Conifer forest vegetation as an indicator of PCB exposure in the region of Swan Hills, Alberta, Canada.

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INTRODUCTION

Polychlorinated biphenyls (PCBs) have been tightly regulated in Canada, dating back to regulations under the Environmental Contaminants Act in 1977 and more recently under the Canadian Environmental Protection Act. These have prohibited commercial, maunufacturing or processing uses which has had the effect of taking PCB containing materials out of industrial use except for pre-existing uses in sealed electrical transformers and capacitators. However, the shortage of viable treatment / destruction options has resulted in the storage of PCBs at thousands of locations across Canada. Alberta constructed the only stationary PCB incinerator in Canada at the Alberta Special Waste Treatment Centre (ASWTC) near Swan Hills with operations commencing in 1987. In October 1996, a leak in the incinerator facility was detected. This leak has been estimated to have released 2 - 5 kg PCBs. Resulting health concerns associated with measured PCB residues in samples of deer, moose and fish after the incident led Alberta Health to issue a health advisory on the consumption of wild game within a 30 km radius of the plant site.

Due to the time-lag between the accidental PCB release, public notification that a release occurred and the initiation of sampling efforts, methods such as air, surface water and ground water sampling were not feasible. We determined that vegetation samples, specifically spruce needles, were a viable medium to initiate study of the extent of PCB contamination due to the accidental release of PCBs from the ASWTC. The use of vegetation as indicators of environmental contamination has been explored and supported recently by a number of studies (Rapaport & Eisenreich 1988; Muir et al. 1993; Simonich & Hites 1994, 1995a, 1995b; Bacci et al. 1990; Paterson et al. 1991; Hauk et al. 1994). Vegetation, due to its surface area and lipid content, can behave as a significant sink for organochlorine compounds, on regional and global scales (Simonich & Hites 1995a; Horstmann & McLachlan 1996). Undertaking a study of the extent of source/time specific PCB contamination in the region surrounding the ASWTC through forest vegetation sampling is a first step in addressing further issues of the forest ecosystem impact, human health risks, and ultimately, the risk management implications of hazardous waste disposal.

METHODS

The Swan Hills region, 250 km NW of Edmonton, Alberta, Canada, rises to an elevation of about 1200 m asl (4000 ft asl). The region is largely covered with mixed forests of spruce, pine, fir, birch and aspen, interspersed with peat-bogs. Forestry and oil/gas production are the primary economic activities in the region, aside from recreational and subsistence fishing and hunting (moose, deer, bear). White spruce, *Picea glauca,* is the most abundant species and was therefore chosen for sampling efforts. Witches' hair (lichen), *Alectoria sarmentosa,* was also sampled at one site. Snow samples were collected at the same time (see Blais et al, this volume). Samples were collected in March 1997 to 20 km in all directions from the ASWTC, but efforts were focused in the easterly direction because Environment Canada weather information indicated winds out of the west during the days immediately after the October 1996 PCB release. Further samples were collected in July 1997 and March 1998. Samples were frozen (-50°C) until extraction. Needles were manually separated from twigs and 5 g subsamples were ultrasonically extracted in acetone/hexane (20/80), solvent exchanged to hexane and then cleaned up using acid silica gel/activated silica gel followed by elution through Florisil SPE tubes. The extract was concentrated to a final volume of 1.0 mL. A 200 μL sample aliquot was shipped to the National Laboratory for Environmental Testing, National Water Research Institute, Burlington, Ontario, for GC-ECD analysis. Analysis was done on an HP 5890 Series II GC with electron capture detection and a 30 m x 0.25 mm; 0.25 μm DB-5 capillary column (J&W Scientific). The instrument was calibrated using a 6 point calibration curve ($r^2 > 0.99$), from which 2-point curves most closely bracketing the sample concentration ranges were used for quantitation.

RESULTS AND DISCUSSION

PCB data were blank-subtracted on an individual congener basis prior to calculating ΣPCB values (Table 1). The data show a clear relationship of ΣPCB with distance and direction from the ASWTC. The prevailing winds on the days immediately surrounding the process gas release were from the west. Site 13B (1) and (2) are method duplicates (avg = 33 ng/g_{ww}, % deviation from average = 7.5); Sites 8B1-3 and 8A1-3 are site triplicates (8B avg = 6.9, sd = 0.99; 8A avg = 3.0, sd = 3.4). Sites 13B and 8B are located within 6 km E-SE of the incinerator, whereas Site 8A is located 9.5 km NW. Thus, the resolution of the data does not allow concentration trends to be distinguished greater than 5 km from the incinerator. Note that the lichen sample from site 15B, the nearest site downwind of the incinerator, has 3x greater ΣPCB than the spruce needles at the same site, although the congener pattern is identical (Figure 1). Lichens offer many advantages over conifer needles for such biomonitoring, such as: they lack a cuticle and its associated wax-like components, which can cause substantial analytical interferences in PCB quantitation; they provide a much greater surface area per unit mass for adsorption of lipophilic

Table 1. Summary of ΣPCB in samples analysed from 1997 sampling. The data is organized in order of distance from the ASWTC in order to highlight the effect of incinerator vicinity on ΣPCB concentration.

Sampling Date	Site i.d.	Distance from ASWTC (km)	Direction	ΣPCB (ng/g_{ww})
Mar-97	*Site 15 B4 (lichen)*	0.7	E	285
Mar-97	*Site 15 B2*[1]	0.7	E	91
Mar-97	*Site 7 A*	0.9	W-NW	10
Jul-97	*Site 7 A*	0.9	W-NW	21
Mar-97	*Site 13 B (1)*[2]	1.6	E-SE	30
Mar-97	*Site 13 B (2)*	1.6	E-SE	35
Mar-97	*Site 14 B*	1.6	E-SE	37
Mar-97	*Site 17 B*	1.8	NE	39
Jul-97	*Site 17 B-BL*[3]	2.1	NE	19
Mar-97	*Site 10 B*	3.6	E-SE	5
Mar-97	*Site 6 A*	3.9	W-SW	9
Jul-97	*Site 6 A*	3.9	W-SW	15
Mar-97	*Site 8 B1*	5.5	E-SE	6
Mar-97	*Site 8 B2*	5.5	E-SE	8
Mar-97	*Site 8 B3*	5.5	E-SE	7
Jul-97	*Site 8 B*	5.5	E-SE	10
Mar-97	*Site 11 A*	5.7	SE	6
Mar-97	*Site 18 B*	6.2	NE	2
Mar-97	*Site 7 B*	9.4	E-SE	4
Mar-97	*Site 8 A1*	9.5	NW	7
Mar-97	*Site 8 A2*	9.5	NW	1
Mar-97	*Site 8 A3*	9.5	NW	2
Mar-97	*Site 5 A*	10.4	W-SW	2

[1]Sample i.d. designating a site-duplicate.
[2]Sample i.d. designating a laboratory method duplicate (sample split).
[3]BL = boat launch area at Chrystina Lake. July sample collected at southeast corner of lake, wheras site 17B is located near southwest corner of lake.

substances from the air; they receive their nutrients and water from the atmosphere, thus are well suited to monitoring airborne contaminants (Muir et al. 1993). For Site 7A, the nearest upwind site, the congener pattern in the needles is weighted in the tetra to hexa congeners, and ΣPCBs are approximately 10 to 20% of the concentrations measured at the downwind site. Differences between the congener patterns in the March and July samples at Site 7A may be explained by temperature effects on K_{OA} and K_{PA}, and needle growth and its duration of exposure.

The presence of the similar higher chlorinated congener pattern in samples from sites 13B, 14B, 15B and 17B, and the lack of this pattern in the sites within 3 km to the west of the incinerator, suggests that this PCB congener mixture is representative of the emissions in October 1996. Confirmation that this PCB pattern matches that of the October 1996 release may not be complete until the ASWTC site monitoring data is publically released. Due to the low temperature and wind direction at the time of the release, the less volatile congeners were primarily deposited within 2-3 km east of the ASWTC. PCB patterns measured at other sites, such as at Site 7A, 0.9 km west, are likely more representative of long term, fugitive and stack-gas emissions.

CONCLUSIONS AND FUTURE RESEARCH

Results from the 1997 sampling indicate that conifer needles provide a good relative method for determining the extent of regional contamination due to fugitive and accidental emissions from a hazardous waste incinerator. The PCB congener-specific data assist in determining source or time-specific emissions, i.e. the presence of higher chlorinated congeners only downwind and < 3 km from the incinerator are likely indicative of the October 1996 release.

From the single sample of lichen reported here, and literature information (Muir et al 1993), it appears that lichen (Witches' hair) will make as good or better indicator than needles. This is likely due to its increased surface area and lower amounts of interferring co-extractants - e.g. terpenes. Samples of witches' hair lichen were collected in March 1998 at the same sites, as well as new sites in a NE to SE quadrant from the ASWTC.

The analytical resolution of the PCB data for the 1997 data did not allow concentration or congener pattern trends to be distinguished beyond 5 km from the incinerator. We anticipate that lichen samples collected in March 1998 will allow greater sensitivity for evaluating effects of distance from the ASWTC.

ACKNOWLEDGMENTS

The authors would like to thank Linda Kimpe, Nola Low, Sean Backus, Mike Comba and Environment Canada for technical, analytical and financial support for this project.

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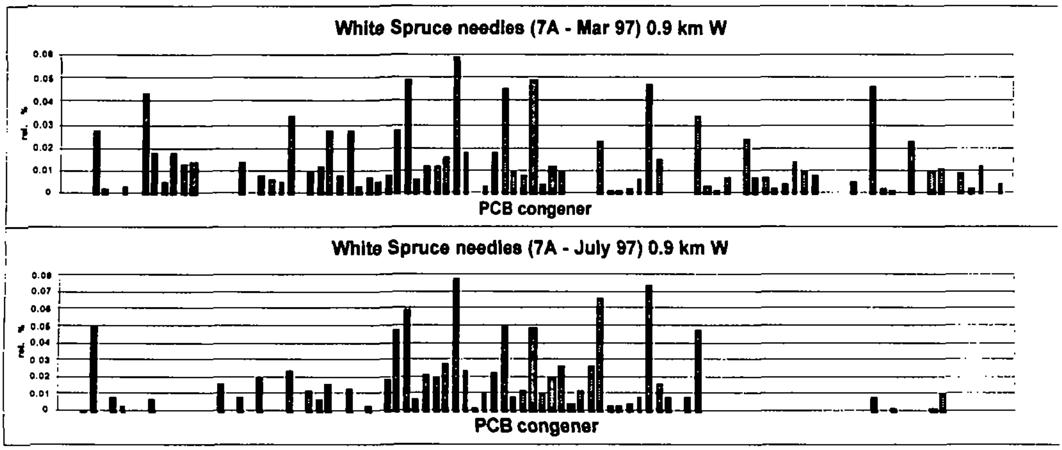

Figure 1. PCB congener patterns from March and July spruce needles from Site 7A, 0.9km W of ASWTC., up-wind during the October 1996 release.

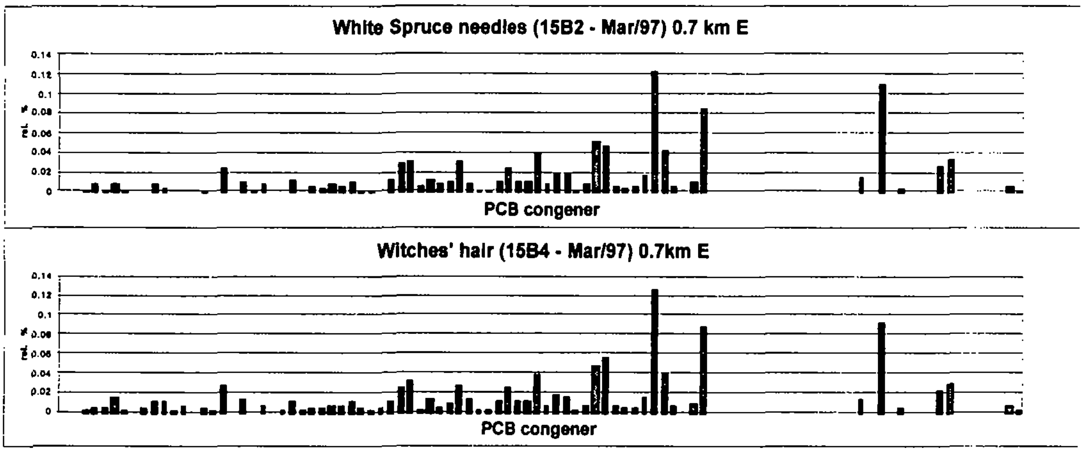

Figure 2. Spruce needle and lichen samples from Site 15B, 0.7 km E of the ASWTC incinerator - down-wind during the October 1996 release. ΣPCB concentrations: 90 and 290 ng/g_{ww}, respectively.