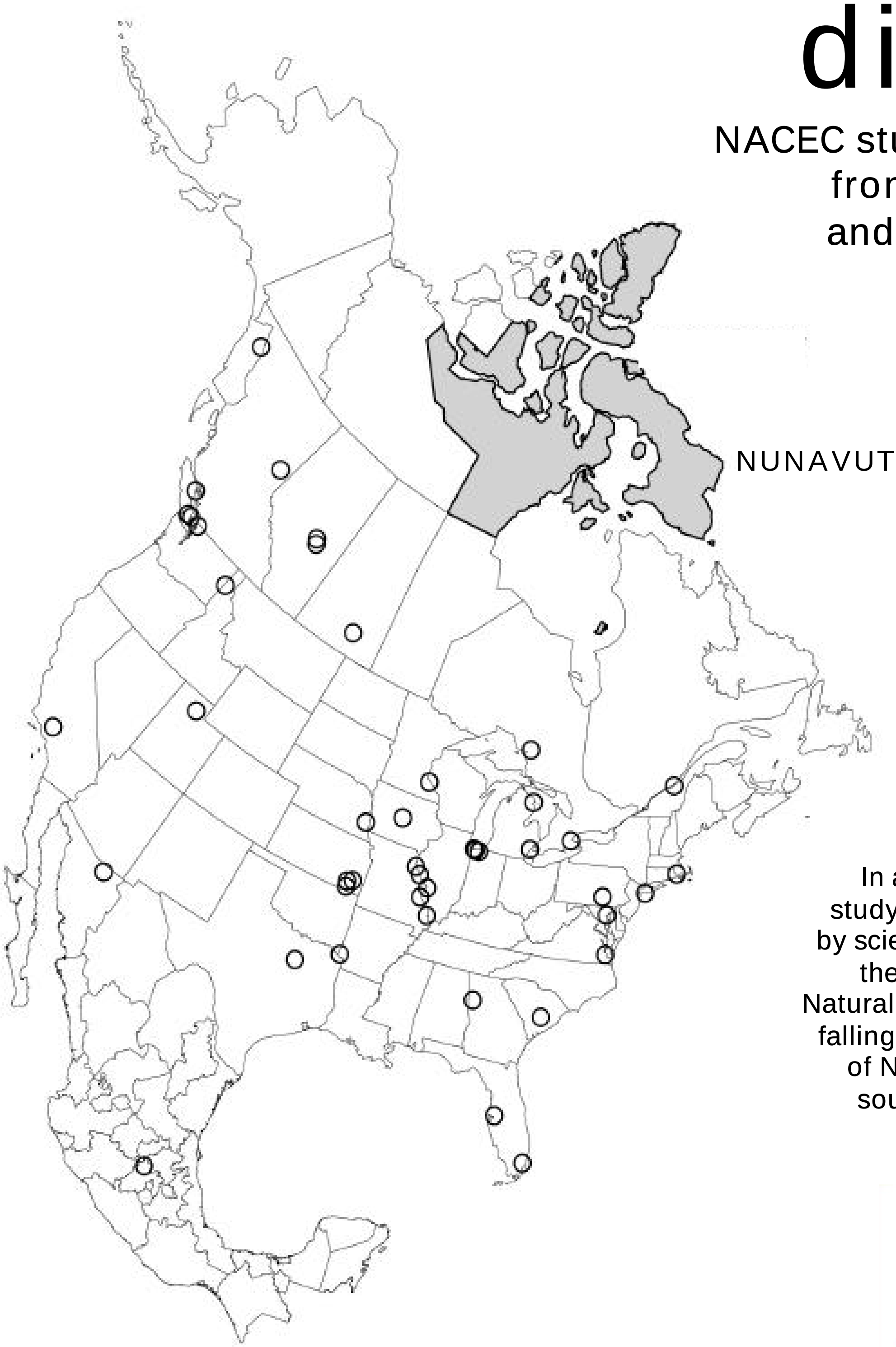
Tracking dioxins

NACEC study tracks dioxins from Canada, Mexico and the United States to the Arctic



In a groundbreaking NACEC study conducted by a team led by scientist Barry Commoner of the Center for the Biology of Natural Systems (CBNS), dioxins falling in the new polar territory of Nunavut are linked to their source regions thousands of kilometers away.

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For years, dioxins have been detected in the Arctic diet of fish, seal and caribou meat and, recently, in Inuit mothers' breast milk. There are few sources of these carcinogenic toxins in the Arctic, so they clearly migrate to the region from somewhere else. But where they come from has not been known until now.

Scientists have long recognized that air pollution can travel long distances and fall on communities thousands of kilometers away. These downwind communities typically have little control over the far-away pollution sources, or even the ability to identify the upwind source regions most affecting their local environment. Now the North American Commission for Environmental Cooperation (NACEC), through work conducted by the Center for the Biology of Natural Systems at the City University of New York, has helped develop a cost-effective tool to aid local communities in identifying the pollution sources most affecting them.

The tool used in this assessment is an adaptation of the Hybrid Single-Particle Lagrangian Integrated Trajectory (Hysplit-4) model, an air transport model created by scientists with the US National Oceanic and Atmospheric Administration (NOAA) during the 1980s. NOAA scientists originally developed this powerful technique to track radioactive material in the atmosphere and applied it to radiation releases such as the Chernobyl reactor incident.

Recently, researchers at CBNS developed a new dioxin chemistry component for the Hysplit model, which extended its capabilities. For the NACEC effort, scientists at CBNS used the dioxin adaptation to track "puffs" of dioxin-containing air pollution released at various locations in North America (Canada, Mexico, and the United States) and deposited in eight regions of the polar territory of Nunavut. In doing so, the model was able to evaluate the relative importance of 44,091 identified North American sources that may contribute to dioxins deposited in Nunavut. This study is the first of its kind to "connect the dots" from dioxin source regions to Nunavut receptor sites performed on a continental scale.

NACEC asked scientists at CBNS to study airborne dioxins because of dioxins' known health effects, their persistence in the environment, and their ability to travel long distances through the air far downwind from their original sources. Nunavut is an ideal region to test the model because of the absence of large local dioxin sources that might otherwise complicate an analysis of dioxins' long-range transport.

The study modeled dioxin deposition in Nunavut based on emissions from July 1996 to June 1997, creating a "snapshot" of atmospheric transport during that time. A number of the facilities referenced in the study have reduced or eliminated dioxin emissions since 1997. Nonetheless, the study illustrates the dynamics of long-range transport on a continental scale. Dioxins, like other persistent organic pollutants, may remain present in the environment for years after their deposition.

There are always limitations and uncertainties associated with the use of any specific air transportation model, including the forward-trajectory modeling utilized in this study. Models, however, are important as part of a full range of information tools needed for providing policymakers and the public with a better understanding of the long-range transportation of air pollutants. In this instance, the model was employed to determine the source-receptor relationships for a specific region during a specific time period. These results can be considered in combination with other information, such as dioxin concentration measurements in the indigenous Nunavut population and the local fauna.

Health Effects of Dioxins

Dioxins are a family of some 70 toxic chemicals, consisting of polychlorinated dibenzo dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs), and polychlorinated biphenyls (PCBs). Dioxins are a public health and environmental concern because some types have known carcinogenic and toxic properties that may produce a broad spectrum of adverse effects in humans. These include reproductive dysfunction and developmental abnormalities, suppression of the immune system, chloracne (a severe acne-like disease that sometimes persists for many years), and cancer. EPA characterizes TCDD [2,3,7,8-tetrachlorodibenzo-p-dioxin] as a "human carcinogen" based on the weight of evidence of animal and human studies and characterizes other dioxins as "likely human carcinogens" [US EPA, *Dioxin: Summary of the Dioxin Reassessment Science*, Information Sheet 1, 12 June 2000].

Dioxins are widely distributed in the environment at low concentrations and are not easily broken down by natural processes. Human exposure to dioxin is almost entirely through animal foods, especially those that are rich in fat. As a result, most people have detectable dioxin levels in their tissues that have bioaccumulated over their lifetime. According to the US EPA, "[t]his background exposure is likely to result in an increased risk of cancer and is uncomfortably close to levels that can cause subtle adverse non-cancer effects in animals and humans" [US EPA, Persistent, Bioaccumulative, and Toxic (PBT) Initiative, 2000].

Due to past measures to reduce or eliminate the production of dioxins, levels in the environment have been declining since the early 1970s. Even with this decline, the lifetime risk of dioxins causing cancer is now considered to range as high as 1 in 1,000 to 1 in 100, a ten-fold increase over earlier estimates [US EPA, *Dioxin: Scientific Highlights from Draft Reassessment (2000)*, Information Sheet 2, 12 June 2000]. Children and fetuses may be even more sensitive to dioxins because of their rapid growth and development. This is a much higher risk range than the generally regarded "acceptable" lifetime cancer risk of one in a million typically used as the regulatory threshold for action by the US EPA.

In Nunavut, dioxin concentrations in Inuit mothers' breast milk are twice the levels observed in southern Quebec, yet there are few dioxin sources in Nunavut or within 500 kilometers of its boundaries. Despite the paucity of local sources, elevated dioxin levels appear in fish, seal, and caribou meat that forms the cultural basis of the Inuit diet. This dioxin must have arrived in the Arctic after being transported long distances from regions of high dioxin emissions. Once deposited in the Arctic, dioxins enter the major terrestrial (caribou) food chain mainly through lichen, mosses and shrubs, and enter the marine (fish, seal) food chain chiefly through algae.

Application and Results of the Dioxin Transport Model

The Arctic region provides a textbook case for NACEC's interest in addressing the long-range transport of pollutants across North America. Nunavut is a relatively pristine region with few local dioxin sources, yet relatively high dioxin levels are found there. The Inuit population of Nunavut must be exposed to dioxins in their diet that traveled thousands of kilometers from sources located far from their communities. The challenge is to develop a tool that can locate the source regions of most concern so that control efforts can focus on the sources most likely having the greatest impact in the Arctic. With this goal in mind, NACEC collaborated with leading environmental scientist Barry Commoner at the Center for the Biology of Natural Systems to help develop such a tool.

As expected, the modeling tool used by Dr. Commoner found that only two-thousandths of the total predicted dioxin deposition in Nunavut could be attributed to local sources. About 2 to 20 percent come from sources outside North America, while the vast majority of deposited airborne dioxins come from sources in North America hundreds or thousands of kilometers away from Nunavut.

Dioxins are a byproduct of a number of chemical processes, including some metal refining methods, the chlorinated bleaching of pulp and paper, and, most importantly, the combustion of certain materials, especially plastics. Of the 23 classes of dioxin sources identified in the study, only six classes accounted for 90 percent of all dioxin emissions in North America. These six classes, listed in order from largest to smallest emitting class, are:

- municipal solid waste incinerators,
- backyard trash burning,
- cement kilns burning hazardous waste,
- medical waste incinerators,
- secondary copper smelters, and
- iron sintering plants.

Dioxins may also have natural sources but they are vanishingly small compared to dioxin emissions arising from human activity. For example, lake sediment cores in the United States show dramatic increases in dioxin levels since the 1930s corresponding to increasing industrial activity, with recent decreases since the 1970s likely corresponding to pollution control efforts. The large increase in dioxins since the 1930s indicates that pre-industrial levels were low compared to current deposition amounts.

On a per-country emission basis during the period of study (1996–97), sources in the United States accounted for 62 percent of North American dioxin emissions related to human activity, Mexico accounted for 30 percent, and Canada accounted for 8 percent. Dioxin sources within Nunavut account for less than 0.002 percent of the North American total. (Another achievement of this research was the development of a dioxin inventory for Mexico—the first national inventory ever compiled for this country.) Current dioxin emissions in the three countries may differ from these relative percentages due to recently required reductions from many large dioxin sources that were implemented after the study period.

The amount of dioxin deposited in the Arctic depends on many factors, including the rate of emission of dioxin, the distance between the source and receptor, and the prevailing weather patterns at a given time of the year. The study found that dioxin deposition varied over the year, with high dioxin deposition occurring when the weather patterns favored efficient transport from areas in North America with high emissions. For example, in one Arctic community, Ikaluktutiak, over half of the annual dioxin burden from July 1996 to June 1997 was deposited in two months, September and October.

The study found that only a relatively small number of the over 40,000 dioxin sources in North America contribute most of the dioxin deposited in Nunavut. For example, at the Coral Harbour land receptor area in northern Hudson Bay, only 19 sources contributed 35 percent of the total deposition, 43 sources contributed 50 percent, and 605 sources contributed 75 percent. This illustrates the power of the modeling technique to serve as a "screening tool" for helping policy makers focus first on the relatively small subset of dioxin sources likely having the biggest impact on dioxin deposition in downwind communities.

Overall, the model results indicated that, during the period of study, the greatest contribution to dioxin deposition in Nunavut was due to US sources: 70 to 82 percent depending upon the location within Nunavut. Canadian sources contributed 11 to 25 percent and Mexican sources five to 11 percent. The relatively small contribution of Mexican sources to dioxin deposition in

Nunavut compared to their larger share of the total North American dioxin emission inventory (30 percent) is in part a reflection of their greater distances from the receptor areas compared to US and Canadian sources.

There are limitations in the modeling due to uncertainties in the dioxin inventories used as model inputs. This is a common issue with virtually any emission inventory using such techniques. The strength of this study, therefore, is not in "pinpointing" precise contributions from individual sources, but in providing linkages between a collection of sources within source regions and dioxin deposition in Nunavut.

As noted, the study modeled dioxin deposition in Nunavut based on emissions from July 1996 to June 1997. This was the most recent period with comparable data available from Canada and the United States on dioxin emissions and weather conditions at the time of the study. Countries, however, are constantly revising data on pollutants such as dioxin. Canada and the United States are preparing new inventories of dioxin emissions for 1999 that show a substantial reduction in dioxin emissions since 1996–97.

Already, since the period covered in this study, a number of the major sources and source types identified in the study as contributing to dioxin deposition in Nunavut have come under new requirements to reduce their dioxin emissions. In late 1997, the US EPA adopted regulations that will reduce dioxin emissions from medical waste incinerators by about 95 percent by the year 2002. In

1998, the EPA promulgated a federal plan to ensure a 99 percent reduction in dioxin emissions from large municipal waste incinerators before the end of 2000. Similarly, the EPA also promulgated regulations to reduce dioxin from some hazardous waste incinerators, including cement kilns. Additionally, a number of US states have taken active steps toward dioxin reduction.

In Canada, environment ministers in June 2000 accepted a Canada-wide Standard for Dioxins and Furans that may be endorsed at the next meeting of the federal and provincial environment ministers in November 2000. Six sectors, including waste incineration, burning salt laden wood, residential wood combustion, and electric arc furnace steel manufacturing, have been identified for early action. The municipal waste incinerator in Quebec has undergone modifications to virtually eliminate its dioxin emissions. The model's results are an affirmation of these government efforts to reduce dioxin emissions from some of the largest source types.

Future Directions

The NACEC study helps develop a screening tool for use in identifying and focusing on the most significant pollution source regions affecting local communities. Owing to their toxicity, persistence in the environment, and potential for long-range transport, persistent organic pollutants such as dioxins represent a continental, indeed global, challenge. This study demonstrates the application of a powerful new tool to better understand how these pollutants are transported great distances through the environment. This is of great value because policymakers must increasingly consider all sources—local, distant, large or small—as they seek solutions to better protect human health and the environment.

In the context of Nunavut, the modeling tool suggests a set of sources whose control could significantly reduce the deposition of dioxins in the Arctic. Although a number of the major source groups have already reduced, or are already under obligation to reduce, their dioxin emissions, additional studies should be conducted with updated inventories to assess current source-receptor relationships affecting the Arctic and other regions in North America.

The North American Commission for Environmental Cooperation (NACEC) was established by Canada, Mexico and the United States to help build cooperation among the NAFTA partners in the protection of their shared environment, with a particular focus on the opportunities and challenges presented by continent-wide free trade.

NACEC continues working to reduce or eliminate exposures to harmful pollutants that travel great distances in North America. As part of NACEC's Sound Management of Chemicals initiative, the governments have agreed to take concrete measures to address harmful substances, such as PCBs, DDT, chlordane and mercury. NACEC will soon develop a regional action plan to address dioxins as well. Additionally, NACEC tracks certain North American toxic pollutant emissions in its annual Taking Stock report and supports North American pollution prevention efforts.

For more information, please visit the NACEC web site at: http://www.cec.org