Identifying Sources of PBDEs in the Canadian Arctic

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Abstract

A preliminary study is ongoing with Polybrominated Diphenyl Ethers (PBDEs) to investigate how they are entering and being transferred among landfill leachates, sediments and soils in the Canadian Arctic. The leachability of PBDEs from e-wastes and examination of landfill sites to determine their fate and transport are being investigated. The spatial distribution of PBDE contamination is also being evaluated. The research will help to provide the parameters for a model under development to predict PBDE migration in soil, thereby facilitating best management practices for waste disposal systems.

Introduction

Given the threats of PBDEs and their widespread appearance, including alarming levels reported[1,2] in marine mammals and in Canada's far northern communities, identifying the sources of these compounds in the Canadian Arctic and finding the transfers and accumulation of various PBDE congeners in air, water and soil are of utmost importance. Increasing concentrations of PBDEs in the environment and potential ecological and human health risks also require early implementation of best-management practices to contain PBDEs[3]. Our approach consists of studying the leachability of PBDEs from e-wastes and examining landfill sites to determine the fate and transport of PBDEs. This paper describes preliminary findings with regards to levels of PBDEs in landfills located in the Canadian Arctic. It also identifies future research needs.

With the results obtained from this study we expect to achieve: (1) Improved knowledge of the migration rate of PBDE contaminants from landfill sources, providing a basis to determine the leachate treatment requirements for Canadian Arctic landfills; and (2) New understanding of the concentrations of PBDEs in landfill leachates and their adsorption onto soils and transport by water to nearby aquatic environments or groundwater resources. The first element is of crucial importance with respect to the population in the Canadian Arctic living near landfill sites and should improve the ability to predict and evaluate water, sediment and soil quality near landfill sites. The second will elucidate PBDE contaminant needs and improve the ability to predict and evaluate the impact of PBDEs from Arctic landfills on streams and rivers, while providing mitigation or preventive information for waste management planning. Ultimately, we hope to provide information that can assist with the preparation of mass balance protocols that can be used on sites or systems of virtually any scale.

The Approach

The overall goal of this project is to obtain better understanding of how brominated flame-retardants, specifically PBDEs, are entering the environment in the Canadian Arctic. We will look at their generation, use, consumption, transport and accumulation patterns in order to increase the understanding of global transport of these compounds among different environmental media. Landfill leachate, soil and sediments are important starting points for the experiments and for modelling. We will use the information from landfill samples in the Arctic, including leachate and soils, in the calibration of mass balance models at a local level.

Our proposed work has several connected objectives: (1) To provide improved understanding of sources, transfer steps and other factors affecting the spread of PBDEs in Canada's Arctic environment. (2) To determine the level of PBDEs in leachate from the Northern Arctic landfills and the rate of leaching of PBDEs from electronic wastes. (3) To find the extent of PBDE contamination in soils around the landfill sites. (4) To provide better understanding of the environmental mobility of PBDE and their potential by-products in surface and subsurface soils and the migration rate of PBDEs. (5) To provide information for environmental agencies to formulate regulatory standards, to assess the effectiveness of alternative landfill liners, and to assess Best Management Practices for mitigating PBDE

contamination in the Canadian Arctic. The overarching long-term objective is to improve our knowledge of PBDEs leaching and migration processes by linking types and sources of PBDEs, their transport via water, and characteristics of soil in relation to partitioning of PBDEs. Our research is intended to provide knowledge and modelling tools to anticipate, manage, prevent and mitigate adverse impacts of industrial pollution.

This study should contribute in some or all of the following areas:

1. Investigating the fate of leachate and/or runoff from Canadian Arctic solid waste dump sites by analyzing the concentration of PBDEs;
2. Establishing whether there are correlations between PBDEs in Northern Arctic soil, sediments and water (i.e. water column) and those detected in aquatic species from the same ecosystem (data readily available in the literature);
3. Determining rates of deposition, sources, age, and temporal profiles in soil, sediments and water in the Arctic;
4. Studying the re-entry of these compounds into the atmosphere through volatilization and re-suspension via surface waters, soil and sediment cores; and
5. Assessing the chemical fate of PBDEs in sediments and soil in the Arctic.

Materials and Methods

Preliminary research involves soil and sediment sample collection at designated solid waste disposal sites in selected locations across the Canadian Arctic in the summer of 2004. Soil samples from solid waste disposal sites and background soil samples were collected in order to identify local sources from potential global source deposition. Hand trowels were utilized for soil collection and a sediment-coring device for sediment collection. Leachate samples were collected at representative locations and at positions designated by local authorities. No more than 2-3 days were required at each location to collect samples. Due to the long daylight hours, we were able to optimize the field program. Most of the solid waste disposal sites from which samples were collected contained leachate discharged into the water body nearest to each site. By analyzing the soil/sediment in these areas, we can determine its permeability and thus its leachability potential, which in turn should correlate with the data from analysis of the adjacent water body and sediments. Lake and marine sediment samples were collected to a maximum depth of 2 m from water bodies in close proximity to the selected solid waste disposal sites where the soil samples were to be obtained.

By stratifying the soil and/or sediment, we were able to obtain a temporal profile or biomarker that could date the age of the compounds being sought. Sediment samples were taken. The soil collected at the dumps/landfills was likely to be surficial, to a maximum depth of 1.0 m. Background sampling had to be determined in the field. GPS locates were recorded for all samples, including background locations. As a back-up, the sampling points were logged in a field book and marked on a site location plan.

Determination of Local Source or Long-Range Transport

It is important to establish whether samples should preferentially be collected from lake sediments or marine sediments. In order to address this issue, there were six sediment sample points at four different Arctic water bodies and 6-10 sample points at each landfill site.

In order to determine whether or not there is a local source of PBDEs, marine sediments were collected close to the outfall or effluent discharge from each solid waste disposal site. To assist in the determination of whether there is long-range transport, we also collected sediment samples from a nearby lake. Collection of sediment samples from lake and/or marine environments should assist in inferring the most probable origin. This will be useful in identifying some of the source characterization of PBDEs. We may also find that the lakes are actually conduits for these compounds rather being sinks.

Results and Discussion

The concentration levels that we obtained from soil and sediment samples in this preliminary study are the first to be analyzed in these areas. As such, we do not have information on previous data for PBDEs across the Canadian Arctic. The levels found as PBDE homologue groups were somewhat different for each location sampled (Figure 1). Comparing the results we obtained of PBDE congeners with the general composition of commercial PBDE products we found that both the tetra-BDE and penta-BDE congeners were similar in make-up to the commercial Tetra-BDE product for Iqaluit but not for Yellowknife or Cambridge Bay concentrations. With regards to the deca-BDE congener,

both Yellowknife and Cambridge Bay locations exhibited high concentrations whereas Iqaluit did not. As the deca-BDE congener is considered to be the Deca-BDE product, this could mean the commercial product exists in these locations. With these preliminary results we are unable to conclude at this time whether any degradation of the deca-BDE occurred, and if it did, if it degraded into the lower brominated congeners for Yellowknife and Cambridge Bay. It is interesting to note however that Iqaluit had little deca-BDE compared with the other two sites but had a high concentration of tetra-BDE and penta-BDE congeners, perhaps indicating a degradation or debromination of deca-BDE. The PBDE homologue groups appear to be typical of what other researchers have found when analyzing for PBDE congeners (soils, sediments, adipose tissue), i.e. BDE-47, BDE-99, BDE-100, BDE-153, BDE-154, BDE-183, BDE-209 (Figure 2).

However, confirmatory tests are needed to verify these preliminary results. Previous data for sediments, soils and leachate in the Canadian Arctic and/or North America is sparse.

This project will ultimately assist researchers in filling gaps in preparing mass balance models and in determining the fate and assessing the risk of different industrial and municipal facilities/practices, such as waste disposal on land and in landfills. Once the transport mechanisms are clearer, it should be easier to plan appropriate mitigation and prevention measures.

References

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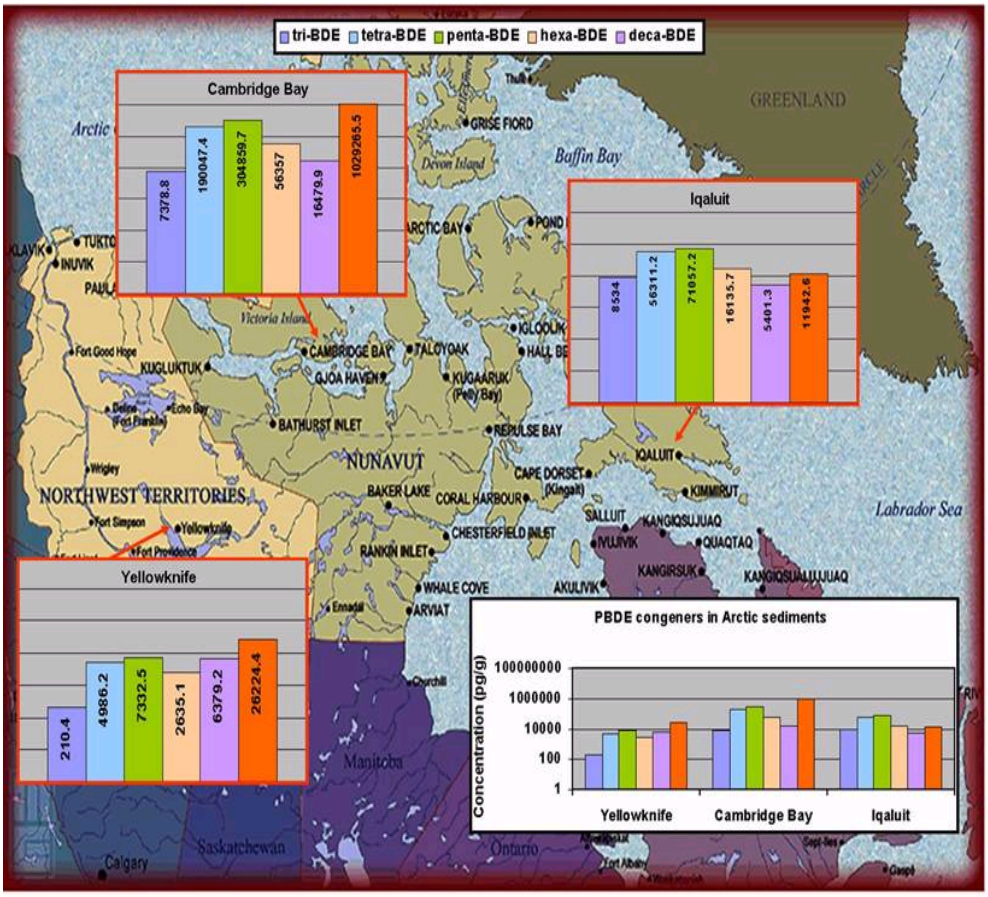

Figure 1. PBDE homologue groups concentrations in Arctic soil and sediments (pg/g)

Figure 2. Percent Distribution of Homologue Groups

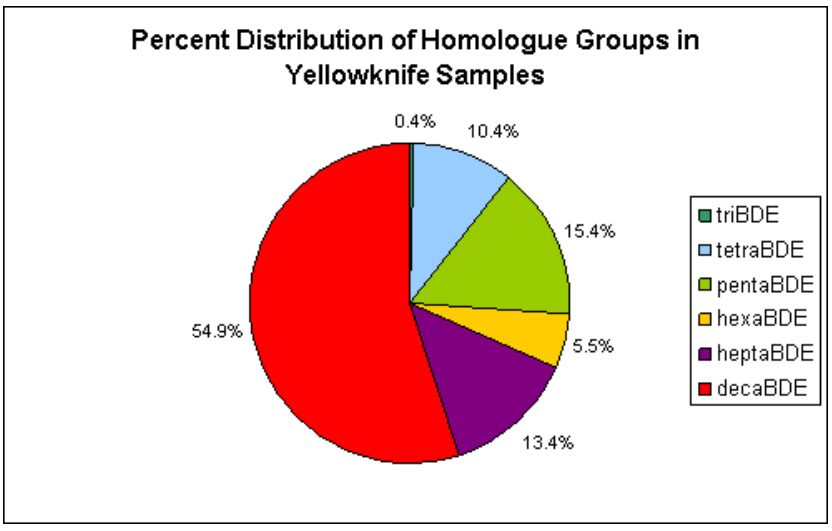

Figure 2A. Percent Distribution of Homologue Groups in Yellowknife Samples

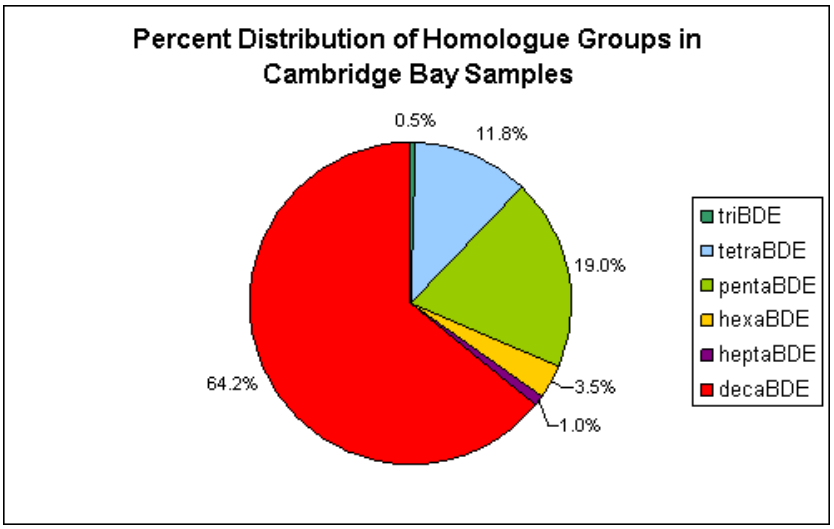

Figure 2B. Percent Distribution of Homologue Groups in Cambridge Bay Samples

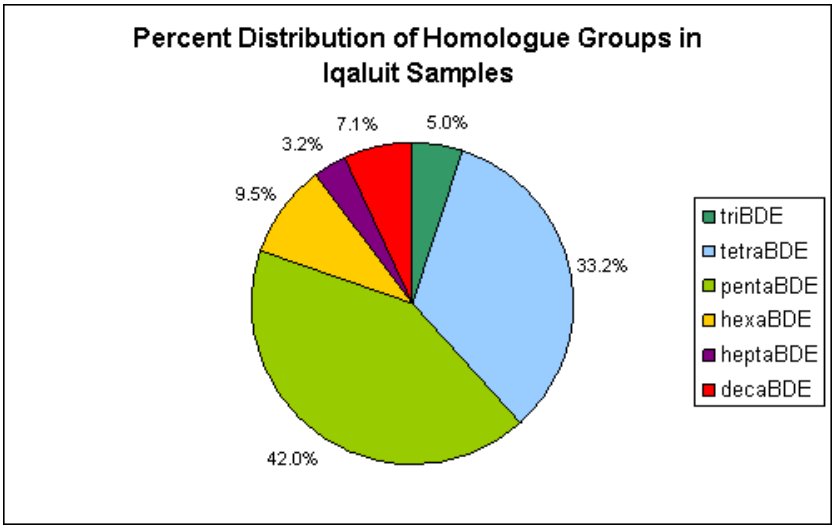

Figure 2C. Percent Distribution of Homologue Groups in Iqaluit Samples