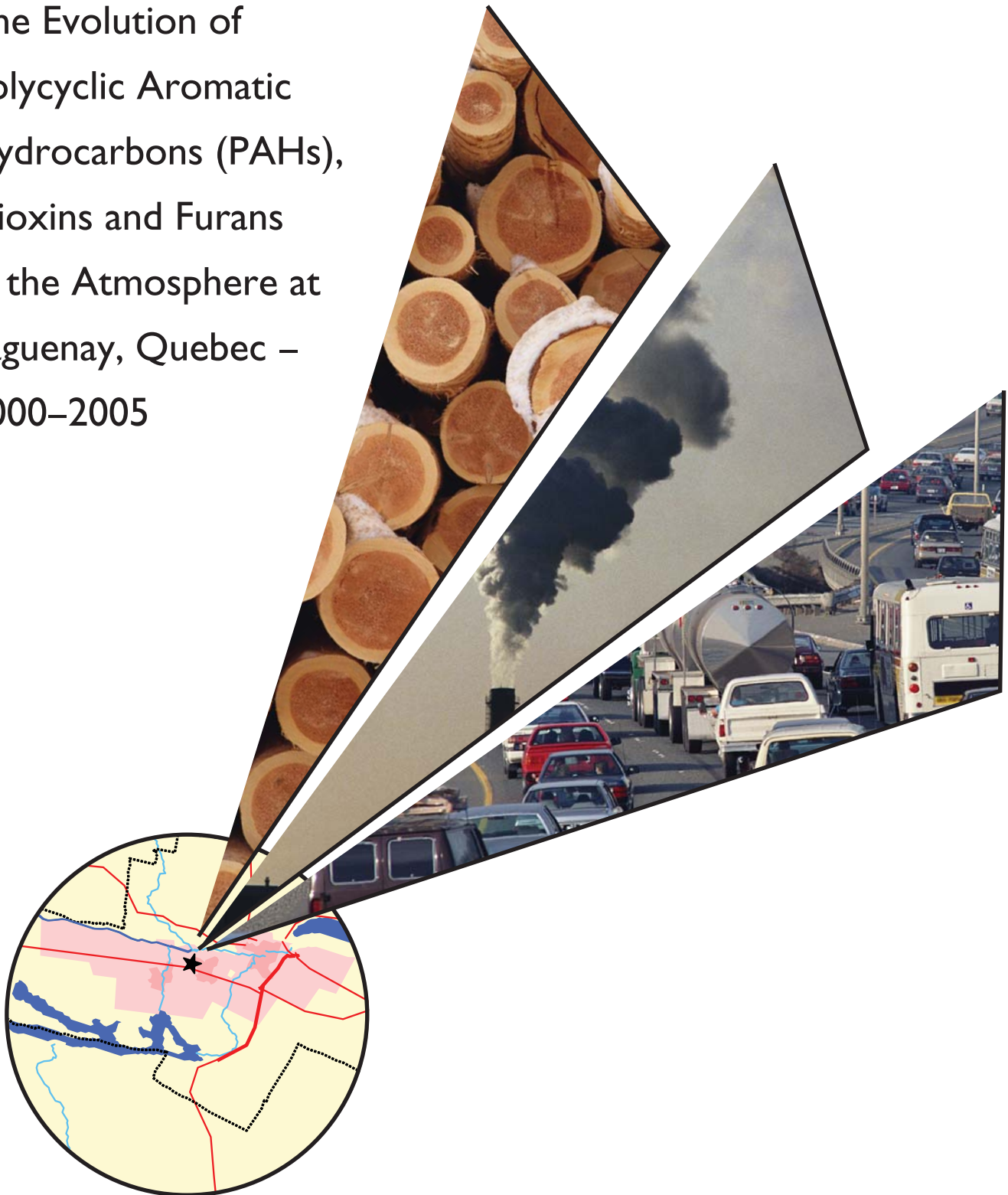




Environment
Canada

Environnement
Canada

The Evolution of
Polycyclic Aromatic
Hydrocarbons (PAHs),
Dioxins and Furans
in the Atmosphere at
Saguenay, Quebec –
2000–2005



The Evolution of Polycyclic Aromatic Hydrocarbons (PAHs), Dioxins and Furans in the Atmosphere at Saguenay, Quebec – 2000–2005

Anne-Marie Carter and André Germain

Comments

If you would like to share your comments on the contents of this report, please send them to

Anne-Marie Carter
Environmental Protection Operations Division
Environment Canada
105 McGill St., 4th Floor
Montréal, Quebec H2Y 2E7

Également disponible en français sous le titre *Évolution des hydrocarbures aromatiques polycycliques (HAP), des dioxines et des furanes dans l'air ambiant à Saguenay, Québec – 2000 à 2005*

Library and Archives Canada Cataloguing in Publication

Carter, Anne-Marie
The Evolution of Polycyclic Aromatic Hydrocarbons (PAHs), Dioxins and Furans in the Atmosphere at Saguenay, Quebec-2000-2005/ Anne-Marie Carter and André Germain.

Text in English and French on inverted pages.

Title on added t.p.: *Évolution des hydrocarbures aromatiques polycycliques (HAP), des dioxines et des furanes dans l'air ambiant à Saguenay, Québec-2000 à 2005.*

1. Polycyclic aromatic hydrocarbons--Environmental aspects--Québec (Province)--Saguenay. 2. Dioxins--Environmental aspects--Québec (Province)--Saguenay. 3. Furans--Environmental aspects--Québec (Province)--Saguenay. 4. Air--Pollution--Québec (Province)--Saguenay--Measurement. 5. Environmental monitoring--Québec (Province)--Saguenay. I. Germain, André, 1953- II. Canada. Environment Canada III. Title: *Évolution des hydrocarbures aromatiques polycycliques (HAP), des dioxines et des furanes dans l'air ambiant à Saguenay, Québec-2000 à 2005.*

GE160.C3C37 2007

363.739'26309714162

C2007-980238-9E

Print version

ISBN 978-0-662-05306-4

Cat. no.: En154-47/2007

Online in HTML and PDF formats at www.ec.gc.ca/cleanair-airpur/

ISBN 978-0-662-47301-5

Cat. no.: En154-47/2007-PDF

Abstract

Historically, high concentrations of polycyclic aromatic hydrocarbons (PAHs) have been measured in Jonquière's ambient air sampling station in the city of Saguenay. This report examines the impact of the April 2004 closure of the Horizontal Stud Söderberg (HSS) potrooms of Alcan's Arvida aluminium smelting plant on the emissions and concentrations of PAHs. The evolution of polychlorinated dibenzo-*p*-dioxins (PCDDs, or dioxins) and polychlorinated dibenzofurans (PCDFs, or furans) in Jonquière's ambient air is also examined. The results are compared with those observed at two other stations in Montréal from 2000 to 2005.

Total PAHs in ambient air

Between 2000 and 2003, annual PAH concentrations at the Jonquière sampling station were about ten times higher than those measured at the stations in Montréal; since the closure of the HSS potrooms, they have been three times higher. At Jonquière, average annual concentrations fell by 76% between 2000 and 2005, thereby revealing the impact of the closure of the HSS potrooms.

Historical data show that the average PAH concentration in the ambient air at Jonquière fell by 91% between 1989 and 2005. This reduction reflects the 97% drop in PAH emissions from Alcan's Arvida plant during the same period.

Dioxins and furans in ambient air

Between 2000 and 2005, a large fluctuation in the values of dioxins and furans was observed at the Jonquière station and the Rivière-des-Prairies station in Montréal, but the numbers were generally a little higher at Rivière-des-Prairies.

Since April 2004, there has been a 46% decline in the median concentration of dioxins and furans, which coincides with the closure of the HSS potrooms. It is unlikely, however, that this reduction was due to the closure of the potrooms as the primary aluminium smelters are not regarded as sources of dioxins and furans and there is a low degree of correlation of dioxins and furans to total PAH concentrations. Dioxins and furans probably come from sources other than the aluminium smelters. It is possible that residential wood heating and the open burning of refuse are responsible in part for the emissions of dioxins and furans. These sources of pollution are sporadic and are distributed all over the region. In addition, wood processing plants, metal recycling plants and foundries may also contribute to emissions of dioxins and furans. Finally, highway transport is another potential source of dioxins and furans.

The influence of the wind on total PAHs and dioxins and furans

Total PAHs were analyzed in terms of wind direction and the number of hours during which the wind blew in a given direction. PAH concentrations rose when the wind blew from the east to the southeast, reflecting the presence of the Arvida plant, and they fell when the wind came from other directions. For instance, before the closure of the HSS potrooms, when the wind blew from the east the average total PAH concentration was 40 times higher than it was when the wind

blew from the west, whereas after the closure of the potrooms the PAH concentration was 7 times higher when there was an easterly, compared with a westerly, wind.

Concentrations of dioxins and furans were found to increase when the wind blew from the northeastern sector to the southern sector and to decrease when the wind blew from other directions. When the wind was calm, a substantial increase in dioxin and furan concentrations was observed, which indicates that the sources were local. The average concentration of dioxins and furans were 2.6 times higher when the wind blew from the east rather than from the west.

National Pollutant Release Inventory

Since 2002, four facilities have reported PAH releases to the National Pollutant Release Inventory in Saguenay, whereas five other facilities have reported releases of dioxins and furans. PAH emissions fell by 86% from 2002 to 2005, and the decline is attributable primarily to the closure of the potrooms the Alcan Arvida plant. Two dioxin and furan emitting facilities—Uniboard Canada and Récupère Sol Inc.—stopped releasing dioxins and furans in 2003 and 2005, respectively and emissions declined by 85% during the 2002-to-2005 period.

Regulations

Quebec's Ministère du Développement durable, de l'Environnement et des Parcs [Department of Sustainable Development, Environment and Parks] has established an air quality criterion with respect to dioxins and furans at the level of 0.06 TEQ (pg/m³) per year. At the Jonquière station, average annual concentrations of dioxins and furans have not exceeded this air quality criterion.

The annual air quality criterion for benzo[*a*]pyrene (BaP) has been established at 0.9 ng/m³. In Jonquière, average annual concentrations exceeded the annual criterion until 2004. In 2005, the average BaP concentration fell dramatically to 0.39 ng/m³, which is below the air quality criterion.

Conclusion

Concentrations of total PAHs and dioxins and furans in the ambient air were measured in the Jonquière district of Saguenay. Since April 2004, a significant reduction in total PAH concentrations at Jonquière has been observed, linked to the closure of the HSS potrooms of Alcan's Arvida plant. Although the values for dioxins and furans also declined during the same period, the decrease could not be directly linked to the closure of the HSS potrooms.

Acknowledgments

The authors wish to thank:

- Tom Dann and the laboratory team of Environment Canada's Environmental Science and Technology Centre, for performing chemical analyses;
- all those involved of sampling operations at the Quebec Ministère du Développement durable, de l'Environnement et des Parcs [Department of Sustainable Development, Environment and Parks] and the City of Montreal; and
- Gilles Morneau of Environment Canada's Meteorological Service of Canada, for the wind rose and the meteorological data.

The comments of the following reviewers were greatly appreciated:

- Lisa Gauthier and Serge Alain, of the Quebec Ministère de Développement durable, de l'Environnement et des Parcs [Department of Sustainable Development, Environment and Parks];
- Jean-François Banville, Paryse Turgeon and Paula Urria, of Environment Canada's Environmental Protection Operations Division
- Gilles Morneau, of Environment Canada's Meteorological Service of Canada;
- André Ayotte, of Alcan's Arvida plant; and
- Claude Gagnon, of the City of Montreal.

Contents

Abstract	iii
List of figures	vii
List of tables	viii
List of abbreviations and acronyms	viii
 <i>Chapter 1</i>	
Introduction	1
 <i>Chapter 2</i>	
Background	2
 <i>Chapter 3</i>	
Sampling sites and schedule	4
 <i>Chapter 4</i>	
Results	6
Releases reported to the National Pollutant Release Inventory	6
Change in PAH concentrations	8
Change in D/F concentrations	10
Jonquière wind rose	12
The relationship between the wind and total PAH concentrations	12
The relationship between the wind and D/F concentrations	15
Regulations	18
 <i>Chapter 5</i>	
Conclusion	19
Recommendations	20
 References	21
 Appendices	23
Appendix 1 The 17 PAHs listed in the NPRI	23
Appendix 2 Toxicity Equivalent (TEQ) factors of the 17 congeners of dioxins and furans	23

List of figures

1	Location of the Jonquière sampling station (JON) and the facilities that declared PAH and D/F releases to the NPRI	6
2	Changes over time in total PAH at Jonquière between 2000 and 2005	8
3	Total annual PAH concentrations at the three stations	8
4	Total PAH concentrations at the three sampling stations for the periods before and after the closure of the HSS potrooms	9
5	Historical graph showing total PAHs in the ambient air and industrial emissions in Saguenay from 1989 to 2005	10
6	Variations over time in atmospheric D/Fs in Jonquière between 2000 and 2005	10
7	Total annual D/F concentrations at the three stations	11
8	D/F concentrations at the three sampling stations for the periods before and after the closure of the HSS potrooms	11
9	Frequency of winds between 2000 and 2005	12
10	Variations in the rates of increase (decrease) in total PAHs relative to the wind direction at the JON station between January 2000 and March 2004	14
11	Total PAH concentrations by direction when the wind blew for 10 hours or more, for the 101 days of sampling between January 2000 and March 2004	14
13	Total PAH concentrations before and after the closure of the HSS potrooms, relative to the number of hours when the wind came from the direction of the Arvida plant (90° to 170°)	15
14	Variations in the rates of increase or decrease in D/Fs relative to the origin of the wind at the JON station between January 2000 and December 2005	16
15	D/F concentrations by direction when the wind blew for 10 hours or more at the JON station between January 2000 and December 2005	17
16	D/F concentrations before and after the closure of the HSS potrooms, relative to the number of hours when the wind came from the direction of the Arvida plant (90° to 170°)	17
17	Annual BaP concentrations at the three sampling stations	18

List of tables

1	Atmospheric emissions of PAHs and D/Fs in Canada	2
2	Number of samples taken at each station per year	4
3	Criteria for declaring PAHs and D/Fs to the NPRI in 2005	7
4	PAH and D/F releases declared to the NPRI in Saguenay between 2002 and 2005	7
5	Wind direction and average wind speed on the days when PAH concentrations were the highest before the closure of the HSS potrooms	13
6	Wind direction and average wind speed on the days when PAH concentrations were the highest after the closure of the HSS potrooms	13
7	Origin and average daily wind speed on the days with the highest D/F concentrations between January 2000 and December 2005	16

List of abbreviations and acronyms

BaP	Benzo[a]pyrene
CEPA (1999)	<i>Canadian Environmental Protection Act (1999)</i>
D/Fs	Dioxins and furans
HSS	Horizontal Stud Söderberg
IARC	International Agency for Research on Cancer
JON	Jonquière air sampling station
m	Metres
NAPS	National Air Pollution Surveillance Network
ng/m ³	nanograms (10 ⁻⁹ grams) per cubic metre
NPRI	National Pollutant Release Inventory
ONT	Ontario Street air sampling station
PAHs	Polycyclic aromatic hydrocarbons
PCDDs	Polychlorinated dibenzo- <i>p</i> -dioxins
PCDFs	Polychlorinated dibenzofurans
pg/m ³	picograms (10 ⁻¹² grams) per cubic metre
RDP	Rivière-des-Prairies air sampling station
t	Metric tonnes
TEQ	Toxicity Equivalent, calculated using the toxicity factors relative to that of 2,3,7,8-tetrachlorodibenzodioxin

Introduction

The Jonquière sampling station is part of the National Air Pollution Surveillance Network. It is located in Parc Berthier, approximately 4 km northeast of the downtown area of the city of Saguenay's Jonquière sector. Polycyclic aromatic hydrocarbons (PAHs) have been measured there since 1989, and polychlorinated dibenzo-*p*-dioxins (PCDDs, or dioxins) and polychlorinated dibenzofurans (PCDFs, or furans) were added to the list of measured parameters in 1995. The Saguenay region is highly industrialized, and several industries are located near the Jonquière station.

In 1998, an Environment Canada report stated that the Jonquière sampling station reported some of the highest concentrations of dioxins and furans (D/Fs) in the ambient air in Canada. A second report, published by Rousseau (2000), concluded that D/Fs measured in this region came primarily from local sources. The results also showed that D/F concentrations were higher when the wind came from the south or southeast and that the concentrations were highest in the winter and lowest in the spring. A third report, by Germain *et al.* in 2002, showed that D/F concentrations measured at Jonquière were close to those measured in Montréal and that only two high values observed in 1996 caused the average D/F concentration at Jonquière to rise for the year.

Environment Canada's 1998 report also showed that the Jonquière sampling station recorded the highest concentrations in Canada of PAHs in ambient air and that these concentrations declined significantly between 1989 and 1996. The report by Germain *et al.* (2002) showed that the levels of PAHs in the air rose in 1997 and 1998 before falling in 2000 and 2001 to a level below that of 1996.

Alcan's Arvida industrial site has been in operation since 1926 (Banville, 2005). At this site, the Centre d'électrolyse Est used the Horizontal Stud Söderberg (HSS) process until its closure in 2004, whereas the Centre d'électrolyse Ouest has been using side-worked prebaked anode cells since 1940. Atmospheric PAH emissions in Jonquière came primarily from the aluminium smelter using the HSS process (Allaire, 1993). These emissions mainly resulted from the use of pitch in the anodic paste required for the production of aluminium. In the case of the prebaked anode cells, the PAH emissions mainly originate from the anode baking furnace, which is equipped with a very effective pollution control equipment that makes it possible to produce aluminium with very low PAH emissions. The Alcan Vaudreuil chemical plant, which is adjacent to the Centre d'électrolyse Est, is home to alumina refining operations.

While this report examines the data obtained at the Jonquière sampling station between 1989 and 2000, it primarily addresses the PAH and D/F concentrations measured in the ambient air at Jonquière between 2000 and 2005 and compares data to those measured at two stations in Montréal. The effect of the closure of the HSS potrooms at Alcan's Arvida plant was verified by studying the changes over time in the substances found in the air and by linking them to the meteorological data, while considering data from the periods before and after the closure. We have also compared the releases reported in the National Pollutant Release Inventory (NPRI).

Background

PAHs come from natural and anthropogenic sources. They are a group of approximately 100 different chemical substances that occur in petroleum hydrocarbons and their by-products and are produced through the incomplete combustion of coal, oil, gas, wood, refuse and other organic substances. In air, they generally occur in gaseous mixtures and in solid form, associated with substances such as soot and creosote. Some PAHs, such as benzo[*a*]pyrene, have been classified by the International Agency for Research on Cancer (IARC) as probable human carcinogens, and several PAHs are listed as toxic substances under the *Canadian Environmental Protection Act* (1999) (CEPA) and appear as a group in Schedule 1 of CEPA.

Forest fires are the largest natural source of PAHs in Canada, while aluminium smelters are the primary industrial source (Table 1). Residential wood heating is also a major source and is responsible for 48% of PAH emissions into the atmosphere in Canada (Germain, 2005). Although a wood-burning stove is merely an individual source and gives off only a small amount of PAHs, wood-burning stoves are collectively responsible for a large portion of total anthropogenic emissions.

Table 1 **Atmospheric emissions of PAHs and D/Fs in Canada**

Sectors	PAHs (t) ^a	D/Fs (g TEQ) ^a
Residential wood heating	1381	3
Residential heating (natural gas, propane, oil, electricity, coal)	32	7
Energy production	n.d.	5
Aluminium smelters	450	0 ^b
Other industries	35	26
Transport	100	9
Total emissions in Canada, excluding open sources ^c	1998	50
Forest fires	2008 ^d	n.d.
Open burning of refuse	n.d.	20 ^e
Total emissions in Canada, including open sources	4664	163

Source: Germain (2005 and 2006).

Legend—n.d.: no data.

^a Year of reference for PAHs: 2000. Year of reference for D/Fs: 1999.

^b Below the threshold of measurability.

^c Open sources include emissions caused by forest fires, dust from roads, agriculture, etc.

^d Lalonde *et al.* (1993).

^e Environment Canada (2001).

D/Fs appear on the lists of toxic substances of various international organizations. Under CEPA, they are considered to be toxic, persistent, and bioaccumulative substances of anthropogenic origin, and they are identified as substances destined for virtual elimination.

D/Fs are substances made up of 75 congeners of PCDDs and 135 congeners of PCDFs. Of all the congeners of D/Fs, 17 congeners are considered carcinogenic by the IARC. These congeners all contain chlorine atoms at positions 2, 3, 7 and 8 on the molecule. Toxicity Equivalent (TEQ) factors have been assigned to each D/F congener for weighting purposes. These TEQs are based on the toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin – the most toxic of the congeners—to which a TEQ of 1 has been assigned. D/Fs are also associated with a variety of non-carcinogenic effects on humans, such as disturbance of the endocrine system, suppression of immune protection, toxicity for fetal development, effects on the skin, cardiovascular diseases and diabetes.

D/Fs are products formed unintentionally during combustion and numerous industrial processes. The primary sources of atmospheric emissions in Canada are municipal waste incinerators, incinerators of hazardous or medical waste, industrial incinerators and boilers. D/Fs can be produced during the manufacture of chlorinated organic chemical substances, cement production, metal melting, burning of wood waste from wood transported in salt water and the combustion of fuels in Kraft recovery boilers used in the pulp and paper sector. According to existing information (ESP Environmental, ExCAL, 2000; Finlay, 2004; United Nations Environment Programme, 2001), D/F emissions from the aluminium-smelting sector are not considered significant (Table 1); however, the production of secondary aluminium, obtained by re-melting scrap aluminium, turnings, chips and other materials containing aluminium, is known for its D/F emissions. Residential wood heating, combustion at sanitary landfills and the open burning of refuse or farmland make up a large number of small sources spread out all over Canada. Natural D/F sources are forest fires and volcanoes.

Sampling sites and schedule

Since 1969, Environment Canada has coordinated the National Air Pollution Surveillance (NAPS) network, whose measuring stations are run by the federal, provincial and municipal governments. For this study, the Jonquière sampling station (JON), located in Berthier Park, near the intersection of Powell and Hoopes streets, was used as reference. The sampling instruments are located 4 m above the ground, on the roof of a small cabin. This station was installed in 1989 in order to verify air quality near the region's industries. Alcan's Arvida plant, where the electrolysis of alumina is performed, and the Vaudreuil chemical complex are located 1.5 km to the east-southeast.

The results obtained in Jonquière were compared to those obtained at two stations located in Montréal. The Ontario Street sampling station (ONT) is located in downtown Montréal and is affected primarily by automobile traffic. The Rivière-des-Prairies sampling station (RDP) is located in a residential area in the northeast sector of the island of Montréal and is affected primarily by residential wood heating in the winter (Carter *et al.*, 2004).

Sampling was performed over a 24-hour period according to the schedule of the NAPS network, once every 12 days for PAHs and once every 24 days for D/Fs. Table 2 shows the number of samples taken at each station from 2000 to 2005.

Table 2 **Number of samples taken per year at each sampling station**

Year	PAHs			D/Fs		
	JON	ONT	RDP	JON	ONT	RDP
2000	24	28	43	11	13	9
2001	24	27	28	14	28	28
2002	27	21	19	12	12	11
2003	26	15	23	12	7	9
2004	26	27	29	11	11	10
2005	21	25	20	9	9	6
Total	148	143	162	69	80	73

PAHs can be found in ambient air in gaseous or particulate form. When they contain fewer than four rings, they are generally found in the gaseous fraction; when they contain more than five rings, they are found in the particulate fraction. Depending on the temperature, compounds with four or five rings can occur in either fraction. To capture them, two different materials are used together: a filter and polyurethane foam set up in a series. Sampling techniques using a high-volume (Hivol) sampler and the analysis method are discussed exhaustively in Germain's report (1997). D/Fs also exist in gaseous or particulate form and are sampled at the same time as PAHs. The method of analysis is discussed in the 1998 Environment Canada report.

The data on wind direction and speed come from the weather station located approximately 3 km southeast of the JON sampling station.

The results obtained were studied by comparing the arithmetic means and medians of the three stations. The exposure of the population to pollutants is generally expressed by comparing the arithmetic mean values, whereas the state of the environment is better reflected by comparing the medians. The statistical tests must often be performed using the medians for data which do not have normal distribution so as to minimize the effect of extreme values. The arithmetic means and the medians have been added to the tables and the figures so that interested readers may make these comparisons.

Results

Releases reported to the National Pollutant Release Inventory

The National Pollutant Release Inventory (NPRI) can provide information on releases and transfers of pollutants in our communities. In Canada, the NPRI is the only inventory that is national in scale, recognized by CEPA and accessible to the public. In general, facilities must report to the NPRI if they meet all the criteria for type of activity and number of employees and if they manufacture, process or otherwise use an amount of listed substances which exceeds the specified threshold for the reported substances. It should be kept in mind that releases reported to the NPRI represent only part of the releases into the Canadian environment. Emissions coming from transport, residential wood heating and the residential use of solvents, for example, are not included in this inventory.

PAH and D/F emissions reported under the NPRI's program in Saguenay were examined. The location of the facilities that declared releases is shown in Figure 1. The substances are reported by the facilities according to the reporting criteria listed in Table 3. For PAHs, facilities must report 17 substances individually to the NPRI or must declare them collectively under "Total PAHs." A list of the 17 PAHs appears in Appendix 1. In addition, two other PAHs—anthracene and naphthalene—can be declared to the NPRI, and the threshold for reporting them is 10 tonnes of substances manufactured, prepared or otherwise used. D/F emissions are declared in grams of toxicity equivalent (g TEQ) for the 17 congeners listed in Appendix 2.



Figure 1 Location of the Jonquière air sampling station (JON) and the facilities that declared PAH and D/F releases to the NPRI

Table 3 Criteria for declaring PAHs and D/Fs to the NPRI in 2005

Criteria	PAHs		D/Fs
Substances	17 different substances	Anthracene, naphthalene	17 congeners
Employees	In total, employees worked 20 000 hours or more during the year.		
Thresholds for substances	At least one PAH was produced incidentally, and the amount of all the PAHs produced and released or transferred totaled 50 kg or more.	10 t manufactured, prepared or otherwise used	No quantitative threshold
Other activities subject to the requirement (the criterion pertaining to employees does not apply)	A PAH was released or transferred by a wood-preserving plant that used creosote, irrespective of the amount released or transferred or of the number of hours worked by the employees.		17 listed activities, including: <ul style="list-style-type: none"> • incineration of hazardous waste • incineration of sludge • primary smelting of base metals • melting recovered aluminium • melting recovered lead • wood preservation using pentachlorophenol

Four facilities in Saguenay reported PAH releases, while five other facilities reported D/F releases. Table 4 lists the total releases by facility—essentially releases into the air, as releases into water were negligible. PAH emissions were observed to have fallen by 86% from 2002 to 2005. This reduction is mainly due to the closure of the HSS potrooms of Alcan's Arvida plant in April 2004; its emissions fell from 102 t to 10 t from 2003 to 2005. D/F emissions fell by 85% during the same period. This decrease can be attributed mainly to Uniboard Canada, which stopped reporting D/Fs as of 2003, and also to Récupère Sol Inc., which reported no releases in 2005.

Table 4 PAH and D/F releases declared to the NPRI in Saguenay between 2002 and 2005

Substances	Facilities	2002	2003	2004	2005
		Amounts of PAHs declared, in tonnes			
13 PAHs	Alcan, Arvida plant	103.2	101.8	27.1	9.6
3 PAHs	Alcan, Grande-Baie plant	2.6	4.8	3.0	4.6
9 PAHs	Alcan, Laterrière plant	—	—	0.39	0.39
12–14 PAHs	Alcan, Vaudreuil plant	0	0	0	—
Total		105.8	106.6	30.5	14.6

		Amounts of D/Fs declared, in g TEQ			
D/Fs	Cascades Canada, Fjordcell	0.003	0.003	0.003	0.003
D/Fs	Cascades Boxboard Group Inc.	0	0	—	—
D/Fs	Les services minéraux industriels Inc., Niobec Mine	0	0	0	0
D/Fs	Récupère Sol Inc.	0.001	0.003	0.002	0
D/Fs	Uniboard Canada Inc., MDF La Baie	0.016	—	—	—
Total		0.020	0.006	0.005	0.003

Change in PAH concentrations

Figure 2 shows PAH concentrations measured at the JON station between 2000 and 2005. The highest values were observed in 2000, with two values approaching 4000 ng/m³. From 2001 to 2004, high values reached over 2000 ng/m³. After the closure of the HSS potrooms in April 2004, only two values exceeded 500 ng/m³.

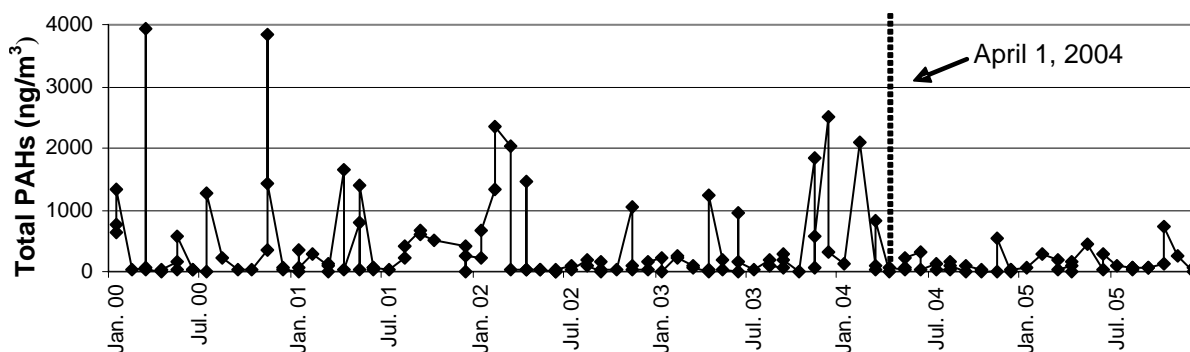
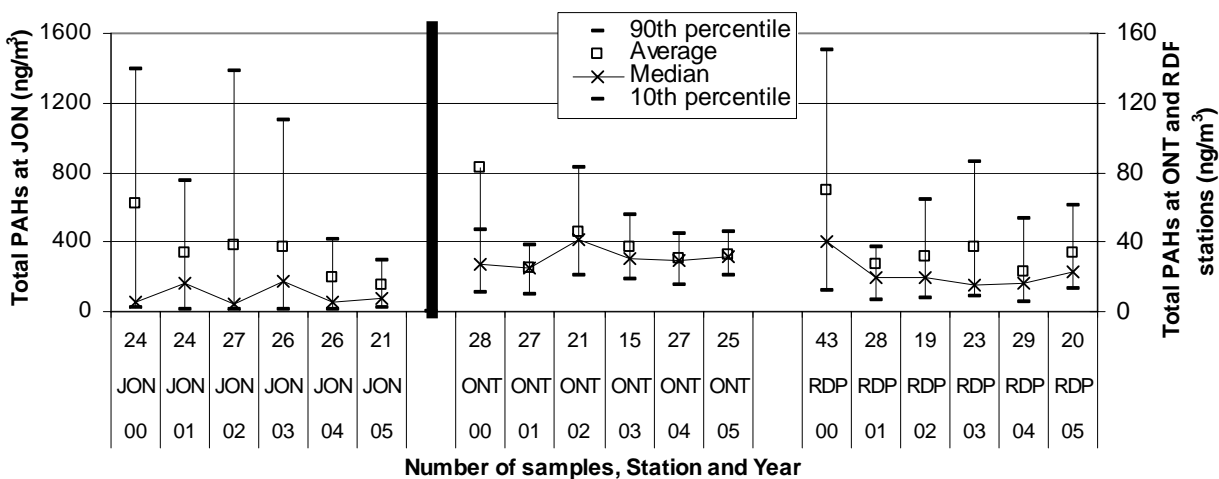


Figure 2 Changes over time in total PAHs at the JON station between 2000 and 2005

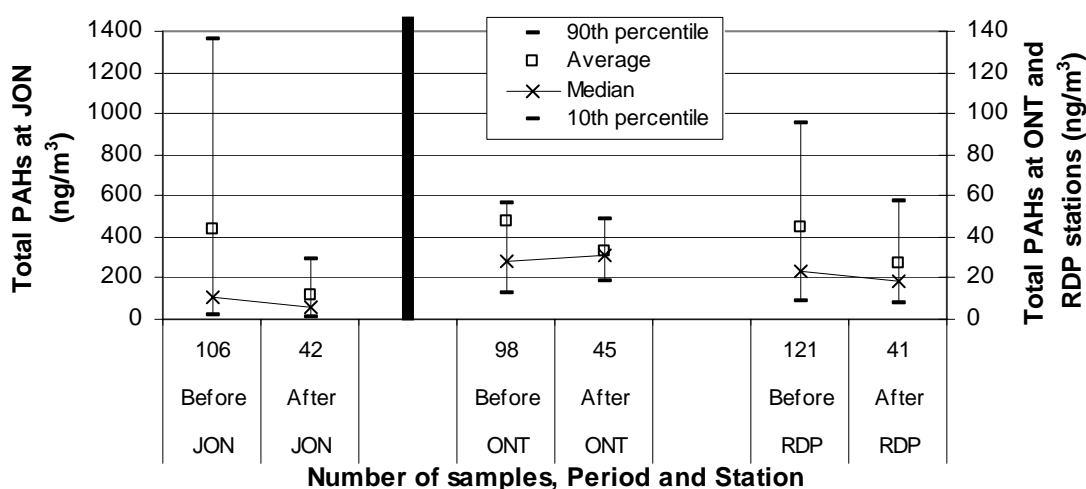
Figure 3 shows the annual PAH concentrations measured at the three sampling stations. PAH values at the JON station were about ten times higher than those measured at the ONT and RDP stations, and different scales have been used in the figures. Average concentrations at the JON sampling station fell by 76% between 2000 (621 ng/m³) and 2005 (148 ng/m³). However, statistical tests performed on the medians do not show any significant difference ($p < 0.05$) in annual concentrations. At the ONT and RDP stations, concentrations generally varied from 20 to 40 ng/m³, and, unlike the JON station, these two stations showed a slight (insignificant) increase in concentrations in 2005 relative to 2004.



Note: Different scales were used for the JON station and the ONT and RDP stations.

Figure 3 Total annual PAH concentrations at the JON, ONT and RDP air sampling stations

A main interest of this study was to evaluate the impact of the closure of the HSS potrooms at Alcan's Arvida plant, which occurred in April 2004. The data were therefore divided into two different periods at the three sampling stations: from January 2000 to March 2004, and from April 2004 to December 2005. Figure 4 shows the results obtained for total PAHs. A large reduction of 72% was observed at the JON sampling station, where average concentrations fell from 436 to 120 ng/m³. Statistical tests on the medians showed that this decrease was significant ($p < 0.05$). It was also observed that average concentrations at the ONT and RDP sampling stations declined slightly for the same periods, but this reduction was not significant. In addition, it was noted that, before the closure of the HSS potrooms, annual concentrations of PAHs at the JON station were about ten times higher than those measured at the Montréal stations; after the closure, they were three times higher.



Note: Different scales were used for the JON station and the ONT and RDP stations.

Figure 4 Total PAH concentrations at the JON, ONT and RDP air sampling stations for the periods before and after the closure of the HSS potrooms

Historical data on ambient PAHs and total industrial releases of PAHs at the JON station are shown in Figure 5. The data on total releases of PAHs for the period from 1989 to 2000 were obtained from Alcan (2003), and data for the period from 2002 to 2005 were obtained from the NPRI. In general, concentrations in the ambient air reflect the same tendencies as the releases from the Arvida plant. From 1989 to 2005, the average PAH concentration in the air declined by 91% (from 1621 to 148 ng/m³), and PAHs released by the Arvida plant declined by 97% (from 380 t to 10 t). We see a great disparity between the average and median values of the ambient air concentrations of PAHs during the 1990s. The fact that maximum PAH values could be as high as 9000 ng/m³ explains these disparities.

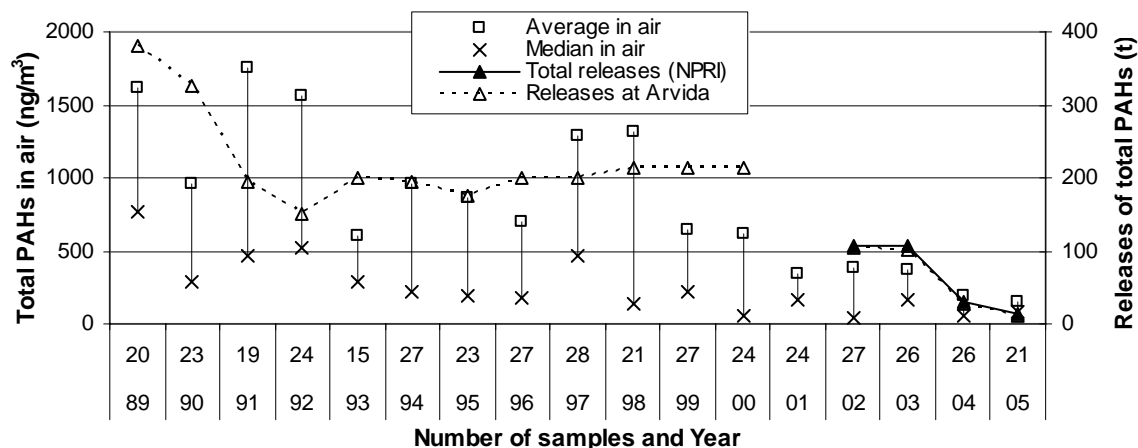


Figure 5 Historical graph showing total PAHs in ambient air and industrial emissions in Saguenay from 1989 to 2005

Change in D/F concentrations

The change in D/Fs measured at the JON sampling station since 2000 is shown in Figure 6. Values are generally below 0.08 TEQ pg/m³. Two dates, however, are exceptional: November 5, 2003 (0.13 TEQ pg/m³), and October 6, 2004 (0.37 TEQ pg/m³). These high concentrations will be examined relative to the wind direction in an attempt to understand these peaks (see page 15). Concentrations declined following the closure of the potrooms on April 1, 2004, with the exceptions of August 19, 2004 (0.078 TEQ pg/m³), and October 6, 2004.

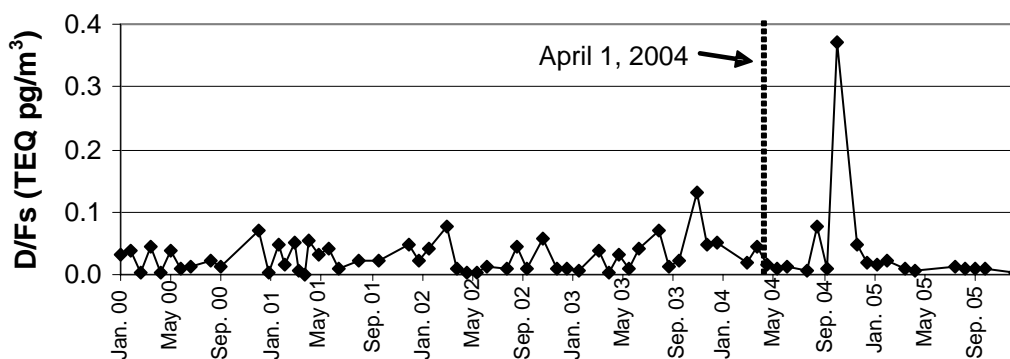


Figure 6 Variations over time in atmospheric D/Fs in Jonquière between 2000 and 2005

Figure 7 shows annual variations in D/Fs measured at the three sampling stations from 2000 to 2005. A large fluctuation in the data was observed at the JON and RDP sampling stations; data were generally higher at the RDP station. There was an increase in concentrations at the JON station in 2003, followed in 2004 by a decline in the median but an increase in the annual average caused by the high value on October 6, 2004. Concentrations declined in 2005. Despite

these fluctuations, there is no significant difference ($p < 0.05$) among the averages or the medians for the six years of data collected at Jonquière. Concentrations fluctuated at RDP station, with averages that were higher in 2000 and 2005. Residential wood heating may be responsible for the variations measured at Rivière-des-Prairies, as the high values generally occur during the winter.

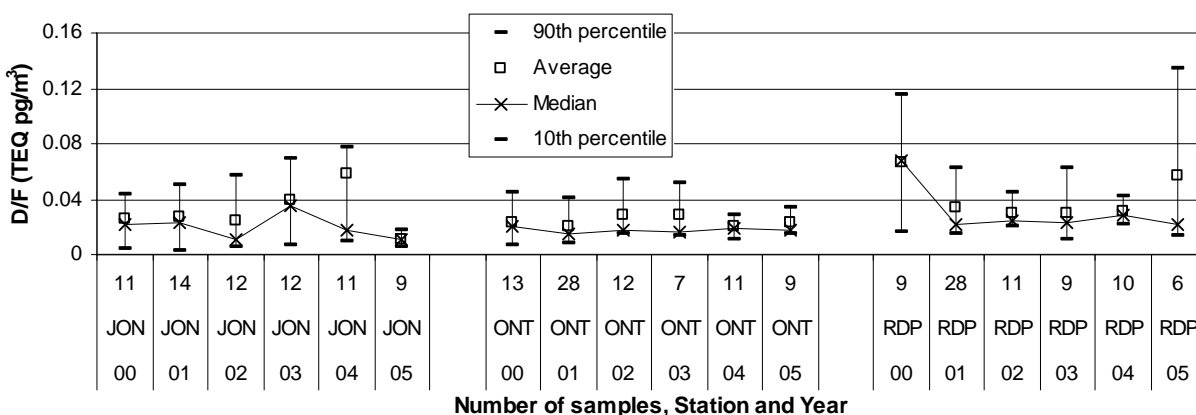


Figure 7 Total annual D/F concentrations at the JON, ONT and RDP air sampling stations

Average and median D/F concentrations at the three stations before and after April 1, 2004—the date of the closure of the HSS potrooms—are shown in Figure 8. At Jonquière, the median declined by 46 % between the two periods, but the average increased because of the high value posted on October 6, 2004. There was no significant difference ($p < 0.05$) between the medians for the two periods. Despite the decline in the median concentration at Jonquière after the closure of the HSS potrooms, we verified whether there was a correlation between the data for D/Fs and those for total PAHs. The correlations obtained were weak for the periods preceding and following the closure of the HSS potrooms ($R^2 = 0.25$ and 0.0015 , respectively). Thus it is unlikely that the D/Fs and the total PAHs came from the same source. For the ONT and RDP stations, increases of 13% and 4%, respectively, were observed in the D/F medians between the two periods.

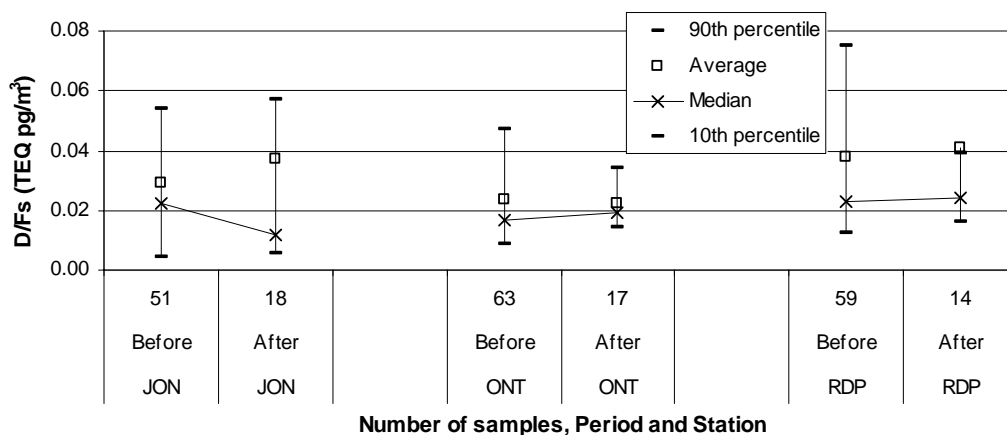


Figure 8 D/F concentrations at the JON, ONT and RDP air sampling stations for the periods before and after the closure of the HSS potrooms

Jonquière wind rose

Figure 9 shows the wind rose for the period from 2000 to 2005, according to 16 compass directions, and the distribution of the wind speeds. There are two axes for the dominant winds: the wind that moves from the west-northwest to the west-southwest, which occurs 36% of the time; and the wind that blows from the east to the east-southeast, which occurs 23% of the time. Calm winds, below 1 km/h, occur only 1.9% of the time, while winds from 1 to 10 km/h and from 11 to 20 km/h occur 36% and 40% of the time, respectively.

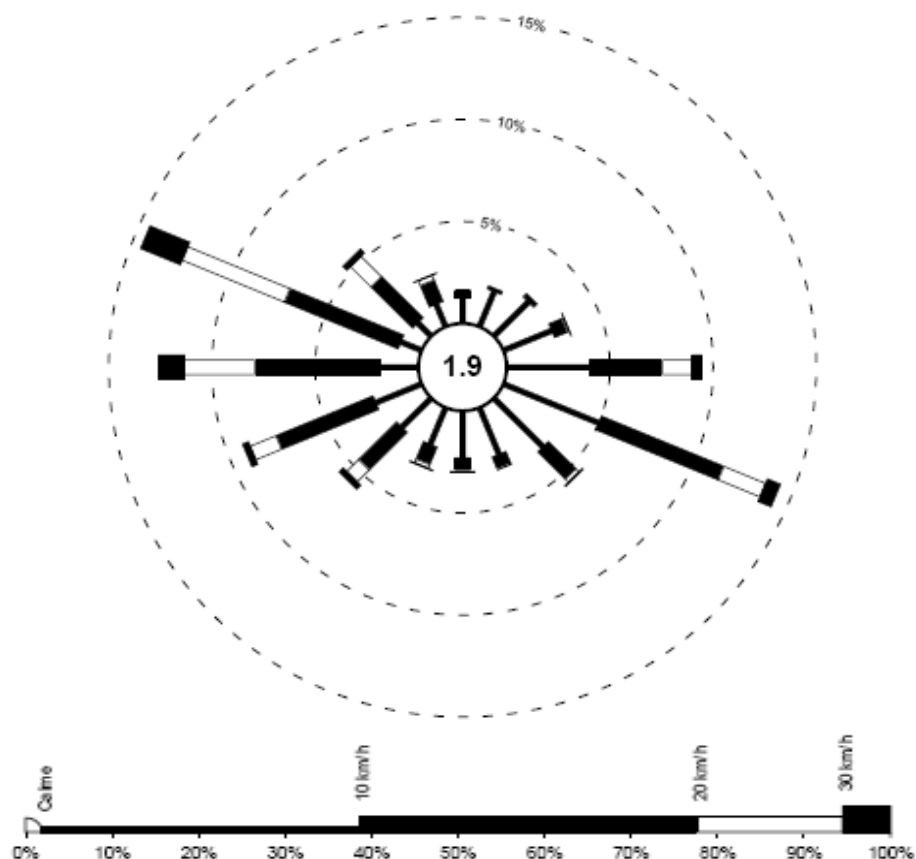


Figure 9 Frequency of winds at Jonquière between 2000 and 2005

The relationship between the wind and total PAH concentrations

The following tables show the origins of the winds and the average wind speed for the ten days on which the total PAH concentrations measured were the highest before (Table 5) and after (Table 6) the closure of the HSS potrooms. With the exception of two dates, the highest values were observed when the wind came primarily from the east before the closure of the HSS potrooms. After the closure of the HSS potrooms, PAH values were high when the wind came from the southeast. It should be noted that the emissions from Alcan's Arvida plant came primarily from the HSS potrooms that were located at the eastern edge of the industrial complex (at approximately 95° relative to the sampling station). Since the closure of the HSS potrooms,

the emissions have come primarily from the east-southeast sector, which is 105° from the sampling station.

Table 5 Wind direction and average wind speed on the days with the highest PAH concentrations before the closure of the HSS potrooms

Total PAHs (ng/m ³)	Dates	Number of hours during which the wind blew in the direction indicated								Wind speed (km/h)
		N	NE	E	SE	S	SW	W	NW	
3936	19-03-2000	0	0	18*	6	0	0	0	0	15.4
3834	14-11-2000	0	0	15	0	0	0	0	0	19.1
2499	11-12-2003	0	0	24	0	0	0	0	0	26.2
2359	25-02-2002	0	0	21	2	1	0	0	0	21.1
2088	21-02-2004	0	0	24	0	0	0	0	0	29.5
2030	09-03-2002	0	0	23	1	0	0	0	0	30.0
1856	05-11-2003	0	1	15	0	2	0	0	3	13.0
1641	07-04-2001	0	1	9	1	6	7	0	0	7.6
1468	14-04-2002	1	1	14	2	5	1	0	0	12.0
1421	26-11-2000	0	1	9	10	0	1	1	0	7.5

*The numbers in bold are values above 10.

Table 6 Wind direction and average wind speed on the days with the highest PAH concentrations after the closure of the HSS potrooms

Total PAHs (ng/m ³)	Dates	Number of hours during which the wind blew in the direction indicated								Wind speed (km/h)
		N	NE	E	SE	S	SW	W	NW	
730	13-10-2005	0	0	10*	9	4	0	1	0	13.4
527	23-11-2004	0	1	13	9	1	0	0	0	12.1
444	10-05-2005	0	0	8	15	1	0	0	0	17.4
303	08-06-2004	2	1	12	2	5	1	1	0	11.8
278	03-02-2005	2	1	7	12	2	0	0	0	6.3
255	30-11-2005	0	2	10	3	7	1	0	1	13.3
218	27-05-2004	3	1	12	4	3	1	0	0	11.9
198	11-03-2005	0	1	15	7	1	0	0	0	12.2
154	28-04-2005	0	0	12	12	0	0	0	0	28.7
149	19-08-2004	4	0	2	7	2	1	3	5	14.1

*The numbers in bold are values above 10.

Total PAH concentrations were thus analyzed according to the direction of the winds and the number of hours for which they blew on the days when samples were taken, between January 2000 and March 2004. Total PAH concentrations rose when the winds came from the east-southeast sector, where Alcan's Arvida plant is located, and fell when the winds came from other directions (Figure 10).

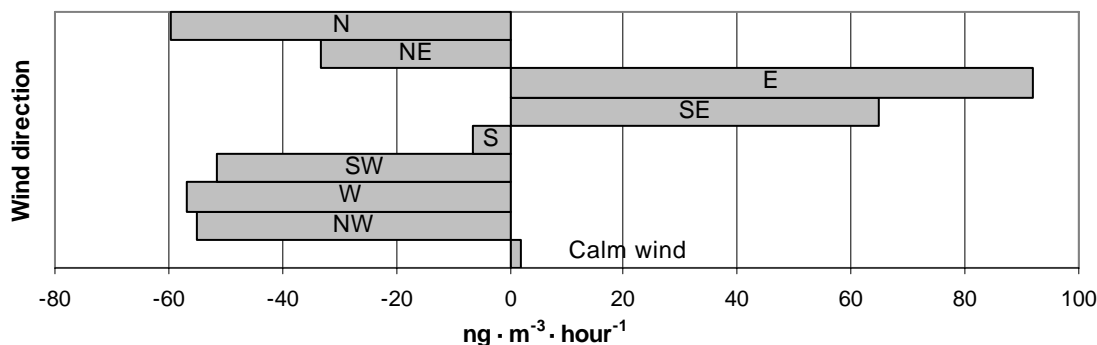
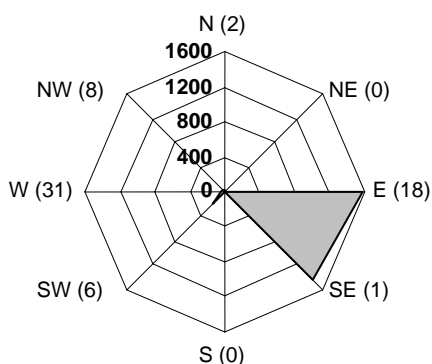


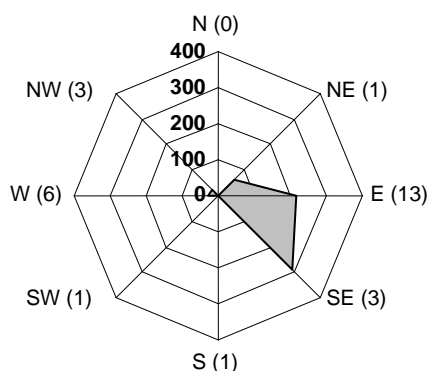
Figure 10 Variations in the rates of increase (decrease) in total PAHs relative to the wind direction at the JON air sampling station between January 2000 and March 2004

Figures 11 and 12 contain wind roses showing average total PAH concentrations according to wind direction on the days when the wind blew for ten hours or more in a single direction, before and after the date of the closure of the HSS potrooms, respectively. The numbers in parentheses represent the number of values used to calculate the averages, out of a possible total of 101 days of sampling between January 2000 and March 2004, and 40 days of sampling between April 2004 and December 2005. Although the wind roses shown have been divided into eight compass points so as to obtain the most data per direction, only a few directions contain enough samples to support the calculation of average concentrations.



Note: Concentrations are in ng/m³.

Figure 11 Total PAH concentrations by direction when the wind blew for 10 hours or more, for the 101 days of sampling between January 2000 and March 2004



Note: Concentrations are in ng/m³.

Figure 12 Total PAH concentrations by direction when the wind blew for 10 hours or more, for the 40 days of sampling between April 2004 and December 2005

Before the closure of the potrooms (Figure 11), average total PAH concentrations were 40 times higher when the wind blew for ten hours or more from the east (1588 ng/m³) compared to the west (41 ng/m³). After the closure of the HSS potrooms (Figure 12), concentrations were seen to be 7 times higher when winds were easterly compared to westerly (215 ng/m³ and 30 ng/m³,

respectively). Despite the small number of samples, we can also see that the average total PAH concentration rose to 292 ng/m³ when the wind came from the southeast, which reflects the presence of Alcan's Arvida plant, located approximately 1.5 km from the sampling station. The levels observed when the wind blew from the east or the southeast have nonetheless been much lower since the closure of the HSS potrooms.

In Figure 13, a comparison is made between the total PAH concentrations measured relative to the number of hours when the wind came from the direction of the Arvida plant, before and after the closure of the HSS potrooms. In general, the higher the number of hours, the higher the total PAH concentrations, both before and after the closure of the HSS potrooms. Nonetheless, PAH concentrations were found to be much lower following the closure of the HSS potrooms.

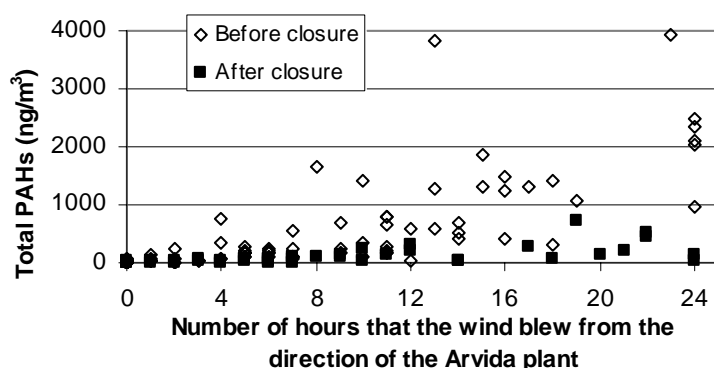


Figure 13 Total PAH concentrations before and after the closure of the HSS potrooms, relative to the number of hours when the wind came from the direction of the Arvida plant (90° to 170°)

The relationship between the wind and D/F concentrations

Since D/Fs, unlike PAHs, were sampled only once every 24 days, there are fewer data with which to perform statistical analyses. For this reason, the data will be studied for the entire January 2000 to December 2005 period.

Among the ten days with the highest D/F concentrations, expressed in Toxicity Equivalent (TEQ), the winds came primarily from the east for four days and from the west for three days (Table 7). On October 6, 2004, D/F concentration rose to 0.371 TEQ pg/m³, a rate almost ten times higher than the median annual rate, while total PAHs were found to be at normal levels. On that day, the dominant winds blew from the southwest to the west for 14 hours and from the east for 7 hours. At present there is no explanation for the high rates of D/Fs on that day (Gauthier and Alain, 2007).

Table 7 Wind direction and average wind speed on the days with the highest D/F concentrations between January 2000 and December 2005

Dates	Concentrations (pg/m ³)			Number of hours during which the wind blew in the direction indicated								Wind speed (km/h)
	TEQ	Total PCDDs	Total PCDFs	N	NE	E	SE	S	SW	W	NW	
06-10-2004	0.371	85.32	8.15	0	0	7	3	0	8	6	0	15.4
05-11-2003	0.132	1.35	4.04	0	1	15*	0	2	0	1	3	13.0
19-08-2004	0.078	10.89	0.89	4	0	2	7	2	1	3	5	14.1
09-03-2002	0.076	0.99	2.45	0	0	23	1	0	0	0	0	30.0
01-08-2003	0.071	0.57	3.66	1	7	8	5	3	0	0	0	7.8
08-12-2000	0.071	4.11	0.91	0	4	0	0	2	3	14	1	8.6
23-10-2002	0.059	1.39	1.54	0	0	0	0	0	8	15	1	14.3
07-04-2001	0.054	0.74	1.59	0	1	9	1	6	7	0	0	7.6
23-12-2003	0.052	0.74	1.42	0	0	16	4	3	0	0	0	7.3
02-03-2001	0.051	1.20	1.37	4	4	4	3	0	4	4	0	6.4

*The numbers in bold are values above 10.

In Figure 14, the variations in the rates of increase or decrease in D/F concentrations are shown according to the origin of the wind from January 2000 to December 2005. For this analysis, the high concentration of October 6, 2004, was excluded, because it had too great an effect on the overall results. D/F concentrations were found to increase when the wind blew from the northeastern sector to the southern sector and to decrease when the wind blew from other directions. The report by Rousseau (2000), which examined D/Fs in Jonquière for the period from 1991 to 1999, shows that D/Fs increased when the winds came from the south and the southeast but remained stable when the winds came from the northeast and the east. This difference in the results obtained cannot be explained. A substantial increase in D/F concentrations was observed when the wind was calm, which indicates that the D/F sources are local. In general, the concentration of pollutants released locally increases in inverse proportion to the wind speed, as the dilution and dispersion of the pollutants in the atmosphere decreases when the wind is not blowing. Note that the sampling station is surrounded by homes, most of which are to the east.

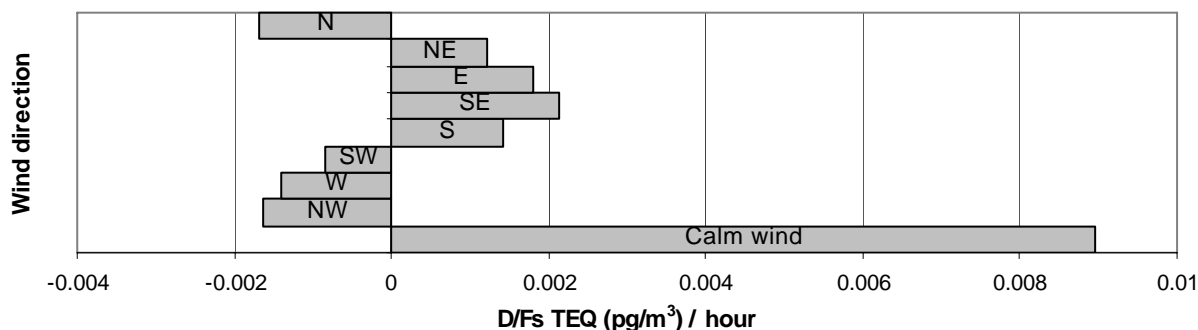
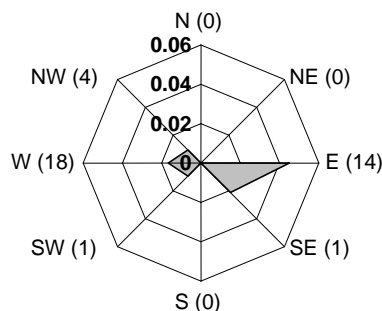


Figure 14 Variations in the rates of increase or decrease in D/Fs relative to the wind direction at the JON air sampling station between January 2000 and December 2005

When we examine average D/F concentrations by direction when the wind blows for 10 hours or more (Figure 15), D/F concentration is 2.6 times higher when the wind comes from the east (0.045 pg/m^3) than when it comes from the west (0.017 pg/m^3). The limited number of data for the other wind directions makes it impossible to obtain statistically reliable results.



Note: Concentrations are in TEQ pg/m^3 .

Figure 15 D/F concentrations by direction when the wind blew for 10 hours or more at the JON air sampling station between January 2000 and December 2005

Figure 16 shows the relationship between D/F concentrations and the number of hours when the wind blew from the direction of the Arvida plant, before and after the closure of the HSS potrooms. Unlike for the PAHs, the closure of the HSS potrooms does not seem to have had an influence on the D/F concentrations. Given the limited number of data, it is difficult to establish a connection between the D/F concentrations and the number of hours that the wind blew from the direction of the Arvida plant. It is possible that residential wood heating and the open-air burning of refuse are responsible in part for the D/F emissions. These sources of pollution are sporadic and are distributed all over the city and the entire region. Furthermore, Germain *et al.* (2002) reported that the metal-recycling plants in Jonquière's industrial park could also be a source of D/Fs because of the combustion of electrical cable waste. Two foundries, two aluminium recovery plants and one wood processing plant, all located in the region, could also contribute to D/F emissions (Gauthier and Alain, 2007). Finally, highway transport is another known source of D/Fs (Germain *et al.*, 2002).

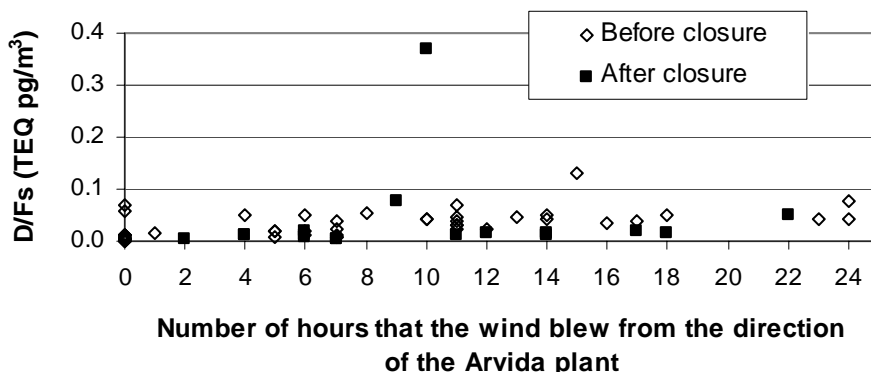


Figure 16 D/F concentrations before and after the closure of the HSS potrooms, relative to the number of hours when the wind came from the direction of the Arvida plant (90° to 170°)

Regulations

Quebec's Ministère du Développement durable, de l'Environnement et des Parcs [Department of Sustainable Development, Environment and Parks] has established an air quality criterion with respect to D/Fs at the level of 0.06 TEQ (pg/m^3) per year. This criterion, defined as a reference threshold used in the management of air quality, is set at the level of the lowest concentration for which there are no adverse effects (Government of Quebec, 2002). Average annual concentrations at the JON station have not exceeded this criterion for air quality, but they did approach it in 2004, mainly because of the concentration measured on October 6, 2004, which came to 0.37 TEQ pg/m^3 , out of a total of 11 measurements taken in 2004 (see Figure 7).

There is no air-quality criterion for total PAHs, but an annual criterion has been established for benzo[a]pyrene (BaP) (Walsh, 2006). This PAH contains five benzene rings and is regarded as carcinogenic by the International Agency for Research on Cancer. This criterion has been established as 0.9 ng/m^3 of BaP, an average annual concentration. Figure 17 shows the average and median annual concentrations of BaP at the three sampling stations. One can see that the concentrations of BaP follow the same trends as total PAHs, shown in Figure 3. At Jonquière, average annual concentrations greatly exceeded the annual threshold until 2004. In 2005, the average concentration of BaP fell to 0.39 ng/m^3 , which is below the criterion for air quality. At the two stations in Montréal, BaP concentrations have been below the annual criterion since 2001. At the ONT station in 2000, the high annual average of BaP was caused by the high value (65.2 ng/m^3) of January 1, 2000. Fireworks that were set off on that date to celebrate the new millennium contributed to an increase in concentrations of atmospheric pollutants (Carter *et al.*, 2004). When the value for January 1, 2000, is excluded, the annual average for the ONT station falls below the annual provincial criterion, whereas the annual average at the RDP station remains above the annual criterion.

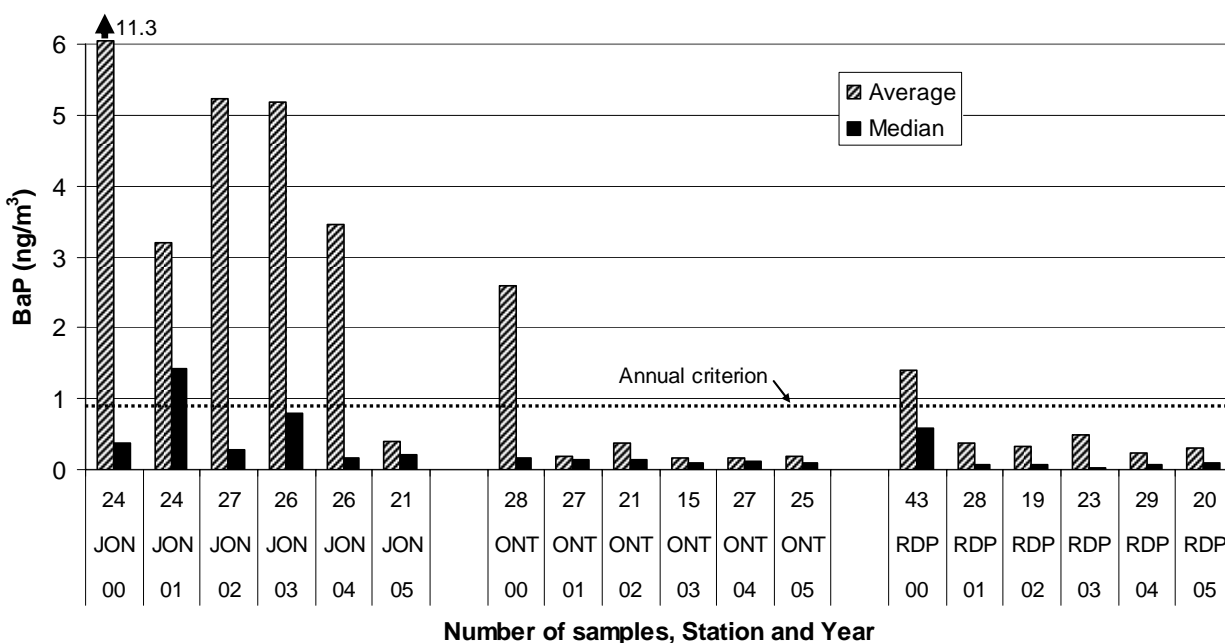


Figure 17 Annual BaP concentrations at the JON, ONT and RDP air sampling stations

Conclusion

This report examines the impact of the closure of the Horizontal Stud Söderberg (HSS) potrooms of Alcan's Arvida plant in April 2004 on the emissions and concentrations of polycyclic aromatic hydrocarbons (PAHs) and dioxins and furans (D/Fs) in the ambient air measured at Jonquière, in the city of Saguenay, Quebec. The results obtained are compared to those observed at two other stations on the island of Montréal from 2000 to 2005.

At Jonquière, total PAH concentrations were almost ten times higher than those measured at the stations in Montréal before the closure of the HSS potrooms and three times higher after the closure. Concentrations of D/Fs were similar at the three sampling stations, with values slightly higher at Rivière-des-Prairies than at Jonquière.

For the period from 1989 to 2005, the reduction in PAH releases from Alcan's Arvida plant is reflected by a decline in PAHs in the ambient air. Specifically, the average concentration of total PAHs in the ambient air declined by 91%, and PAHs released by the Arvida plant declined by 97%. Since the closure of the HSS potrooms in April 2004, an additional decline in total PAHs has been observed, with the average concentration falling to 148 ng/m³ in 2005.

PAH concentrations rose when the winds blew from the eastern sector to the southeastern sector, reflecting the presence of the Arvida plant. For instance, before the closure of the HSS potrooms, the average concentration of total PAHs relative to wind direction was 40 times higher when the wind blew from the east rather than from the west, whereas it was 7 times higher after the closure of the potrooms.

For the period from 2000 to 2005, D/F concentrations at Jonquière declined by 46% after April 2004. Although the decline in the concentrations measured following the closure of the HSS potrooms, the D/Fs did not appear to come from the same source as the PAHs. D/F concentrations were found to increase when the wind blew from the northeastern sector to the southern sector and to decrease when the wind blew from other directions. When the winds were calm, a substantial increase in D/F concentrations was observed, which indicated that D/F sources were local. The average D/F concentration was 2.6 times higher when the wind blew from the east rather than from the west. It is possible that residential wood heating and the open burning of refuse were responsible in part for the D/F emissions. These sources of pollution are sporadic and distributed over the entire region. Wood processing plants, metal recycling plants and foundries, and transportation may also have been sources of D/F emissions.

At the Jonquière station, average annual D/F concentrations did not exceed the criterion for air quality established by the Quebec Ministère du Développement durable, de l'Environnement et des Parcs [Department of Sustainable Development, Environment and Parks], but average annual concentrations of the PAH benzo[*a*]pyrene (BaP) did exceed the criterion for air quality until 2004. The criterion for air quality was not exceeded in 2005, because a large decline in BaP concentrations was observed.

Recommendations

It is appropriate to continue to measure PAH and D/F concentrations at Jonquière in order to observe future trends. Indeed, it will be interesting to monitor the impact on total PAHs over the medium term of the closure of the HSS potrooms at Alcan's Arvida plant. In addition, it is important to track D/F concentrations, since the pollution sources are diverse and difficult to identify.

References

Alcan Inc., 2003. "Environmental Progress at Alcan." September 2003 Presentation.

Allaire, M., M. Barber and S. Friar. 1993. "Atmospheric polycyclic aromatic hydrocarbons (PAH) at point source of emissions. Part B: PAH emissions reductions at a Horizontal Stud Soderberg plant at Jonquière, Quebec, Canada and the evolution of B[a]P in ambient urban air." *Journal of the Air & Waste Management Association*, 43: 85–90.

Banville, J.-F. 2005. *Bilan environnemental pour le secteur des alumineries au Canada*. Internal report. Environment Canada, 60 pp.

Carter, A.-M., A. Germain, J. Rousseau, M. Bisson and C. Gagnon. 2004. *Sampling Program for Residential Wood Heating, Study Report: 1999 to 2002*. Environment Canada, Ministère de l'Environnement du Québec, and Ville de Montréal; 88 pp.

Environment Canada. 2006. NPRI Web Site. The Four New Groupings of ATH Substances—PAHs; http://www.ec.gc.ca/pdb/npri/npri_pah_e.cfm.

Environment Canada. 2006. NPRI Web Site. The Four New Groupings of ATH Substances—D/Fs. http://www.ec.gc.ca/pdb/npri/npri_dioxins_e.cfm.

Environment Canada. 2001. *Inventory of Releases, Polychlorinated dibenzo-p-dioxins substituted in the 2,3,7,8 positions (PCDDs), Polychlorinated dibenzofurans substituted in the 2,3,7,8 positions (PCDFs)*, 46 pp.

Environment Canada. 1998. Environmental Technology Centre. *Ambient Air Measurements of Polycyclic Aromatic Hydrocarbons (PAH), Polychlorinated Dibenzo-p-Dioxins (PCDD) and Polychlorinated Dibenzofurans in Canada (1989-1997)*. Analysis and Air Quality Division Report Series No. AAQD 98-3, 52 pp.

ESP Environmental, ExCAL House, Capel Hendre Industrial Estate. 2000. *Anglesey Aluminium Dioxin and Furan Emissions Survey*. Anglesey Aluminium Metal Limited, 21 pp.

Finlay, P. 2004. *Draft Guidelines on Best Available Techniques and Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants*. 14 pp.

Gauthier, L. and S. Alain. 2007. Personal Communication on February 1, 2007. Ministère du Développement durable, de l'Environnement et des Parcs.

Germain, A. 2005. "Importance et caractéristiques des émissions provenant de la combustion du bois au Canada." Presentation to the Atelier technique sur le smog hivernal, Montréal, October 27, 2005, organized by the Association pour la prévention de la pollution de l'air et du sol.

Germain, A. 1997. *Hydrocarbures aromatiques polycycliques : État de la situation au Québec de 1989 à 1994*. Environment Canada, Montréal, 250 pp.

Germain, A. and J.-F. Banville. 2006. Personal Communication, December 2006. Environnement Canada.

Germain A., Chiu C., Poole G. 2002. *Use of Pine Needles for the Identification of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans Sources to Air in the Jonquière Area*. Environment Canada, Environmental Technology Centre, Montréal, 25 pp.

Government of Quebec. 2002. *Critères de qualité de l'air : Fiches synthèses*. Ministère de l'Environnement, Direction du suivi de l'état de l'environnement, 271 pp.

Government of Quebec. 2002. *Critères de qualité de l'air : Cadre d'application et de détermination*, Ministère de l'Environnement, Direction du suivi de l'état de l'environnement, May 2002, 19 pp.

Lalonde, Girouard, Letendre et associés. 1993. *Rejets de HAP à l'environnement au Canada–1990*. Environment Canada, Montréal, 114 pp.

Rousseau, J. 2000. *Identification des sources potentielles des polychlorodibenzo-p-dioxines (PCDD) et des polychlorodibenzofuranes (PCDF) à l'atmosphère mesurées dans la région de Jonquière entre 1991 et 1999*. Environment Canada, Environmental Protection Branch, Montréal, 85 pp.

United Nations Environment Programme. 2001. *Outil spécialisé (Toolkit) pour l'identification et quantification des rejets de dioxines et de furanes, Version préliminaire*. PNUE Substances Chimiques, Geneva, Switzerland, 192 pp.

Walsh, P. 2006. Personal Communication on September 29, 2006. Ministère du Développement durable, de l'Environnement et des Parcs.

Appendices

Appendix 1 The 17 PAHs listed in the National Pollution Release Inventory*

Substance
Benz[<i>a</i>]anthracene
Benzo[<i>a</i>]phenanthrene
Benzo[<i>a</i>]pyrene
Benzo[<i>b</i>]fluoranthene
Benzo[<i>e</i>]pyrene
Benzo[<i>g,h,i</i>]perylene
Benzo[<i>j</i>]fluoranthene
Benzo[<i>k</i>]fluoranthene
Dibenz[<i>a,j</i>]acridine
Dibenz[<i>a,h</i>]anthracene
Dibenzo[<i>a,i</i>]pyrene
7H-dibenzo[<i>c,g</i>]carbazole
Fluoranthene
Indeno[1,2,3- <i>c,d</i>]pyrene
Perylene
Phenanthrene
Pyrene

* 2005 criteria

Appendix 2 Toxicity Equivalent (TEQ) factors of the 17 congeners of dioxins and furans

Congener	Abbreviation	TEQ
2,3,7,8-Tetrachlorodibenzo- <i>p</i> -dioxin	2,3,7,8-TCDD	1
1,2,3,7,8-Pentachlorodibenzo- <i>p</i> -dioxin	1,2,3,7,8-PeCDD	0.5
1,2,3,4,7,8-Hexachlorodibenzo- <i>p</i> -dioxin	1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-Hexachlorodibenzo- <i>p</i> -dioxin	1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-Hexachlorodibenzo- <i>p</i> -dioxin	1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo- <i>p</i> -dioxin	1,2,3,4,6,7,8-HpCDD	0.01
Octachlorodibenzo- <i>p</i> -dioxin	OCDD	0.001
2,3,7,8-Tetrachlorodibenzofuran	2,3,7,8-TCDF	0.1
2,3,4,7,8-Pentachlorodibenzofuran	2,3,4,7,8-PeCDF	0.5
1,2,3,7,8-Pentachlorodibenzofuran	1,2,3,7,8-PeCDF	0.05
1,2,3,4,7,8-Hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	0.1
2,3,4,6,7,8-Hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	0.01
Octachlorodibenzofuran	OCDF	0.001

