



## Northern Contaminants Program

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in the fish and wildlife species important for the traditional/country food diets of northern Aboriginal peoples. Early studies indicated that a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, were nevertheless reaching unexpectedly high levels in the Arctic ecosystem.

The first phase of the NCP (NCP-I) (1991-1996) focussed on gathering the data required to determine the levels, geographic extent, and sources of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. Results from NCP-I were published in 1997 in the first *Canadian Arctic Contaminants Assessment Report* (CACAR).

During its second phase, which ran from 1998–2003, the NCP focussed on:

- ▶ impacts and risks to human health that may result from current levels of contaminants in key Arctic food species
- ▶ temporal trends of contaminants of concern in important indicator Arctic species and air
- ▶ improved education and communications activities involving northern communities
- ▶ efforts to control contaminant production, use and disposal at the international level

NCP-II addressed these issues under a number of subprograms: human health; monitoring the health of Arctic peoples and ecosystems and the effectiveness of international controls; education and communications; and international policy. The results of the research and related activities conducted during NCP-II are summarized in the *Canadian Arctic Contaminants Assessment Report II* (CACAR II) series of reports, which was released in March 2003. CACAR II is a comprehensive assessment of the last five years of research and related activities on northern contaminants funded under the NCP.

Five fact sheets have been developed, one for each of the CACAR II reports. These fact sheets provide a snapshot of many of the significant NCP research results described in each report.

## Canadian Arctic Contaminants Assessment Report II

# Occurrence, Trends and Pathways in the Physical Environment

The CACAR II technical report *Contaminant Occurrence, Trends and Pathways in the Physical Environment* presents the results of research on the three areas of study identified at the start of NCP-II as priorities for the Arctic biological environment:

- ▶ temporal trends identification
- ▶ physical chemical studies
- ▶ other chemicals of potential concern

After five years of research in these priority areas, significant and useful progress in our understanding of contaminants in the Arctic physical environment has been made. There have also been some unexpected discoveries. This fact sheet describes some of the key research outcomes.

## Persistent Organic Pollutants

**Global and regional gridded emissions inventories for some Organochlorine pesticides such as Hexachlorocyclohexane and toxaphene.** In most parts of the world technical HCH, a mixture of mostly  $\alpha$ -,  $\beta$ - and  $\gamma$ -HCH isomers, was replaced by Lindane (almost pure  $\gamma$ -HCH) during the 1970s and 1980s. This decline in the global use and emissions of technical HCH has resulted in declines of  $\alpha$ - and  $\beta$ - HCH in Arctic air, results that are helping to refine global mass balance models. These results provide strong evidence that international action to reduce global POPs use can have a direct impact on levels in the Arctic. Lindane use, particularly as a seed treatment for corn and canola, continues to supply the Arctic with fresh  $\gamma$ -HCH. Several countries that have been major consumers of lindane, including Canada, have recently taken steps to end the use of lindane and this should result in reduced emissions. Asia remains a significant source of  $\gamma$ -HCH.



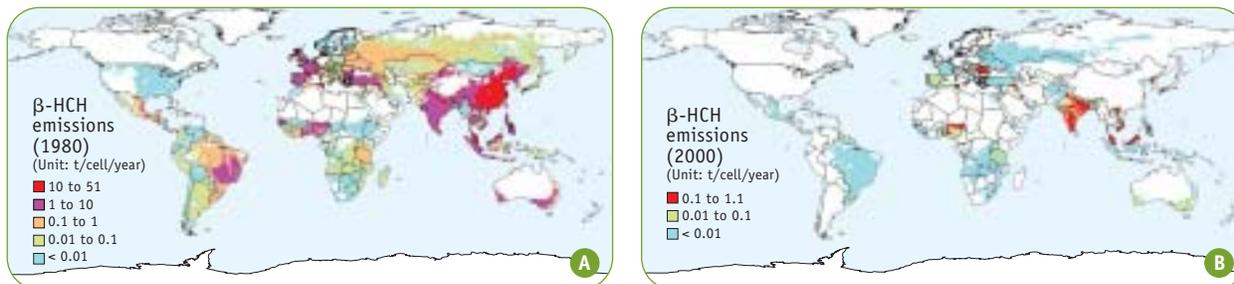


Figure 1: Global estimates of  $\beta$ -HCH emissions for 1980 (A) and 2000 (B).

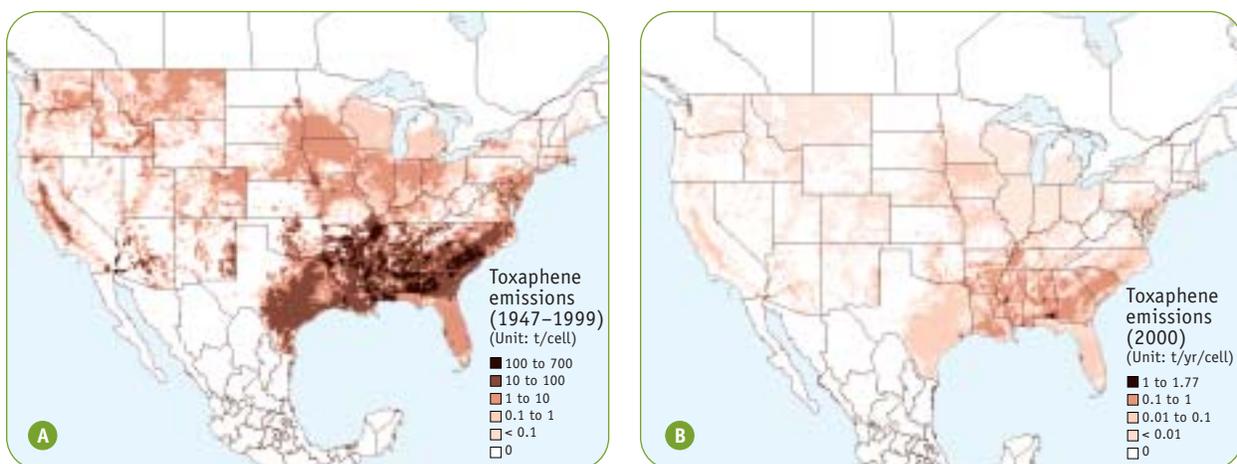


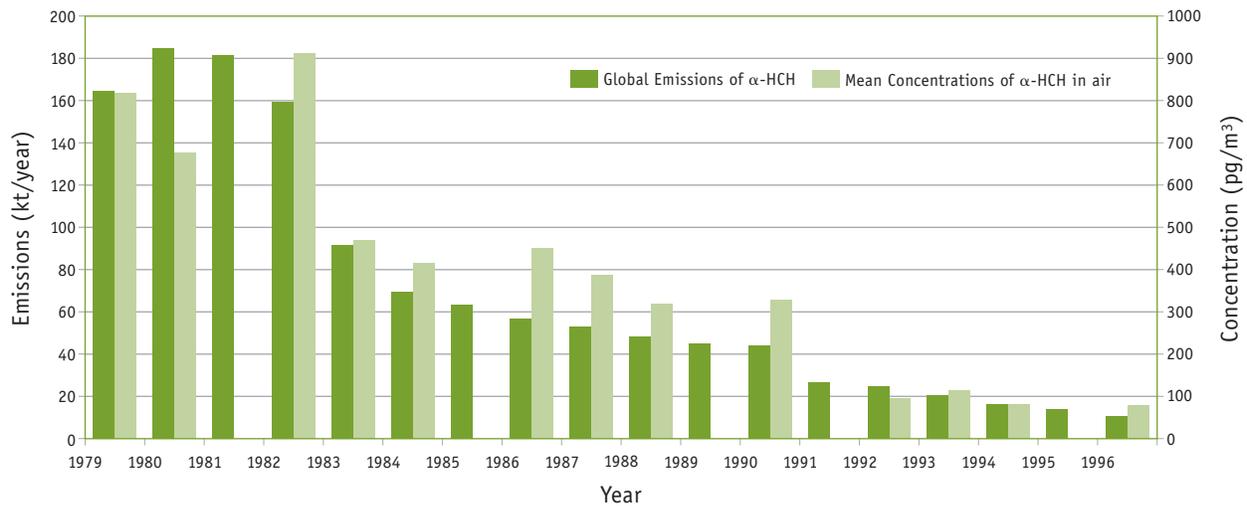
Figure 2: Total toxaphene emissions in the United States on a  $1/4^\circ$  longitude X  $1/6^\circ$  latitude resolution grid system. a) 1947–99, b) 2000. Around 90% of total emissions in 2000 are from the southeastern part of the United States.

Soil residues of organochlorine pesticides from past and present use continue to supply these contaminants to the atmosphere. The exchange of toxaphene between soil and air has been well described based on such physicochemical properties as partitioning coefficients and vapour pressure. An emissions inventory based on distribution records for toxaphene in the United States suggests that 29 kt remains in agricultural soil. Despite its deregistration two decades ago, toxaphene volatilization from soil residues contributed 360 t of toxaphene to the atmosphere in 2000. The source shift from direct emissions to soil residues is reflected in toxaphene congener profiles being measured in Arctic air.

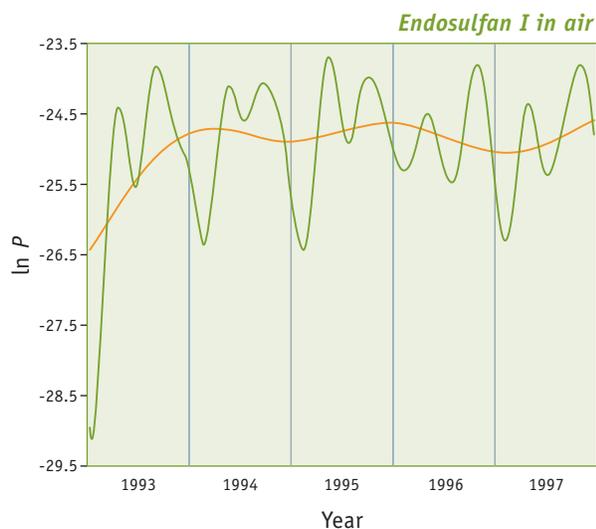
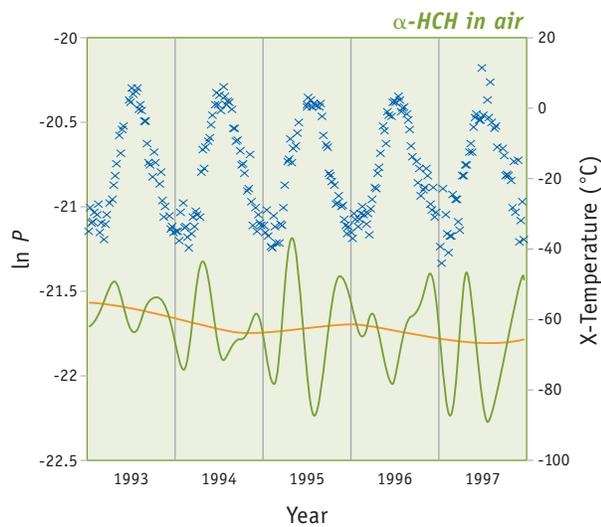
**Decreasing atmospheric trends in most “legacy” persistent organic pollutants (POPs) over the last 5-10 years.** Organochlorine POPs measured in air at Alert include, from most to least abundant,  $\Sigma$ HCH and HCB >  $\Sigma$ PCB >  $\Sigma$ chlordanes > dieldrin >  $\Sigma$ DDT. The concentration of most POPs, which were reviewed in the first CACAR and which have received international attention through the United Nations, have been declining in Arctic air. Observations at Alert, Nunavut, have confirmed this trend for PCBs, DDT, chlordane, and HCH. The isomer ratios for chlordane and DDT indicates that

the current sources are dominated by weathered soil residues, and that fresh applications of these pesticides are in decline. Spikes in isomer ratios, indicative of fresh pesticide, are also measured periodically suggesting occasional current applications in some places.

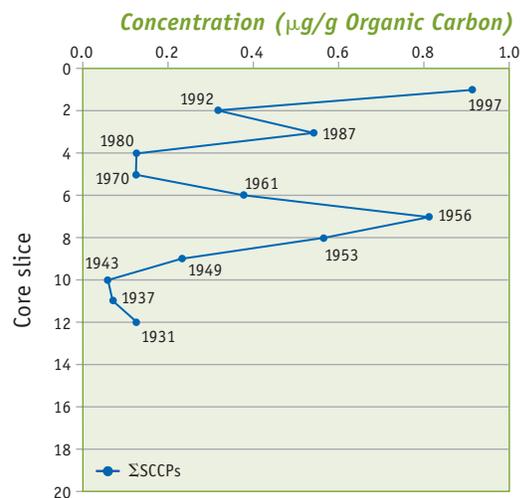
**The observation of “new chemicals” in the Arctic abiotic environment.** A new generation of POPs has been measured in Arctic air, seawater, and freshwater sediments including brominated flame retardants (in particular polybrominated diphenyl ethers, PBDEs), perfluorinated alkane compounds (PFAs), short chain chlorinated paraffins (SCCPs) and polychlorinated naphthalenes (PCNs). PBDE concentrations in ringed seal are rising at such a rate that they could soon reach the levels seen for some PCB congeners. Endosulfan, trifluralin and methoxychlor, currently used in the circumpolar countries, were also detected. Unlike most other organochlorine pesticides, concentrations of endosulfan in Arctic air have not declined over the last seven years. The detection of these POPs in the Arctic environment, far from potential sources, could provide the evidence needed to bring about global bans under the LRTAP and Stockholm conventions.



**Figure 3:** Long term and recent trends in concentrations of  $\alpha$ -HCH measured in Arctic air. Long term trends clearly reflect the reduction in use of technical HCH.



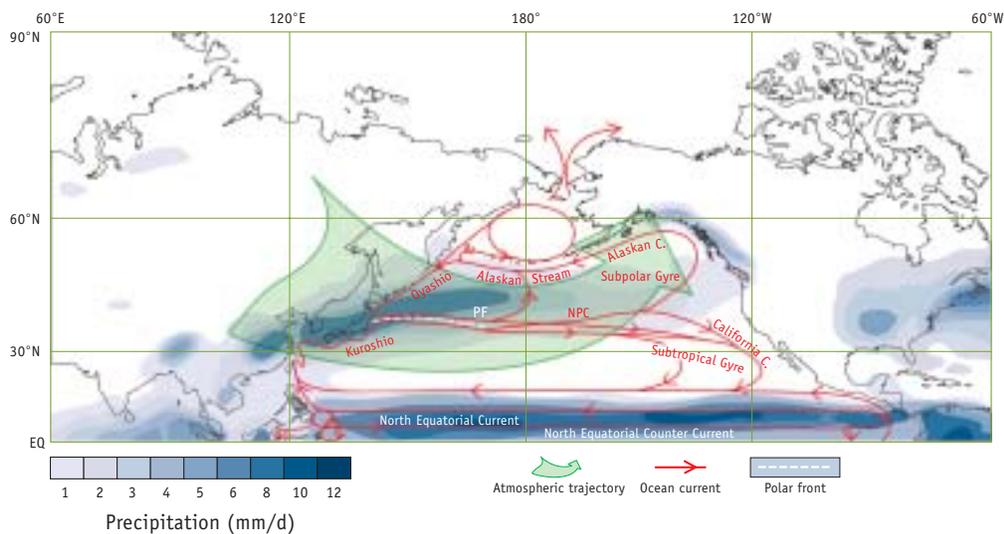
**Figure 4:** Trend and seasonal cycle of endosulfan I in air at Alert, Nunavut.



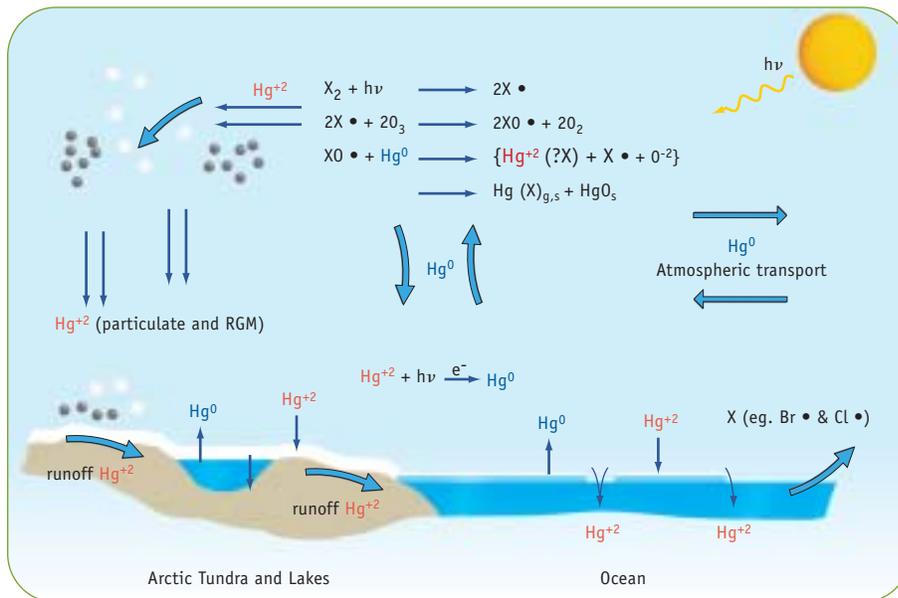
**Figure 5:** Historic profile of SCCPs in a lake sediment core from Devon Island, Nunavut.

### Identification of a dominant oceanic pathway for $\beta$ -HCH.

It has been well established that  $\alpha$ -HCH is transported to the Arctic through the atmosphere as a classic example of cold condensation. As such, latitudinal trends in marine  $\alpha$ -HCH display increasing concentrations from south to north with the highest concentrations in the Arctic Ocean. Concentrations of  $\beta$ -HCH, however, are higher in the North Pacific Ocean than they are in the Arctic. Most of the  $\beta$ -HCH originating in Asia appears to have been deposited in the north Pacific Ocean and then delivered to the Arctic Ocean through the Bering Strait. These observations are consistent with  $\beta$ -HCH having a lower Henry's law constant and being washed out of air before it arrives in the Arctic. The result is a delay in the transport of  $\beta$ -HCH to the Arctic Ocean. This hypothesis, if confirmed, implies that other persistent contaminants that partition strongly into water or onto particles could be delivered to the Arctic by ocean currents.



**Figure 6:** Long term and recent trends in concentrations of  $\alpha$ -HCH measured in Arctic air. Long term trends clearly reflect the reduction in use of technical HCH.



**Figure 7:** While the mechanism of MDEs remains poorly understood, they have been associated with drops in ozone and increases in bromine oxide suggesting the involvement of these species in the atmospheric process.

## Heavy Metals

### **New insights into the atmospheric pathways, processes and environmental behaviour of mercury.**

Under NCP-II Canadian scientists discovered a phenomenon now known as mercury depletion events (MDE) wherein atmospheric mercury is converted from the gaseous elemental state to a more reactive form which is rapidly deposited on Arctic surfaces during polar sunrise. The atmospheric processes that lead to MDEs are still not completely understood. Observations to date, however, indicate that ultraviolet solar radiation,

ozone and marine derived species of chlorine and/or bromine play important roles. Since their discovery at Alert, MDEs have been observed at other sites throughout the Arctic, sub-Arctic (Kuujuaaraapik) and the Antarctic. Enhanced mercury deposition through MDEs could contribute significantly to high levels of mercury observed in Arctic biota. Mercury concentrations measured in dated sediment core samples from Arctic lakes suggest that mercury fluxes to the lake sediments have increased two to three- fold over the past century.

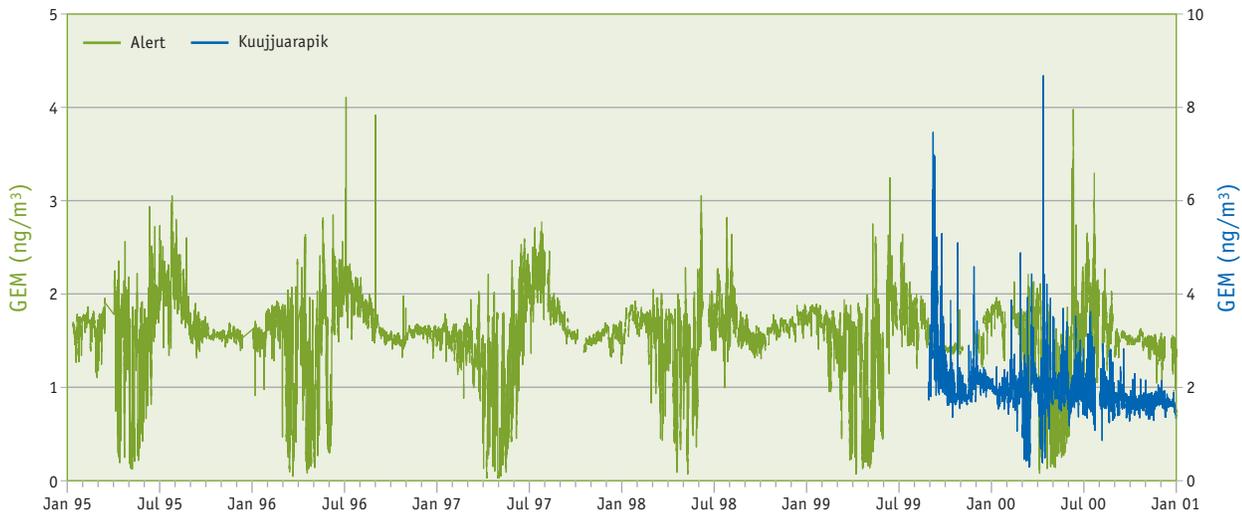


Figure 8: Gaseous Elemental Mercury (GEM) measurements (hourly averages) at Alert, Nunavut and Kuujjuarapik, Quebec.

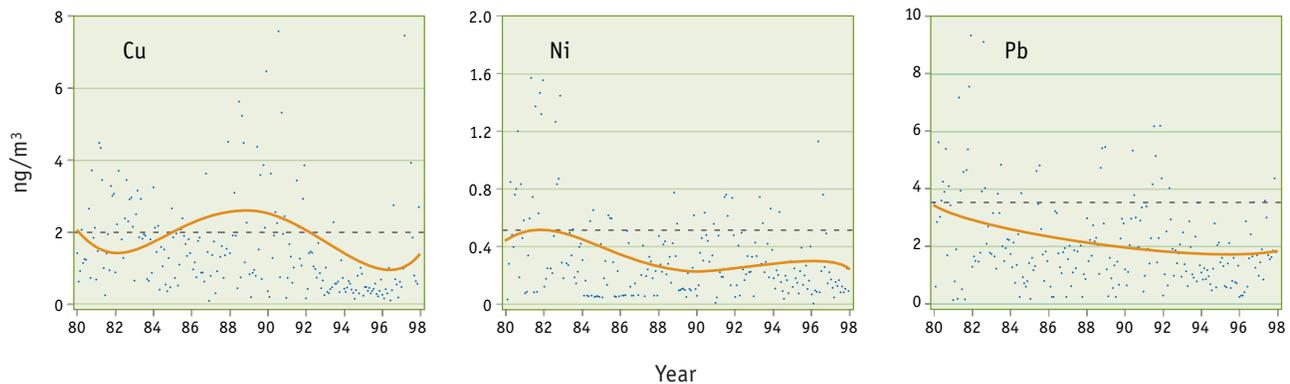


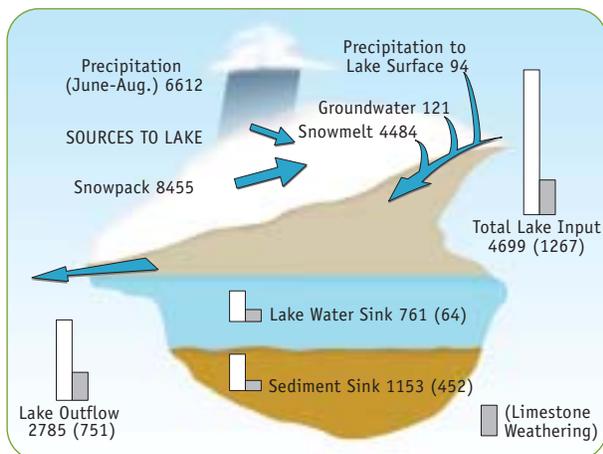
Figure 9: Metal concentrations over a twenty year record of weekly measurements at Alert, Nunavut.

**Relatively stable atmospheric concentrations of anthropogenically- derived heavy metals including copper, lead and nickel.** A large suite of elements have been measured in air at Alert over the past twenty years. These elements derive from both natural sources and anthropogenic sources such as smelter emissions. Anthropogenically-derived metals such as copper, nickel and lead displayed seasonal variations with maxima occurring during the winter months when the concentration of airborne aerosols is also greatest. Observations based solely on the winter data suggests a general decreasing trend in the concentrations of anthropogenically derived metals such as copper, nickel and lead.

### Processes and Change

#### **Continued development and refinement of contaminant process studies and models for POPs and mercury.**

In direct response to the needs arising from recent UNEP and UN-ECE protocols on POPs, a variety of simple models have been developed that allows the assessment of a chemical's overall persistence and spatial range using information on its physicochemical properties. These models take into account the influence of a chemical's distribution in environmental media on its ability to persist and be transported over long distances. Models of precipitation scavenging of contaminants from air have advanced our understanding of deposition processes. Snow's capacity to adsorb non-polar organic contaminants is dictated by specific surface area, which in natural snow varies over two orders of magnitude (approximately 0.01 to 1 m<sup>2</sup>/g).

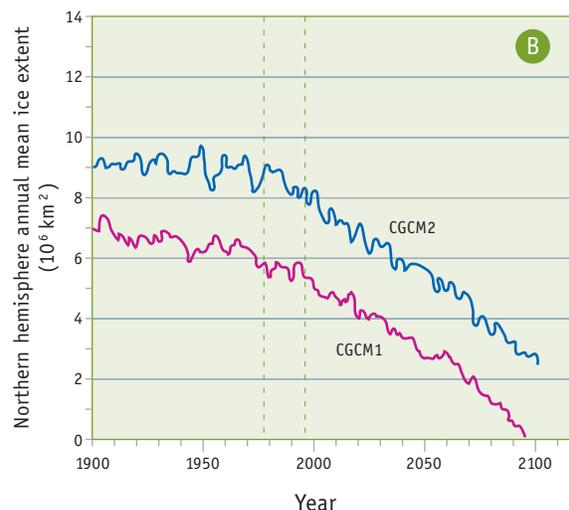
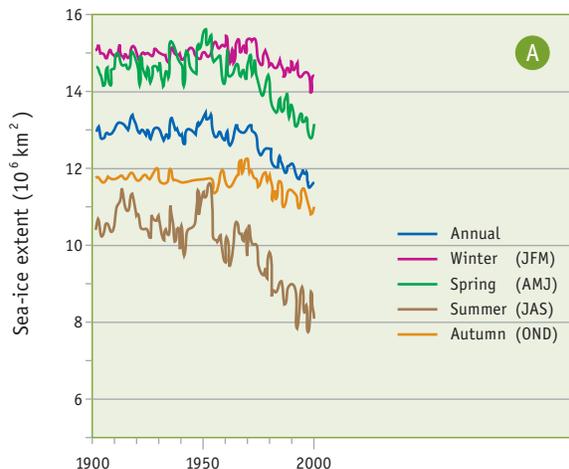


**Figure 10:** Mercury budget (mg) for Amituk Lake, Nunavut, Canada

Typically surface area decreases over a time scale of days as the snow ages leading to partial volatilization of semi-volatile contaminants.

In the Amituk Lake basin, most of the contaminant burden that is delivered from the seasonal snowpack melt is not retained, but instead conveyed to other terrestrial and marine systems. This was well demonstrated by a mercury mass balance. Surprisingly rapid rates of microbial decay have been estimated for several POPs in Amituk Lake and for HCHs in the Arctic Ocean. Microbial degradation in freshwater and marine systems is emerging as a dominant removal mechanism for many POPs.

**System changes brought on by climate variability or climate change, are having an effect on contaminant pathways.** The Arctic exhibited remarkable changes during the 1990s in its wind and weather patterns, ice cover, ice thickness, ice drift patterns, permafrost, hydrology, ocean-currents, precipitation and temperature patterns. These climate changes have significant consequences for contaminant pathways. For example, the diversion of Russian river inflow eastward into the Canada Basin and similar changes in ice drift trajectories during the early 1990s meant that associated contaminants also entered the Canada Basin thence to flow out through the Archipelago. Even more consequential and widespread changes are likely to occur in contaminant magnification pathways including cryoconcentration, attachment to organic-rich particles, and food-web biomagnification. Recent change in the Arctic's ice climate and ecosystem structure mean that a great deal of caution is required when interpreting contaminant trend data collected for the past couple of decades.



**Figure 11:** Time series from 1900 to 2000 of annual and seasonal sea-ice extent in the Northern Hemisphere. B) Model projections of annual mean sea ice extent for the Northern Hemisphere as simulated by CGCM1 (Canadian Global Coupled Model) and CGCM2 where the latter model differs from the former in mixing parameterization.

**For more information** on Occurrence, Trends and Pathways in the Physical Environment please consult the CACAR II series of reports, available from the Northern Contaminants Program Secretariat:

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