# CANADA'S NORTHERN CONTAMINANTS PROGRAM: MONITORING AND RESEARCH IN SUPPORT OF THE STOCKHOLM CONVENTION

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**Introduction**

Canada's Northern Contaminants Program (NCP) was created in 1991 in response to growing scientific evidence that man-made chemicals were present in the Arctic environment and people at concentrations of toxicological significance[1]. The program immediately implemented a surveillance and research program to better understand the sources and pathways responsible for transporting these contaminants to the Arctic; to assess contaminant concentrations in abiotic media, fish and wildlife across the Canadian Arctic; to evaluate ecosystem health risks; and to assess human exposure and health risks, particularly in the aboriginal population. The first phase of the NCP culminated with the publication of the Canadian Arctic Contaminants Assessment Report (CACAR I) in 1997[2,3]. These results represented a significant contribution to the foundational science that compelled the Arctic Council and the global community to act on persistent organic pollutants (POPs) and develop the United Nations Environment Programme's Stockholm Convention on POPs.

From the outset, NCP has been a key partner in the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP), which has resulted in effective integration of monitoring, research and assessment planning at the circumpolar scale. NCP monitoring and research plans, as described in strategic Blueprints[4], are designed to complement, and effectively implement, AMAP monitoring and assessment plans on a national level in Canada. Through the coordinating efforts of AMAP, geographically comprehensive and comparable datasets now exist for POPs throughout the circumpolar Arctic region. Working together with Aboriginal partners and the Indigenous Permanent Participants of the Arctic Council, the NCP and AMAP, along with other Arctic nations, are very effective at communicating scientific results on Arctic pollution to international policy makers. The Northern Contaminants Program has evolved over 23 years into a multidisciplinary science program aimed at conducting policy relevant monitoring and research on long-range contaminants, including POPs, that supports the implementation of the Stockholm Convention. The program includes long-term monitoring of POPs in arctic seawater, air, fish, wildlife and people for all 23 POPs listed in the Annexes of the Stockholm Convention (that occur in the Arctic), as well as those which are considered future candidate POPs. Long-term monitoring is complemented by research into pathways, processes, modeling and effects of contaminants in Arctic ecosystems, as well as ongoing research and assessment of human health risks. Implementation of its environmental and human health monitoring and research programs is accompanied by an extensive communication and outreach program to ensure that results are effectively used to inform the public and policy makers about issues surrounding Arctic pollution. Through these actions the NCP aims to reduce and wherever possible eliminate long-range contaminants such as POPs from the Arctic environment while ensuring the protection of public health from current risks.

This presentation will summarize current environmental monitoring and research activities under the NCP and provide a synopsis of the latest results with a discussion of future directions. Details about human health related activities and results will be presented separately and in conjunction with the AMAP presentation.

**Materials and methods**

The NCP is run by a Secretariat at Aboriginal Affairs and Northern Development Canada. Overall direction of the program, however, comes from an interagency Management Committee that includes representatives from federal and territorial government departments and northern Aboriginal organizations. Through this committee the program employs a consensus based participatory management approach to decision making. Several Management Committee members are directly or indirectly involved with the Stockholm Convention through participation in the Conference of Parties and/or other bodies such as the POP Review Committee and Global Monitoring Plan.

Table 1. Overview of NCP POPs monitoring program media (2003-3013)

| Media | Locations | Sampling years[1] | Frequency |
|---|---|---|---|
| Air - high volume | Alert | 1992–2013 | 7 day continuous |
| Air - passives | Up to 7 arctic/sub-arctic locations | 2005–2013 | Quarterly |
| Arctic char (searun) | Cambridge Bay, Pond Inlet , Nain | 2004–2013 | Annual |
| Arctic char (landlocked) | Lakes Resolute, Char, Amituk and Hazen | 2004–2013 | Annual |
| Burbot | Fort Good Hope, Great Slave Lake West Basin and East Arm | 2004–2013 | Annual |
| Lake trout | Lake Laberge, Kusawa Lake, Great Slave Lake West Basin and East Arm | 2004–2013 | Annual |
| Caribou | Northern Yukon and Southwestern Nunavut (Porcupine, Qamanirjuaq herds) | 2006, 2008 | Single study |
| Ringed seals | Arviat, Resolute, Sachs Harbour and other locations to 2009 | 2004–2013 | Annual |
| Beluga | South Beaufort, Cumberland Sound | 2004–2013 | Annual |
| Polar bears | West Hudson Bay and other locations | 2004–2013 | Annual |
| Seabirds (thickbilled murre, blacklegged kittiwakes | Prince Leopold Island, Coats Island | 2004–2013 | Annual |

The main research and monitoring activities that support the Stockholm Convention are described in Blueprints for Human Health and Environmental Monitoring and Research[4]. The Human Health subprogram incorporates all of the major research and monitoring activities required for conducting human health risk assessments, including human biomonitoring, dietary exposure assessment, laboratory based toxicology, epidemiological research including cohort studies, and risk/benefit assessment. Details of the Human Health subprogram and results will be presented separately and in conjunction with the AMAP presentation.

The Environmental Monitoring and Research subprogram incorporates a long-term core monitoring plan with a complementary research agenda. The primary goal of the monitoring plan is the measurement of temporal trends. Research priorities are designed to complement trend assessment by improving our understanding of how POPs cycle in the environment, how trends might be affected by factors such as global emissions and climate change, and to assess toxicological risks to fish and wildlife. An overview of recent sampling is outlined in Table 1[5]. The plan incorporates regular sampling and analysis of air, fish and wildlife at set locations on an annual basis, or in the case of air, continuously. Air samples are collected by both active and passive filtration methods. Air sampling filters collected by high volume samplers at Alert, Nunavut in the high Arctic are collected on a weekly basis, while passive samplers deployed at Alert, Little Fox Lake, and Coral Harbour, are sampled quarterly as part of the Global Atmospheric Passive Sampling (GAPs) network. Annual sampling of fish and wildlife is carried out at numerous locations throughout the Arctic (Table 1), and largely in cooperation with local harvesters. POPs analysis of biota samples has been carried out annually since 2004 but in 2013 was scaled back to a biennial schedule. Table 2 lists the different groups of POPs that have been measured in various media as part of NCP monitoring and research activities[5].

The NCP coordinates a quality assurance and quality control program (QAQC) that conducts annual interlaboratory comparison studies between participating NCP and AMAP analytical laboratories. The suite of POPs included in the QAQC program mirrors that of the monitoring and research program. Results are used to monitor data quality and to guide laboratories in improving their analytical methods. A synopsis of QAQC project results (2005-2012) can be found in *Canadian Arctic Contaminants Assessment Report III – POPs in Canada's North*[5].

**Results and discussion**

Temporal trends of POPs in air, fishes, seabirds, seals, beluga and polar bears obtained under NCP are given in Table 3 (green for declines and red for increases). Results for air monitoring indicate that many legacy POPs, e.g. polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs), are declining. The decline of legacy POPs were generally more rapid in 1993-2001 as compared to 2002-2011 at Alert (82° 30′ N, 62° 20′ W). Most PCBs in air showed a decline (1993-2011) but rates have slowed and some relatively heavier congeners have increased slightly in recent years which may be associated with increase in boreal forest fires that release previously deposited organic chemicals, e.g. PCBs. Changes associated with sea-ice cover and cryosphere in general could also be a factor. Lindane (banned in Canada in 2004) showed accelerated declining concentrations in air after 2001. Pesticide α-endosulfan showed steady concentrations in 1993-2001 but slight declining

Table 2. Major groups of POPs and other persistent organics in environmental compartments of the Canadian Arctic determined under the NCP core monitoring and research programs

| | **NCP I (1991-1996)** | **NCP II (1997-2002)** | **Current NCP (2003-2013)** |
|---|---|---|---|
| PCBs[1] | Air, snow, sediment, seawater, biota | Air, seawater, sediment, biota | Air, snow, seawater, biota |
| OC pesticides[2] | Air, snow, sediment, seawater, biota | Air, seawater, sediment, biota | Air, snow, biota |
| Chlorobenzenes | Air, snow, sediment, seawater, biota | Air, seawater, sediment, biota | Air, snow, biota |
| Chlorinated dioxins/furans | Biota | Air, sediment, biota | Biota |
| Chlorinated naphthalenes (PCNs) | | Air, biota | Air, biota |
| Chlorinated paraffins | | Air, sediment, biota | Biota |
| Endosulfan | | Air, seawater, biota | Air, seawater, biota |
| Polybrominated diphenyl ethers (PBDEs) | | Sediment, biota | Air, snow, seawater, sediment, biota |
| Hexabromocyclododecane (HBCDD) | | | Air, snow, seawater, biota |
| Other Brominated and chlorinated flame retardants | | | Air, snow, seawater, biota |
| Penta and hexabromobiphenyls | | | Air, biota |
| Current use pesticides[3] | | | Air, snow, seawater, lake water, biota |
| Perfluorooctane sulfonate (PFOS) and other perfluoro-alkyl acids and alcohols | | | Air, snow, seawater, lake water, sediment, biota |
| Siloxanes | | | Air |

[1]various congeners depending on the study; [2]DDTs, hexachlorocyclohexanes (HCHs), chlordanes, toxaphene; [3]Current use pesticides including dacthal, chlorothalonil, chlorpyrifos, pentachloronitrobezene (PCNB), trifluralin

Table 3. Overview of time trends of selected POPs and persistent organics in Canadian arctic air and biota. Estimated for all results from early 1990s to 2011.

| | Air | Burbot[1] | | Lake trout[2] | | | Landlocked char[3] | | Sea-birds[4] | seals[5] | | | Beluga[6] | | Polar bears[7] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FGH | GSL | KW | LL | GSL | H | A | PLI | SBS | LS | HB | SBS | CS | HB |
| PCBs | | | | | | | | | | | | | | | |
| ΣCBz | | | | | | | | | | | | | | | |
| ΣHCH | | | | | | | | | | | | | | | |
| ΣCHL | | | | | | | | | | | | | | | |
| ΣDDT | | | | | | | | | | | | | | | |
| toxaphene | | | | | | | | | | | | | | | |
| endosulfan | | | | | | | | | | | | | | | |
| SCCPs | | | | | | | | | | | | | | | |
| PCNs | | | | | | | | | | | | | | | |
| PCDD/Fs | | | | | | | | | | | | | | | |
| ΣPBDEs | | | | | | | | | | | | | | | |
| HBCDD | | | | | | | | | | | | | | | |
| PFOS and precursors | | | | | | | | | | | | | | | |
| PFCAs and precursors | | | | | | | | | | | | | | | |

| | |
|---|---|
| | Limited or no results to assess trends |
| | No statistically significant change (typically < 3%/yr) |
| | Significant declining trend (typically > -5%/yr) |
| | Significant increasing trend (typically > +5%/yr) |
| | Significant increase in the early 2000s, currently stable or declining |

[1]FGH = Fort Good Hope, GSL = Great Slave Lake - East Arm and West Basin
[2]LL & KW = Lake Laberge and Kusawa; GSL = Great Slave Lake - East Arm and West Basin
[3]H = Lake Hazen. A= Amituk Lake
[4]PLI = Prince Leopold Island, Lancaster Sound
[5]SBS = Southern Beaufort Sea (Ulukhaktok, Sachs Harbour), LS = Lancaster Sound (Resolute, Arctic Bay and Grise Fiord), HB = Hudson Bay (Arviat and Inukjuaq)
[6]SBS = Southern Beaufort Sea (Hendrickson Is); CS= Cumberland Sound (Pangnirtung)
[7]HB = Hudson Bay – for all compounds except PFOS and PFCAs where results for N. Baffin Island and Baffin Bay were used

concentration in 2006-2011 which may reflect reduced usage in Canada, USA and Europe. Neutral per- and polyfluoroalkyl substances (PFASs) were monitored in air at Alert from August 2006 to 2012. PFOS precursors MeFOSE and EtFOSE showed no decline in trends; reflecting the voluntary phaseout of the production of PFOS, PFOA, and PFOS-related products by their largest producer 3M in 2000. In contrast, PFCA precursors 6:2, 8:2 and 10:2 FTOHs, which were not regulated at the time of measurement, showed increasing tendencies in air at Alert.

Declining concentration trends in biota is most apparent for OCPs and less evident for PCBs and chlorobenzenes (ΣCBz). In marine species, percent annual declines of ΣDDT ranged from 2.5 %/y in Lancaster Sound thick-billed murre eggs to 11 %/y in polar bear fat in western Hudson Bay, WHB). Declines of chlordane-related compounds (ΣCHL) ranged from 1.2 %/y in murre eggs to 7.4%/y in blubber of ringed seals in Hudson Bay, while polar bears (WHB) showed no decline. α-HCH showed rapid decline in seals, beluga and polar bears, while β-HCH increased in the same species with great spatial variability in trends. The case of β-HCH highlights the importance of long-range ocean transport (LROT) from the Pacific Ocean via the Bering Sea and possibly Russian freshwater inputs. The detection of perfluorinated alkyl acids such as PFOS and PFOA in arctic seawater, as well as global modeling, has also shown the importance of LROT of contaminants.

PBDEs generally increased in seals, seabirds, beluga, and polar bear samples from 1990s to early 2000, then followed by a decline. e.g. ΣPBDEs reached maximum concentrations in northern fulmar and thick-billed murre eggs in 2005 and 2006, respectively, and declined to levels similar to those in the early 1990s within 3 years. The declines in PBDEs and PFOS in biota appear to be related to bans and voluntary phase outs of these substances in North America and Europe over the period 2001-2004. Hexabromocyclododecane (HBCD), a replacement flame retardant, appears to be increasing, with undetectable concentrations in biotic samples from the 1990s and early 2000s, but increased well above detection during 2005-2011 for burbot, lake trout, landlocked arctic char, and ringed seals.

The NCP continues to support the Stockholm Convention Global Monitoring Plan (GMP) and Effectiveness Evaluation through air, biota, lake and sea water, snow and sediment monitoring, as well as human biomonitoring, for time trend and LRT assessments. Further work is needed to determine whether climate change, especially warming trends, is affecting POPs transport to the Arctic. More focus will be placed on new candidate chemicals for both Stockholm Convention and the UNECE LRTAP Convention lists in order to fully assess their importance as contaminants in the biological environment. Archived samples are available under the NCP to allow for retrospective analysis to build time trends for new contaminants. It is recognised that there is a lack of time trends of atmospheric POPs in the western and eastern Canadian Arctic. POPs monitoring using passive air samplers at 7 arctic sites and a flowthrough air sampler in the Yukon station of Little Fox Lake will increase the spatial coverage of measurements. To better understand the fate and trends of LROT of contaminants, time series data for POPs and new contaminants in seawater are being collected. NCP recognises the importance of examining the relationship between physiological endpoints and POPs; and recommends that emphasis be placed on the multiple ecological, biological, and physical (natural and anthropogenic) variables that need to be considered when analyzing contamination in species and when comparing data between studies.

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**References:**
1. Barrie LA, et al. (1992); *Sci. Total Environ*. 122(1/2): 1-278
2. Van Oostdam J, et al. (1999); Thematic Issue: Contaminants in Canadian Arctic Ecosystems, *Sci. Total Environ*. 230(1-3): 1-207
3. Macdonald RW, et al. (2000); Special Issue: Sources, Occurrence, and Pathways of Contaminants in the Canadian Arctic, *Sci. Total Environ*. 122(1/2): 1-278
4. NCP Blueprints - http://www.science.gc.ca/default.asp?lang=En&n=7A442CC3-1
5. NCP (2013); Canadian Arctic Contaminants Assessment Report III: Persistent Organic Pollutants in Canada's North. Muir DCG, Kurt-Karakus P. and Stow J. (Eds), Aboriginal Affairs and Northern Development Canda, Ottawa. Xxiii +487 pp. (available on-line at http://www.northerncontaminants.ca/done/index.html)