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Elevated PCB Contamination of Coastal Plants Near Polynyas in the High Arctic

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During the Arctic Light Trans-Ellesmere Island Ski Expedition, coastal samples of saxifrage (*Saxiofraga oppositofolia*) were collected from 81 to 77 °N to measure the long-range transport and deposition of cesium (France et al. 1993), lead (France and Blais in prep.) and organochlorines (R. France and D. Muir, unpubl. data) to this region of the High Arctic. Preliminary analysis of sporadically collected lichens had revealed the most abundant organochlorine (OC) contaminants on Ellesmere Island to be toxaphene, S-PCBs (sum of polychloronated biphenyls), S-HCHs (sum of hexachlorocyclohexanes), S-CHLOR (sum of chlordanes), S-DDT (sum of DDT isomers) and S-CBz (sum of chlorobenzenes) (R. France and D. Muir, unpubl. data). Saxifrage transect data showed that although all these OCs displayed northward decreases in their concentrations which matched those of cesium in the plants, the relationship for S-PCB had the lowest slope and largest amount of variance left unexplained. Cesium activity was itself thought to be a convenient estimator of the cumulative precipitation and deposition of southernly originating trace contaminants.

Several studies have likewise noted dissimilar regional patterns in PCB deposition and uptake compared with those simultaneously determined for other OCs (e.g. Carlberg et al. 1983; Norstrom et al. 1988; Larsson and Okla 1989; Larsson et al. 1990; Muir et al. 1993). The purpose of the present study was to investigate the somewhat divergent pattern of PCB uptake by saxifrage on Ellesmere Island. These represent some of the first data concerning PCB concentrations in vascular plants from anywhere in the High Arctic.

Second to the latitudinal range, the most obvious difference that existed among sampling sites was whether or not they were situated beside polynyas. Polynyas are annually recurring areas of open water surrounded by ice that are kept from freezing by the combined effects of wind, tidal fluctuations and upwellings (Sterling and Cleator 1981), and are of critical importance in providing winter refugia for marine mammals and as spring staging grounds for migrant birds (e.g. Sterling and Cleator 1981; France and Sharp 1992).

Proximal association with polynyas was thought to be of putative importance to plant bioaccumulation due to the high water-air transfer volatilization of PCBs (e.g. Anderson and Parker 1990; Achman et al. 1993) which has been suggested to exacerbate the deposition from long-range sources at coastal compared to inland sites in Sweden through the localized effects of seaspray aerosols (Larsson and Okla 1989). My expectation was therefore for a similar pattern to exist in the High Arctic of Ellesmere Island such that saxifrage located near polynyas would exhibit higher tissue residues of PCBs than those from plants collected elsewhere.

MATERIALS AND METHODS

Saxifrage samples were obtained from 7 coastal sites along a transect from 81 to 77 °N. Particulars concerning site selection, location and sample collection are described in France et al. (1993). Two of the sampling sites were situated nearby the small polynyas of Flagler Bay and Makinson Inlet (France and Sharp 1992). In addition to latitude and presence of polynyas, the following information was documented for each sampling site: distance from coast, elevation, substrate typology, site topography, plant water content, windbreaks or obstructions within 100m, surrounding area characteristics (1000m) and site orientation. Triplicate samples were analyzed for PCBs using procedures described in Muir et al. (1993).

RESULTS AND DISCUSSION

The average S-PCB concentration of saxifrage from the two polynya sites was found to be significantly higher (t-test, $p < 0.05$) than that of plants from the 5 other non-polynya sites (Fig. 1). When S-PCB residues are expressed in relation to cesium activity from France et al. (1993) to standardize for inter-site differences in the long-range northward transport of trace pollutants, the increased PCB contamination of saxifrage from polynya sites remained evident. Elevated S-PCB concentrations for saxifrage from polynya compared to non-polynya sites were due to higher abundances of all measured homologs. The only physical site variable that was found to be significantly different between the two data groupings was the water content of plant samples:

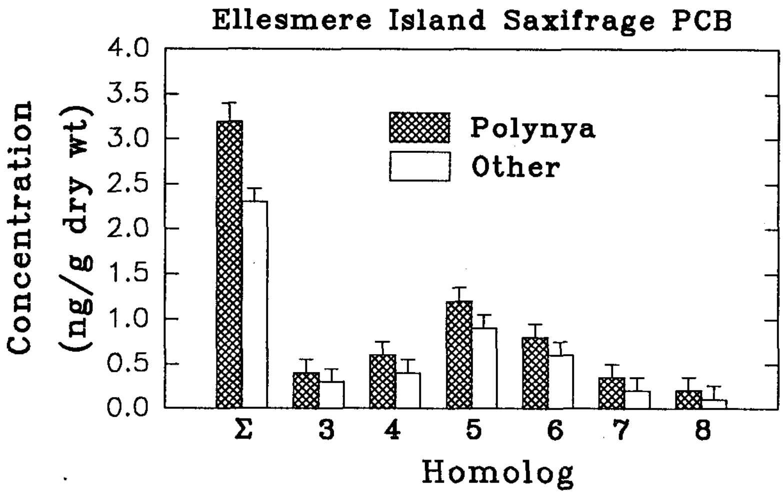

Figure 1. Concentrations of summed PCBs and individual homologs (ng/g dry wt) of saxifrage samples collected from polynya and other sites on Ellesmere Island (data are means ± SEs).

10.6 ± 1.4 % for polynya sites and 7.9 ± 1.0 % for non-polynya sites.

The higher S-PCB concentration in saxifrage located nearby permanently open bodies of water on Ellesmere Island is therefore in agreement with the expectations predicted from Larsson and Okla's (1989) work on fallout in Sweden.

There is no guarantee, however, that elevated toxicant concentrations will always exist for plants near coastal water. For example, it is possible that localized meteorological differences may supersede any effect of volatilization from surface waters. Data from Larsson and Okla (1989) indicate that site-specific differences in the amount of precipitation can produce differences in PCB fallout of an even greater magnitude than that believed to be produced through coastal seaspray effects. These authors supposed that such locally produced clean precipitation could wash-out any long-range effects and thereby obscure demonstration of systematic regional patterns in PCB deposition.

For Ellesmere Island, Gregor and Gummer (1989) determined that the coastal oasis of Alexandra Fiord, located nearby the Flagler Polynya, was the cleanest of 12 Arctic sites with respect to snow PCB concentrations. The loosely packed snow found at Alexandra Fiord implied that the area was receiving larger quantities of locally induced precipitation than the other sites. This was supposed by Gregor and Gummer (1989) to result in a dilution of the concentration of pollutants transported to the Arctic from long-range sources so that the PCB content of the snow at Alexandra Fiord was only 2 % of that found at the Agassiz Ice Cap located 175 km further to the north on Ellesmere Island. Other coastal sites in the Canadian Arctic were also considered to be less polluted compared to inland or snowbound sites.

It would be erroneous, however, to simply regard polynyas as being typical arctic coastal sites. Polynyas, through the act of maintaining open water at just above freezing despite being surrounded by substantially colder winter air, create an enormous thermal vapour flux which might be expected to produce a localized microclimate very dissimilar from that for coastal regions that are ice-bounded for up to 10 months of the year (Sterling and Cleator 1981). Condensation of this vapour in the form of snowfall might explain why saxifrage collected from near the two polynyas in the present study were significantly wetter than plants obtained from other areas.

Although it had been the intention of the present sampling design to collect only plants growing on exposed windswept ridges or beaches that were free of snow for much of the year, this was easier to accomplish in early May at the start of sampling when snowfall was abundant than it was in late June towards the end of the Expedition when snowmelt was proceeding and therefore purposeful selection of snow-free sites made more problematic. The increased water moisture of plants from the polynya sites may imply a greater supply of snow cover to such locations. This is important because accumulation of cesium has been shown to be reduced for arctic vegetation collected from such mesic sites (e.g. Hutchison-Benson et al. 1985) presumably as a result of the protective cover of snow. Because PCB uptake by plants proceeds through foliar assimilation due to atmospheric transfer rather than by root relocation, it may be inferred that the higher snow associated with polynyas could likewise produce lower toxicant residues in plants growing there. At the same time, because much of the High Arctic can be regarded as a desert, any increased moisture is very beneficial to plant growth and system productivity.

Despite the possibility of a resultant growth dilution of saxifrage near polynyas due to increased moisture present in the area, the observation that S-PCB concentrations were still higher than in inland sites implies an overwhelming influence of increased volatilization at polynyas.

A high percentage of PCBs in seawater are absorbed to suspended particles at high latitudes (Tanabe et al. 1983). Generally low concentrations of suspended particulate matter in the arctic water column leads to low rates of sedimentation and therefore increased residence times of particulate-reactive chemicals. As a result, there is normally little chemical transformation that occurs when PCBs and other OCs are transferred between air, snow and seawater compartments (Hargrave et al. 1988). In contrast, in situations of high productivity such as may occur under fast-ice, it is the higher chlorinated PCBs that will be preferentially removed from the polar water column due to increased sedimentation of particles (Tanabe et al. 1983). This may explain why plants near open water polynyas have elevated concentrations of high chlorinated homologs compared to plants located near ice-bound shorelines where sedimentation and removal of these homologs might be higher. The dichotomy between the two locations in terms of low chlorinated homologs is still, however, unexplained by this scenario.

In the end, we are left with some as yet unknown factor such as perhaps a difference in the rate of volatilization between polynya and non-polynya sites which might explain the difference in PCBs accumulated by respective proximal terrestrial plants. Although volatilization is dependent on water temperature and therefore might be expected to be lower or absent in the Arctic (Iwata et al. 1993), the rapid wind movements often associated with keeping the water of polynyas ice-free may serve to maintain a role of these areas as regional sources rather than as sinks for PCBs. Given the much longer time period of water-air volatilization which can take place at polynyas compared to other, typically ice-bound arctic coastlines, the increase in low chlorinated, high volatility PCB homologs of saxifrage from near polynyas might simply be a result of the presence of such PCB homologs in the openwater followed by their ongoing removal and overland dispersal.

Obviously, the previous hypotheses will remain only speculations until detailed sampling of PCB transfers is undertaken in polynyas. Given the acknowledged importance of such regions to sustaining productivity in the High Arctic (e.g. Stirling and Cleator 1981; France and Sharp 1992), direction of environmental sampling effort to polynyas would be a profitable future direction worth pursuing further.

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