Historic PCB Congener Profiles in an Ice Core from Svalbard, Norway

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Introduction

Polychlorinated biphenyls (PCBs) are found throughout the Arctic, but have higher concentrations in Eurasia than in North America. The total PCB content in polar bear adipose tissue from Svalbard, Norway, for example, is greater than in Canadian or Alaskan bears.[1] Air PCB concentrations are also higher on Svalbard than in the Canadian Arctic.[2] Atmospheric contaminant transport to Svalbard results from nearness to sources and climatic effects. Svalbard is closer to potential sourcesbecause the human population is much higher in arctic regions of Scandinavia and Russia than in North America.[3] Since PCBs have been banned from further productionor open use western Europe, Japan, the USA and Canadasince the 1970s, declining inputs to Svalbard and elsewhere might be expected. But the effect of the bans is not well known because there is very limited PCB temporal trend data for the European Arctic.[2] Svalbard is also affected by the North Atlantic Oscillation (NAO), a seasonal and long-term shift in atmospheric pressures over the North Atlantic that influences winds and atmospheric distribution patterns. It has changed since 1980, resulting in greater transfer of airborne contaminants from Eurasia to the North Atlantic region that includes Svalbard.[4]

Our goal is to identify historic PCB amounts and congener patterns in an ice core from Svalbard in an effort to identify types of sources and the characteristic PCB congeners that remain in ice over time. PCBs were not produced on Svalbard. Whether or not they were used in any of the five coal-mining communities located there is not known.

Methods and Materials

In April 2000, a 60-meter ice core was drilled near the summit of Lomonosovfonna (elev. 1250 m.a.s.l.), the highest ice cap in Eurasia (figure 1). Two snow/firn samples from what would become the top meter of ice representing the previous two winters came from a pit next to the bore hole. The core was analyzed for electrical conductivity and density in the field, resulting in estimates of water equivalent deposition. It was dated based on accumulation since the ^{137}Cs input peak in 1963. These dates are in reasonable agreement with the Nye model using a water equivalent accumulation of ~0.5 m yr^{-1}. After being shipped to Tromsø, Norway, the upper 38 meters of the core were divided into 6 separate samples beginning at 1 meter depth. The 8 samples (2 snow/firn + 6 ice) were melted in stainless steel cans, and contaminants were extracted by pumping at 200 mL min^{-1} through pre-cleaned XAD-2 in Teflon tubes. In a clean room [Environment Canada, Burlington] PCBs were extracted by elution of XAD-2 in a chromatography column with methanol and dichloromethane. These were combined, carefully evaporated and exchanged to hexane. PCBs were separated from polar compounds by elution through silica-gel with hexane. Results for eighty PCB congeners are reported here. PCB data were blank corrected using results from XAD columns taken to the field, unused, and returned with samples. Total PCBs in blanks represented no more than 20% of PCBs in samples.

We used fuzzy c means clustering (FCM) to identify and map 2 different congener patterns in this suite of samples.[5] The FCM cluster centroid compositions were then compared to Aroclor mixtures in an effort to identify parent materials or mixes. While it is possible that Aroclors were not the source of PCBs observed, they have similarities to other PCB mixtures.[6]

Results and Discussion

Some variability is apparent between deeper layers in the core and surface snow/firn from the two most recent winters (figure 2). The peak ∑PCB concentration, ~748 pg L^{-1}, occurred over three core layers between 1972 and 1998. The most recent of these three layers (1995 – 1998) has a lower concentration than layers below, indicating that concentrations may have been dropping before 1995 which would be consistent with surface concentrations that are about half the peak value. The trend in our top two samples does not suggest a continuing decline. Average ΣPCB concentrations in spring snow in 2001 at Ny-Ålesund, about 110 km to the WNW and 830 meters lower elevation, were 742 pg L^{-1}, similar to our peak value.[8] Villa et al. noted ΣPCB up to 1400 pg L^{-1} into the early 1990s from an alpine glacier in Italy, nearly double our peak amount. [9] But their value after 1993, ~450 pg L^{-1}, is similar to our values after 1998.

Our analysis of this core did not reach a background concentration by 1938, suggesting that summer melt had carried some PCB downward in the core. However, this effect is limited by burial of seasonally refrozen melt so the PCB profile is protected from downward movement once ice layers have formed. The melt index for this core suggests that dating resolution is about 5 years.[7]

FCM of the congener profile results indicated a binary (2 cluster) system with little gradation between them. Surface samples are dominated by PCBs 101, 110, 118, 153+132+105 and 138+163 and are associated with Fuzzy Cluster 2 (FC2, Table 1). The five samples below (dating back to 1951), exhibit a lighter pattern, dominated by PCB 52, 84, 95, 110 and 118 (FC1, Table 1). Only the bottom sample (1938 – 1951) exhibits a congener pattern intermediate between the two “end-member” patterns (Figure 2, Table 1) indicating that it may be a mixture. FC1 was most similar to Aroclor 1248, and FC2 most similar to Aroclor 1254, although neither is a good match.

All samples here are dominated by pentachlorobiphenyls. Blais et al. noted that PCB homologue concentrations in snow varied with elevation, with less volatile penta-CB congeners favorably condensing from the atmosphere at higher temperatures at altitudes below 1400 m.a.s.l., and more volatile congeners condensing at the colder temperatures of higher altitudes.[10] Observations elsewhere follow this trend.[9] This study also supports the Blais et al. observations suggesting that the lower molecular mass congeners tend to remain in the gas phase at Svalbard.

References

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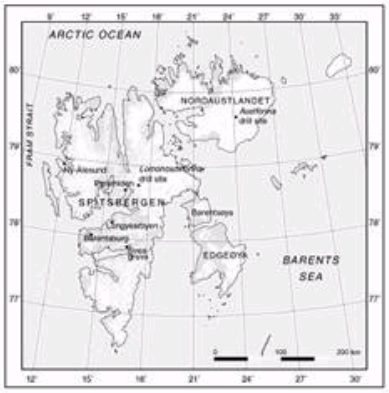

Figure 1. Map of Svalbard and the

Lomonosovfonna drill site.

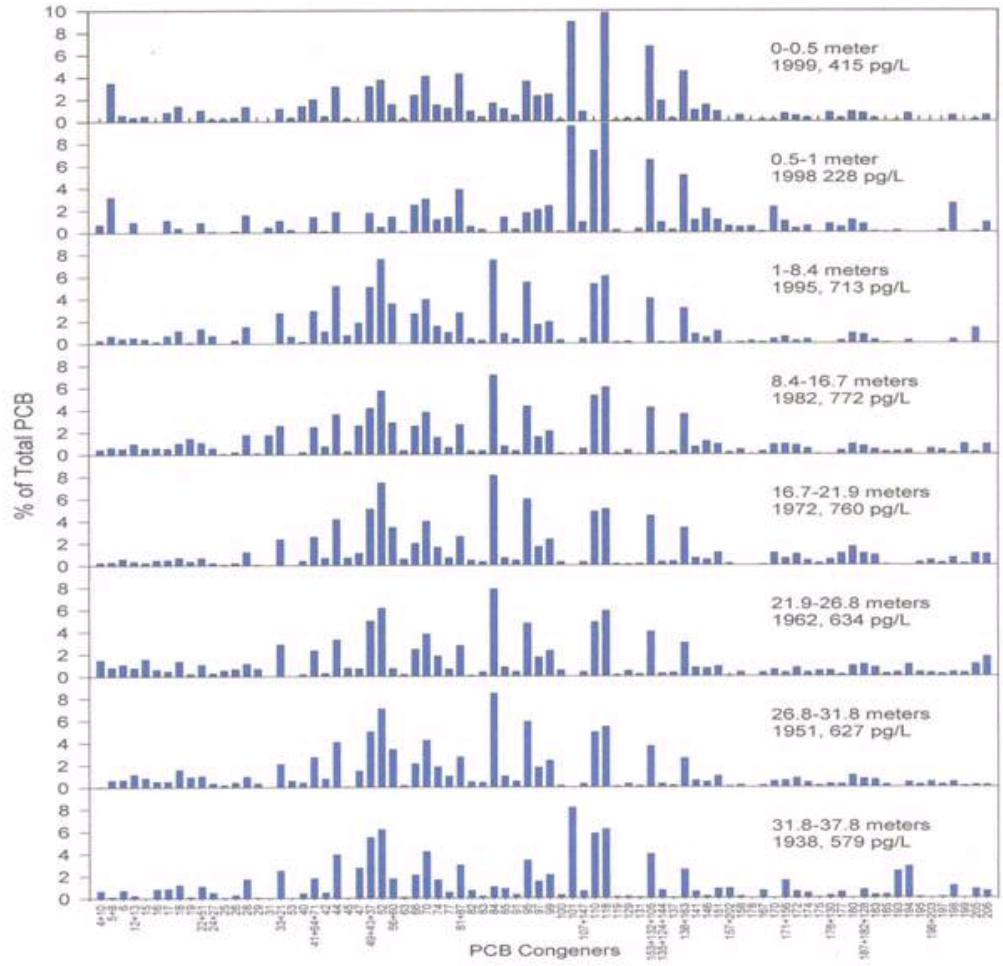

Figure 2. PCB congener profiles from the 2000 Lomonosovfonna ice core. Core depth ranges, deepest years, and total PCB are indicated.

Table 1. Fuzzy Cluster Memberships

Sample	FC1	FC2
0-0.5 m	0.115	**0.885**
0.5-1 m	0.1014	**0.8986**
8.40 m	**0.9675**	0.0325
16.65 m	**0.9475**	0.0525
21.86 m	**0.9728**	0.0272
26.82 m	**0.9388**	0.0612
31.81 m	**0.9778**	0.0222
37.78 m	0.3178	**0.6822**