial emissions to the annual average concentration of PM_{10} at the various areas in Hamilton were estimated using dispersion models. The contribution from long range atmospheric transport is assumed to be the same as rural concentrations. Contribution from urban activities is derived by subtracting the industrial/long range transport from the annual average concentrations.

Contributions During Worst Days

On the worst days (inversion conditions) with light winds from the northeast, industrial and local urban contributions will overwhelm the long range transport contributions. These conditions are illustrated in Figure 4.8 which shows the average upwind and downwind concentrations of a number of pollutants over a series of northeast wind days.

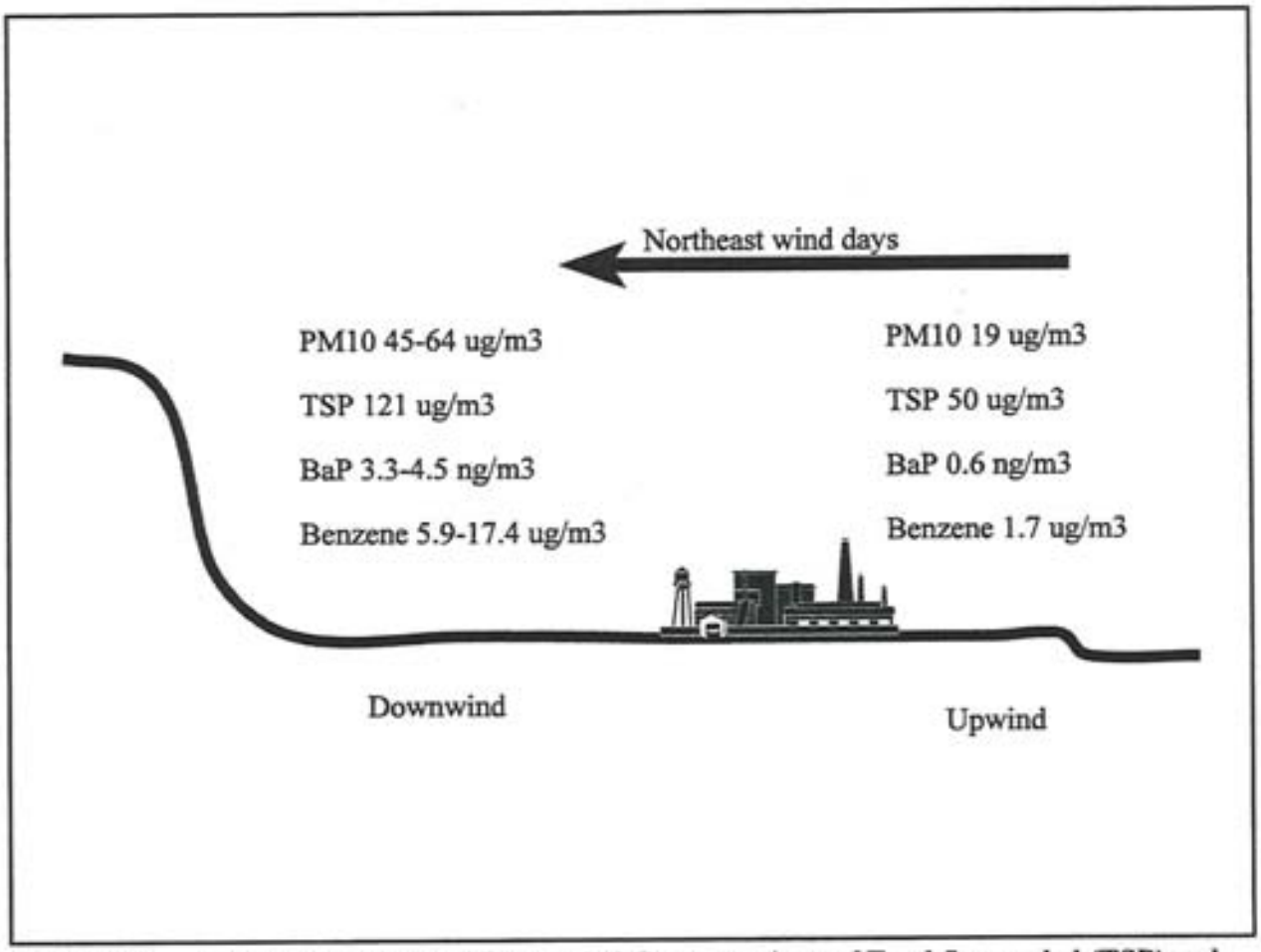

Figure 4.8: Average Upwind and Downwind Concentrations of Total Suspended (TSP) and Inhalable (PM_{10}) Particulate, Benzo[a]Pyrene (B[a]P) and Benzene on Northeast Wind Days

4.2.2 Analysis of Industrial, Urban, Suburban and Rural Contributions to PM_{10} Composition

The air concentrations of contaminants observed at rural monitors[8] can be compared with data from urban and suburban sites, such that estimates of the fraction of the urban air concentrations

[8] Rural monitors are located in Egbert, north of Toronto.

which are transported from the rural to the urban setting can be assessed. Similar estimates can be made between urban or suburban sites affected by industrial or other localized emission sources.

The typical rural PM_{10} concentration in Southern Ontario is about 15 $\mu g/m^3$, of which approximately 12 $\mu g/m^3$ is estimated to enter the urban area (see Table 4.2). The Hamilton urban PM_{10} concentration range is between 20-35 $\mu g/m^3$. By subtracting the rural from the urban concentration, it can be concluded that the remaining 40-65% of urban PM_{10} contributions must come from the urban activities (from industry and other sources). A similar pattern is observed for the coarse fraction of PM_{10} (2.5 - 10μm in diameter). The rural concentration of the coarse particles is approximately 6 $\mu g/m^3$ whereas the urban concentration is 12 $\mu g/m^2$.

Table 4.2: Inhalable Particulate (PM_{10}) Concentrations and Composition - Contribution from Long Range Transport (LRT) vs Local Urban Sources

COMPOUND	URBAN ($\mu g/m^3$)	RURAL ($\mu g/m^3$)	SOURCE(S)
PM_{10}	20 - 35	15	LRT and Local
$PM_{2.5}$-10	12	6	Local
$PM_{2.5}$ - Fraction of Unknown Composition ($PM_{2.5}$ less sulphates, nitrates, ammonia and SOA)	≈9	≈3 - 4	LRT and Local
Sulphates	4.5 - 6	4 - 5	LRT
Nitrates	1 - 1.5	0.5 - 1	LRT and Local
Ammonia	≈2	≈1.5	

SOA - secondary organic pollutant, concentration is assumed to be about 1 $\mu g/m^3$
Urban Data - Hamilton PM_{10} and Environment Canada acid aerosol data
Rural Data - Nanticoke PM_{10} and Environment Canada acid aerosol data at Egbert.

The smaller particles (less than 2.5 μm in diameter, $PM_{2.5}$) contain a significant fraction of sulphates, nitrates, ammonia compounds, and secondary organic compounds. These chemical constituents are formed in the atmosphere from secondary reactions of sulphur dioxide, nitrogen oxides, and volatile organic compounds. Sulphate levels in $PM_{2.5}$ in rural areas (4-5 $\mu g/m^3$) are similar to the levels found in the Hamilton area (4.5-6 $\mu g/m^3$). This suggests that sulphates in the Hamilton area are primarily a result of long-range transport from locations outside the region. A

similar trend is observed for ammonia, also indicating long-range transport as the major contributor to ammonium compounds in $PM_{2.5}$. Unlike sulphates, urban nitrate levels in $PM_{2.5}$ (1-1.5 $\mu g/m^3$) are slightly elevated in comparison to rural levels (0.5-1 $\mu g/m^3$), with rural concentrations that are 50% to 70% of urban concentrations. This suggests that local sources and long-range transport both contribute to the nitrate loading in Hamilton. There is limited data on secondary organic compound levels and composition in $PM_{2.5}$, so it was not possible to establish typical urban and rural values for these compounds.

After accounting for sulphates, nitrates, and ammonium compounds, a fraction of $PM_{2.5}$ remains unknown in composition. This portion is likely to consist of organic and elemental carbon particles, soil particles, and metals. The urban level of this unknown component (9 $\mu g/m^3$) is higher than the rural levels (3-4 $\mu g/m^3$), thus suggesting strong influence from urban sources.

Tables 4.3 and 4.4 show values upwind /downwind of the industrial zone for total suspended particulate (TSP) and PM_{10}. For particulate, concentrations downwind of the industrial area are elevated compared to upwind levels (See Figure 4.8 also).

Iron and Steel (I&S) emissions are currently under review by the MOE and the industry. There is significant uncertainty over the emissions inventory for particulate (total)(Table 5.1). Fugitive dust (e.g., re-suspended road, agriculture, and construction dust) is not accounted for in these estimates, leading to the further uncertainty surrounding the total emissions of particulate. This is discussed in chapter 5. For further information on emissions and modelling for particulate in Hamilton-Wentworth refer to Table 5.1 in the following chapter.

4.3 Environmental Effects

Airborne particles can make surfaces dirty and, depending on the material, may lead to corrosion. Examples of this include corrosion of automobile paint surfaces by iron particles. Particles in the air can cause haze and obscure visibility. Inversion days are noticeable usually because of increased haze.

Complaints are frequently received about dust and black fallout and there have been instances of different industrial operations causing impacts in their immediate neighbourhoods. One example is discussed in the case study (4.2) on Redlands Quarries below. These types of effects are largely of aesthetic concern. They are sufficiently important in Hamilton-Wentworth that they are dealt with in a separate report (HAQI, 1997a).

Case Study 4.1: Summer 1995 McMaster University Air Particulate Sampling Program

In the summer of 1995 McMaster University conducted an intensive six-week particulate sampling campaign at six sites in Hamilton, primarily near downtown and industrial areas. This work was undertaken in collaboration with MOE. Monitoring for inhalable particulate and polycyclic aromatic hydrocarbons (PAHs) was included.

Daily average concentrations of inhalable particulate material were compared with daily average wind direction/wind speed. Using this approach it was possible to determine the inhalable particulate loadings attributable to normal urban activities, such as vehicle emissions, normal roadway dust, and industry.

The concentration range of inhalable air particulate (15-35 $\mu g/m^3$) and the concentrations of PAHs were typical of urban areas such as Toronto, Montreal or Vancouver. The lowest values (15 $\mu g/m^3$) were obtained on days with steady, strong winds; these low values were obtained upwind of the industrial sector and are similar to values obtained at rural sampling sites in Ontario. Of this 15 $\mu g/m^3$, about 12 $\mu g/m^3$ are estimated to come from outside the urban area. Particulate samplers situated downwind of the major industrial area showed that industrial activities often contributed an additional 15-25 $\mu g/m^3$, and as much as 75 $\mu g/m^3$ in a worst case scenario. The values for benzo[a]pyrene agree well with MOE data and are consistent with the calculated emissions modelled for industry.

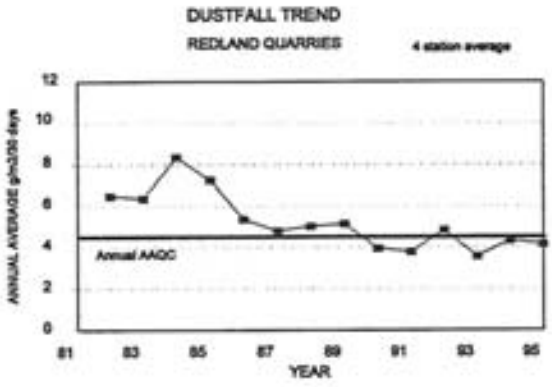

Figure 4.9: Dustfall Trends from Redland Quarries

The development of new chemical markers for PAH permitted the distinction between diesel emissions and coke oven/coal tar emissions. This new method showed that urban background samples collected upwind of the industrial area had chemical signatures typical of diesel engine emissions while samples collected downwind of the industrial area had signatures typical of coke oven and coal tar emissions.

Case Study 4.2: Redlands Quarries

Due to ongoing complaints of fallout, airborne particulate have been measured near Redland Quarries, a limestone quarry operation in the Town of Flamborough. The company has taken remedial measures by installing numerous pollution control devices at both the processing plant and at the actual quarry operations located further north of the plant. Over the years, these measures have resulted in significant improvements in dustfall and suspended particulate emissions. Fugitive dust releases appear to be the only remaining observable emissions, and are noticeable in the immediate vicinity of the processing plant when winds are high. Dustfall trends from the Redland Quarries site are shown in figure 4.9.

TABLE 4.3: UPWIND VS DOWNWIND (OF INDUSTRIAL ZONE) TOTAL SUSPENDED PARTICULATE CONCENTRATIONS (TSP) DURING FULLY NORTHEAST OR SOUTHWEST WIND DAYS (HIGHEST CONCENTRATIONS)

SOUTHWEST WIND DAYS					NORTHEAST WIND DAYS				
DATE		DOWNWIND TSP (µg/m3)	UPWIND TSP (µg/m3)		DATE		DOWNWIND TSP (µg/m3)	UPWIND TSP (µg/m3)	
		29102-Beach	29113-Gertude				29025-Barton	29102 - Beach	
1994	JAN 20	130	49		1993	JUN 12	105	51	
	JUL 1	183	53			JUN 24	130	54	
	AUG 30	142	44			AUG 17	98	41	
	DEC 22	178	99			SEP 22	91	67	
1995	JAN 3	129	69			DEC 15	96	25	
	FEB 8	122	67	1	1994	MAY 14	90	55	
	FEB 14	179	94			AUG 12	128	57	
	MAR 4	169	88			OCT 17	115	50	2
	MAR 10	124	66		1995	MAY 9	132	36	
	MAY 21	173	75			JUN 2	205	58	
	JUL 14	139	42			JUN 20	172	76	
	AUG 1	190	126			JUN 26	137	47	2
	AUG 31	194	125						
GEOMETRIC MEAN		156	72		GEOMETRIC MEAN		121	50	

1 upwind from 29025 - Barton
2 upwind from 29105 - Nash

TABLE 4.4: UPWIND VS DOWNWIND (OF INDUSTRIAL ZONE) PM_{10} DURING FULLY NORTHEAST OR SOUTHWEST WIND DAYS (HIGHEST CONCENTRATIONS)

SOUTHWEST WIND DAYS					NORTHEAST WIND DAYS				
DATE		DOWNWIND PM_{10} (µg/m3)	UPWIND PM_{10} (µg/m3)		DATE		DOWNWIND PM_{10} (µg/m3)	DOWNWIND PM_{10}(µg/m3)	UPWIND PM_{10} (µg/m3)
		29302-Beach	29313-Gertude				29313-Gertude	29300-Kelly	29302 - Beach
1993	MAR 2	110	73	1	1993	DEC. 15	78	44	40
	OCT 28	65	17		1994	MAR. 9	48	71	12
	NOV 9	130	26			MAY 14	52		26
	DEC 3	62	20			MAY 26	52	26	20
	DEC 9	65	22	1		AUG 12	55	48	29
1994	JULY 1	55	30			NOV 16	65	31	8
	JULY 19	51	39		1995	FEB 2	73		13
	JULY 31	51	44			MAR 28	84	45	14
	NOV 4	51	23			MAY 9	65	43	8
	DEC 22	65	50			JUN 2	81	88	22
1995	MAY 21	50	36			JUN 14	61	27	15
	JULY 14	55	42			JUN 20	88	58	25
	AUG 31	60	60			AUG 25	53	53	45
GEOMETRIC MEAN		64	34		GEOMETRIC MEAN		64	45	19

1 - upwind from 29000- Elgin/Kelly

5 COMMON POLLUTANTS

Since 1970, MOE has measured several common pollutants on a real-time basis in Hamilton-Wentworth. These pollutants have environmental and human health effects, can be compared to provincial AAQCs, and are useful indicators of general air quality. They include sulphur dioxide, carbon monoxide, nitrogen oxides and ozone.

5.1 Ambient Air Monitoring

Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas and has a pungent odour at concentrations greater than 0.5 parts per million (ppm). It can damage vegetation and is a human respiratory irritant. It can be oxidized into various forms of sulphate particles, which can lead to other health effects and acid rain. Measurement of SO_2 involves fluorescence of SO_2 with pulsed ultraviolet radiation. In Hamilton, there are currently seven such monitors.

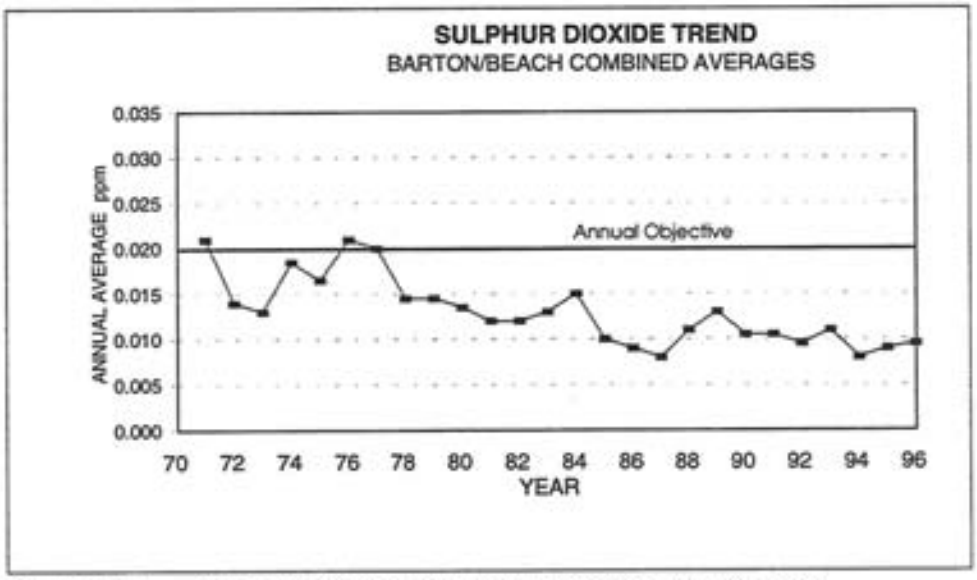

Figure 5.1: Sulphur Dioxide Trend in Hamilton-Wentworth

Figure 5.1 illustrates the SO_2 trends reported by the two oldest stations in downtown Hamilton (Barton/Sandford and Beach Blvd.). Large improvements in SO_2 air concentrations occurred in the 1970s, followed by more stable levels in recent years. The concentrations in Hamilton-Wentworth have been below the MOE's yearly, daily, and hourly ambient air quality criteria for nearly twenty years.[9] However, the Health group has determined that existing SO_2 levels are sufficient to cause adverse health impacts.

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[9] AAQC for SO_2 are 0.25 ppm (1 hour), 0.1 ppm (24 hours) and 0.02 ppm (1 year).

The most significant source of SO_2 outside of the downtown area is the generating station at Nanticoke. However, in the last 21 years, there has been one only acute SO_2 event that was traced to the Nanticoke Generating Station (NGS). That was on August 14,1987 when two Hamilton stations (29000 and 29114) exceeded the hourly ambient air quality criterion (.29 and .38 ppm respectively). These two hours in Hamilton have been the only such exceedances ever measured in Hamilton since 1976 (and there were only a few before that). If emissions do not increase at NGS, it is unlikely such an event will occur again. There have been no hourly exceedances at any Nanticoke SO_2 monitor since 1989.

Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless, poisonous gas produced as the result of the incomplete combustion of fuels. It is readily absorbed into the blood, thus reducing the blood's ability to carry oxygen. Those suffering from heart disease are at greatest risk to CO exposure. Exposure to elevated levels can lead to impairment of vision, manual dexterity, learning ability, and at very high levels, death. Measurement involves the ability of CO to absorb infra-red radiation. Two monitors are currently in use In Hamilton. Levels of CO have decreased greatly since the 1970s due to more stringent automotive emission controls. CO levels are well below all provincial ambient air quality standards and criteria.[10] However, as with SO_2, the Health group has determined that existing CO levels are sufficient to cause adverse impacts on human health.

Nitrogen Oxides (NO_x)

Nitrogen (N_2) makes up approximately 80% of the air humans breathe. In this form, it is harmless and essential to all life. In high temperature fuel combustion, nitrogen reacts with atmospheric oxygen to produce various forms of nitrogen oxides (NO_x). Of these, nitric oxide (NO) and nitrogen dioxide (NO_2) are the most important contributors to air pollution. NO_x reacts with volatile compounds (VOCs) in the air in the presence of sunlight to produce ground level ozone (see below). Other chemical reactions lead to the production of nitric acid, which is a component of acid rain, and fine nitrate particles, which contribute to health effects.

Nitric oxide is the primary NO_x emission from combustion sources. It is subsequently oxidized in the atmosphere to form NO_2, which is a reddish brown gas with an irritating odour at concentrations above 0.1 ppm. Figure 5.2 illustrates the yearly trend of NO_2. Large NO_2 reductions in the 1970s are followed by a more moderate downward trend since 1980. Concentrations tend to be slightly higher near the industrial zone. Nitrogen dioxide AAQCs have not been exceeded at any station, except for a discontinued one in the early 1980's.[11] This latter site (North Park on Beach strip) was located immediately adjacent to a major highway.

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10 AAQC for CO are 30 ppm (1 hour) and 13 ppm (8 hours).

11 AAQC for NO_2 are 0.2 ppm (1 hour) and 0.1 ppm (24 hours). There are no AAQC for NO or NO_x at present.

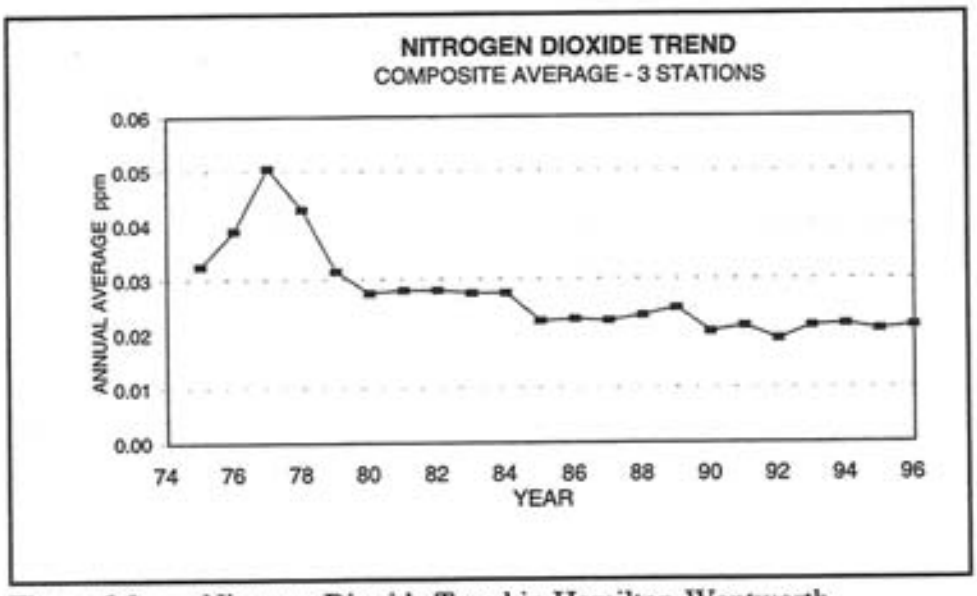

Figure 5.2 Nitrogen Dioxide Trend in Hamilton-Wentworth

Ozone (O_3)

Ground level ozone forms as a result of chemical reactions involving two groups of pollutants - NO_x and VOCs. Nitrogen oxides and VOCs emissions are generated by a wide range of sources including vehicle exhaust, coke ovens, industrial boilers and furnaces, and vapours from gasoline pumps. High levels of ozone occur more often during sunny, hot and dry summers. The effect of

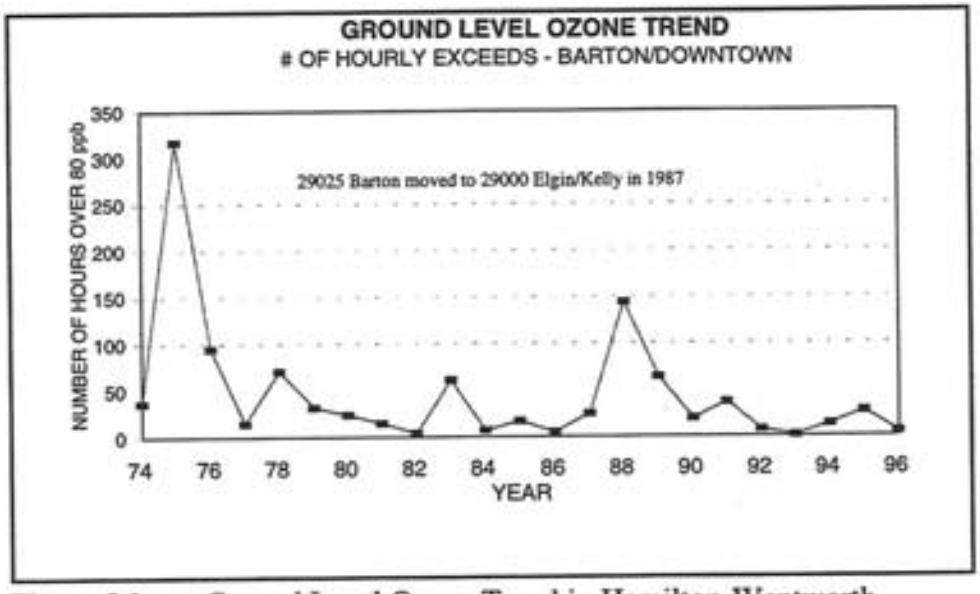

Figure 5.3 Ground Level Ozone Trend in Hamilton-Wentworth

climatic variability is clearly shown in Figure 5.3. For example, the summer of 1988 was hot, dry and sunny, resulting in frequent exceedances of the AAQC.[12] In the other years, Hamilton's ozone levels at the four Air Quality Index (AQI) stations show no distinct trend.

Over 50% of the ozone affecting Ontario comes from sources in the U.S. Nitrogen oxides and VOC emissions from the U.S. midwest contribute to ozone levels in southern Ontario. Ozone is formed downwind of the sources of NO_x and VOC emissions. Therefore, rural concentrations of ozone are often higher than levels in the urban centres, even though there are much higher emissions of NO_x and VOCs in urban centres. Urban centres also generate pollutants which chemically react with ozone, thus initially destroying some of it.

5.2 Emissions and Modelling

Ontario's iron and steel production is concentrated in Hamilton-Wentworth. In 1990, this area was responsible for 36,500 tonnes of SO_2 emissions and 39,400 tonnes of NO_x emissions. In comparison, in 1990, Ontario total emissions for SO_2 and NO_x were 1,192,000 tonnes and 659,000 tonnes respectively. By 1994, the provincial total emissions for SO_2 had dropped from 1,192,000 tonnes to 619,000 tonnes per year; but, SO_2 emissions from the iron and steel sector remained relatively constant during this time.

Table 5.1 summarizes the MOE common pollutants and particulate emission inventory for the Hamilton-Wentworth region for the year 1990. The pollutants in the MOE inventory include, sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), carbon monoxide (CO), and total particulate matter (PM).[13] Emissions of pollutants are classified into 16 sectors for area sources and 9 sectors for point sources. The area sources include vehicle emissions, dry cleaning operations, and fuel marketing processes. Iron and steel, carbon black and other manufacturing are categorized as point sources. Non-industrial emissions from area sources were estimated by apportioning the total provincial production and/or consumption data to the Hamilton-Wentworth area.

Sulphur dioxide emissions are generated primarily from the combustion of coal or fuel oil. The iron and steel (I&S) sector is the major source of SO_2 emissions in Hamilton-Wentworth (83%). Carbon black manufacturing, marine and vehicle emissions also contribute to SO_2, but to a lesser extent (12% combined). Vehicles and I&S production are the major sources of NO_x and VOCs in the area; the I&S sector accounts for 35% of NO_x and 27% of VOC emissions; vehicles account for 38% of NO_x and 23% of VOCs. The I&S sector, along with vehicles, are the major emitters of CO, accounting for 94% of emissions. I&S released 368,226 tonnes (71%) of CO, while vehicles released 120,878 tonnes (23%).

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12 AAQC for O_3 is 80 parts per billion (ppb) (1 hour).

13 Refer to chapter 4 for a discussion of particulate emissions.

A pollution rose is a technique for pointing out the direction of the sources of airborne contaminants. It can be adapted for many parameters. Figure 5.4 shows a pollution rose for SO_2 at the Elgin/Kelly site in Hamilton. The 1995 annual average SO_2 concentrations for each wind direction are plotted to form this pollution rose. The rose indicates that the highest average SO_2 levels are associated with winds passing over the industrial and heavy traffic areas from the eastnortheast.

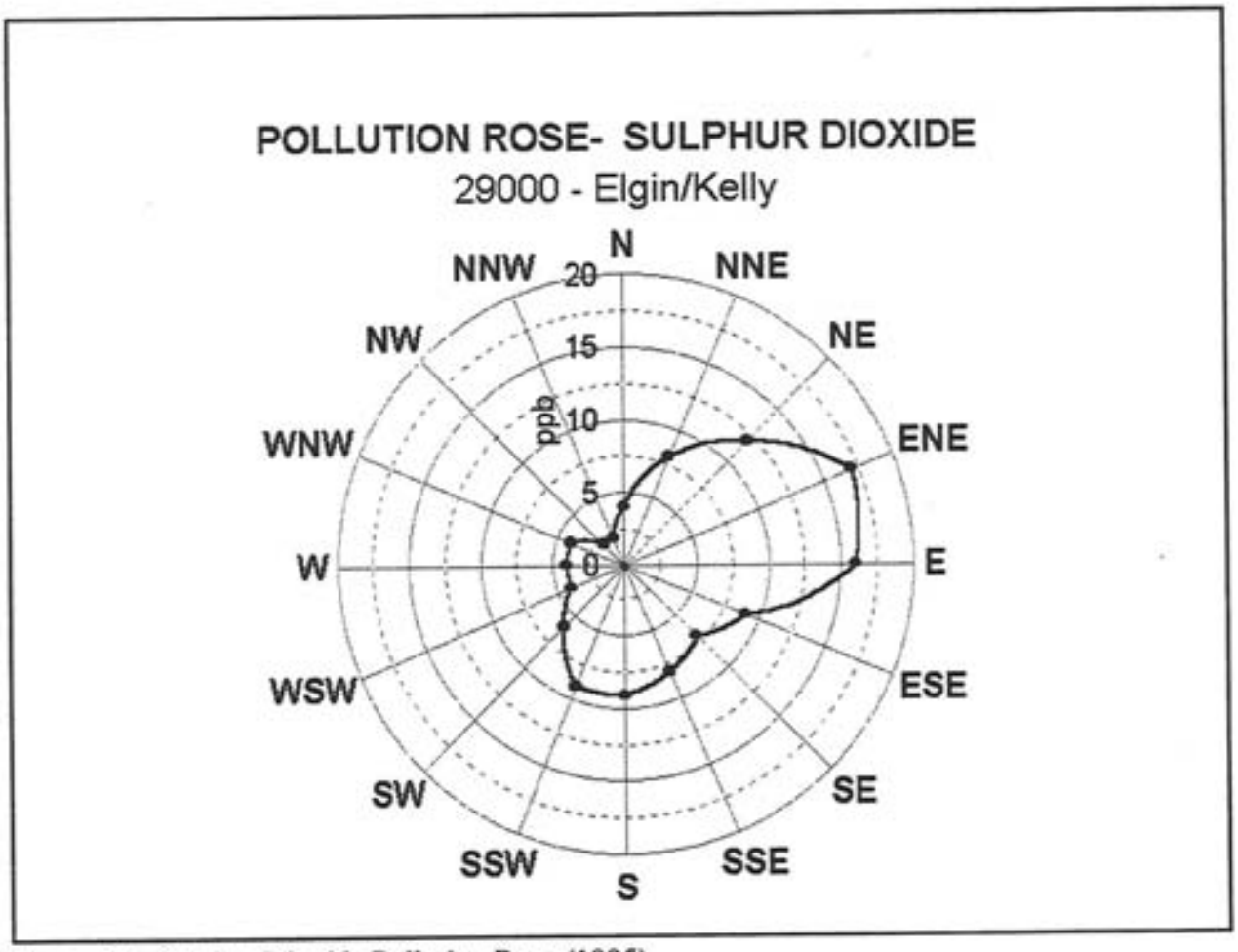

Figure 5.4: Sulphur Dioxide Pollution Rose (1995)

Table 5.1: 1990 Emissions of Common Pollutants and Particulate in Hamilton-Wentworth (MOE) (tonnes)

Sector	SO_2 (tonnes)	No_x (tonnes)	VOC (tonnes)	PM (tonnes)	CO (tonnes)
AREA SOURCES Total Vehicles	1,118	15,054	13,934	1,479	120,878
Off-Hwy Engines	389	4,276	1,783	367	18,918
Railway	67	830	40	45	332
Aircraft	4	31	32	5	210
Marine	1,145	650	436	108	1,249
Residential	291	970	6,217	1,561	11,418
Commercial	191	536	20	30	112
Industrial	546	145	3	47	42
Incineration	0	0	0	0	0
Forest Fire	0	0	0	0	0
Other Fires	0	0	0	0	0
Dry Cleaning	0	0	327	0	0
Surface Coating	0	0	7,101	0	0
General Solvent Use	0	0	9,159	0	0
Fuel Marketing	0	0	2,542	0	0
Misc. Processes	0	0	2	0	0
Subtotal	**3,751**	**22,491**	**41,597**	**3,641**	**153,159**
POINT SOURCES Agricultural Implement	0	53	4	70	5
Asphalt	8	8	5	90	42
Carbon Black	2,170	2,637	66	68	60
Glass Manufacturing*	57	195	14	42	13
Iron and Steel Production	30,475	13,614	16,214	NA	368,226
Metal Rolling, Casting	8	28	122	51	19
Sewage Sludge Incineration*	33	138	104	144	15
Vegetable Oil Mills	0	25	985	73	6
Other Manufacturing	7	202	970	646	24
Subtotal	**32,757**	**16,902**	**18,485**	**NA**	**368,410**
TOTAL	**36,509**	**39,393**	**60,082**	**NA**	**521,569**

NA-not available *** - these sources are no longer operating in Hamilton-Wentworth**

5.3 Environmental Effects

Historically, areas close to a source of SO_2, such as metallurgical plants processing sulphide ores, or coal fired power stations, have experienced acute SO_2 injury to vegetation. At present, AAQC for SO_2--established to protect vegetation--are not being exceeded at any of the monitoring stations in Hamilton-Wentworth. Sulphur dioxide can react with water, oxygen and other atmospheric pollutants to form sulphuric acid, which is a primary component of acid rain. However, acid rain is not considered to have significant environmental impact in Hamilton-Wentworth[14]. Similarly, NO_x can react to form nitric acid, which is also a component of acid rain. In addition, NO_x can also increase haze and reduce visibility.

CO has long been recognized for its human health effects. However, there is no evidence of environmental impacts in Hamilton-Wentworth.

Ozone is the most significant air pollutant affecting vegetation. Ozone injury on bean plants and white ash trees typically appears as black or red-brown stipples on the upper surface of the leaves, on tobacco plants as irregular-sized grey or copper spots on the leaves' upper surface, and on the lower surface of the leaves of tomato and potato plants. (Ozone injury to potato plants can occur on both upper and lower leaf surfaces.) In conifers, such as Eastern white pine, O_3 causes chlorotic mottle and/or "tip burn" on affected needles. The severity of vegetation injury can vary between location and over time since it is dependent on the species and its susceptibility, the physiologic condition of the plant, and meteorological conditions favorable for ozone formation (Gizyn, 1997). Studies have shown that crop and ornamental plant yield in Ontario could be increased by up to $70 million annually if MOE's one-hour ozone AAQC of 80 parts per billion was met (MOEE, 1996a). In Ontario, O_3 injury to sensitive vegetation is most common in the southern regions of Ontario.

MOE's Phytotoxicology Section inspects ozone-sensitive crops at experimental sites in rural areas west of Toronto. Sensitive vegetation in Hamilton-Wentworth is expected to be injured at the same rate as the crops inspected by MOE (MOEE, 1996b), since ozone concentrations in Hamilton-Wentworth are similar to the levels in those rural areas.

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[14] See Chapter 9 for more information

6 METALS

Airborne metals exist largely in the form of particulate matter and are routinely monitored in Hamilton. They include lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), and vanadium (V). In recent years specialized monitoring for hexavalent chromium (Cr(vi)) and total mercury has also been conducted.

If particulate metals are emitted to the air; depending on the size of the particles, they can be carried throughout the region and deposited various distances from the source. Larger particles are deposited relatively close to the source. Some metals, such as arsenic and mercury, have a large gaseous element and can be easily transported much longer distances through the air.

It is possible for metals to cause various human health effects and other environmental effects such as soiling, corrosion, and vegetation damage. Some airborne metals have been reported to affect the circulatory, respiratory, gastrointestinal and central nervous systems of animals. Animals are affected by airborne metals when gases or small particles are inhaled or when particles suspended in food or water are ingested. Heavy metals deposited onto soils can accumulate to levels that are toxic to soil invertebrates, like worms. Invertebrate activity rates, invertebrate community structure, and biomass could decrease in metal-polluted soils. There are no reported environmental effects of the above airborne metals at the levels typically found in Hamilton. It is possible that other metals, such as mercury, for which little data exist have measurable environmental impacts.

6.1 Ambient Air Monitoring

Airborne metals are collected by standard high volume (hivol) filter samplers and inhalable particulate (PM_{10}) samplers. Once every six days, these instruments gather particulate for 24 hours (midnight to midnight) on a pre-weighed glass-fibre filter while a known volume of air is passed through the filter. Once the total particulate concentration is determined by weighing the exposed filter, a portion is cut from the exposed filter and scanned by X-ray fluorescence for metals. In Hamilton, the filters from six hivol and four PM_{10} samplers are currently analyzed for metals.

Historical data from the Barton/Sandford site for lead and manganese are shown in figure 6.1. This site is centrally located (see Figure 6.2) and has the longest continuous history of any air monitoring site in Hamilton. Airborne lead levels show a dramatic decline beginning around 1981 with the introduction of unleaded gasoline. Manganese levels dropped around 1991. Similar trends were reported by Reid et al. (1993) for all of Ontario.

The distribution of lead within the city, based on annual averages for 1993 is shown in Figure 6.2. Airborne lead concentrations are higher near the major industrial emitters. Iron, manganese,

lead and chromium are the metals which display a gradient from the industrial area, but all are generally within acceptable levels i.e. less than the AAQC.[15]

Five dustfall stations across the city were also analyzed for these metals. The only metals showing a significant gradient in dustfall from the industrial area were iron and manganese. Although elevated above background levels, iron and manganese are still below the AAQC based on health effects. These data indicate that the industrial area is a strong source of iron and manganese in Hamilton; and a weak source of lead and chromium. The other metals show little spatial variability suggesting that sources are more dispersed.

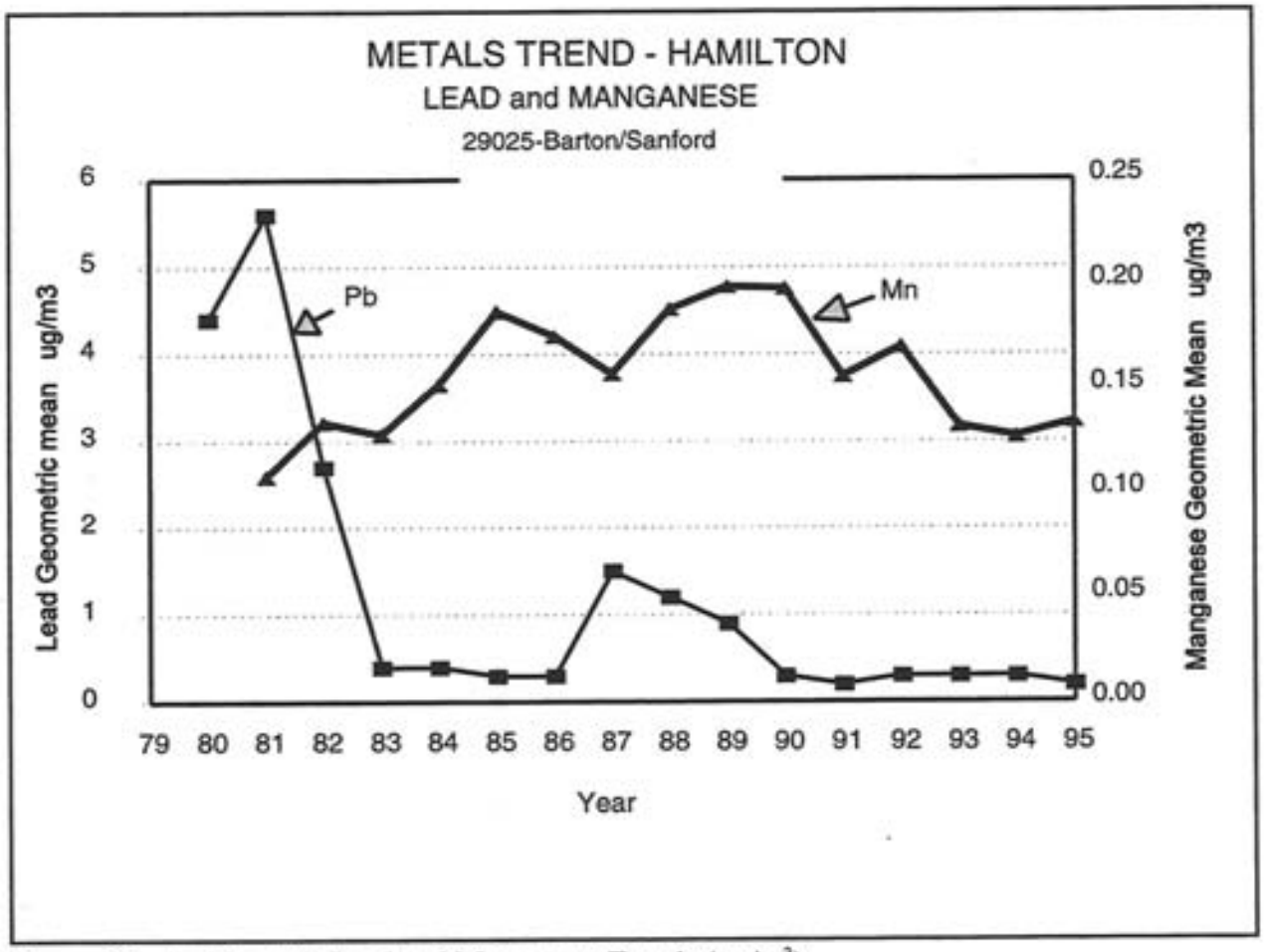

Figure 6.1: Ambient Air Lead and Manganese Trends ($\mu g/m^3$)

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[15] AAQC (24 hours) exist for Lead (5 $\mu g/m^3$ and 2 $\mu g/m^3$ (30 day geometric mean), Cadmium (2 $\mu g/m^3$), Manganese (2.5 $\mu g/m^3$), Nickel (2 $\mu g/m^3$) , Vanadium (2 $\mu g/m^3$) and metallic iron (4 $\mu g/m^3$). The AAQC for Mn is under review.

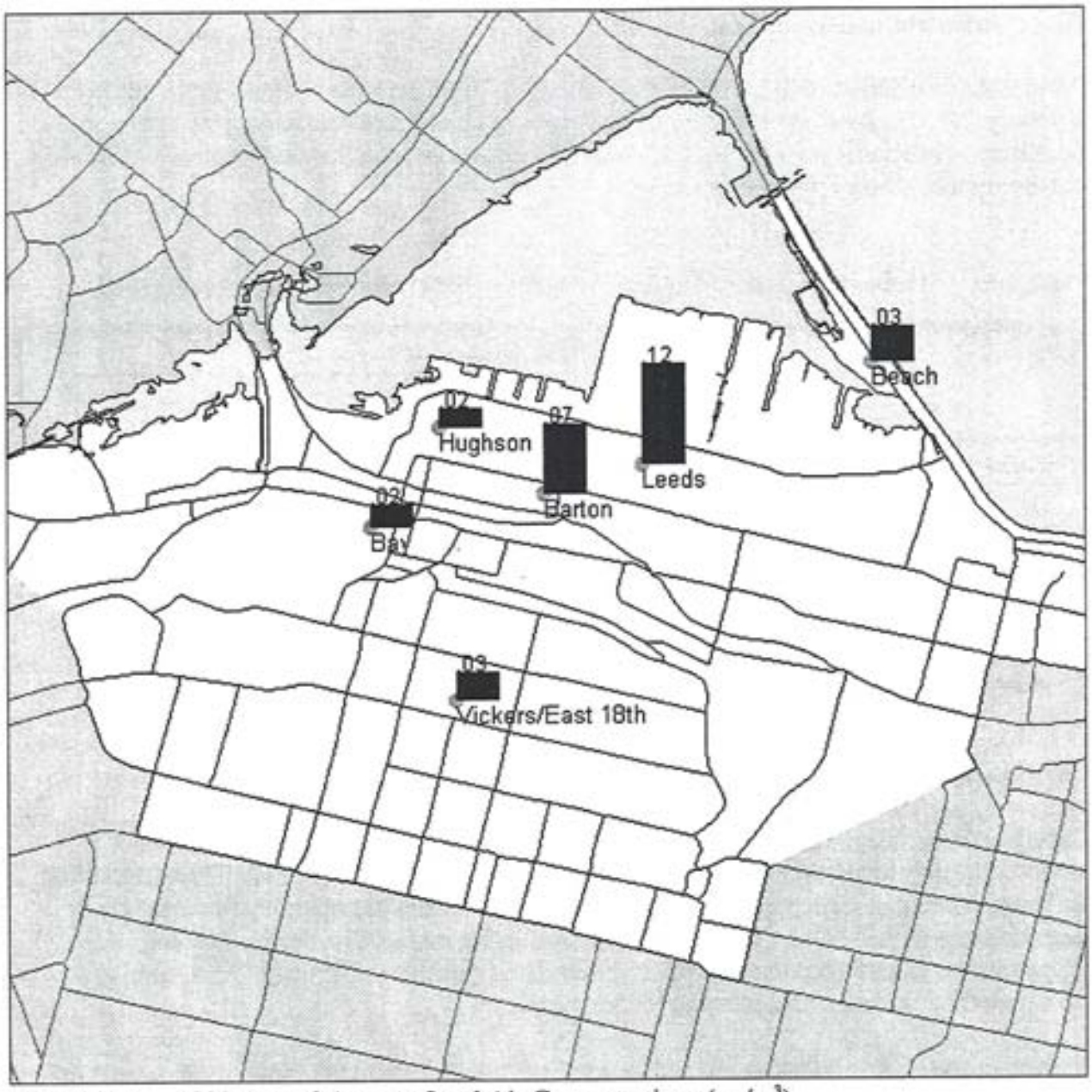

Figure 6.2: 1993 Annual Average Lead Air Concentrations ($\mu g/m^3$)

6.2 Emissions and Modelling

Data for the iron and steel industrial sectors are available through the National Pollutant Release Inventory (NPRI). Releases of selected metals are shown in Table 6.1. Among the more significant atmospheric releases are 4.2 tonnes of manganese from Stelco. For more information and discussion, please refer to Chapter 11.

Table 6.1: National Pollutant Release Inventory (NPRI) for Specific Metals (1994)

Compound	1994 NPRI Releases to the Air (tonnes)				
	Columbia Chemical	Dofasco	Slater Steels	Stelco (Hilton Works)	Reutgers VFT Inc.
Chromium	NL	0.13	NL	NL	NL
Lead	NL	0.038	1.2	1.1	NL
Manganese	NL	0.6	1.1	4.2	NL
Nickel	NL	0.02	NL	NL	NL

NPRI - National Pollutant Release Inventory
NL - not listed or reported in NPRI

6.3 Environmental Effects

The effects of airborne metals on vegetation are usually limited to accumulation. In 1987, a survey collecting silver maple tree foliage at 10 stations across the City of Hamilton (excluding the "mountain") that were previously sampled in 1977, reported significantly lower lead concentrations at these sites. These data are shown in Figure 6.3. The decline in foliar concentrations is attributed to elimination of lead from gasoline in the early 1980s. Similar trends are reported for surface water concentrations of lead.

Most other metals in vegetation and soil data come from an assortment of point source surveys and complaint investigations, conducted from the mid 1970s to the present. These smaller surveys may demonstrate local effects from small point sources.

In the past, iron particles (especially iron oxides) have been reported to cause some surface and paint damage to vehicles in Hamilton-Wentworth. This is no longer occurring due to control measures undertaken by specific sources. There is no reported evidence to suggest biotoxic or bioaccumulative effects of airborne metals in Hamilton-Wentworth. However, there is limited information on these effects in the region.

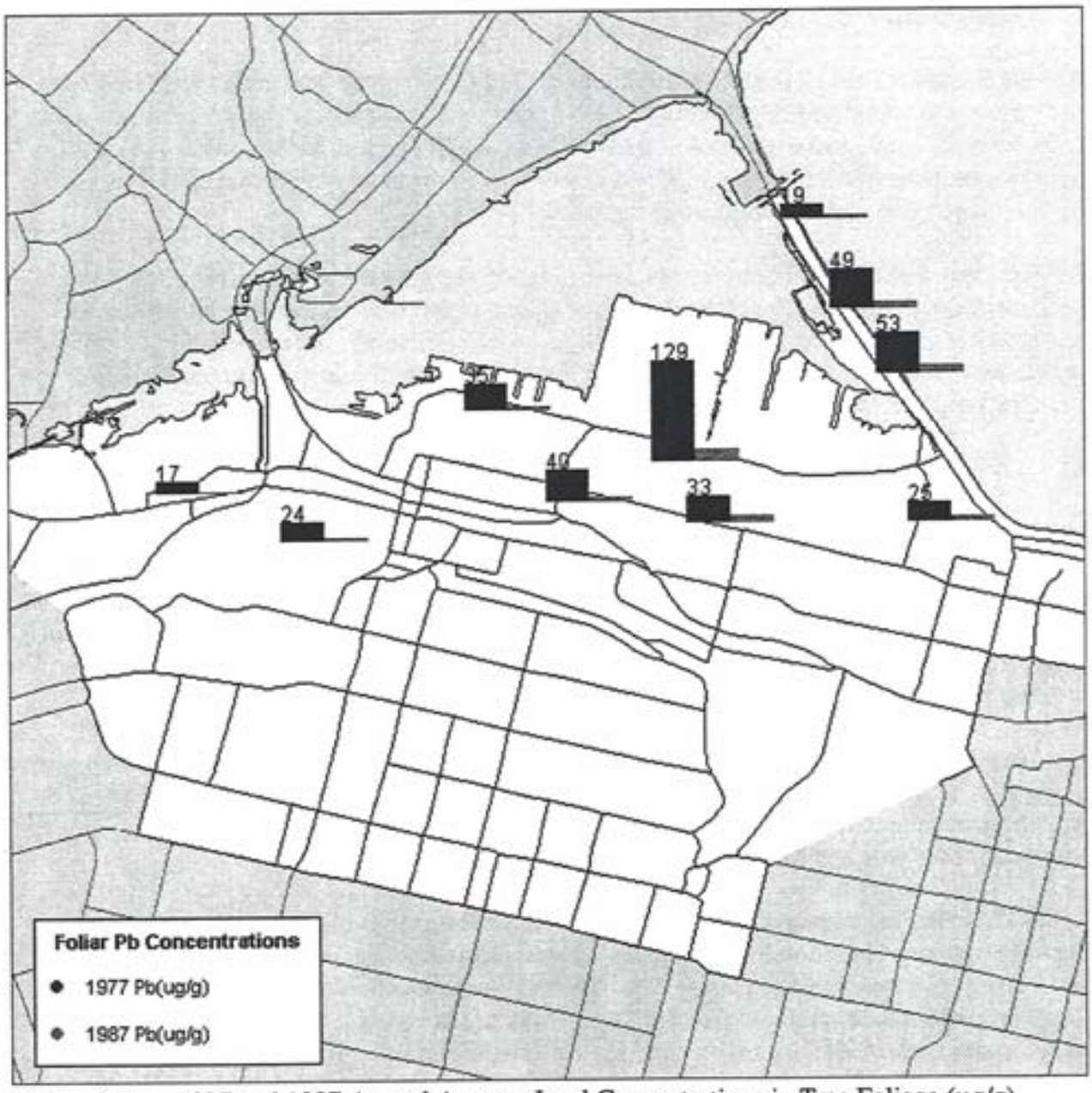

Figure 6.3: 1997 and 1987 Annual Average Lead Concentrations in Tree Foliage (µg/g)

7 FLUORIDE

Fluoride is a ubiquitous element in crustal material and any industry that processes or uses such materials is a potential source of fluoride compounds to the atmosphere. The steel industries are major users of crustal materials such as iron ore and coal. In the past, the Hamilton steel making industries used the fluoride mineral, fluorspar, as a flux in the basic oxygen furnaces. Fluorspar use for this purpose was discontinued in the late 1980s.

The Hamilton Brick Co., a brick manufacturing plant at the base of the escarpment near Gage Park, is a current source of fluoride. Fluoride compounds are released from the kilns when the clay products are being baked. Another Hamilton source of fluoride is the appliance manufacturing plant, CAMCO, on Longwood Road. The enamel coatings process for these household appliances releases fluoride during baking operations

7.1 Ambient Air Monitoring

Ambient air monitoring for fluoride compounds is routinely performed by exposing lime-coated paper to the atmosphere for a one month period. During this period ambient air fluorides, both gaseous and particulate forms, react with and are retained by the lime coating. The coating is then analyzed for fluoride by the ion selective electrode method. The results of this type of monitoring are reported as fluoridation rates and are expressed in micrograms of fluoride that has reacted with and been retained by 100 square centimetres of lime-coated paper in a 30 day period.

The fluoridation rate objective was established to provide protection to vegetation against injury by ambient air fluorides. The objective is more stringent during the growing season. From April to October the objective is 40 micrograms/100 square centimetres/30 days while for the remainder of the year it is 80 micrograms/100 square centimetres/30 days.

Figure 7.1 shows the contours of the five-year 1990-94 average fluoridation rates across Hamilton and near Hamilton Brick. Figure 7.2 shows the annual average fluoridation rates for two series of monitoring stations over time. The first series of seven stations consists of general Hamilton stations located across the city. These stations have been in place since 1970. The second series consists of five stations established around Hamilton Brick in 1988. These measurements show steady overall improvements in fluoride levels across Hamilton. Fluoridation rates near Hamilton Brick also show significant improvements, especially around the late 1980s. However, while the air quality criteria are rarely exceeded at the general Hamilton stations, they are still regularly exceeded near Hamilton Brick.

7.2 Emissions and Modelling

There are no air emission inventory data for fluorides.

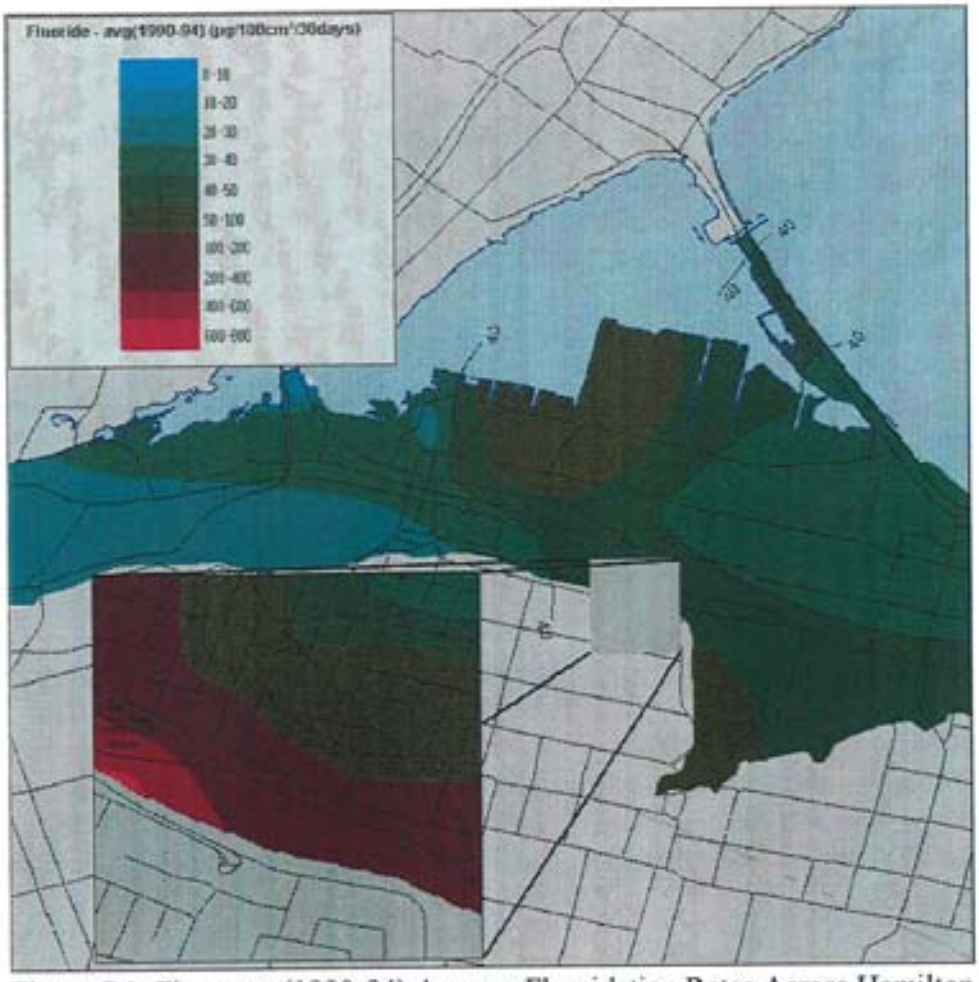

Figure 7.1: Five-year (1990-94) Average Fluoridation Rates Across Hamilton (ug/100 cm^2/30 days)

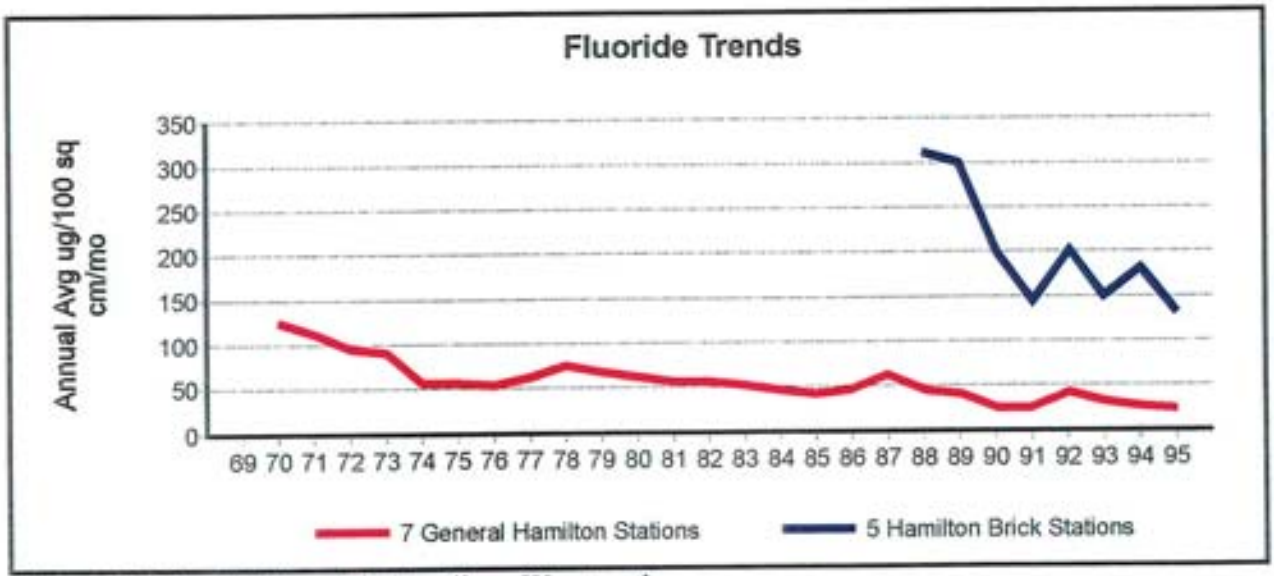

Figure 7.2: Fluoride Trends in Hamilton-Wentworth

7.3 Environmental Effects

The concern about fluoride is based primarily on its toxicity to vegetation. Airborne compounds of this element are deposited onto foliage, absorbed into the tissue, and then translocated to the leaf margins or needle tips. When concentrations reach toxic levels, tissue is killed. The concentrations at which injury becomes visible can be quite variable. Particularly sensitive species such as apricot, gladiolus and Manitoba maple can show injury at relatively low foliar concentrations of fluoride, while tolerant species can accumulate very high concentrations without any apparent ill effects. Injury development also depends on a variety of other variables, including the rate at which the fluoride is accumulated, as well as various plant physiological and climatic conditions.

The MOE's Phytotoxicology Section has conducted investigations focusing on fluoride sources in Hamilton to document effects on vegetation. The subjects of three such investigations are discussed here.

Surveys to document the accumulation by vegetation of fluoride emitted by the steel industries have been conducted since 1970, with the most recent in 1987. Surveys consisted of examinations of foliage for fluoride injury, and collections of foliage from silver maples, a very common tree in cities, for chemical analysis. There were 13 such sampling locations across the lower city. Figure 7.3 and 7.4 consist of contour maps depicting tree foliage fluoride as determined in 1977 and in 1987. Significant reductions from 1977 to 1987 are evident from the data in these figures.

Investigations near Hamilton Brick were conducted in 1986, 1987 and 1991, focusing on fluoride contamination of tree foliage and documenting injury to this foliage by excessive concentrations. The most recent survey in 1991 involved sampling foliage from 12 locations, all of which were within a kilometre of the brick yard. Injury to the foliage attributable to fluoride along with highly elevated fluoride concentrations was identified at the two closest (within 100 metre) locations.

CAMCO manufactures major domestic appliances (white goods). During the high temperature enamelling process, fluorides are released to the atmosphere. The most recent 1990 survey around CAMCO consisted of a collection of tree foliage from 11 locations within 500 metres of CAMCO, plus two more distant control locations. Elevated foliar fluoride concentrations occur at locations close to the plant, however they are not high enough to injure vegetation.

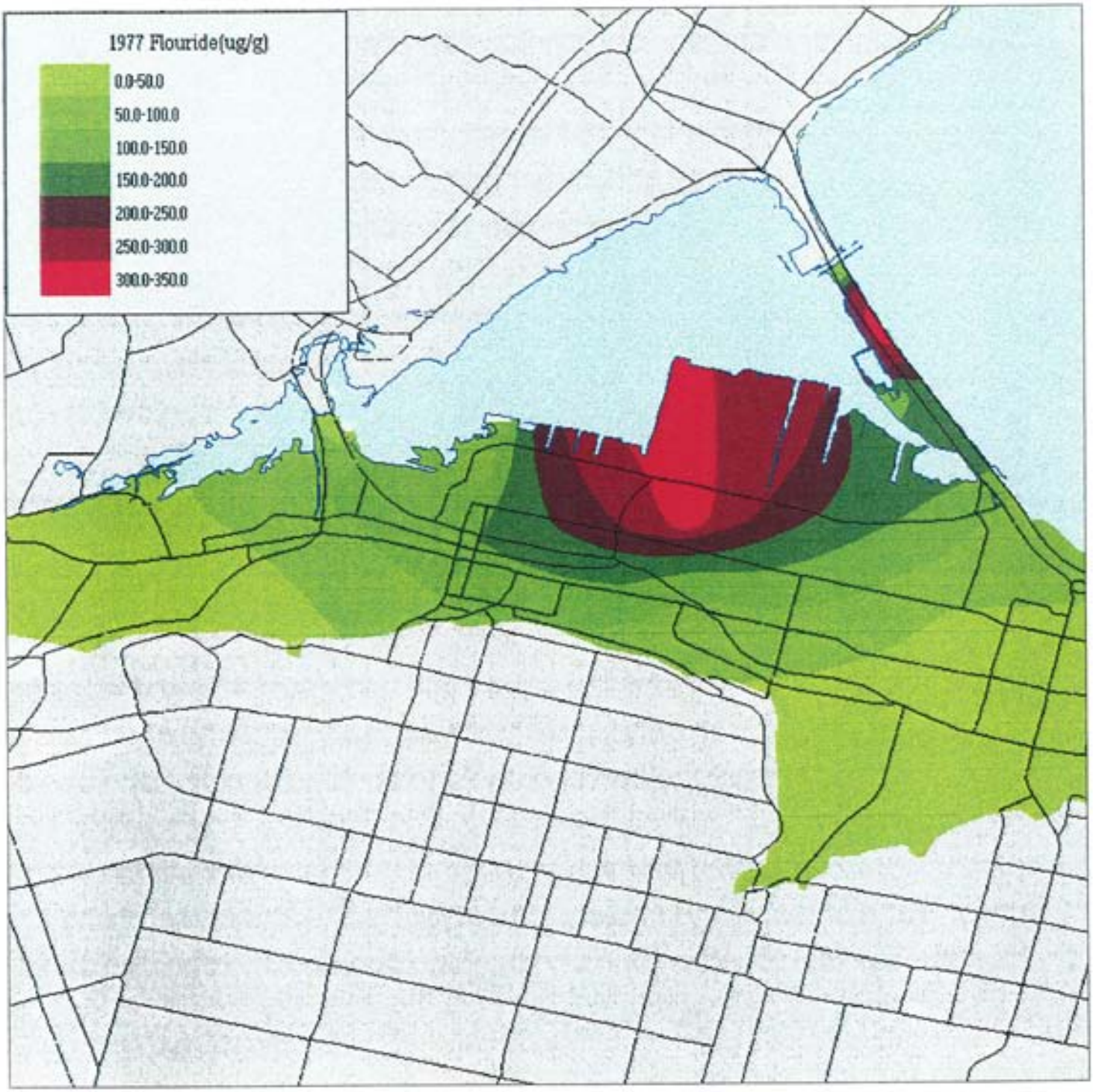

Figure 7.3: 1977 Fluoride Concentrations in Tree Foliage (ug/g)

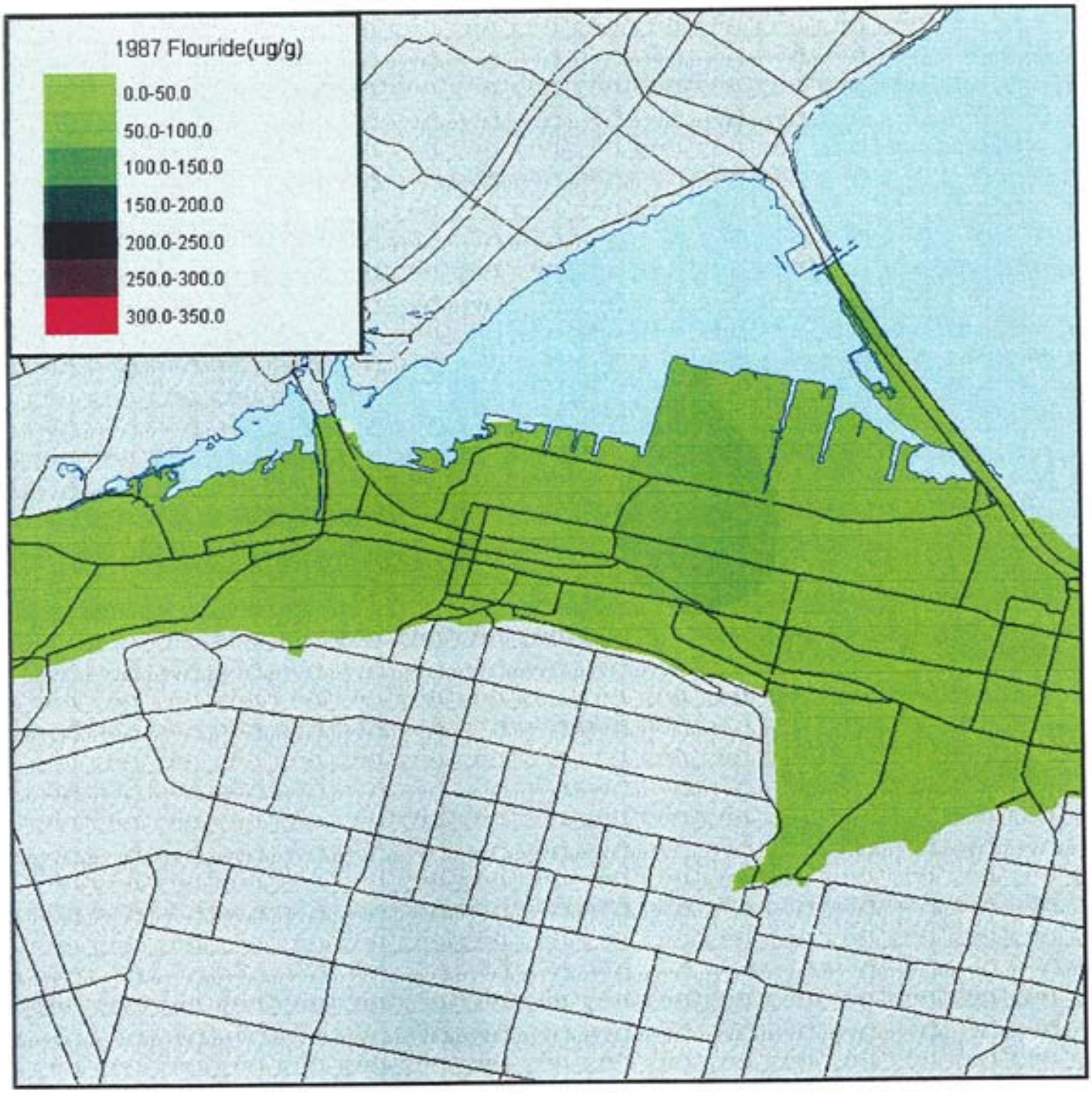

Figure 7.4: 1987 Fluoride Concentrations in Tree Foliage (ug/g)

8 VOLATILE ORGANIC COMPOUNDS (VOCs)

Volatile organic compounds (VOCs) are pollutants which exist in the atmosphere, primarily in gaseous form. They are generated by a wide variety of industrial, transportation, and natural sources, including iron and steel production, vehicles, household paints, lawnmowers and natural vegetation. Some VOCs are known human carcinogens and several more are strongly suspected of being carcinogenic; others can aid in the destruction of stratospheric ozone--the layer which shields the earth from excessive levels of ultraviolet radiation; and many VOCs react with nitrogen oxides in the presence of sunlight to form ground-level ozone.

The Environment Work Group of HAQI has focused on four specific VOCs:

benzene
1,3-butadiene
naphthalene
isoprene

Benzene and 1,3 butadiene are known human carcinogens and are generated by a number of industrial and transportation sources. Isoprene originates primarily from natural sources and contributes to the formation of ground-level ozone, particularly in rural areas. Naphthalene is a highly odorous VOC which is generated by a range of industrial operations, including the textile industry, the steel industry and coal tar processing. It is found in fungicides; and emitted by coke ovens.

8.1 Ambient Air Monitoring

Volatile organic compounds are regularly monitored at five MOE sites within the city of Hamilton.[16] Once every 12 days, 24-hour samples are collected using carbon adsorbent cartridges, which are then processed and analyzed by gas chromatography.

Five-year (1990-1994) average concentrations for VOCs monitored in Hamilton are presented in Table 8.1. Isoprene and 1,3 butadiene display relatively low levels and little variation across the city. This is due to the fact that isoprene is mainly from natural sources outside of Hamilton, and 1,3 butadiene is from vehicle emissions that are prevalent throughout Hamilton.

The highest benzene levels are recorded at the Gertrude/Depew site, located within the industrial area (Figure 8.1). In north Hamilton, benzene and naphthalene levels are strongly influenced by industrial activity. Coke ovens at the steel mills and related coal tar operations are known sources of these contaminants. Motor vehicles, gasoline stations, and bulk fuel terminals are also key emitters of benzene. Benzene levels at the Vickers site on the mountain are lower than the other

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[16] In the summer of 1993, 60 homes in Hamilton were also sampled, both indoor and outdoor, for VOCs (Bell et. al, 1994).

monitoring sites since it is least influenced by industrial emissions and traffic. The Pier 25 and Beach Blvd. sites are slightly further away from the industrial area than the Gertrude site, and are affected proportionately less.

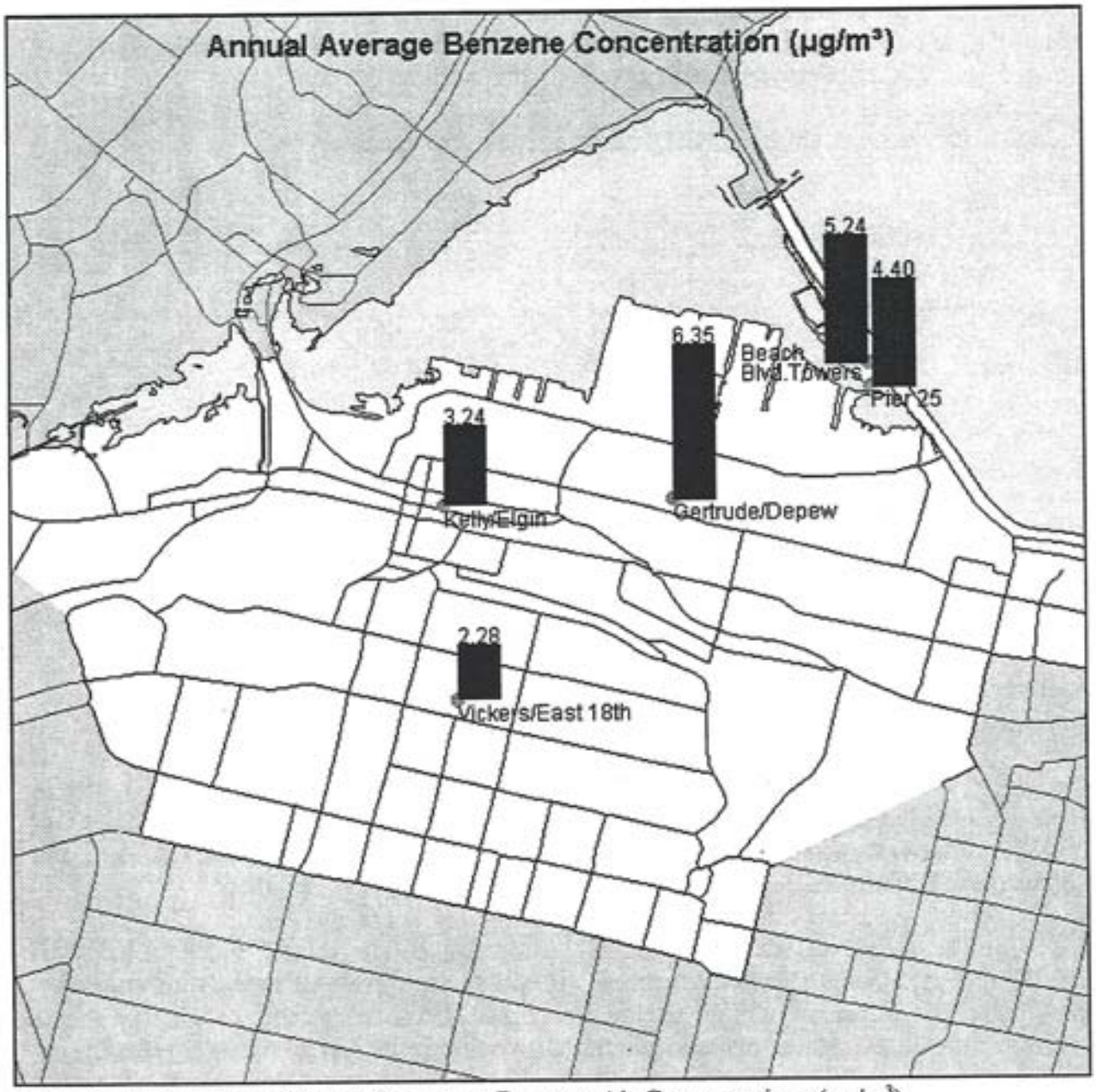

Figure 8.1: Five-year (1990-1994) Average Benzene Air Concentrations (µg/m³)

Table 8.1: Five-Year (1990-94) Average Volatile Organic Compound (VOC) Concentrations in Hamilton

Contaminant	Monitoring Sites				
	29000 Elgin/ Kelly ($\mu g/m^3$)	29113 Gertrude/Depew ($\mu g/m^3$)	29547 Pier 25 ($\mu g/m^3$)	29102 Beach Blvd ($\mu g/m^3$)	29114 Vickers ($\mu g/m^3$)
Benzene[a]	3.24	5.36	3.93	4.42	2.44
1,3-Butadiene	0.13	0.05	0.05	0.1	0.06
Naphthalene*	1.18	2.13	2.77	2.57	0.87
Isoprene	0.18	0.15	0.09	0.17	0.15

* Only 1995 yearly average concentrations are presented for naphthalene. 1995 samples were analyzed by GC/MS whereas previous data were analyzed by GC/FID.

a Table values are slightly different than graph values due to difference methods of calculating averages.

8.2 Emissions and Modelling

Volatile organic compound emission inventories are generally not available. Some VOC data are available through the National Pollutant Release Inventory (NPRI) (Table 8.2). Among the more significant atmospheric releases reported via the NPRI, are 452 tonnes of benzene and 11.3 tonnes of naphthalene from Dofasco, 284 tonnes of benzene and 1.8 tonnes of naphthalene from Stelco's Hilton Works.

Table 8.2: National Pollutant Release Inventory (NPRI) for Benzene and Naphthalene (1994)

Compound	1994 NPRI Releases to the Air (tonnes)				
	Columbia Chemical	Dofasco	Slater Steels	Stelco (Hilton Works)	Reutgers VFT Inc.
Benzene	NL	451.8	NL	283.6	0
Naphthalene	0	11.3	NL	1.8	0

NPRI - National Pollutant Release Inventory
NL - not listed or reported in NPRI

Benzene emission estimates are also available from the Strategic Options Process (SOP). The SOP is described in chapter 11. Benzene emissions from the SOP are listed in Table 8.3.

Table 8.3: Summary of 1993 Benzene Emissions from Coke and Byproduct Plants Reporting in the Strategic Option Process (SOP)

Company	1993 Air Emissions (tonnes)
	Benzene
Stelco (Hilton Works)	328.3
Dofasco	454.4

Table 8.4 shows the upwind /downwind levels of benzene on days with fully northeast or southwest winds (also see Figure 4.8). For VOCs, downwind concentrations are elevated compared to their upwind counterparts. For example, downwind benzene concentrations tend to average about 6-17 $\mu g/m^3$ depending on distance from the industrial zone, compared to only 2 $\mu g/m^3$ upwind.

8.3 Environmental Effects

There is no evidence to suggest that there are environmental impacts in Hamilton-Wentworth at the concentrations measured.

TABLE 8.4: UPWIND VS DOWNWIND (OF INDUSTRIAL ZONE) BENZENE CONCENTRATIONS DURING FULLY NORTHEAST OR SOUTHWEST WIND DAYS (HIGHEST CONCENTRATIONS)

SOUTHWEST WIND DAYS				NORTHEAST WIND DAYS					
DATE		DOWNWIND (µg/m3)	UPWIND (µg/m3)	DATE		DOWNWIND (µg/m3)	DOWNWIND (µg/m3)	UPWIND (µg/m3)	
		29102-Beach	29113-Gertude			29113-Gertude	29000-Kelly	29102 - Beach	
1993	JAN 19	9.3	4.8	1994	MAR 27	42.0	3.0	2.9	
	OCT 10	8.4	1.6		MAY 14	9.6	5.8	2.5	
1994	AUG 30	8.5	1.5		MAY 26	8.8	4.7	0.6	1
1995	JAN 9	12.0	2.7		OCT 17	15.0	5.7	2.3	
	JAN 21	7.5	3.9		DEC 16	9.7	4.8	2.5	1
	OCT 12	12.2	1.7	1995	FEB 26	24.0	7.1	1.1	
	OCT 24	8.0	3.2		MAY 9	26.0	5.7	0.6	1
	NOV 5	12.0	1.0		JUN 2	21	14.5	2.0	
	DEC 11	14.8	1.6		JUN 26	10.0	4.8	1.5	
1996	APR 21	11.2	1.5		SEP 6	7.6	3.3	1.4	
AVERAGE		10.4	2.4	AVERAGE		17.4	5.9	1.7	

1 - upwind from 29547 - Pier 25

9 ACID RAIN

Rain water generally contains small amounts of impurities. These impurities can be dust particles or gases absorbed from the air. The impurities (in particular CO_2) cause the rain drops to be slightly acidic i.e. pH 5.6. However, a pH of less than 4.5 in rain is almost certainly caused by air pollution.

Acid rain is caused by the release of the gases SO_2 (sulphur dioxide) and NO_x (nitrogen oxides). The main sources of SO_2 in North America are coal-fired power stations and primary metal industries. The main sources of NO_x emissions are vehicles and other fuel combustion sources.

Sulphur dioxide reacts with air and water vapour in sunlight to form sulphuric acid. Likewise NO_x forms nitric acid. These reactions take hours, or even days, during which time polluted air may move hundreds of kilometres. Thus acid rain can fall far from its source. Acid rain can be in the form of acid snow, acid fog or mist, acid gas, and acid dust. All of these "acids" are related air pollutants, and can harm your health, cause hazy skies and damage the environment and your property. Sulphate and nitrate are known to be a factor in reducing visibility and creating widespread haze in Hamilton-Wentworth. This particulate component of "acid rain" , i.e., sulphates and nitrates, form a major part of inhalable and respirable particulate burden in Hamilton-Wentworth. As such, they are implicated in serious health effects (Pengelly et. al., 1997).

A considerable fraction of the acid rain in Ontario is caused by pollutants from big coal-burning power plants in the midwest and the Ohio valley in the U.S. These plants burn midwestern and Appalachian coals, some of which contain more sulphur than other coals. Key Ontario sources of acid rain are the nickel smelters in Sudbury and coal fired thermal generating stations, including the Nanticoke generating stations located to the south of Hamilton-Wentworth. Emissions from Nanticoke rarely impact on Hamilton-Wentworth due to the relative absence of southerly winds.

9.1 Ambient Air Monitoring

The Ministry of the Environment operates two province-wide acid cumulative and event deposition monitoring networks (Acid Precipitation in Ontario Study (APIOS) wet and dry). Acid rain sites are located at rural locations to assess long range transport of acid rain and minimize local influences. The Ministry does not operate any acid deposition monitoring sites within the borders of Hamilton-Wentworth.

The primary constituents of acid rain (NO_x and SO_2) are monitored directly in air at four sites in Hamilton-Wentworth. These are discussed in Chapter 5. The acid aerosols (sulphates and nitrates) on the TSP filters are monitored by the MOE at five sites. In addition, sulphate is measured on the filters of four PM_{10} samplers. The federal government has been monitoring acid

aerosols (small particles) in air at one site in downtown Hamilton to further assess these respirable fractions.

Sulphate comprises a large portion of the measured particulate matter on the filters. The sulphate particles tend to occur in small particle sizes because they are formed by gas- to- particle chemical reactions in the atmosphere. The conversion of sulphur dioxide to sulphates takes place as sulphur dioxide travels north from the U.S. midwest Similarly, local sulphur dioxide emissions are converted to sulphates as they are carried by the winds to areas outside of Hamilton-Wentworth.

The yearly average concentrations of particulate sulphate in Hamilton show a small gradient from the industrial area (MOEE, 1996c), indicating some contribution from local industry. On days of elevated sulphate concentrations, winds are generally from the south-west and levels outside the city are comparable to those within Hamilton. This indicates sulphates are due to long range transport from distant sources. However, there are occasions when elevated sulphate levels occur with winds from the northeast, thus indicating there are also local contributions (e.g., industries).

It should be noted that the sulphate/nitrate analyses (in TSP filters) are subject to some error due to the measurement methodology. Tests with filter media indicate that the glass fibre TSP filter can cause as much as 8 $\mu g/m^3$ on average of spurious sulphate formation from gaseous sulphur dioxide and nitrogen oxides (MOE, 1987). The PM_{10} sulphate levels are not prone to this error due to the use of a different filter. For this reason the data should be primarily used for evaluation of trends rather than use of absolute values.

9.2 Emissions and Modelling

As mentioned earlier, long range transport is a significant contributor to the acid problem in Ontario. There are also Ontario sources such as coal burning electric power generating stations. Although there are no electric power generating stations in Hamilton-Wentworth, Nanticoke generating station (NGS) is nearby to the south of Hamilton-Wentworth. However, winds rarely blow from the direction of Nanticoke to Hamilton. Low NO_x burners have been installed and low sulphur coal is being used at the NGS. There are no flue gas scrubbers in place.

9.3 Environmental Effects

It is unlikely that acid rain is harming wildlife, crops or vegetation in the area. The soils in southern Ontario, including Hamilton-Wentworth, have a considerable neutralizing capacity and thus direct environmental impacts are unlikely. Acid-related damage to surface waters, soils, and forests is more likely to occur in areas lacking the alkaline rocks and soils necessary to neutralize these acids. There may be chronic low level effects that are not discernible in our monitoring.

Acidic precipitation has the potential of affecting vegetation either directly or indirectly. The former would include acute injury of foliar surfaces or leaching of base cations from this foliage.

The latter would include mechanisms where soil chemistry is altered to a point where soil fertility is impaired, or where potentially toxic soil elements become more readily available through soil acidification.

Acid rain has been linked with the death of trees in Europe and North America. In spite of a great deal of research, no one yet knows exactly how acid rain harms forests. Most of the forests of Europe consist of huge areas of one tree species. This encourages the spread of plant pests and diseases. It seems likely that acid rain weakens the trees, perhaps helped by other pollutants such as ozone, and then leaves the trees open to attack by disease. Forest health surveys conducted by the MOE have observed that forests in regions of Ontario with thin, base-poor soils have a higher incidence of trees exhibiting symptoms of tree decline.

9.4 Programs Currently in Place

Ontario's Countdown Acid Rain Program (initiated in 1985) caps Ontario SO_2 emissions at 885,000 tonnes by the year 1994. Reductions were required and completed by the four biggest Ontario SO_2 sources; INCO, Falconbridge, Algoma Steel at Wawa, and Ontario Hydro. It should be noted that Ontario's 1994 SO_2 emissions are about 619,000 tonnes. Emissions in 1996 were about 667, 000 tonnes.

Programs to control SO_2 and NO_x emissions and acid rain are also national or international in scope. Sulphur dioxide emissions declined throughout the 1970s in Canada and the U.S. , in response to a number of factors, including regulatory pressure for industries to use fuels with lower sulphur contents. Efforts to control SO_2 emissions were renewed in the early 1980s as the extent of the environmental damage being caused by acidic deposition was becoming more apparent. Control programs led to reductions in SO_2 emissions between 1980 and 1985 of about 20% in Canada and 10% in the U.S. From 1985 through 1989, SO_2 emissions in the U.S. remained relatively constant. In 1985, Canadian SO_2 emissions were about 17.5% those of the U.S. Nitrogen oxides emissions have proved to be more difficult to control than SO_2 emissions. Nitrogen oxides emissions increased about 14% between 1980 and 1985 in Canada and decreased slightly (about 3%) between the same years in the United States.

Further NO_x emission cuts are planned by both Canada and the U.S. under Annex 1 of the Air Quality Agreement, the United States is obligated to implement a NO_x control agreement with a view to a reduction of total annual emissions of NO_x of approximately 1.8 million tonnes from 1980 levels of 18.9 million tons (Canada/United States Air Quality Agreement 1991). Attempts to reduce NO_x emissions are largely in response to the role this air pollutant plays in the formation of ground-level ozone.

Despite past efforts to reduce SO_2 and NO_x emissions; areas of Canada remain at risk from acid rain. The federal and provincial governments are working with stakeholders to draft a National Acid Rain Strategy for Post-2000 to help protect acid sensitive areas and human health in Canada.

10 DIOXINS, FURANS AND POLYCYCLIC AROMATIC HYDROCARBONS

Long-term (or chronic) exposure to many contaminants can lead to cancer, organ damage, genetic mutation, reproductive damage, birth defects, and other biological harm. As a result, there is great public concern about such contaminants. However, as with all materials the toxic effects depend on the dose received. Standards are usually set on a "worst case" basis of very long exposure times and large safety factors.

Persistence and bioaccumulation depend on the properties of a substance, conditions in the environment, and the ecosystem under consideration. A persistent substance degrades very slowly in the environment, therefore having a long half-life. Bioaccumulation is the process by which a substance accumulates in a living organism. The higher an organism is in the food chain, the higher the concentration of that substance.

Contaminants which are linked to long-term health effects usually persist in the environment and are often bioaccumulative.[17] Significant local sources of polycyclic aromatic hydrocarbons (PAHs) do exist in Hamilton-Wentworth. Atmospheric inputs of PAHs from steel mills are thought to contribute significantly to PAH levels in harbour sediments. The municipal solid waste incinerator is a known source of chlorinated dibenzo dioxins and furans (PCDD/Fs). Less is known about other local sources of chlorinated dibenzo PCDD/Fs. Atmospheric inputs of polychlorinated biphenyls (PCBs) are not thought to be significant and may be declining, as new uses of PCBs are prohibited and older stocks continue to be decommissioned under strict regulations.

PAHs are a class of compounds which can cause cancer if there is sufficient intake to the body. The environmental impacts of these constituents varies. PAHs are contained in coal derivatives, and some petroleum products. For example, the Benzo[a]pyrene (B[a]P) concentration in crude oil is about 1-13 ppm. They are also present in creosote, a wood preservative used for railway ties and coal tar pitch used in driveway sealant. Coke making, wood preservation, waste incineration, wood burning, diesel engines and any incomplete combustion process (including barbecuing) are prominent sources of atmospheric PAHs; since PAHs are produced mainly through the combustion or pyrolysis of organic matter. PCDD/Fs are a family of related persistent organic chemicals, composed of 75 different kinds of dioxins and 135 furans. Not all of these chemicals are considered toxic; only 17 congeners are considered toxic.[18]

Dioxins and furans are the by-products of the high temperature combustion (sintering, electric arc-furnace steel-making, and waste incineration) of raw materials containing chlorine and

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17 For more information on bioaccumulation, please refer to RAP, 1992.

18 Dioxins and Furans are a group of compounds with similar backbone structures, each compound has chlorine or hydrogen atoms at different positions. Compounds are referred to as congeners if they have the same backbone structures (i.e., dioxins and furans).

organic compounds. Dioxins and furans are very persistent in the environment. For example, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD) has a half-life of 10 or more years. The toxic potency of the PCDD/PCDF congeners is commonly expressed in terms of Toxic Equivalent Factors (TEQ) which are relative to the most toxic congener, 2,3,7,8 TCDD.

10.1 Ambient Air Monitoring

A limited data base exists for dioxins and furans in ambient air. Until the recent Plastimet fire all measurements were collected at the downtown Air Quality Index (AQI) station at Elgin/Kelly, by both Environment Canada and MOE. Ambient air monitoring of 2,3,7,8 TCDD (TEQ) in Hamilton (Elgin/Kelly) between 1992 and 1995 showed concentrations to be well below the 24-hour average of 5 picograms (TEQ)/m^3 as laid out by the Ambient Air Quality Criteria. The maximum recorded concentration was 0.4 pg/m^3, with no particular wind direction influencing the reading. Dioxin levels in Hamilton are comparable to most other urban cities in North America.

Intensive dioxin sampling was conducted during and after the Plastimet fire, both for air concentrations as well as soil, vegetation and soot on surfaces. Air concentrations exceeded guidelines in the immediate vicinity of the fire while the fire was burning, then returned to levels well below guidelines once the fire was extinguished. Marginally higher PCDD/Fs were detected on foliage near the fire, but returned to background levels following rain washing of the foliage. Soil and soot levels were within clean-up guidelines offsite from the fire.

Sampling of PAHs in Hamilton began in 1992, with 29 compounds routinely analyzed. Only B[a]P has standards/guidelines. The AAQCs for B[a]P in air are 0.3 ng/m^3 (annual average), 1.1 ng/m^3 (24-hour average) and 3.3 ng/m^3 (1/2 hour average). Sampling and analysis are conducted by MOE at three stations and by Environment Canada at one station. B[a]P readings are highest on the Beach Strip and in the industrial zone.

Figure 10.1 illustrates the spatial variation for B[a]P. Stations closer to the industrial zone show much higher concentrations, thus indicating industrial sources as the prime source of these contaminants. The B[a]P annual ambient air criterion is exceeded at all of the monitoring stations, especially in the industrial zone.

Table 10.1 shows upwind /downwind levels at monitoring stations for benzo[a]pyrene (B[a]P). Downwind concentrations are elevated compared to their upwind counterparts. For example, B[a]P downwind levels average 4.5-6 µg/m^3 versus 0.5 µg/m^3 upwind.

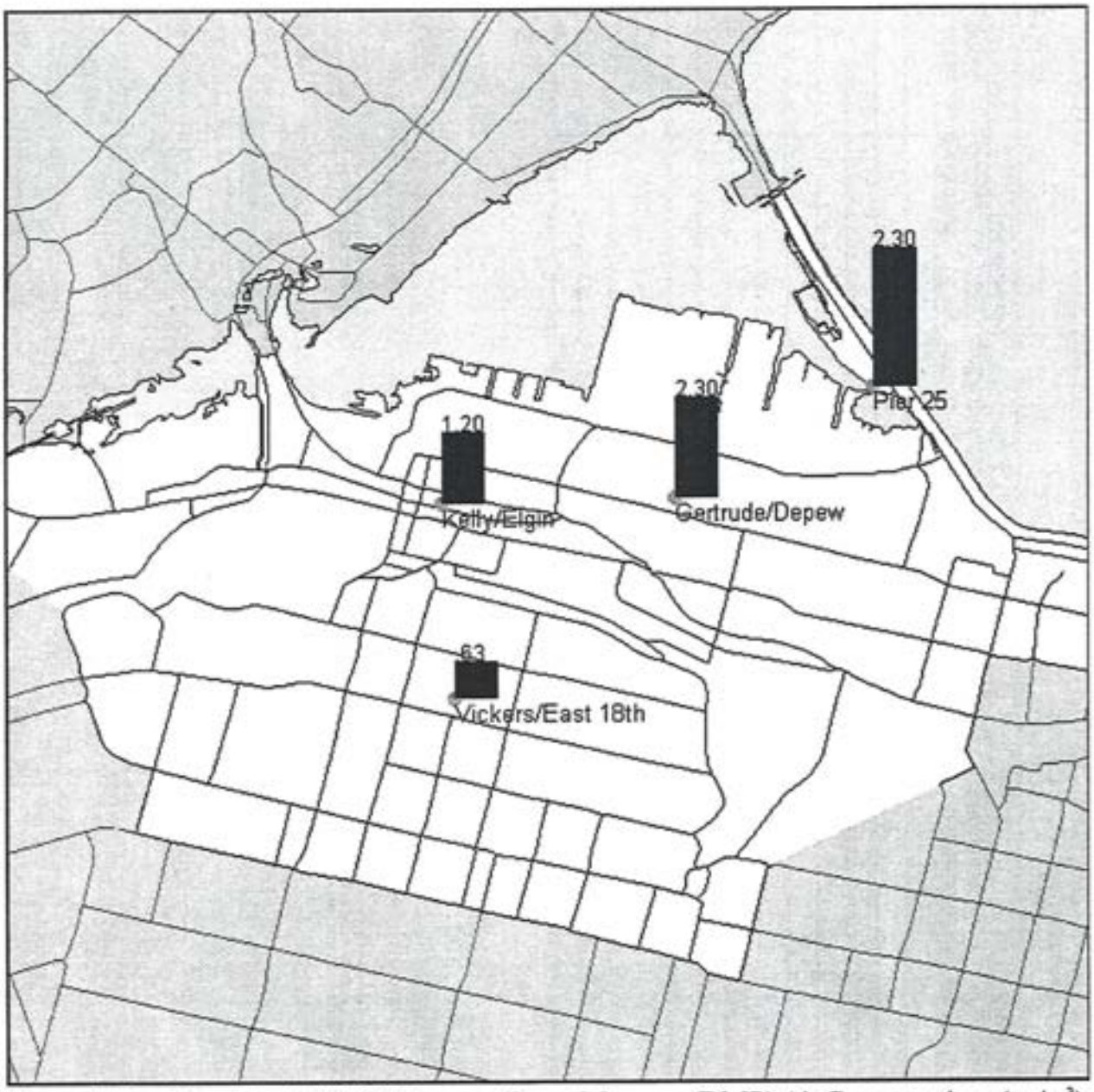

Figure 10.1: Five Year (1990-94) Average Benzo[a]pyrene (B[a]P) Air Concentrations (ng/m^3)

TABLE 10.1: UPWIND VS DOWNWIND (OF INDUSTRIAL ZONE) BENZO[a]PYRENE (B[a]P) CONCENTRATIONS DURING FULLY NORTHEAST OR SOUTHWEST WIND DAYS (HIGHEST CONCENTRATIONS)

SOUTHWEST WIND DAYS (ng/m3)				NORTHEAST WIND DAYS (ng/m3)				
DATE		DOWNWIND BaP 29547-Pier 25	UPWIND BaP 29113-Gertude	DATE		DOWNWIND BaP 29113-Gertude	DOWNWIND BaP 29000-Kelly	UPWIND BaP 29547-Pier 25
1993	FEB 24	13.5	1.7	1993	APR 13	6.1		0.0
	NOV 3	6.4	0.2		JUN 24	6.3		0.8
	DEC 21	8.5	0.7		SEP 16	13.6		1.3
1994	MAR 15	7.8	1.2	1994	MAY 14	6.4	3.9	2.0
	APR 20	7.5	1.3		AUG 6	1.7	3.2	1.2
	OCT 29	5.8	0.2		SEP 23	3.4	6.5	0.0
	NOV 22	3.2	0.4		OCT 17	15.0	1.2	0.4
1995	OCT 12	7.3	0.0		DEC 12	4.0	1.0	0.9
	OCT 24	5.6	0.5	1995	FEB 26	2.4		0.1
	NOV 5	8.3	0.1		MAY 9	3.0	4.7	0.2
	NOV 17	3.0	0.5		JUN 26	2.7	3.9	0.1
	DEC 11	6.6	0.3		AUG 25	1.7	1.7	0.1
AVERAGE		6.1	0.5	AVERAGE		4.5	3.3	0.6

10.2 Emissions and Modelling

The data on release of these compounds to the air in Hamilton-Wentworth are scarce. The National Pollutant Release Inventory (NPRI) is the most important source of information on toxic releases in Hamilton-Wentworth (MOEE, 19976d, Environment Canada, 1996). Unfortunately, dioxins, furans, and PCBs are not among the 178 substances listed in the NPRI. Only two PAH species, anthracene and naphthalene, are reportable substances under the NPRI program. Under the Accelerated Reduction/Elimination of Toxics (ARET) program, releases of 2,3,7,8-TCDD, 2,3,7,8-TCDF, PCBs and 17 constituents of PAHs are listed. A total of 278 Hamilton-Wentworth facilities have participated in ARET to voluntarily reduce the release of listed substances, including Dofasco, Stelco, Slater Steels, and Ruetgers VFT Inc.

Ortech (1992) reported 9 kg of PCDD and 26 kg of PCDF were released into the atmosphere in Ontario in 1985. Solid waste incinerators, industrial sources and stationary fuel combination accounted for 46%, 27%, and 26% of PCDD emissions and 24%, 53% and 24% of PCDF emissions respectively.[19] Solid waste incineration encompasses municipal waste, sewage sludge, industrial waste and commercial/institutional (e.g., biomedical) incineration. Residential wood combustion is the most significant source for stationary fuel combustion emissions. Gasoline vehicles are among the other small contributors to PCDD/F.

Environment Canada (Napier, 1996) reported PCDD/F may be formed as unwanted byproducts during the high temperature decomposition and combustion of material that contain chlorine and organic compounds. Atmospheric emissions of PCDD/Fs have been documented in European and one Canadian iron sintering plant (at Algoma). The annual Algoma Steel Sintering plant emissions of PCDD/Fs were estimated to be 32 grams per year based on testing in 1994. There are no similar estimates available for Stelco's Hilton Works sintering plant.

European studies have also found PCDD/F emissions from electric arc furnaces (EAFs). Environment Canada (Napier, 1996) reported no published data were found for other steelmaking processes or steel finishing operations in North America. The emissions of PCDD/F are likely to be affected by the quality of the raw materials used in sintering plant and EAFs, as well as the treatment/control of the offgases.

The Solid Waste Reduction Unit (SWARU) in Hamilton processes and incinerates municipal solid waste (MSW). A number of stack tests have been conducted at the facility over the years. A test (ORTECH, 1990) in 1988 reported 1.42 µg/s of PCDD and 0.96 µg/s of PCDF emission from line number 2, which is equivalent to emissions of 0.012 µg/s as dioxin and furan (TEQ). A test during the same period with 5% scrap tires reported slightly lower values of 0.33 µg/s PCDD and 0.49 µg/s PCDF emissions.

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19 These percentages do not total 100% due to uncertainty caused by rounding to the nearest whole number.

Recently, SWARU installed a system to inject dry lime to scrub the acid gas (e.g., hydrochloric acid) emissions. Another series of stack tests was conducted in January 1997. The emission rate of total dioxins and furans is reported to be 0.22 µg/s (TEQ). The corresponding point of impingement (POI) concentration (downwind of the facility) was estimated to be 1 picogram TEQ per cubic metre (pg TEQ/m^3), which is well below the MOE's POI limit of 15 pg TEQ/m^3 (CRA, 1997). Annual emission of dioxins and furans is estimated to be 4.56 grams (TEQ) with the current 5-day operation (Envirometrex, 1997). The sewage treatment plant sludge incinerator was also a source of dioxin and furan emissions in Hamilton-Wentworth. However, the incineration of sewage sludge was stopped in January 1996.

Steel making, specifically the production of metallurgical coke, is the single largest source of anthropogenic PAHs in Ontario. In the Steel Strategic Options Report (Napier, 1996) 1993 levels of PAHs from the steel manufacturing facilities were estimated at 45.4 tonnes/year from Dofasco and 45.7 tonnes/year from Stelco-Hilton Works (Table 10.2). These two sources comprise nearly one half of the total PAHs released into the air from the steel industry in Ontario. No estimates were available for dioxins, furans, PCBs, and on PAH releases from other industrial sectors within Hamilton.

Table 10.2: Summary of 1993 PAH Emissions from Coke and Byproduct Plant Reporting in the Strategic Option Process (SOP)

Company	1993 Air Emissions (tonnes)	
	PAHs	B[a]P
Stelco (Hilton Works)	45.7	1.73*
Dofasco	45.4	1.72

*Derived by author from PAHs release data based on 3.8% of B[a]P in PAHs

10.3 Environmental Effects

Many wildlife populations have, in recent decades, begun to show reproductive abnormalities, immune dysfunction, neurobehavioral impairment, and elevated incidence of cancers and tumours. PAH in contaminated sediments in Hamilton Harbour have been linked to an increased incidence of fish tumours and other deformities. Liver and skin neoplasms and epidermal papillomas have been reported on several species of fish in the harbour. In Hamilton Harbour, for example, fish were commonly found to contain B[a]P and fluorene concentrations between 1 and 10 µg/g (d.w.), and carcinogenic papillomas were found on 30% of white suckers. In contrast, on the eastern side of Lake Ontario concentrations of B[a]P and fluorene in fish were between 0.1 and 1 µg/g, and only 6% of the white suckers had papillomas (RAP, 1992a).

10.4 Distribution in the Environment

In Canada, the highest concentrations of ambient air PAHs have been measured near aluminum smelters in Quebec; near coke making operations in Hamilton and Sault Ste. Marie; and in urban areas where heating by wood combustion is prevalent. The highest concentrations of PAHs in water were reported from ditches beside utility and railway lines. Few studies are available concerning the presence of PAHs in groundwater. Little data is available on the levels of PAHs in drinking water.

In Hamilton harbour, the 1988/89 reported median sediment concentration for total PAHs was 285 µg/g, with a range from 1.6 to 1470 µg/g. Median and maximum concentrations of B[a]P were 9.5 µg/g and 69.2 µg/g. Biodegradation half-lives in sediments range from 0.3 to 129 days for naphthalene and from 0.3 to 58 years for B[a]P.

Dioxins and furans generally attach to particles. They are widely distributed in air, water, and soil but they tend to accumulate in soils and sediments. In Ontario, air concentrations of total dioxins and furans range between 0.4 to 36.7 picograms/m^3, while drinking water concentrations range from non-detect to 46 picograms octachlorodibenzodioxin per litre. Urban soils (backyards, public areas, and parkland) contain between 50 to 14,100 picograms per gram of total dioxins and furans.

In 1983, the Phytotoxicology Section collected soil samples from 14 sites in the vicinity of the SWARU incinerator in northeast Hamilton. Dioxin levels in these soils were not significantly different from levels typically found in other urban soils (Gizyn, 1997). Intensive testing across the city after the Plastimet fire showed levels of 4 to 8 pg in soil, well below the cleanup guideline of 1000 pg/g, from non-detect to 32 pg (TEQ) in vegetation, non-detect in garden vegetables, and 0.1 to 2.9 ng (TEQ)/m^2 (well below the acceptable limit of 25 pg/m^2 (TEQ) in soot. Surface swab samples showed the surface concentrations declined quickly in the weeks subsequent to the fire. Dioxins do not pose an increased threat to biota or humans in Hamilton-Wentworth as a result of the Plastimet fire.

Atmospheric loadings to Hamilton Harbour are believed to be significant. Relative atmospheric loadings of several compounds to Hamilton Harbour (Table 10.3) are estimated in the Hamilton Harbour Stage 1 RAP report (RAP, 1992). Not all of the compounds identified as having an environmental impact were included due to lack of data. Loadings were calculated for the harbour's water surface[20].

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20 The atmospheric loading is calculated only for the Harbour water surface. If stormwater runoff from the watershed is included, the contribution from the atmospheric loading will increase.

Table 10.3: Estimated Atmospheric Loadings of PAH, PCB and PCDD/F to Hamilton Harbour

Contaminant	Atmospheric Loading	Atmospheric Loading (%)
PAH	0.116 kg/day	6%
PCB	0.007 kg/day	18%
PCDD/PCDF	no estimates available	no estimates available

Source: RAP, 1992

10.5 Routes of Exposure

There are a number of different paths toxics can take to gain entrance into the body (either human or animal). The most direct routes are via breathing, eating, drinking, and skin absorption.

Bioaccumulation of toxics occurs when plants or animals which contain toxics in their tissue are consumed. All Canadians, like citizens in most industrialized countries, have detectable concentrations of toxics in their body; they are highly concentrated in body fat and fatty organs. Toxics can also be passed from mother to child through breastfeeding (in both humans and animals). PAHs generally are not bioaccumulative, due to rapid metabolism by the body. PAH bioconcentration factors can range from 4 to 7800 (low to very high). In contrast, dioxins and furans readily bioaccumulate in fatty tissues, in particular the 17 very toxic 2,3,7,8 congeners. They are found in most species of wildlife and appear in the natural and human food chains. In southern Ontario, levels of dioxins measured in humans are well below any toxic effects.

11 SOURCES OF AIR POLLUTION

Hamilton-Wentworth air is influenced by emissions which occur at local, regional, and global scales. Emissions such as odours and particulate tend to have local impacts (within several kilometres of the sources)[21]. Acid rain and ground-level ozone are considered to be wider scale problems because impacts come from emission sources which are several hundred/thousand kilometres away. Some pollutants such as greenhouse gases (GHG) and chlorofluorocarbons (CFCs) have global scale impacts. For example, emissions of GHG from around the world (including emissions from Hamilton-Wentworth) could contribute to global temperature changes. This combination of pollutants originating at the local, regional, and global levels complicates the examination of the specific sources of air pollution in Hamilton-Wentworth.

For the purposes of the Hamilton-Wentworth Air Quality Initiative (HAQI), Municipal boundaries were used to define the study area. Although we were aware that emissions of pollutants outside the municipal boundaries could influence air pollution inside the region of Hamilton-Wentworth, we decided to focus our attention on local sources and their effects.

This chapter deals with apportioning the contributions from different sources to the loadings at a particular receptor (site). The actual contribution is very site specific and depends on the distance from the source(s) and meteorological conditions. In order to apportion the sources in Hamilton-Wentworth, a combination of emissions inventory , modelling and data interpretation must be employed. Techniques that were used in this study (in addition to ambient monitoring of spatial variations of concentrations) include[22]:

- emissions inventories;
- back trajectories;
- assessment of chemical composition and atmospheric chemistry;
- source oriented monitoring and dispersion modelling.

11.1 Emissions Inventories

An air emission inventory is a compilation of sources and quantities of atmospheric pollutants. The MOEE has compiled an emission inventory of 'common pollutants' for the Hamilton-Wentworth Region (1990). This was discussed in chapter 5. An emissions inventory of toxic air pollutants is available from the National Pollutant Release Inventory (NPRI). This includes emissions from sources within the Region of Hamilton-Wentworth.[23] In 1994, 19 companies

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21 Depending on size; some fine particulate may be transported longer distances i.e. more than several kilometres.

22 The results obtained using some of these techniques are discussed in earlier chapters.

23 The NPRI is not a comprehensive inventory; it only focuses on major emitters and does not include emissions from transportation sources.

Table 11.1: Summary of 1994 National Pollutant Release Inventory in the Hamilton-Wentworth Area

Companies	City	1994 NPRI Toxic Releases of Total Reported Substance (tonnes)			
		Air	Water	Land	Total
Dofasco	Hamilton	660.4	49	0.017	709.1
Stelco Hilton Works	Hamilton	420.4	57	7.000	484.9
Camco	Hamilton	108.2	NA	NA	108.3
Ball Packaging	Hamilton	33.4	0	0	33.4
Niagara Paint	Hamilton	19.8	NA	NA	20.3
Slater Steels	Hamilton	9.4	NA	0.390	10.6
GSW Heating Products	Hamilton	10.4	0	0	10.4
Stelwire Ltd., Parkdale Works	Hamilton	7.8	NA	NA	8.8
Procter & Gamble	Hamilton	4.5	0	0	4.5
Frost Wire Products	Hamilton	3.5	0	0	3.5
Reutgers VFT Inc.	Hamilton	NA	NA	NA	0.9
Heckett Multiserv	Hamilton	NA	NA	NA	0.6
Alumabrite Anodizing	Hamilton	NA	NA	NA	0.2
Montank	Hamilton	0.13	0	0	0.2
Baycoat	Hamilton	0.02	NA	NA	0.1
Nelson Steel	Stoney Creek	2.1	0	0	2.1
North American Zinc	Stoney Creek	1.16	0	0	2.1
Androx	Stoney Creek	NA	NA	NA	1.2
Bartek	Stoney Creek	NA	NA	NA	0.3
Total		1281.2	106.0	7.4	1399

NA - not available
Source: MOEE (1996)

within the Region of Hamilton-Wentworth reported to the NPRI. The emissions of each facility are identified in Table 11-1. These companies released (to all parts of the environment, air, water and land) a total of 1396 tonnes of listed substances in Hamilton, and 3.8 tonnes in Stoney Creek, for a total of 1400 tonnes. Of these releases, 1281 tonnes (92%) were discharged to the atmosphere.[24]

Inventories for selected operations are also available, such as the Strategic Options Process (SOP) for the iron and steel sector [25]. The Strategic Options Process (SOP) was launched in April 1995 by Environment Canada to consider potential options for the management of sixteen toxic substances released and used by the Canadian Steel Manufacturing sector and assessed as toxic under the Canadian Environmental Protection Act (CEPA). These substances include benzene, PAHs, arsenic and its compounds, cadmium and its compounds, hexavelant chromium and its compounds, lead, mercury, soluble nickel, inorganic fluorides, dichloromethane, tetrachloroethylene, trichloroethane, trichloroethylene, PCDD and PCDF.

11.2 Back-Trajectory Analysis

This type of analysis involves measuring ambient air pollution and then tracing it back to the source(s) using wind speed and direction information. Wind speeds and direction are broken down into various time intervals. The length of the pollution plume (vector) is determined by the wind speed. Vectors can be mapped according to wind direction, with the receptor as the starting point. The vectors can then indicate suspected sources. Examples of a series of total reduced sulphur (TRS) back trajectories for two monitoring stations (Beach Blvd. and Hillyard) during high TRS levels are presented in Figure 11.1. The back trajectories indicate that for the plume impacting on the Beach Blvd.--the source is most likely to be Dofasco. For the Hillyard site, the plume of TRS is likely to have come from Stelco (Figure 11.1).

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24 Emissions of 178 toxic pollutants are reported under the NPRI. Facilities must report through the NPRI if they meet the following criteria:

- have 10 or more full time employees; and
- used 10 tonnes or more of a listed substance; or
- the listed substance is used at a concentration greater than or equal to 1% by weight.

25 Among the recommendations, the SOP has proposed:

- 90% reduction of 1993 benzene emissions by the year 2015; and
- 70% reduction of 1993 PAH emissions by the year 2015.

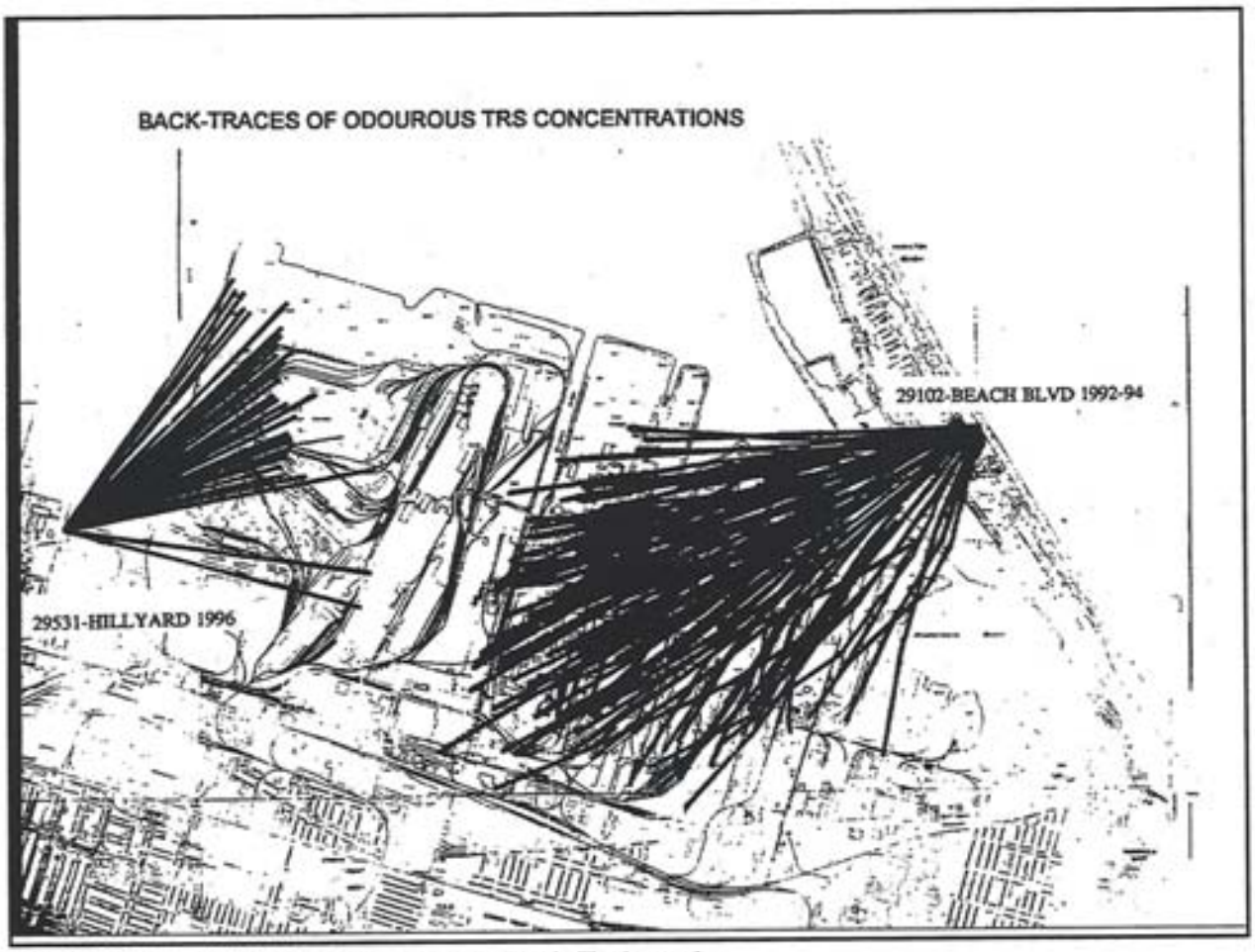

Figure 11.1: Total Reduced Sulphur Back Trajectories

11.3 Source Oriented Monitoring and Dispersion Modelling

Dispersion modelling[26] can be combined with monitoring data around a source to 'back calculate' an estimated emission strength for the source. Two types of monitoring data were used in the HAQI for such an assessment:

- annual average concentration patterns and annual average modelling calculations,
- differences between upwind and downwind concentrations over a 24-hour period and 24 hour modelling calculations.

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26 Dispersion models use mathematical calculations to estimate the dilution of pollutants as it travels downwind from the emission sources. Back Calculations uses measured downwind pollutant concentrations and dispersion modelling results to back calculate the source strength.

The Hamilton industrial core was considered a single, large-volume source for modelling purposes (This is appropriate for emissions which tend to originate from a number of low-level emitters across the industrial area). Using the above methods, emissions estimates were generated for a number of compounds originating from the industrial zone of Hamilton.

Emissions estimates for PM_{10}, benzene, and benzo[a]pyrene are summarized in Table 11.2. Dispersion modelling back calculations showed a range of emission strengths, due to variations in the up/downwind pairs; these variations are expected with this type of generic-volume source modelling.

Table 11.2 Estimated Emissions of Selected Pollutants - From Dispersion Modelling Back-Calculations for the Hamilton Industrial Area

Compound	Annual Emissions (tonnes)
PM_{10}	1400 - 2400
Benzene	200 - 800
Benzo(a)pyrene	0.1 - 0.3

The PM_{10} emissions for the Hamilton industrial area are estimated to be between 1400-2400 tonnes per year (including fugitive emissions), using this technique. Actual PM_{10} emissions rates are higher than this figure since particles in the range of 2.5-10 µm can deposit onto the ground prior to reaching the monitors.

The benzene emission is estimated to be between 200-800 tonnes per year. This is consistent with the 735 tonnes reported by NPRI in Table 8.2 and 782 tonnes reported by SOP in Table 8.3 for coke oven/byproduct plants. This agreement between the three methods suggests that benzene emissions are reasonably accurate.

Back calculations estimated B[a]P emission to be between 0.1 - 0.3 tonnes per year. SOP reported B[a]P emissions of 1.72 tonnes per annum from Dofasco, and 1.73 tonnes for Stelco, for a combined B[a]P emission of 3.45 tonnes (see Table 10.2). This is significantly higher than the values estimated through the back calculations. The difference in estimates between the two can be due, in part, to a combination of errors in the emission factor, the coke oven PAH source profile, and the source parameters in the modelling.

12 CONCLUSIONS

The conclusions of this report are as follows.

- As opposed to health impacts, there is little or no evidence of any direct damage to the environment in Hamilton-Wentworth from air pollution. There is evidence of limited vegetation damage in specific areas (near a brick plant) due to fluoride emissions. The monitored ambient air ozone concentrations in Hamilton-Wentworth are high enough to cause damage to some plants. These levels are typical of southern Ontario.

- Average annual urban PM_{10} levels in Hamilton are between 20-35 $\mu g/m^3$, with a 12 $\mu g/m^3$ contribution from rural sources. This suggests that long-range transport accounts for approximately 40-70% of the PM_{10} loadings in Hamilton.

- Combining analysis of urban and rural concentrations for winds from different wind directions with dispersion modelling suggests the following:

  1) The typical rural background concentration of PM_{10} is approximately 15 $\mu g/m^3$ (annual average), mainly due to long range transport of pollutants with some local contribution.

  2) Industrial emissions result in annual ambient PM_{10} levels ($\geq$30 $\mu g/m^3$) near the industrial area, which can be more than two times background levels. On average, near the industrial area in downtown Hamilton, it is estimated that 45% of the PM_{10} is due to industries, 15% is due to urban activities and 40% is due to long range transport.

  3) In the wider urban areas, the typical annual average ambient PM_{10} concentration is 27 $\mu g/m^3$. It is estimated that 15% of the PM_{10} is due to industry, 30% is due to urban activities and 55% is due to long range transport.

  4) In suburban areas, the typical annual average ambient PM_{10} concentration is 21 $\mu g/m^3$. On average, it is estimated that 10% of the PM_{10} is due to industry, 20% due to urban activities and 70% is due to long range transport.

- At present, there is significant uncertainty surrounding total particulate, PM_{10}, and $PM_{2.5}$ emissions. Limited data suggest that iron and steel sector and vehicles are likely to be significant contributors to particulate matter of all size ranges.

- Inhalable particulate (PM_{10})levels in urban areas of Hamilton-Wentworth are comparable to other cities in Southern Ontario. PM_{10} levels in Hamilton's industrial areas are higher than levels in other urban areas of Hamilton.

- When monitors are directly downwind of the industrial core, concentrations of TSP, PM_{10}, benzene, and B[a]P are higher than upwind levels.

- The iron and steel sector is the major emitter of SO_2 and CO in the Hamilton-Wentworth area.

- Vehicles and the iron and steel sector contribute equally to NO_x and volatile organic emissions, which contribute to the formation of ground level ozone (downwind).

- Industrial emissions are the major sources of B[a]P, benzene and naphthalene.

- Back-trajectory analysis suggests high TRS levels are likely to have originated from Dofasco and Stelco.

- Sulphates and ammonium compound levels in Hamilton are similar to rural levels. This suggests strong influences by long-range transport.

- Nitrate levels are higher in Hamilton than in a rural setting, suggesting a combination of long-range transport and local impacts on nitrate loadings.

- The Environment Workgroup was able to assemble a data set to enable air pollution impacts and sources to be identified and evaluated. This data set is not comprehensive because of limited monitoring.

13 RECOMMENDATIONS:

Significant improvements have been made over the last 20 years by industries and in vehicle technologies. These improvement are reflected in better air quality in Hamilton-Wentworth for some pollutants. While there is still room for more reductions in emissions to improve air quality, there is a need to identify the most cost effective measures that will derive the most benefits.[27] The choice of control measures is becoming more complicated because of uncertainty over the relative importance of different sources of pollution, secondary formation (e.g. ozone) and long range atmospheric transport. The Environment Workgroup proposes the following recommendations for improving air quality in the region.

13.1 Particulate, PM_{10} AND $PM_{2.5}$

Inhalable particulate (PM_{10} and $PM_{2.5}$) levels are influenced by both localized sources and long range transport. At the local level, there are also a wide range of sources including fugitive emissions (eg. road dust), point sources (e.g. industrial stacks) and residential sources (e.g. wood burning fireplaces). The recommendations for particulate, PM_{10} and $PM_{2.5}$ are as follows.

13.1.1 Vehicle Emissions

Vehicles and diesel vehicle emissions are believed to be a significant source of particulate in the area.

It is recommended that an emission inventory of diesel vehicle emission be developed for Hamilton-Wentworth.

It is recommended that options (e.g., bike paths, public transit, car pooling) for promoting reduction in vehicles usage and vehicles kilometers travelled be implemented.

It is recommended that regulatory capabilities for the OPP, MOE and/or MOT be imcreased to ticket black smoking diesel or other vehicles.

13.1.2 Fugitive Emissions

We believe fugitive emissions are likely to be important sources of particulate in the Hamilton-Wentworth area.

It is recommended that a program of fugitive dust control be implemented by industry and municipalities in Hamilton-Wentworth. Such programs would include:

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[27] A list of existing program related to ground level ozone and criteria pollutants is included in appendix 1.

- **Determining and implement BACT[28] on a site specific basis;**
- **Establishing by-laws in planning and licencing requiring paving or dust suppression of non-paved areas;**
- **Establishing by-laws addressing fugitive dust controls or limiting size of outside storage of dust sources e.g. salt piles;**
- **Municipalities/MTO target trucking firms for vehicle standards to prevent fugitive blow off from loads;**
- **Mandatory vehicle emission testing for vehicles sold or residing in Halton and Hamilton Wentworth;**
- **Industry establish standards for trucking firms under their contracts, which will prevent fugitive blow off from loads and vehicles; and**
- **Municipality more actively enforce "streets bylaw" and hold individual sites accountable for clean up of 'drag out'.**

As a minimum, the fugitive dust program should consider the following measures:

- **regular sweeping and cleaning of roads within the industrial area and within the industrial sites;**
- **application of water or other dust suppression on unpaved road in all industrial sites during hot dry periods;**
- **application of storage pile dust control techniques (e.g., covering, wind fences, pile orientation) where not currently applied;**
- **cleaning stations for trucks to prevent drag out of dirt;**
- **covering of open trucks; and**
- **measures for material transfer (e.g., covering of conveyors, minimize drop distance of materials, etc.)**
- **increased planting of tree screens and other vegetation; and**
- **paving of heavily used trucking areas where currently unpaved.**

13.1.3 Development of New Point Source Programs

Particulate of all types are also emitted from point sources (e.g., stacks), which in many cases can be controlled by equipment such as baghouses, electro-static precipitator and scrubbers. In addition, pollution prevention measures are often more cost effective than the use of end of the pipe controls. The present MOE Regulation 346 does not take into consideration total loadings into the atmosphere by all industrial sources. Controls of point sources beyond the basic requirements of Regulation 346 are needed to improve upon air quality in the Hamilton-Wentworth airshed.

- **It is recommended that each company in Hamilton-Wentworth develop and implement action plans to reduce particulate emissions at source.**

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[28] Best Available Control Technology (BACT).

- **It is recommended that each company in Hamilton-Wentworth develop and implement action plans to install BACT for those particulate emission sources which can not be reduced at source.**

- **MOE develop a policy to require Best Available Control Technology (BACT) in Certificates of Approval (Air) (C of A) issued for particulate matter for significant sources in Hamilton-Wentworth.**

- **MOE amend existing C of A (Air) to impose conditions requiring the establishment and implementation of maintenance and operational procedures for process and control equipment.**

- **MOE should consider the aggregate emissions from a facility and background ambient pollutant levels prior to issuing a C of A for modifications of existing facilities and new facilities.**

13.1.4 Residential Sources

Sources such as fireplaces and other residential fuel combustion also contribute to the PM_{10} and $PM_{2.5}$ levels in Hamilton-Wentworth.

It is recommended that residential wood burning fireplace/stove standards be adopted by the province and/or municipalities.

13.1.5 Ambient Air Quality Criteria and Source Performance Standards

The MOEE has proposed an interim ambient air quality criterion in Ontario for PM_{10} of 50 $\mu g/m^3$ to help identify the extent of the problem and to determine future control actions.

It is recommended that Ontario, in conjunction with the federal government, finalize ambient air quality criteria for PM_{10} and $PM_{2.5}$.

It is recommended that source performance standards/guidelines be developed for significant sources of PM_{10} and $PM_{2.5}$, as one component in an overall strategy for achieving attainment of the PM_{10} and $PM_{2.5}$ ambient air quality criteria.

13.1.6 Long Range Transport

Long range transport also contributes to the PM_{10}, $PM_{2.5}$, smog and toxics levels in Hamilton-Wentworth and Canada. The Ontario Minister of Environment and Energy, Norm Sterling, has taken several steps to encourage the U.S. States to deal with transboundary pollution. The Minister met recently with various governors in 11 U.S. states to promote clean air and water. A

formal submission was also made to Carol Browner, Administrator of the U.S. Environmental Protection Agency arguing for tougher standards for smog-causing pollutants.

It is recommended that the provincial and federal governments continue to develop an overall plan to address the issue of long range transport of PM_{10}, $PM_{2.5}$, and other smog related pollutants into the Hamilton-Wentworth area.

13.2 GROUND LEVEL OZONE

Ground level ozone forms from the reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight. On hot summer days, more than 50% of the ozone affecting southern Ontario comes from sources in the United States. In response to the smog ground level ozone problem, the Ontario Ministry of the Environment is developing an Ontario Smog Plan that will reduce emissions of contaminants that contribute to smog. One of the goals of the plan is to reduce Ontario emissions of nitrogen oxides and volatile organic compound emissions by 45%, relative to a 1990 emission baseline.

Reduction of NO_x and VOC will help in reducing ground level ozone levels in Hamilton and areas downwind. It is recognized that the I&S sector and the transportation/vehicle sectors are already engaged in discussions at the provincial level for developing an overall Ontario Smog Plan. The I&S sector is also engaged in discussions in the SOP which will lead to reductions for VOCs. In addition, energy efficiency measures by industry have and will lead to further reductions in NO_x emissions.

Over 30 Codes of Practice and Guidelines have (or are being) developed under the 1990 Phase I NO_x/VOC Management Plan (CCME, 1990). These codes cover sectors/equipment such as industrial boilers/heaters, bulk gasoline terminals and service stations, vehicle emissions, surface coating operations, organic chemical plants, etc.

It is recommended that the industrial sector (e.g., iron and steel, carbon black) continue to investigate the feasibility of implementing further NO_x reductions.

It is recommended that industries implement the CCME codes of practices and guidelines for reducing NO_x and VOC emissions.

It is recommended that options proposed by the transportation workgroup be considered for potential improvements in air quality.

While the SOP addresses VOC sources from the iron and steel (I&S) sector, other sectors such as vegetable mills and metal rolling should also consider actions to reduce VOCs.

A large number of spray painting, solvent use and residential sources also contribute to the VOC loading. A public awareness program should be developed to promote the reduction of VOCs from these sources. This program should encompass:

- **implementation of codes of practices developed by Canadian Council of Ministers of Environment;**
- **use of low-volatility solvent products by industry;**
- **implementation of environmental management system by industries;**
- **community based marketing strategies to promote actions to improve air quality;**
- **web page on air quality in Hamilton-Wentworth;**

13.3 CARBON MONOXIDE

Carbon monoxide levels are dominated by vehicles and the iron and steel sector emissions.

It is recommended that programs directed at reducing CO from industrial sources be initiated.

It is recommended that options proposed by the transportation workgroup be considered for potential improvements in air quality.

13.4 BLACK FALLOUT

The sources of black fallout are under evaluation as part of the Hamilton Air Quality Stakeholder Committee. A number of goals have been developed by the committee.

It is recommended that the following goals of the Hamilton Air Quality Committee Stakeholders Committee be adopted:

- **Finalize particulate emission inventory for Stelco and Dofasco by November and September 1997 respectively.**

- **Create Pareto analysis (80/20 rule) list of major particulate contributors at Stelco and Dofasco (by date).**

- **Meet with Board of Directors of Hamilton Industrial Environmental Association and develop and implement mechanism to ensure industrial commitment to HIEA and real measurable environmental improvement.**

- **Prepare and present a united position and request to senior MOE management for specific inkind support activities in Hamilton.**

- **Prepare and distribute newsletters.**

- **Expand Community involvement in this Committee.**
- **Become the implementation body in conjunction with HIEA for the recommendations arising from the Hamilton Air Quality Initiative.**
- **Expand Municipal involvement in this Committee.**
- **Obtain funding to establish a secretariat function for this Committee.**
- **Obtain air quality improvement action plans for all HIEA members.**
- **Publicly commend good performers**

13.5 BENZENE AND PAH

Benzene and PAH levels are dominated by vehicles and the iron and steel sector emissions. The I&S sector is engaged in discussions in the SOP which will lead to reductions for these contaminants.

It is recommended that the (I&S) industrial sector implement the recommendations of the Strategic Options Process (SOP).

It is recommended that options proposed by the transportation workgroup be considered for potential improvements with regard to vehicle emissions.

13.6 TOTAL REDUCED SULPHUR (TRS)

Odour complaints are received due to TRS in Hamilton. The TRS smell is likely to contribute to a negative impression of Hamilton. Total reduced sulphur levels are dominated by the iron and steel sector emissions and are a major cause of malodours.

It is recommended that a program be developed to reduce TRS emissions from known industrial sources.

It is recommended that the province develop/adopt an ambient air quality standard for TRS.

13.7 EMISSIONS INVENTORY AND ATMOSPHERIC MODELLING

Emission inventory and dispersion modelling are important components to understanding the sources that contribute to the ambient air levels. Emission inventories for PM_{10}, $PM_{2.5}$ and toxics are currently not available. Other emission inventories are considered inadequate to properly address our understanding of sources.

It is recommended that MOE/EC work with industry and other parties to compile an emission inventory for pollutants identified as high priority by the human health workgroup (e.g., PM_{10}, $PM_{2.5}$ and toxics).

Atmospheric modelling and source apportionment techniques are also crucial to understanding the contributions from local sources and long range transport. PM_{10}, $PM_{2.5}$ and ground level ozone are complex regional phenomena, therefore, modeling of these pollutants are generally conducted by sophisticated models on a regional scale.

It is recommended that MOE/EC use existing ozone regional modeling results to further refine the contributions from transboundary pollutants in Hamilton-Wentworth.

It is recommended that the MOE/EC conduct research to develop a validated $PM_{10/2.5}$ modelling package.

For pollutants with localized impacts (e.g., PM_{10}, dust fall, black fallout, suspended particulate matter), modelling can be used to provide guidance in developing an effective mitigation strategy.

It is recommend that localized modeling (e.g., Industrial Source Complex (ISC) model, CAP) also be undertaken to further refine the estimates of relative contributions of different sources to the ambient levels in Hamilton-Wentworth.

13.8 ENVIRONMENTAL IMPACTS

The linkage and impacts of air pollution on the environment and ecosystem have not been investigated extensively in Hamilton-Wentworth. The movement of pollutants between the different media (air, water, soil) has to be considered to gain a better understanding of the impacts of air pollution.

It is recommended that inputs (e.g., multi-media inventories) be developed to facilitate the multi-media modeling of pollutants in Hamilton-Wentworth.

Atmospheric deposition to the Hamilton-Harbour watershed is an important consideration in the remediation of the harbour.

It is recommended that a multi-media sampling program be undertaken to determine the deposition of airborne pollutants to the Hamilton Harbour watershed.

13.9 MONITORING

A good quality ambient air monitoring network is essential to generate information for the assessment of health impacts, and to monitor progress in environmental performance.

It is recommended that partnerships be developed between MOE, Environment Canada, industry and municipality, to fund and operate a comprehensive monitoring program.

13.10 DATABASE DEVELOPMENT

A set of geo-referenced ambient air quality data was processed and compiled by the Environment Workgroup. These data will be made available to the public in future years. The expertise developed during this project could be transferred to other municipalities and organizations.

It is recommended that the Hamilton-Wentworth ambient air quality data be processed for access and use by the community in the future. Resources need to be provided to regularly update the database.

It is recommended that the technical expertise developed in the HAQI be transferred and promoted for other communities and organizations in Ontario and elsewhere.

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APPENDIX 1: EXISTING PROGRAM RELATED TO GROUND LEVEL OZONE AND CRITERIA AIR POLLUTANTS

GROUND LEVEL OZONE AND CRITERIA AIR CONTAMINANTS

Under the *Canada - United States Air Quality Agreement*, the two countries committed to reduce emissions of sulphur dioxide and nitrogen oxides. In addition, Canada and U.S. will review standards/objectives for ground-level ozone and will monitor progress in existing international efforts to address air toxics.

1. Eastern Canada Transboundary Smog Issue Group, consisting of Environment Canada and the Eastern Canadian provinces, is currently engaged in a joint project with the *North East States for Coordinated Air Use Management* (NESCAUM) to assess the status of modeling and monitoring of transboundary ozone. This project is supported by the North American Council for Environmental Cooperation.

2. Environment Canada participates as an observer in the U.S. initiative to address smog, *Ozone Transport Assessment Group* (OTAG). OTAG involves 37 eastern states aimed at developing domestic regional strategies.

3. The *Program to Develop a Joint Plan of Action for Addressing Transboundary Air Pollution* was signed on April 7, 1997, by Environment Minister and the Administrator of the U.S. Environmental Protection Agency. In this agreement, Canada and United States commit to the development of measures to address transboundary air pollution, particularly the transport of ground level ozone and particulate matter, the two main components of smog.

AIR TOXICS

1. The *Canada-U.S. Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin* was signed by President Clinton and Prime Minister Chretien in 1997. This strategy sets quantifiable reduction targets and time frames for specified persistent toxic substances in the Great Lakes Basin. This is intended to accelerate action on Annex 15 of the *Canada-U.S. Great Lakes Water Quality Agreement*. Domestically, Canada is implementing the strategy through the *Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem.*

2. As part of the *United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution*, work is under way to develop protocols on persistent organic pollutants (POPs) and heavy metals. The POPs protocol will address a list of pesticides and industrial chemicals and the heavy metals protocol will focus on lead, mercury and cadmium.

3. The *Commission for Environmental Cooperation* (CEC) was established under the *North American Agreement on Environmental Cooperation* to address transboundary and regional environmental concerns in North America. CEC will coordinate the development of regional action plans for the phase-out or management of PCBs, DDT, chlordane and mercury.

4. Recommendations are under development to the *United Nations Environmental Program Governing Council* on how to proceed towards a globally legally binding mechanism on POPs.