

Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic (INCATPA), Canada

Hayley Hung^{1)*}, Yi-Fan Li¹⁾, Alexandra Steffen¹⁾, Jianmin Ma¹⁾, Ashu, Dastoor¹⁾, Tom Harner¹⁾, Ed Sverko²⁾

1) Air Quality Research Division, Atmospheric Science and Technology Directorate, Science and Technology Branch, Environment Canada, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4, Canada

* Corresponding author: hayley.hung@ec.gc.ca

2) National Laboratory for Environmental Testing (NLET), National Water Research Institute, Environment Canada, Burlington, Canada

Abstract

Persistent organic pollutants (POPs) and mercury are toxic chemicals that persist in the environment and can be transported by air and water over long distances from southern source regions to the remote Arctic. In cold environments, these chemicals can deposit onto the Arctic's surfaces and accumulate in Arctic wildlife, country foods and subsequently northern people to alarmingly high concentrations. Collaborating with other air monitoring programs for contaminants, INCATPA (International JC endorsed project #327) will measure these chemicals in air in the Canadian, Russian and American Arctic, as well as at potential source regions on the Asian Pacific Region and in North America. This will give us information on where these chemicals have come from, how much from which region and what climate conditions influence their movement to the Arctic. Data collected will be incorporated into environmental transport models to determine how future climate change will affect contaminant transport to the Arctic.

1. Introduction

The presence of anthropogenic pollutants such as persistent organic pollutants (POPs), other semivolatile organic pollutants (SOCs) and mercury (Hg) in the Arctic ecosystem has raised significant international concerns in recent years, especially in circumpolar countries such as Canada. This is mainly because (1) these chemicals are persistent in the environment and can be transported over long distances from source regions to the remote Arctic (Hung et al., 2005; Li and MacDonald, 2005, Macdonald et al., 2000); (2) they tend to bioaccumulate and biomagnify through terrestrial and aquatic food chains (Falandysz et al., 1999; Kucklick and Baker, 1998); (3) most northern and indigenous populations rely on a high fat diet of country food which is a major source of human exposure to these chemicals and (4) most northern peoples have not used or directly benefited from activities associated with the production and use of such chemicals (AMAP, 1998). Armed with scientific knowledge gathered over the years, Canada plays a leading role on the international negotiation table in regulating the production, use and emission of POPs and Hg (UNEP, Stockholm Convention on

POPs, UN-ECE Long Range Transboundary Air Pollution (LRTAP) Protocols on Heavy Metals and POPs, North American Commission for Environmental Cooperation (CEC) Sound Management of Chemicals Initiative and the Arctic Environmental Protection Strategy).

The atmosphere is considered to be the primary and most rapid pathway of pollutant transport to the Arctic. Studies conducted under the Northern Contaminants Program (NCP), the Canadian National Implementation Plan of the Arctic Monitoring and Assessment Programme (AMAP), as well as others, have associated episodes of high POP concentrations measured in the Arctic to transport by air masses originating from various regions in the south. For instance, transport of POPs from Asia to the Canadian Arctic has been identified at Tagish, Yukon, where high concentration episodes of banned pesticides, e.g. chlordanes, DDTs and HCHs (hexachlorocyclohexanes), have been linked to air masses passing over Asia 5 days previously (Bailey et al., 2000). Air concentrations of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) peaked when the air mass origin shifted from North Atlantic and North

America eastwards into Russia and Eurasia (Hung et al., 2002). Such transport can occur in as short as 5 to 10 days. As stated above, these pollutants have the tendency of depositing on terrestrial and aquatic surfaces and can bioaccumulate through the food chain. Deposition of this kind has been assessed by the Western Airborne Contaminants Assessment Project (WACAP) in National Parks along the U.S. and Alaskan Pacific coasts. In a study associated with WACAP, Killin et al. (2004) have shown linkages between elevated air concentrations of SOCs measured at the Cheeka Peak Observatory in Washington and trans-Pacific transport events in March and April 2002. In terms of mercury, the recent discovery of atmospheric conversion of Hg(0) in the springtime in the Arctic resulting in increased deposition of reactive Hg species to the environment encourages scientists to determine how much Hg(0) is brought to the Arctic via the atmosphere in order to establish overall Hg input to this region.

In collaboration with different air monitoring programs, INCATPA will measure these chemicals in air in the Canadian, Russian and American Arctic, as well as at potential source regions in the Asian Pacific Region and in North America, including Canada, the USA, Russia, China, Japan and Vietnam. This will give us information on how these chemicals transport to the Arctic from different regions on the Pacific Rim and what climate conditions influence their movement to the Arctic. Data collected will be incorporated into environmental transport models to determine how future climate change will affect contaminant transport to the Arctic.

2. Objectives and Proposed Activities

The current project aims at advancing our knowledge of the factors and mechanisms which influence intercontinental transport of pollutants and our understanding of the relative contribution of intercontinental versus intracontinental transport to the Arctic.

Research will focus on:

- (1) fingerprinting chemical compositions of air masses from different parts of the Pacific;
- (2) identifying key chemical properties, e.g. vapour pressures and air-surface partition coefficients, and atmospheric dynamics, e.g. large-scale wind systems, geopotential heights, air temperatures, precipitation etc., dictating chemical transport to the Arctic;

- (3) quantifying the relative contribution and major pathways of intercontinental versus intracontinental input of pollutants into the Arctic region; and identifying atmospheric circulation patterns leading to trans-Pacific pollutant transport to the Arctic;

- (4) assessing and forecasting the potential influence of changes in atmospheric circulation patterns and climate variability on the long-range transport of pollutants to the Arctic;

- (5) assessing the impacts of the transport of pollutants to the Arctic considering climate change and changes in sources (collaborating with other IPY studies being undertaken – OASIS [Ocean-Atmosphere-Sea Ice-Snowpack] for Hg and CFL [Circumpolar Flaw Lead system study] for Hg and POPs).

We plan to achieve these objectives through coordinated source-receptor measurement of atmospheric pollutants coupled with multi-media transport modelling. It is proposed that simultaneous air sampling for Hg, POPs (e.g. chlordanes, DDTs, dieldrin, HCHs, toxaphene, polychlorinated biphenyls [PCBs]) and other anthropogenic chemicals (e.g. endosulfan, polybrominated flame retardants, polycyclic aromatic hydrocarbons [PAHs] and current-use pesticides) be conducted along both sides of the Pacific Ocean at potential sampling stations shown in Figure 1. These sampling sites include locations in eastern China, Vietnam, Japan, eastern Russian Arctic and sub-Arctic, the western Canadian Arctic, Alaska and the west coast of the U.S. This project will make use of existing air monitoring facilities for atmospheric pollutants established under AMAP, the Global Atmospheric Watch (GAW) program conducted by the World Meteorological Organisation (WMO), as well as other national and university-based studies in Asia and North America.

Coordinated high volume air sampling of POPs will be conducted at each site to track intercontinental transport episodes. This will be complemented by a Canada-led global passive air sampling network - GAPS (Global Atmospheric Passive Sampling) (Figure 2). The passive air samplers (PAS) provide time-integrated air concentrations of POPs over 3-month and 1-year periods (Gouin et al., 2005; Shen et al., 2004) which are ideal for investigating accumulated or time-integrated effects over seasonal and yearly timeframes.



Fig. 1. Potential sampling sites under INCATPA

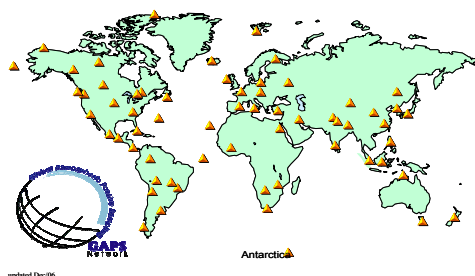


Fig. 2. Location of air sampling sites under GAPS

In 1995, the understanding of the atmospheric behaviour of Hg in the Arctic air was revolutionized through the discovery of atmospheric conversion of Hg(0) in the springtime. This conversion results in an increased amount of reactive Hg deposited to the Arctic environment. If there was an increase in emissions of Hg from southerly sources or an enhancement in transport to the Arctic as a result of climate variations, a significant increase in the amount of Hg could be deposited to this environment. INCATPA proposes to assess the likelihood and impact of this possible scenario.

Under INCATPA, we propose the addition of 1 site in Russia and 1 in China to the existing AMAP Hg measurement sites at Alert, Nunavut; Amderma, Russia; and Little Fox Lake, Yukon. For ambient air continuous Hg measurements, all sample analysis will be performed with the Automated Tekran® Mercury Vapour Analyser as used in AMAP, NCP and the Canadian Atmospheric Mercury Measurement Network. This instrumentation is used worldwide to make continuous measurements of Hg in air.

Two global-scale three-dimensional, multi-compartment atmospheric transport and soil/air, water/air exchange models developed to investigate the transport of POPs (CanMETOP [Canadian Model for Environmental Transport of Organochlorine Pesticides] and MEDIA

[Multicompartment Environmental Diagnosis and Assessment Model]), as well as the Global/Regional Atmospheric Heavy Metals Model (GRAHM) will be used to forecast the atmospheric transport of POPs and Hg. The use of these transport models will help to interpret air monitoring results and estimate the effect of climate change on the long-range transport of pollutants to the Arctic. Currently, the CanMETOP provides a unique tool in numerical assessments of the fate and budget of organochlorine pesticides in North America, and has been extensively used in pesticide studies (Ma et al., 2003). MEDIA has been employed in numerical studies of global transport of α - and γ -HCHs (Koziol and Pudykiewicz, 2001).

Under INCATPA, meteorological analyses associated with the modeling investigation with CanMETOP and MEDIA will be carried out to determine major atmospheric circulation patterns that play significant roles in atmospheric transport of POPs from source regions. For target chemicals with available emission inventories, long-term (> 30 y) atmospheric trends in Arctic air will be estimated to predict temporal and spatial variations of POPs in the Arctic as a result of changes in global POP usage and emissions. Spatial and temporal correlation patterns between POP air concentration in the Arctic and atmospheric circulation characteristics (air temperature, wind, pressure etc.) associated with climate variability (Ma et al., 2004) will be built to improve our understanding of the inter-annual fluctuations and long-term trends of POPs.

In the Arctic, Hg transforms and interacts from very short to long time-scales, therefore understanding Arctic Hg cycling require a multi-scale Hg global model. EC's global/regional atmospheric heavy metals model (GRAHM) is an Eulerian, multi-scale, on-line, high resolution (horizontally and vertically) model (Dastoor and Larocque, 2004). For INCATPA, the influence of climate change on the transport, intensity and frequency of the episodes and the deposition of Hg in the Arctic will be studied.

3. Concluding Remarks

The INCATPA project will provide insight into the source-receptor relationship of POPs and mercury. This information is essential in our future ability to forecast the transport and impact of these pollutants on the Arctic ecosystem.

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