HUMAN SOURCESA AND ACTIVITIES ASSOCIATED WITH DIOXIN-LIKE COMPOUNDS AND POPs IN THE ENVIRONMENT

THE LINK BETWEEN ANTHROPOGENIC SOURCES OF DIOXIN AND THE HUMAN FOOD CHAIN: SOURCE-TO-RECEPTOR AIR TRANSPORT

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Introduction

The exposure of the general population to dioxin – for example in the United States – occurs almost entirely (98%) through ingestion of foods, especially those containing animal fat[1]. This results from the emission of airborne dioxin by anthropogenic sources; thus, deposited on feed crops (such as dairy pasture), dioxin becomes concentrated in milk fat. A modified version of the HYSPLIT air transport model has been used to rank U.S. and Canadian sources with respect to their contributions to the concentration of airborne dioxin at U.S. dairy farms[2]. The results show that remedial action can be efficiently directed to the relatively few sources that are chiefly responsible for the dioxin content of milk. In the present study, this approach has been applied, on a continental scale, to the deposition of airborne dioxin, emitted by sources in Canada, the United States and Mexico, at receptors in Nunavut, in the Canadian Arctic. These receptors serve as avenues of entry into the food chains that supply the local Inuit population with their indigenous diet, which has a high fat content. The dioxin concentration in Inuit mothers' milk is twice the level observed in southern Canada[3].

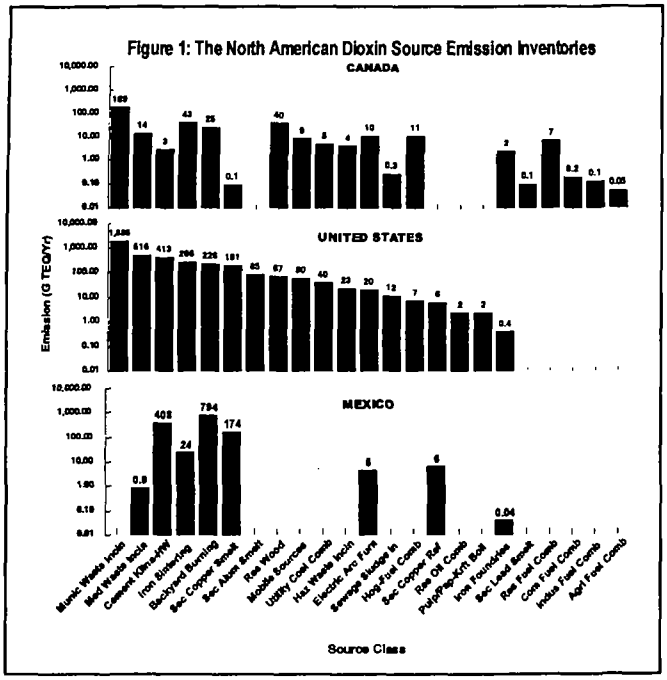
Methods

The modified version of the HYSPLIT-4 air transport model developed by NOAA was used to estimate dioxin deposition at eight widely separate sites in Nunavut[4,5]. At each site, receptor areas (5,000-27,000 km^2), one on land and the other an adjacent marine area, were specified by latitude and longitude.

Results and Discussion

A North American inventory of geocoded dioxin sources was established, for the period 1996-1997, based on inventories available from Environment Canada and the U.S. EPA[6,7]. These were supplemented with inventories of backyard burning in Canada, the United States and Mexico developed from demographic data (per capita residential waste production, rural/urban population density), and an emission factor derived from Lemieux[8]. The Mexican inventory is provisional, since emissions from industrial sources were based on throughput and emission factors derived from U.S. and European facilities. The total North American inventory (see Figure 1) consists of 44,098 sources, of which 5,350 are point sources and 38,748 are area sources (e.g., backyard trash burning, vehicles). The total inventory emits 5,600 g TEQ (midpoint estimate) of dioxin annually; of this total, Canadian, U.S. and Mexican sources emit 6.5%, 68.3% and 25.2% respectively.

Model runs to estimate deposition flux at each of the 16 receptors due to dioxin emitted from each of the North American sources were carried out for the period July 1, 1996 through June 30, 1997. The total annual dioxin deposition flux at each of the receptors is shown in Figure 2. Deposition flux at marine receptors (midpoint estimates) ranges from a high of 149 pg TEQ/m^2 at the southernmost receptor, Sanikiluaq, to 10 pg TEQ/m^2 at Arctic Bay, the most northern receptor. Deposition flux at the marine receptors is generally about twice that at adjacent terrestrial receptors, reflecting the greater receptivity of water to particulate dioxin.

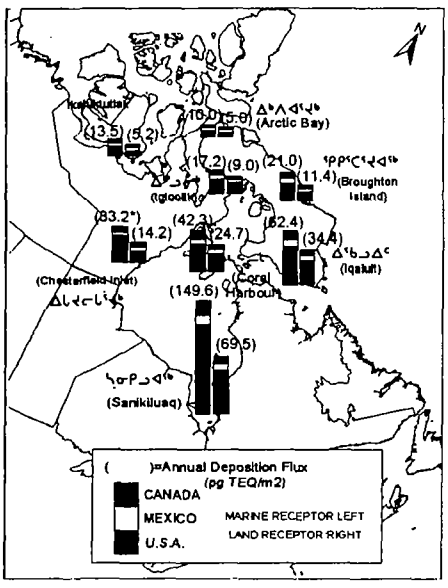


A very small percentage of the sources are responsible for most of the deposition flux at the receptor. Thus, at a typical land receptor, Coral Harbour, only 28 sources (0.06% of the total) account for 50% of the deposition, 335 sources (0.76%) for 75% of the deposition, and 2,284 sources (5.18%) for 90% of the deposition. Figure 3 shows the cumulative contributions of the individual sources to 50% of the total deposition at the Coral Harbour land receptor, ranked in descending order of that contribution. The 10 highest-ranked sources are U.S. facilities; facilities as distant as Florida and Mexico also occur in the top 28 sources.

Several main factors govern the source/receptor relationships: the rate of emission from the source; the distance of the receptor from the source; the receptor's geographic orientation to the source (which in turn governs the influence of weather patterns *en route* on the efficiency of airborne dioxin transport). The efficiency with which the dioxin emitted by a given source is transported to a given receptor–i.e., the percent of the emitted dioxin deposited at the receptor–is represented by the Air Transport Coefficient (ATC), so that: *deposition = emission x ATC.*

As a means of demonstrating the interaction among these factors, the relevant data have been collated on a common polar stereographic 100x100 km grid of North America. The resultant

Fig. 2. Annual Dioxin Dep. Flux (pg TEQ/m^2) at Nunavut receptors



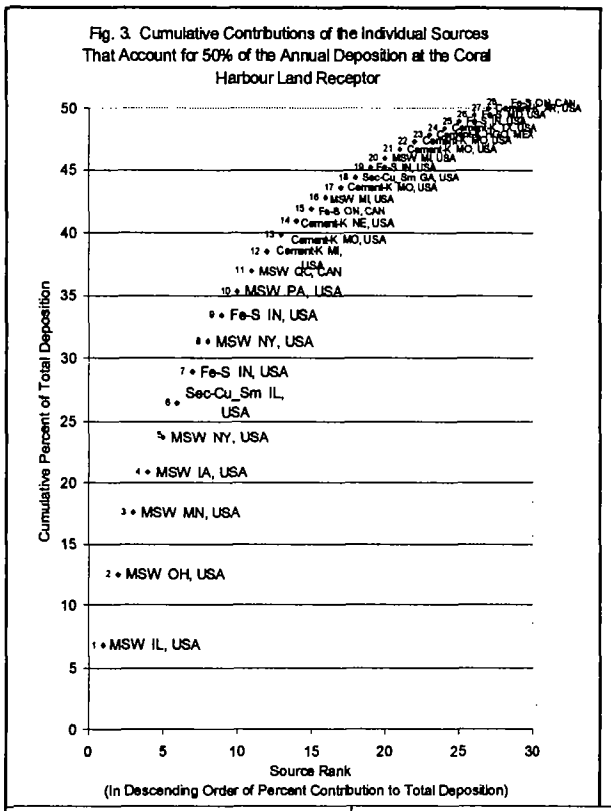


Fig. 3. Cumulative Contributions of the Individual Sources That Account for 50% of the Annual Deposition at the Coral Harbour Land Receptor

maps are presented in Figures 4-6. Fig. 4 shows that the entire area of Nunavut is free of sources that emit more than 0.1 gram TEQ annually; there are virtually no sources within 500 km of the Nunavut border. There is a high concentration of intense sources in the eastern half of the United States. The intense levels of dioxin emissions in Mexico are due to cement kilns and "backyard" trash burning, which represents about half of the total national emissions. Fig. 5 describes the geographic variation in the efficiency with which airborne dioxin is transported to the Ikaluktutiak land receptor from the sources in each of the North American grid zones. As expected, the highest values of ATC are close to the receptor. The successive zones of declining ATC values extend chiefly to the south of Ikaluktutiak, indicating that meteorological conditions (averaged over the year) favor efficient transport (e.g., due to wind speed and direction) from sources located due south of the receptor. The ATC values for sources in the eastern half of the U.S. and Mexico are at the lower end of the range. Figure 6 is a map, for each grid zone, of the quotient:

Fig. 4. Geographic Distribution of Annual Dioxin Emissions from North American Sources

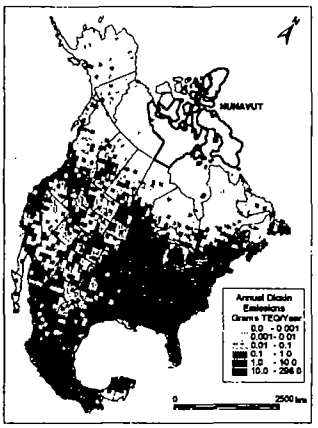


Fig. 5. Geographic Distribution of Annual Dioxin ATC to Ikaluktutiak Land Receptor

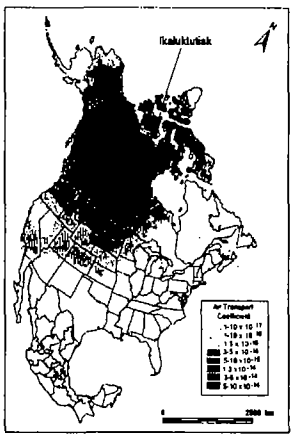


Fig. 6. Geo. Distribution of Dioxin Source Contributions to Deposition at Ikaluktutiak Land Receptor

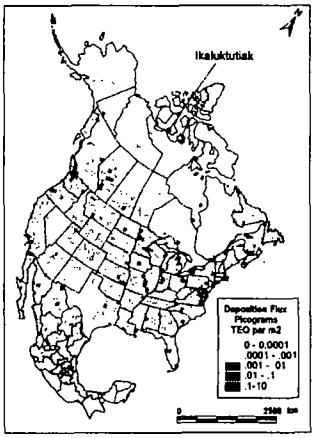
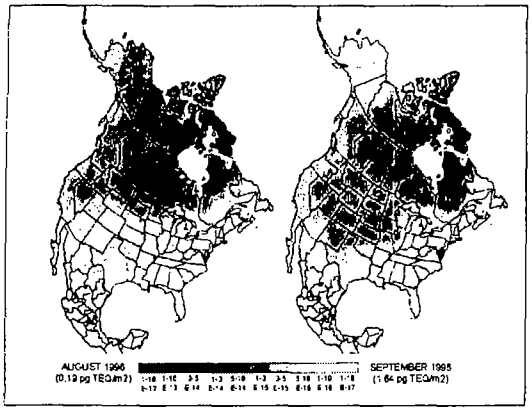


Fig. 7 Air Transport Coefficient Maps and Deposition Flux (pg TEQ/m^2), Ikaluktutiak Land Receptor



dioxin emission (in grams/year) x ATC. This represents deposition at the receptor (expressed as pg TEQ/m^2). As can be seen by over-laying Figs. 4 and 5, dioxin emitted by sources in northwest Canada and U.S., which occurs at relatively low rates, is efficiently transported to the Ikaluktutiak receptor. In contrast, dioxin intensely emitted by sources in eastern U.S. is much less efficiently transported to the receptor. The net result is that the annual dioxin deposition flux at the Ikaluktutiak land receptor (5.2 pg TEQ/m^2) is the second lowest in Nunavut.

Of the three main factors that determine the source's contribution to dioxin deposition at the receptor, only the weather pattern varies with time; source-receptor distance is fixed, and the model assumes a constant rate of source emissions. Figure 7 illustrates the strong influence of month-to-month variations in weather pattern on dioxin deposition. In August, when ATC values (i.e., transport efficiency) are *high* only in northwest Canada and U.S., where source emissions are low, deposition amounted to only 0.19 pg TEQ/m^2. In September, when moderately *high* ATC values extend into the areas of the U.S. Midwest and east, where source emissions are also high, deposition increased to 1.64 pg TEQ/m^2, the maximum monthly value, representing 32% of the annual total.

Thus, the known occurrence of dioxin in Nunavut is due to air transport from distant sources, chiefly in the U.S., less in Canada, and marginally in Mexico. There is no feasible way to protect the Inuit's traditional and culturally important diet from this threat, but remedial action *can* be taken if directed toward the *sources*—which, as shown, are relatively few and identifiable.

References

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