Issues Related to Benzene in Eastern Montreal

André Germain[1]
Jacques Rousseau[1]
and
Tom Dann[2]

Environment Canada
[1]Environmental Protection Branch, Quebec Region
Air Issues Section
and
[2]Environmental Technology Centre
Analysis and Air Quality Division

Montreal, Quebec

2001

Environment Canada Environnement Canada

Acknowledgements

For comments and complementary information received regarding the preliminary version of the document.

Jean-François Banville of Environment Canada, Quebec Region
Yves Bourassa of the Communauté urbaine de Montréal
Thérèse Drapeau of Environment Canada, Quebec Region
Pierre Frattolillo of the Association industrielle de l'est de Montréal
Chantal Roberge of Environment Canada, Quebec Region
Stacey Smythe of Environment Canada, Western Region

And

Frédérick Gauthier of Environment Canada, Quebec Region for the mapping

Notice to reader :

In this report results are presented in units of microgram per cubic meter or $\mu g/m^3$. Some agencies prefer to express concentrations in parts per million (ppm) or parts per billion (ppb). We refer to ppb units when we provide a comparison with standards or criterion from the United Kingdom.

Published by authority of the Minister of the Environnment

Catalogue number: EN40-644/2001E-IN

ISBN: 0-662-30990-1

Executive summary

In 1994 and 2000, reports from Environment Canada stated that the Pointe-aux-Trembles (PAT) station in Montreal had the highest mean and maximum levels of benzene in Canada during the periods 1989-1993 and 1989-1998 respectively. In another report published in 1999, Dann reported the benzene levels measured between 1989 and 1998 by Environment Canada, together with the values obtained by the Ontario Ministry of the Environment (OMOE) for the period 1989-1996. A comparison of the results obtained at PAT with those obtained at more than 70 stations in the country, including several operated by Ontario, showed that PAT came first in terms of the maximum value measured over 24 hours, and second after Sault Ste Marie in terms of the mean value.

In order to explain this situation, we have investigated the sources of benzene emissions on the Communauté urbaine de Montréal (CUM) territory, compared levels measured in ambient air of Montreal with those from other stations in Canada, looked at temporal trends, checked if benzene levels where varying with wind directions and looked into mitigation measures that occurred on the CUM territory.

Motor traffic is responsible for the major part of benzene emissions on the Island of Montreal but not at the PAT site where they come mostly from industrial sources located nearby. Indeed, the highest levels were recorded when the winds were blowing from the west-south-west and western sectors, which is where the industrial plants that reported major atmospheric releases of benzene are located.

If we look only at the amount of benzene released and reported to the NPRI by industries, we would expect there to be more benzene in the ambient air in Hamilton (Ontario) than at PAT. However, this report confirms that the PAT station is the one with the highest benzene levels in Canada during the period 1989–2000 and that only one station located in Sault Ste Marie had a higher mean value. Excluding the PAT site, there is approximately twice as much benzene measured in ambient air of Montreal than Toronto. The location of the stations with respect to industries releasing benzene and local meteorology are probably responsible for the high levels measured in PAT. Closeness of the stations to streets with heavy traffic could explain the differences between Toronto and Montreal for downtown sampling stations.

Between 1989 and 2000, the benzene values declined in the air samples collected on the Island of Montreal, with declines of 68% at the Ontario Street station and 60% at PAT; in the period 1992-2000, they dropped by 41% at the Maisonneuve Street station. At PAT, the benzene values rose and fell a few times during this period, before a marked decrease of 65% was observed in the benzene levels between 1997 and 2000. The decrease in the mean benzene level recorded in the ambient air at PAT reflects the 62% drop in emissions reported to the NPRI by the three main benzene point sources located in eastern Montreal during the period 1994 to 1999.

The implementation of Phase I of the CUM's gasoline vapour recovery plan helped to reduce the benzene emissions resulting from the sale and distribution of gasoline by at least 90%. In addition to the CUM by-law on gas vapour recovery, Canadian Environmental Protection Act (CEPA) has helped to promote a decrease in benzene releases to the atmosphere. Since July 1, 1999 in Canada, and since December 1, 1999 on the Island of Montreal, a regulatory measure has been in effect requiring that gasoline contain less than 1% benzene. The requirement to reduce the fuel distribution flow rate, which came into effect on February 1, 2001 across Canada (it came into force in early December 1999 in the Montreal region), also helped to reduce gasoline and benzene releases. In addition, the new automobile emissions standards provided for 2004 models will serve to reduce the emissions from motor vehicles.

Introduction

In 1994, an Environment Canada report stated that the Pointe-aux-Trembles (PAT) station in Montreal (Figure 1) had the highest mean (8.6 µg/m^3) and maximum (126 µg/m^3) levels of benzene in Canada during the period 1989-1993 (Dann, 1994). In 2000, Dann (2000) reported that the benzene values measured at the PAT station (mean of 9.0 µg/m^3; maximum of 126 µg/m^3) were still the highest recorded for all the Environment Canada stations in the period 1989-1998. He also reported that the highest results for a rural area were obtained at L'Assomption, near Montreal. In another report published in 1999, Dann reported the benzene levels measured between 1989 and 1998 by Environment Canada, together with the values obtained by the Ontario Ministry of the Environment (OMOE) for the period 1989-1996. A comparison of the results obtained at PAT with those obtained at more than 70 stations in the country, including several operated by Ontario, showed that PAT came first in terms of the maximum value measured over 24 hours, at 126 µg/m^3, but second after Sault Ste Marie (10.3 µg/m^3) in terms of the mean value.

This report uses the benzene emissions reported to the National Pollutant Release Inventory (NPRI) and those estimated by the Communauté urbaine de Montréal (CUM) with the aim of comparing the results obtained at the PAT station with those measured elsewhere in Montreal and Canada, establishing a link between the benzene data and meteorological conditions, examining temporal trends and attempting to explain why the PAT station has among the highest benzene levels observed at stations in Canada.

Sampling sites and schedule

Environment Canada measures benzene and other volatile organic compounds (VOCs) at more than 50 urban and rural sites scattered across the country. The sampling is carried out with the participation of provincial and municipal governments. In Montreal, benzene is measured at three different stations, two of them in the downtown area, at Saint-Jacques market (corner of Ontario and Amherst streets) and on Maisonneuve Street, are mostly influenced by motor traffic; the third site is located in the PAT district on the eastern part of the island and is mostly influenced by industries. Incidentally, Dann (1994) estimated that local industries (point sources) were responsible for 70% of the benzene measured at the PAT station in the early 1990s. A gas station was located approximately 200 m west of the sampling site until its closure January 1^{rst} 2000. The PAT and Ontario Street stations have been in operation since 1989, and the

Maisonneuve Street station since 1992. More than 600 samples had been collected at the first two sites and more than 450 at the Maisonneuve Street station by the end of 2000. Benzene is also measured at five other Environment Canada stations in Quebec.

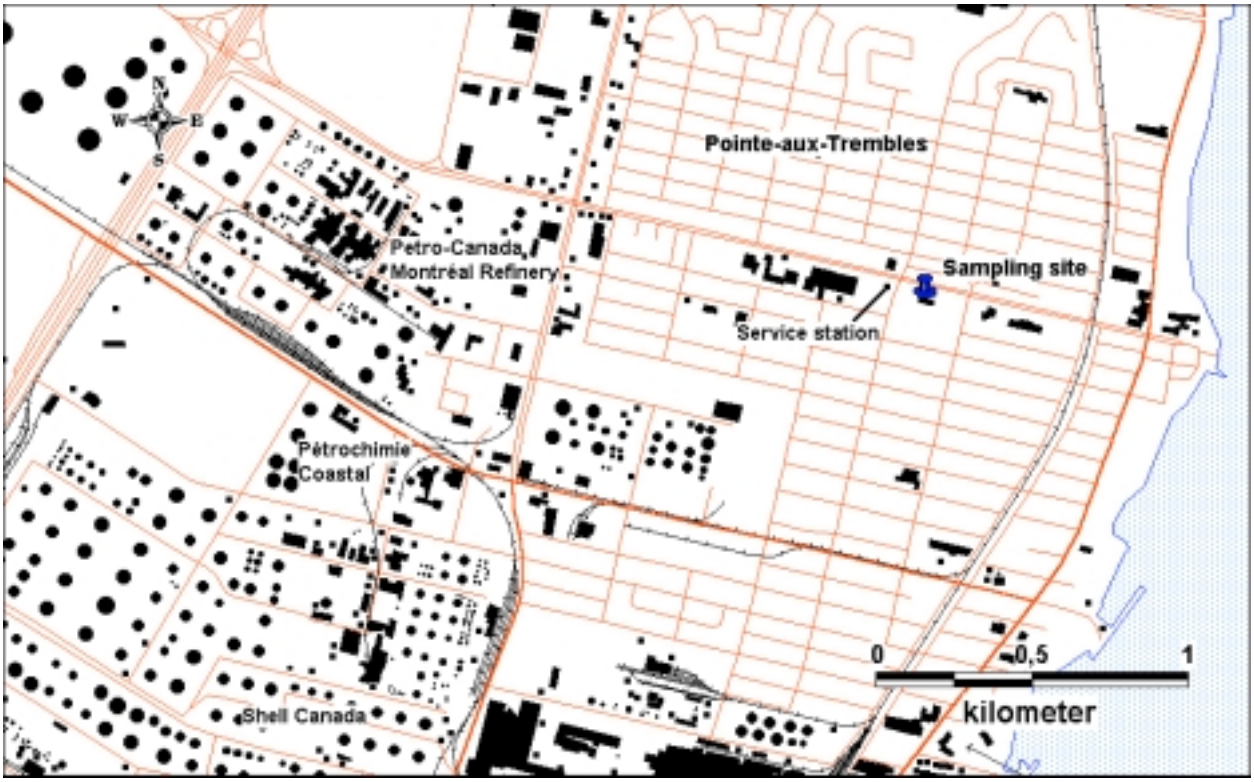

Figure 1 Location of the sampling station at Pointe-Aux-Trembles and point-source emissions of benzene near the station

Each sample is collected over a 24-hour period using a 6-litre stainless steel *Summa*® canister with a Xontech® sampler. The air inflow rate at the canister is about 10 to 15 mL/min for a total volume of 14 to 21 litres per sample. Sampling is performed at the different stations in accordance with the schedule of the National Air Pollution Surveillance Network (NAPS), that is, one sample is collected every six days. Analysis is performed according to EPA method TO-14 using a cryogenic pre-concentrator followed by high performance gas chromatography and quadrupole mass spectra detection (GC-MS). The detection limit for this method is 0.1 µg/m^3 and replicability is good with variability of 5-8% for a sample in which the concentrations are greater than 0.25 µg/m^3.

At the Ontario Ministry of the Environment (OMOE), the method of analysis used has changed over the years. Sampling used to be done using the Carbotrap B and Carbosieve S adsorbent

cartridges, in sequence, and the analysis was performed on-site with gas chromatography and a flame ionization detector (GC-FID). Later, analysis was performed in the laboratory but the samples were collected with the same cartridges. The latter were prepared by Ministry employees. Since 1993, sampling has been carried out with Carbopak B, Carbopak C and Carbosieve S-III cartridges, which are commercially available. Analysis is done with low resolution GC-MS (Dann, 1999).

Results

Emissions reported to the NPRI

Benzene is included in the list of substances that have to be reported to NPRI if the installation that manufacture, process or use it otherwhise respect certain criteria. Among them, the amount involved has to be greater than 10 tonnes. We have to keep in mind that quantities reported to NPRI represent only a fraction of releases or transfers in the canadian environment.

Table 1 presents the benzene emissions reported for the years 1994 to 1999 for Alberta, Ontario, Quebec, and Canada as a whole. Ontario has the highest releases, and the three provinces together are responsible for the majority of benzene emissions in the country. Since the inception of the NPRI, the quantities of benzene released to the environment by companies have increased slightly in Alberta, but decreased by 52% in Ontario, by 55% in Quebec and by 43% in Canada as a whole. The companies *Algoma* in Sault Ste Marie (Ontario) and *Dofasco* and *Stelco* in Hamilton (Ontario) have reported higher benzene emissions (Table 2) than all of the companies in Quebec combined (Table 1). It should be kept in mind, however, that these emissions are generally estimated by the companies on the basis of emission factors.

Table 1 Change in benzene releases (tonnes) reported to the NPRI by facilities in three provinces and for Canada as a whole

Year	Province			Canada
	Alberta	Ontario	Quebec	
1994	368[a]	2031	165	2682
1995	567	1409	157	2226
1996	502	1410	136	2126
1997	444	1141	118	1773
1998	455	956	109	1586
1999	414	978	73	1523

a: Values rounded to the nearest unit

Table 2 Change in benzene releases reported by industrial plants located in eastern Montreal, in Hamilton (Ontario) and in Sault Ste Marie (Ontario)

	1994	1995	1996	1997	1998	1999
Quebec						
Eastern Montreal						
Petro-Canada	67.67	69.20	63.85	39.62	32.70	21.97
Shell Canada Ltd	25.15	25.84	26.29	25.18	14.21	12.87
Pétrochimie Coastal du Canada ltée	0.27	1.69	5.80	17.95	7.58	stopped
Ontario						
Hamilton						
Dofasco	451.78	457.82	455.59	314.48	290.69	253.18
Stelco Inc. Hilton Works	283.6	170.92	225.95	237.93	178.62	203.91
Sault Ste Marie						
Algoma Steel Inc. – Algoma Steel Main Works	238.26	165.23	164.38	165.24	163.82	164.48

(Source: Environment Canada's Internet site on the NPRI)

Emissions of gas vapours and benzene within the territory of the CUM.

In Quebec, some 7.2 billion litres of gas were sold in 1989. In 1994, approximately 5.4 billion litres of gas were loaded or transhipped at the six terminals on the Island of Montreal and some 1.4 billion litres of gas were sold within the territory of the CUM (CUM, 1995). These figures show that 75% of the gas sold in Quebec transits through the Island of Montreal (more specifically, in its eastern sector), and nearly 20% of all the gas used in Quebec is sold there. The CUM has also determined that VOC emissions totalled 2.83 kg per 1000 litres of gas handled, or nearly 5,800 tonnes per year in total, of which 135 was benzene. The

implementation of Phase I of its by-laws on vapour recovery in gas distribution networks is designed to reduce the emissions to 1.46 kg/1000 litres during the different handling operations, from the bulk storage tanks to refuelling of automobiles. Automobile use is also a major source of benzene emissions to the atmosphere. The CUM estimated that motor vehicles released some 44,000 tonnes/y of VOCs within the Island of Montreal in 1989, including 1760 t/y of benzene (Table 3). These emissions represented 10 times the quantity of VOCs emitted by industries that have to report to NPRI and by gasoline sales on the Island of Montreal in 2000.

Table 3 Estimation of benzene emissions within the area of the CUM (1994)

Source	Benzene emitted (t/y)
Motor vehicles	1760
Petroleum refining	100
Distribution of gas	135
Domestic use of solvent	80

(Reproduced from CUM, 1995)

Benzene levels measured in Montreal and elsewhere in Canada

Table 4 presents the summary statistics on benzene values measured between 1989 and 2000 at the sampling stations located on Island of Montreal, as well as at certain stations used as a comparison. The latter are located in the suburbs of Montreal (Brossard), the rural area (L'Assomption, Sainte-Françoise) and Ontario (Hamilton, Sault Ste Marie and Toronto). Table 4 also gives the values for the year 2000 for a few of these stations. It can be seen that the PAT station has the highest maximum value for the period 1989-2000 but that the mean values and the 90^{th} percentile (90^{perct}) are higher at the station located on Bonney Street at Sault Ste Marie. A few stations in Hamilton show high mean, median and 90^{th} percentile values for benzene, but they are nonetheless lower than those at PAT and Sault Ste Marie. The maximum value measured at the Gertrude/Depew station in Hamilton is of the same order of magnitude as that observed at Sault Ste Marie. The maxima levels of benzene measured at Hamilton may be twice as high as those measured in downtown Montreal. The values for Toronto are generally lower than those obtained for Montreal. The maximum value (19 $\mu g/m^3$) measured at the Stouffville station, which is located near two major highways in the region, is much lower than the maximum value measured at PAT. If the PAT site is excluded, the mean level of benzene measured in Montreal is comparable to that obtained in Hamilton; however, it is twice as high as

the level measured in Toronto. The importance of motor traffic near the downtown Montreal sampling sites compared to those of Toronto could explain these results.

Table 4 Comparison of the benzene levels measured in Montreal and elsewhere in Canada between 1989 and 2000 (selected sites)

City and station	Sampling	n	Mean	Standard deviation	Median	90 perct.	Maximum
	Start – End		µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Montreal							
PAT	1989-2000	635	8.3	8.9	5.4	19.0	126.3
Ontario Street	1989-2000	615	3.3	1.9	2.8	5.9	14.8
Maisonneuve Street	1992-2000	476	5.1	2.3	4.7	8.0	16.6
PAT	2000	56	4.0	4.0	3.0	8.1	23.5
Ontario Street	2000	58	2.0	1.3	1.6	3.2	6.5
Maisonneuve Street	2000	55	3.4	1.4	3.1	4.9	8.3
Brossard	1993-2000	382	1.2	0.9	1.0	2.2	9.6
L'Assomption	1996-1997	321	0.9	0.8	0.7	2.1	4.9
Sainte-Françoise	1993-1999	319	0.6	0.4	0.5	1.0	2.9
Hamilton							
Elgin/Kelly	1989-2000	593	3.4	3.3	2.1	7.8	25.9
Beach Boulevard	1991-1996	132	4.7	3.7	4.2	9.3	23.2
Gertrude/Depew	1992-1996	114	6.4	9.6	3.1	12.4	65.7
Vickers/East 18th	1991-1996	130	2.3	2.4	1.4	4.8	14.1
Pier 25	1992-1996	125	4.3	3.4	3.4	8.5	16.2
Elgin/Kelly	2000	53	2.5	2.5	1.6	4.8	14.9
Sault Ste Marie							
Bonney Street	1994-1996	70	10.3	12.5	7.2	28.9	60.1
Toronto							
Perth/Ruskin	1989-2000	611	2.3	1.5	2.0	3.8	16.6
Elmcrest Road	1993-2000	322	1.8	1.2	1.5	3.2	10.7
Stouffville	1989-2000	578	1.1	1.2	0.9	1.9	19.2
Perth/Ruskin	2000	60	1.6	1.2	1.3	2.6	8.5
Elmcrest Road	2000	60	1.3	1.0	1.0	2.3	5.0
Stouffville	2000	54	0.8	0.5	0.6	1.5	2.5

(Reproduced in part from Dann, 1999)

The mean benzene levels measured in the ambient air reflect the magnitude of the releases that occur near the stations. Although the PAT station is located beside Boulevard Saint-Jean-Baptiste and about 200 m from a gas station (until its closure in January 2000), the presence of major industrial plants cannot be overlooked. Dann (1994) estimated that local industries (point sources) were responsible for 70% of the benzene measured at the PAT station in the early 1990s. Although the emissions reported to the NPRI by the industries located near the station

are more than seven times lower than those reported by Hamilton industries, the benzene levels are higher at PAT. The distance between the PAT station and the two refineries (1.5-2 km about) is less than the distance between a few of the Hamilton stations and *Dofasco* and *Stelco* (2-8 km). In contrast, three of the stations in Hamilton are located less than 1.5 km from industrial plants and one of them, Gertrude/Depew, is situated on the property of *Dofasco*. With regard to Sault Ste Marie, the sampling station is located about 1.5 km north of the *Algoma Steel Main Works*. The benzene levels there are higher than at PAT, and the station is probably affected by *Algoma* part of the time.

Temporal change in the benzene concentrations measured on the Island of Montreal

Figure 2 shows that the percentile values 10, 25, 50 (median), 75 and 90^{perct} along with the mean benzene value increased and decreased several times between 1989 and 2000 at PAT. It can also be seen that the distribution of data varies more between 1989 and 2000 but becomes more uniform in 1999 and 2000 when the levels declined substantially.

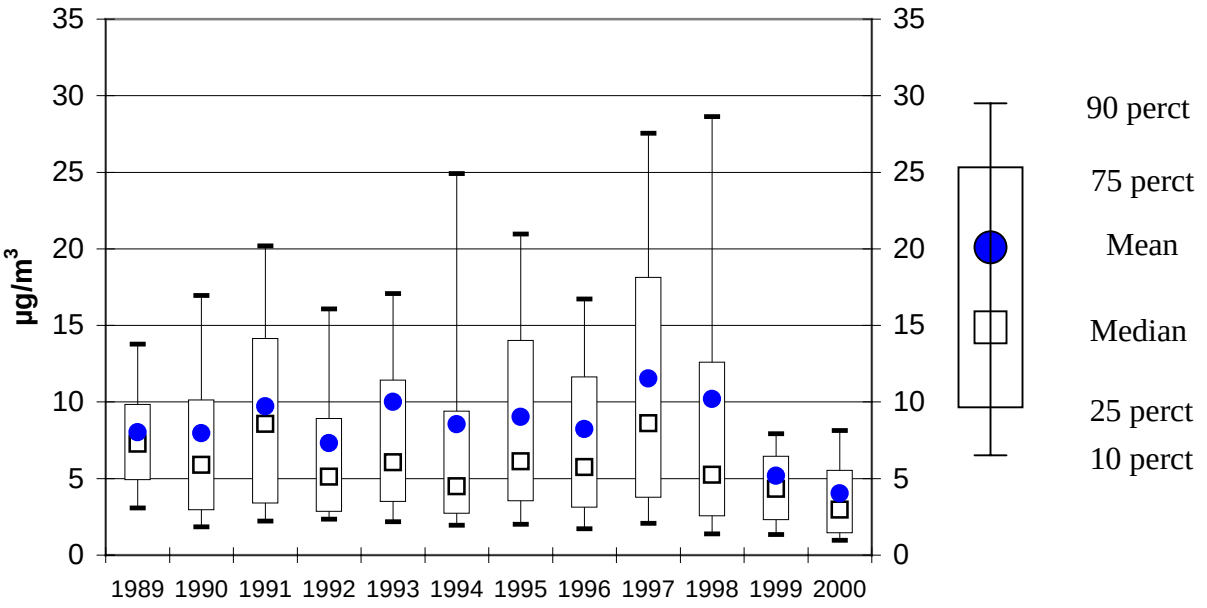

Figure 2 Temporal variation in benzene levels at PAT

Figure 3 highlights PAT benzene median levels presented in Figure 2 and compare them with twose from the other two sampling stations on the Island of Montreal during the period 1989-2000. At PAT, the values show highs and lows, with major increases in 1991 and 1997 and

sharp declines in 1992 and 1998. At the other two stations, the median values follow a general downtrend over the years. At PAT, the largest decrease occurred between 1997 and 1999 (49%), whereas at the stations on Ontario and Maisonneuve streets, a drop of 33% was posted for this period. Decreases of 60% and 68% respectively were posted at the PAT and Ontario Street stations in the period 1989-2000 and 41% at the Maisonneuve Street station in the period 1992-2000. In comparison with the initial data obtained between 1984 and 1986 by Environment Canada (Dann, 1994), the mean benzene level decreased by 78% (from 18.2 µg/m^3 to 4.0 µg/m^3) at PAT.

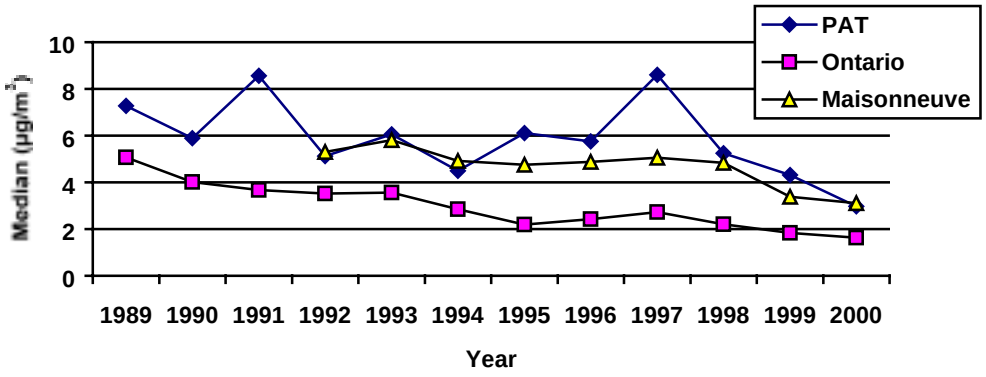

Figure 3 Temporal variations in benzene levels measured on the Island of Montreal

At Hamilton, the benzene levels dropped by more than 50% at the stations located near the steel mills and by nearly 50% in the central part of town between 1992 and 1999. However, the reduction in benzene emissions reported by *Dofasco* and *Stelco* for the period 1994 to 1999 is not reflected in the levels measured at the Beach Boulevard station, which lies in the path of the region's prevailing winds. The benzene levels there rose by 30% between 1992 and 1999 (CAH, 2001).

Variation in relation to wind direction

We sought to identify one or more benzene point sources at PAT by looking at the provenance of the winds measured 10 metres above the ground during the period 1989-2000. We also examined the variation in benzene level in relation to wind direction and the number of hours the wind blew from this direction for a given sector. Overall, the concentrations increased when the wind came from the areas west and west-south-west of the station and decreased when it came from other directions (Figure 4). A more detailed analysis showed that the concentrations

increased most when the wind blew from the directions 250° to 270°, that is, from the facilities owned by *Petro-Canada* (refinery and terminals), part of *Pétroles Coastal du Canada* and the terminal owned by *Ultramar* (Figure 5).

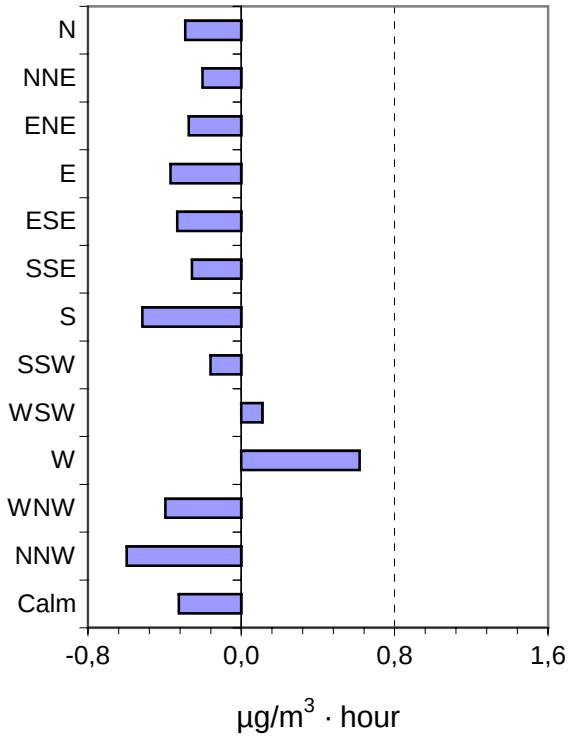

Figure 4 Variation in the rate of increase (decrease) of benzene in relation to wind direction at the PAT station

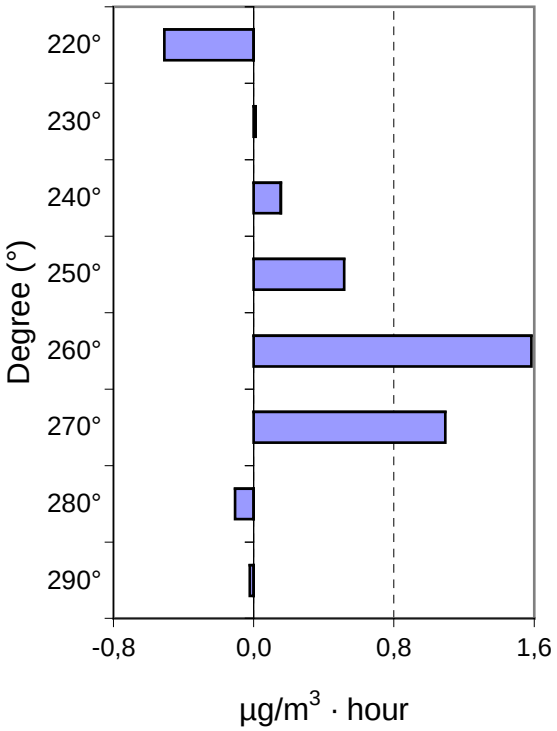

Figure 5 Variation in the rate of increase (decrease) of benzene in relation to wind direction at the PAT station

Table 5 shows the median benzene levels according to the duration and direction of the winds. Between 1989 and 1998, the benzene concentrations generally tended to decline when the wind blew for at least five hours from sectors between the north-north-east and the south (Table 5a. By contrast, the benzene concentrations increased when the wind came from the south-south-west, west-south-west and west sectors. When the winds blew for at least 10 hours from a given direction (Table 5b), the levels show a marked increase for the western sector, particularly in the period 1996 to 1998. However, the benzene levels dropped considerably for nearly all wind directions between 1998 and 1999, with the sharpest drop being posted for the

direction west, that is, nearly 70%. The levels continued to decline in 2000, when the decrease attained 85% for the western sector compared with 1998.

Table 5 Mean benzene concentration (µg/m^3) according to wind direction at PAT

a) Wind direction observed for at least 5 hours during a day of sampling*

	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	CALM
1989	5.1	4.5	3.8	6.2	6.2	6.7	5.5	8.6	12.0	11.8	6.1	5.2	6.6
1990	3.2	5.9	7.1	2.2	3.4	4.6	14.1	6.9	11.1	11.1	9.7	6.0	**
1991	3.5	3.7	3.6	6.9	10.7	3.0	4.0	14.2	15.4	13.3	12.3	8.2	7.8
1992	16.1	4.7	4.8	5.8	5.7	4.2	12.5	7.7	9.9	11.6	5.8	9.6	4.9
1993	3.3	3.4	2.4	3.5	4.3	5.2	11.8	19.8	11.5	9.7	8.5	3.7	8.7
1994	4.7	3.1	3.0	4.2	6.1	5.2	8.6	6.7	12.4	19.0	13.8	4.1	7.5
1995	7.1	5.5	5.5	2.7		5.7	5.4	9.9	12.5	13.2	5.9	9.5	4.4
1996	4.3	4.5	3.8	6.0	14.9	7.8	5.3	10.6	12.9	17.0	2.9	1.9	
1997	7.3	5.9	7.6	3.0	4.6	10.4	5.2	10.7	13.8	21.7	11.8	11.1	
1998	4.1	3.8	3.2	1.4		3.4	4.4	11.6	15.4	22.6	11.7	5.6	6.8
1999	5.6	2.5	2.3	0.9		3.0	4.2	4.7	7.9	7.1	4.4	5.2	3.7
2000	2.8	1.9	1.7	0.9	1.9	3.7	3.4	7.8	5.7	4.6	2.1	8.6	9.6

* : Sampling period of 24 hours
** : an empty cell means that no value is available

Table 5 (cont'd) Mean benzene concentration (µg/m^3) according to wind direction at PAT

b) Wind direction observed for at least 10 hours during a day of sampling

	N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW	CALM
1989	**	3.0	1.8		3.7	6.2	6.0	10.3	12.4	13.7	6.3		5.1
1990	1.5	2.1	2.9		2.1	4.1	7.1	5.9	8.5	17.5	13.9		
1991		2.6	5.1			2.4	3.3	4.8	14.2	16.5	14.3	4.3	
1992		3.3	2.1			5.5		12.1	8.9	13.5	10.6		
1993		3.1	1.8		5.7	7.3		12.0	11.7	12.2	9.7		11.7
1994		2.0	2.8		8.2			8.5	16.6	18.9	18.4		11.7
1995		2.8	0.9			3.8	2.7	6.6	10.4	16.8	6.1		
1996	4.8	3.9	1.4			3.5	4.8	10.7	14.2	25.7	2.9	1.2	
1997	1.6	2.7				5.8	2.8	4.6	14.2	29.9	3.1	4.3	
1998	3.9	2.2	0.8			2.7		5.6	19.3	35.6	2.3	1.3	
1999	1.0	3.1	1.6			2.7	2.5	3.2	6.8	11.2	3.4	1.1	3.7
2000	3.1	2.0	2.5			2.2			6.1	5.1	0.9	6.1	

* : Sampling period of 24 hours
** : an empty cell indicates that no value is available

Mitigation measures

A number of factors explain the drop in benzene levels observed at the three sampling stations on the Island of Montreal in general and at PAT, in particular. Noteworthy ones include the corrective measures *Petro-Canada* put in place to deal with fugitive emissions, the installation of gas vapour recovery equipment at the terminals and at gas stations as requested by the CUM by-laws along with the installation of floating roofs with double seals on benzene tanks (even those not requiring floating roofs under the existing by-laws), the installation of floating roofs with double seals on some other tanks, control of fugitive emissions from various refinery equipment and VOC vapour recovery in the oil separators. The CUM estimates that the by-laws on gas vapour recovery equipment has resulted in a decrease of at least 90% in the benzene emissions associated with the sale of gasoline (Table 6). It reported to the Environment Commission on September 20, 2000 that VOC emissions were 4,400 t/y in 2000 (excluding the automobile sector) based on the the following values (CUM, 2000a):

1. 3000 t/y from refinery operations
2. 1000 t/y from terminals (including gasoline storage tanks)
3. 400 t/y from industrial plants

The results for the year 2000 show that the reduction in the rate of gasoline flow in nozzles, a measure implemented within the territory of the CUM in December 1999, combined with the reduction in the benzene content of gasoline to less than 1%, likewise in effect since December 1 on the Island of Montreal, has had a positive effect on the benzene concentrations in the ambient air. These two measures were required under the *Canadian Environmental Protection Act (CEPA)*. It should be noted that the reduction in dispensing nozzle flow rates was introduced earlier than planned in Montreal, whereas the measure reducing the benzene content of gasoline was delayed in accordance with an agreement with refinery operators. The latter measure was supposed to come into effect on July 1, 1999 pursuant to CEPA, whereas the pump flow rate reduction was to take effect in February, 2001 in Canada. New automobile emissions standards are planned for 2004 models; they should help to reduce these emissions (EC, 2001).

The suspension of operations by the company *Pétrochimie Coastal du Canada ltée* (on January 1, 1999) also brought about a drop in the benzene levels measured in the air at PAT. The closure on January 1, 2000 of the gas station located about 200 m from the sampling station

may also have had an impact on the benzene level, but not as pronounced an effect as that produced by the CUM by-laws and the CEPA provisions.

Table 6 Change in gas vapour and benzene emissions at the terminals and gas stations located within the territory of the CUM

	Terminals			Gas Stations	
	Gas vapour		Benzene	Gas vapour	Benzene
	(L/y)	(t/y)	(t/y)	(L/y)	(t/y)
Before 1998	5 000 000	3170	85	2 000 000[a]	30
On May 7, 1998	1 300 000	825	22	380 000	6
On June 1, 1998	1 000 000	635	17	200 000	3
On January 1, 1999	300 000	127	5	200 000	3

a: equal to 1200 t/y (Adapted in part from CUM, 1998 and Bourassa, 2000)

Compliance with standards

There are few standards pertaining to the benzene level in the ambient air. CUM by-law 90 mentions three levels; the first must not be exceeded during a period of 15 minutes at the edge of a company's property (375 µg/m^3), and the second and third levels correspond to the levels in the ambient air that must not be exceeded during a period of one hour (260 µg/m^3) and eight hours (150 µg/m^3) respectively (CUM, 1986). Our samples cannot be compared with these standards because they were not collected at the edge of an industrial property and because they were collected over a period of 24 hours.

The Quebec Department of the Environment (MENV) annual air quality criterion for benzene is 0.1 µg/m^3 (Walsh, 2000). The benzene levels measured in all the samples collected in Quebec exceed this criterion, even those collected in the rural environment. However, the MENV has a management criterion, which it uses to assess new industrial projects. The latter must not increase the maximum benzene level for a 24-hour period to more than 10 µg/m^3. It is nonetheless interesting to note that at least 20% of the samples collected at PAT exceeded this level between 1989 and 1998, whereas only 5% of samples exceeded it in 1999 and 2000. At the stations on Ontario and Maisonneuve streets, the benzene concentrations exceeded this threshold much less often, and in 2000 none of the values were higher than it (Table 7). No other samples collected in Quebec and analysed by Environment Canada exceeded this criterion. The annual mean benzene values measured between 1989 and 2000 at the PAT and Maisonneuve stations were lower than the ambient air quality standards currently in effect in the

United Kingdom (5 ppb or approximately 16 µg/m^3) and in the State of Texas (United States; 12 µg/m^3) but higher than the long-range criterion (1 ppb or 3.25 µg/m^3 and 3 µg/m^3 respectively). Between 1989 and 1998, they were higher than the European Union's permissible level of 5 µg/m^3 (Smythe, 2000) but they fell below this criterion in 2000.

Table 7 Exceedances (%) of the MENV benzene management criterion in Montreal

Year	Station		
	PAT	Ontario Street	Maisonneuve Street
1989	21.7	9.4	-[a]
1990	26.4	0.0	-
1991	37.2	2.2	-
1992	21.8	0.0	3.8
1993	30.2	1.8	7.5
1994	24.5	1.7	6.0
1995	37.7	0.0	1.7
1996	29.3	0.0	8.9
1997	42.4	0.0	5.9
1998	30.4	3.0	2.2
1999	5.2	0.0	1.8
2000	5.4	0.0	0.0

a: - no sample

Conclusion

Automobiles are responsible for the major part of benzene emissions occuring in the Island of Montreal but at the PAT sampling site, benzene comes mostly from nearby industries. Indeed, the highest levels were recorded when the winds were blowing from the west-south-west and western sectors, which is where the industrial plants that reported atmospheric releases of benzene are located.

If we look only at the benzene releases reported to the NPRI by industries, we would expect there to be more benzene in the ambient air in Hamilton (Ontario) than at PAT. However, this report shows that the PAT station is the one with the highest benzene levels in Canada during the period 1989–2000 and that only one station located in Sault Ste Marie has higher values than those at PAT. Excluding the latter (PAT), there is approximately twice as much benzene in

the air in Montreal as compared with Toronto. The location of the Montreal sampling stations near streets with heavy traffic could explain these results.

Between 1989 and 2000, the benzene values declined in the air samples collected on the Island of Montreal, with declines of 68% at the Ontario Street station and 60% at PAT; they dropped by 41% at the Maisonneuve Street station in the period 1992-2000. At PAT, the benzene values rose and fell a few times during this period, before a marked decrease of 65% was observed in the benzene levels between 1997 and 2000.

The 60% decrease in the mean benzene level recorded in the ambient air at PAT corresponds to a 62% drop in emissions reported to the NPRI by the three main benzene point sources located in eastern Montreal during the period 1994 to 1999. The implementation of Phase I of the CUM's gasoline vapour recovery plan helped to reduce the benzene emissions resulting from the sale and distribution of gasoline by at least 90%, a situation that has improved air quality downtown and in eastern Montreal.

The use of differing sampling methods by Environment Canada and the OMOE could explain some variances; however, the location of the stations in relation to benzene-emitting industries and local meteorological conditions are likely the main causes of the high levels measured at PAT. The analysis of meteorological data was not performed for the other cities where major point sources of benzene exist.

In addition to the CUM by-law on gas vapour recovery (CUM, 2000b), CEPA has helped to promote a decrease in benzene releases to the atmosphere in Montreal. Since July 1, 1999 in Canada, and since December 1, 1999 on the Island of Montreal, a regulatory measure has been in effect requiring that gasoline contain less than 1% benzene (versus 1.7% on average in Quebec in 1998; Tushingham and Collins, 1999). The requirement to reduce the fuel distribution flow rate, which came into effect on February 1, 2001 across Canada (it came into force in early December 1999 in the Montreal region), will also help to reduce gasoline and benzene releases. In addition, the new automobile emissions standards provided for 2004 models will serve to reduce the emissions from motor vehicles.

Recommendation

It is important to continue recording the benzene levels in PAT to see whether the decreases observed in 1998, 1999 and 2000 continue. It should be kept in mind, however, that the advent of the company *Interquisa* and the resumption of operations by *Pétrochimie Coastal du Canada* could result in an increase in benzene concentrations in the ambient air at PAT. It is therefore recommended that benzene levels and VOCs continue to be measured at PAT.

References

Bourassa, Y. (2000) Personnal communication with A. Germain, October 25, 2000

CAH (Clean Air Hamilton) (2001) Clean Air Hamilton, Progress Report 2000. Planning and Development Department, City of Hamilton, Hamilton (Ont), 51 p.

CUM (Communauté Urbaine de Montréal) (2000a) Baisse des concentrations de benzène. Air ambiant - Est de Montréal. Présented to the Commission de l'environnement de la CUM in September 2000

CUM (2000b) Règlement 90-3 Règlement modifiant le règlement 90 relatif à l'assainissement de l'air By-law amending By-law 90 pertaining to air purification. Accessed on CUM web site December 1st, 2000
http://www.cum.qc.ca/cum-fr/air-eau/reglairf.htm

CUM (1999) Projet de contrôle des émissions de vapeurs, Distribution de l'essence. Présented to the Commission de l'environnement de la CUM in May 1999

CUM (1995) Réglementer la récupération des vapeurs dans les réseaux de distribution d'essence, Phase 1. Document de réflexion. Présented to the Commission de l'environnement de la CUM in June 1995

CUM (1986) RÈGLEMENT (BY-LAW) 90. Règlement relatif à l'assainissement de l'Air et remplaçant les règlements 44 et 44-1 de la Communauté. By-law pertaining to air purification and replacing By-laws 44 and 44-1 of the Community. Communauté urbaine de Montréal (Montréal) 65 p.

Dann, T. (2000) Ambient Air Measurements of Benzene in Canada (1989-1998) in *Proceedings of the Air & Waste Management Association's 93rd Annual Conference & Exhibition.* Salt Lake City, Utah, June 18-22, 2000, 14 p.

Dann, T. (1999) Ambient Air Concentrations of Benzene in Canada (1989-1998) Report Series AAQD 99-1 Environmental Technology Centre, Analysis and Air Quality Division, Environment Canada, Ottawa (Ontario) 28 p.

Dann, T. (1994) Ambient Air Measurements of Benzene at Canadian Monitoring Sites (1987-1993) Report Series No PMD 94-4 Environmental Technology Centre, Pollution Measurement Division, Environment Canada, Ottawa (Ontario) 55 p.

Environnement Canada (2001) Providing Cleaner Air to Canadians. Environnment Canada, Ottawa (Ont) 8 p.

Environnement Canada. NPRI internet site http://www.npri-inrp.com/queryformf.cfm accessed in October 2000

Smythe, S. (2000) Personnal communication with A. Germain, November 27, 2000

Tushingham, M. et J. Collins (1999) Survey of Benzene, Aromatics and Olefins in Canadian Gasoline -–1998. Oil, Gas and Energy Branch, Environment Canada, Hull, Qc, 16 p.

Walsh, P. (2000) Personnal communication with A. Germain, November 24, 2000