PCBs IN SOILS IN AND AROUND DUMP SITES AND SEWAGE EFFLUENTS IN THE CANADIAN NORTH

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Introduction

Persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) are carbon-based chemical compounds and mixtures[1]. Due to their persistence and semi-volatility, PCBs are transported to remote marine environments by atmospheric transport[2]. Of particular concern is the depositions of PCBs are transported from continental areas to polar region[3]. Exposure to dioxin-like PCBs (dl-PCBs) is of concern because of their toxicity, which include endocrine disruption, hypovitaminosis A, hypothyroidism, carcinogenicity, neurotoxicity and reproductive effects in humans and wildlife[4-5]. Even in minute quantities, PCBs in wildlife in pristine Arctic environment can cause cancers, neurological and learning disabilities, hormonal (endocrine) disruption, and subtle changes to reproductive and immune systems[5].

The Canadian North is remote, containing polar region with a perennial frozen sea. The North appears to have a greater capacity for storage of POPs as compared to other regions; therefore, once POPs enter the Arctic, they are readily incorporated within biological systems[6]. All of these forces contribute to a growing burden of pollutants in Arctic air, water, animals, and humans[7]. Given the health threats of PCBs, their widespread appearance, including alarming levels reported in marine mammals and birds[6,8-9]**.** In Canada's far northern communities, mass balances are needed to indicate the sources, transfers and accumulation of the various PCB congeners in air, water and soil[7]. Studying the leachability of PCBs from electronic wastes (e-wastes) and examination of landfill sites to determine the fate and transport of PCBs are logical and important starting points[10]. Such factors as the nature and extent of PCBs contamination, their potential mobility, their bio-availability and their cumulative amount in vegetation, soil, and drainage water must be known. The spatial distribution of PCBs contamination around landfill areas could assist in determining the sources and spread of PCBs.

As for studies reported elsewhere[10], the vast majority of products containing PBDE compounds are already disposed of in landfills (~80%) and the rest incinerated in and around the Canadian Arctic. It has also been found that sediments in the water surrounding landfill and sewage treatment facilities have ng/g range concentrations of PBDEs[11-12]. However, there are no reported studies quantifying the distribution of PCBs in landfill soils and the mechanism of leaching of PCBs from such sites. Consequently, in this study we examine profiles of PCBs in soil samples collected in impacted sites near three major communities in the Canadian arctic and in background locations. The sites selected were assessed to be impacted by landfill leachate (dumpsites) and wastewater effluents[10].

Materials and methods

A sampling trip was made to three northern Canadian locations (Yellowknife "YELL", Iqaluit "IQA", and Cambridge Bay "CAM"). Twenty four soil samples (YELL=3, IQA=15, CAM=6) were collected (with the depths of 0-20 cm below surface). The detailed sampling locations are shown in Figure 1. Multiple samples were collected at both the Iqaluit and Yellowknife landfills. A sample from a dumpsite in Cambridge Bay was also collected for comparison purposes. YELL and IQA samples were drawn from town locations, including close to wastewater effluent discharge areas. Most sites sampled contained sewage effluent or leachate discharged into the water body nearest each site. Hand trowels were used for soil collection. Samples were refrigerated at 4°C until analysis.

A total of eighty major PCB congeners were analyzed in this study. The soil samples were extracted and the analysis is described elsewhere[13]. Briefly, soil was extracted with dichloromethane using Soxhlet extractor for 16 hours. The extract was cleaned using alumina-silica gel column chromatography. After

concentration, the extract was cleaned again using size exclusion chromatography (Phenomenex Co., 100Å column) to remove biogenic materials. PCBs were analyzed using gas chromatography with ^{63}Ni µ-electron capture detector (GC/µ ECD).

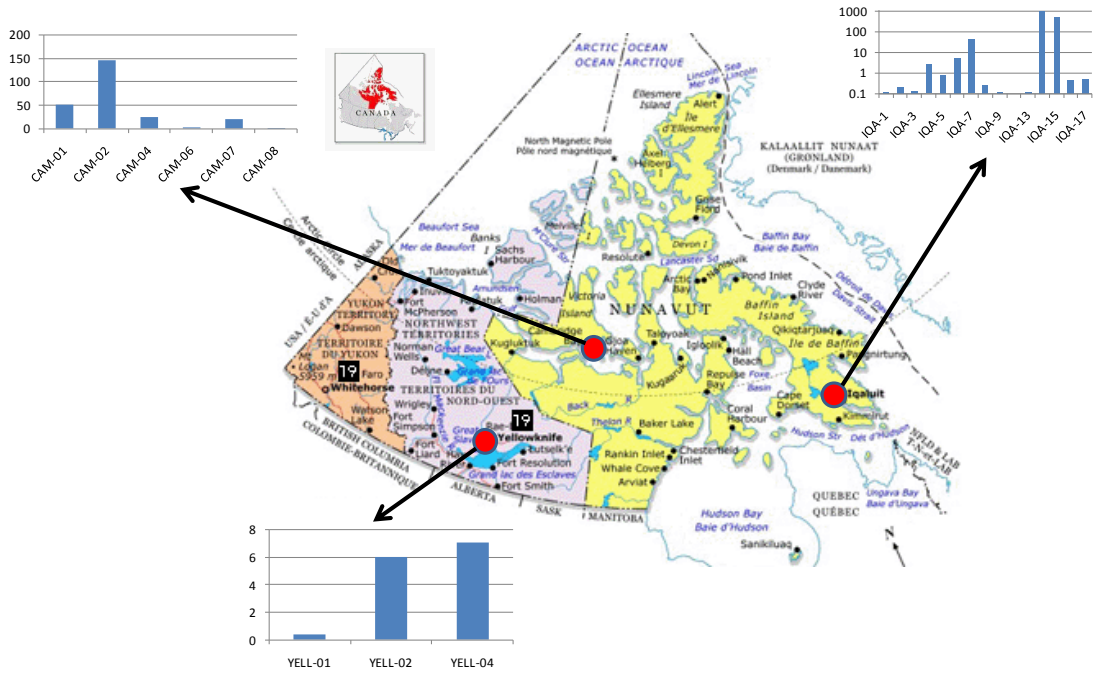

Figure 1. The map showing sampling locations and total PCBs concentrations from the soil.

Quality assurance/quality control (QA/QC) procedures included analysis of duplicates, standard reference materials, and spiked internal standards. In the PCBs analyses, internal standards were added at the beginning of the procedure and carried through the extraction, cleanup, and instrumental analysis steps to determine recovery. The following specific quality assurance steps were used to ensure measurement accuracy and precision: one procedural blank, one matrix spike, one duplicate spike and one standard reference material were run with each batch of not more than 20 samples.

Results and discussion:

Eighty major PCBs congeners analyzed and twenty two PCBs were detected in the soils from the Canadian Arctic (Table 1). Concentrations of PCBs in IQA were found to be higher (0.11-1111 ng/g dry weight basis), following in decreasing order of CAM (0.07-145 ng/g dry weight) and YELL (0.4-7.1 ng/g dry weight) (Table 1 and Figure 1). Contamination profiles of PCB congeners were different between Iqaluit "IQA" samples, while PCBs congener profiles were similar in Yellowknife "YELL" and Cambridge Bay "CAM" areas. The overall highest total PCB concentrations measured in soil samples from the major dumpsites and neighboring areas were those from Iqaluit. The higher PCBs from IQA14 and IQA15 were significantly greater than what was measured in corresponding background locations IQA 1-9, 12-13 and 16-17. The background sample sites were chosen to be representative of clean and undisturbed soils. The large difference in concentrations observed between dumpsites and background soil samples suggest PCB deposition into these dumpsites from materials discarded within[10]. The levels measured in background soil samples are assumed to reflect deposition from atmospheric transport. There were significant variations between the lowest and highest concentration measured in soil samples within each of the dumpsites that could be attributed to multiple factors including the historical movement of material within each site and the drainage characteristics of the site[10].

PCBs -153, -170 and -180 were found to be an important congener measured in most of the dumpsite soil samples in IQA. PCB-52 was a major congener from YELL and lower chlorinated PCBs (e.g. PCB -8, -18, -28, -44 and -52) were the predominant contributors in CAM soils. Soil samples were collected from various locations within each of the three communities. These samples were gathered with the intent to characterize soils in areas close to known sources of contamination (i.e. landfills, dumps). Metal dumps are a common occurrence in Northern Canada. However, they are not typically located close to the municipal dumps and can be found inside of the town boundaries or haphazardly situated in remote areas, many times adjacent to a major body of water[10].

Iqaluit: Three locations were sampled within the current dumpsites in operation and contamination-free area of Iqaluit. A significant concentration gradient was observed in the PCB concentrations among soil samples from this site. The total PCB concentrations measured intwo other sites, IQA-6 (decommissioned military dump) and IQA-7 (former metal dump from the 1940s) were close to the levels typically measured in the background sites examined, reflecting atmospheric deposition. It should be pointed out that IQA-6 and IQA-7 had no linkages to the main landfill of Iqaluit. The materials deposited at these two sites were primarily metal drams etc., not deemed to contain PCBs as they have been there since the 1940s[14].

Yellowknife: Soil samples were collected in three locations (YELL-01, 02 and 04) within the landfill. Two of the locations (YELL-02 and 04) had extremely similar PCB concentrations when compare to YELL-01 which is also close to landfill. These findings suggest that site morphology, drainage characteristics, and management of the materials in the landfills play an important role on the amount of PCBs deposited into the soil of the specific site[14]. The findings also point to the need to collect soil samples underneath materials discarded for a more comprehensive site evaluation.

Cambridge Bay: Six samples were collected across the Cambridge Bay region in an attempt to characterize the soils for the presence of PCBs. There was only one municipal dump and one metal dump in the area. The soil samples collected from metal dump (CAM-08) had the lowest overall PCB concentration. Lower concentration in CAM-06 was unexpected considering that this dump consists of paints in metal drums are known to contain PCBs. The PCB profiles of CAM-06 were unique among all six samples examined however different when compare to IQA and YELL. The origin of PCBs at this location is most likely due to various sources.

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Table 1. Concentration (ng/g dry weight) of PCBs in soils from Canadian Arctic.

Location	IQA-1	IQA-2	IQA-3	IQA-4	IQA-5	IQA-6	IQA-7	IQA-8	IQA-9	IQA-12	IQA-13	IQA-14
PCB 8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.03	<0.001	<0.001	<0.001	<0.001	0.34
PCB 18	0.01	0.08	0.01	0.003	0.002	0.06	<0.001	0.10	0.02	0.004	0.02	8.4
PCB 28	0.002	0.008	0.002	0.003	0.001	0.1	0.37	0.005	0.001	0.001	0.003	20
PCB 29	<0.0006	<0.0006	<0.0006	0.03	<0.0006	<0.0006	0.02	0.01	0.003	<0.0006	0.005	0.17
PCB 44	0.02	0.02	0.01	0.03	0.02	0.11	<0.009	0.05	0.01	0.02	0.02	30
PCB 52	0.003	0.01	0.002	0.06	0.01	0.28	0.09	0.005	0.001	0.005	0.003	50
PCB 66	0.002	0.006	0.005	<0.001	<0.001	<0.001	0.07	0.002	0.001	0.001	0.002	18
PCB 87	0.003	0.004	0.004	0.10	0.03	0.15	0.10	0.002	0.001	0.002	0.002	23
PCB 101	0.01	0.01	0.01	0.20	0.05	0.32	0.70	0.01	0.002	0.005	<0.004	94
PCB 105	0.003	0.004	0.005	0.06	0.01	0.05	0.10	0.001	0.001	0.001	0.002	16
PCB 110	0.01	0.01	0.01	0.28	0.08	0.38	0.22	0.005	0.001	0.004	0.004	74
PCB 118	0.01	0.01	0.01	0.16	0.04	0.21	0.55	0.003	0.001	0.002	0.004	38
PCB 128	0.002	0.002	0.002	0.06	0.02	0.05	<0.001	0.002	<0.001	<0.001	<0.001	14
PCB 138	0.01	0.02	0.01	0.41	0.13	0.50	0.53	0.01	0.003	0.01	0.01	89
PCB 153	0.01	0.02	0.02	0.46	0.13	0.56	0.55	0.01	0.004	0.01	0.01	284
PCB 170	0.003	0.005	0.005	0.15	0.04	0.22	0.14	0.02	0.001	0.004	0.004	103
PCB 180	0.01	0.01	0.02	0.36	0.19	1.6	36	0.04	0.02	0.03	0.02	198
PCB 187	0.003	0.01	0.01	0.18	0.05	0.27	0.76	0.003	0.001	0.004	0.004	0.73
PCB 195	0.001	0.001	0.001	0.04	0.01	0.1	<0.0004	<0.0004	0.0004	0.001	0.001	20
PCB 200	0.0005	0.0004	0.0004	0.01	0.002	0.03	0.01	<0.0004	<0.0004	<0.0004	<0.0004	6.9
PCB 206	0.0004	0.0007	0.0009	0.03	0.005	0.04	0.20	0.001	0.007	0.001	0.0005	9.0
PCB 209	0.002	0.001	0.004	0.004	0.002	0.056	0.30	0.01	0.03	0.005	0.002	6.1
∑ PCB	**0.11**	**0.22**	**0.14**	**2.6**	**0.81**	**5.0**	**40**	**0.27**	**0.11**	**0.10**	**0.12**	**1111**

Table 1 Continues.,

Location	IQA-15	IQA-16	IQA-17	YELL-01	YELL-02	YELL-04	CAM-01	CAM-02	CAM-04	CAM-06	CAM-07	CAM-08
PCB 8	0.03	0.01	<0.001	0.01	<0.001	<0.001	<0.001	12	0.01	0.03	<0.001	<0.001
PCB 18	0.19	0.006	0.004	0.02	0.04	<0.001	0.02	24	0.01	0.04	0.08	0.001
PCB 28	0.18	<0.0003	0.0004	0.002	<0.0003	<0.0003	0.04	23	<0.0003	0.01	0.02	0.002
PCB 29	0.04	<0.0006	<0.0006	0.004	0.02	0.51	0.071	0.21	0.10	0.002	0.03	0.007
PCB 44	13	0.01	0.02	0.02	<0.009	1.1	0.76	12	<0.009	0.06	0.66	0.02
PCB 52	31	<0.001	0.001	0.06	0.70	5.1	2.0	10	0.002	0.11	1.4	0.004
PCB 66	3.4	<0.001	<0.001	<0.001	<0.001	<0.001	0.05	6.4	1.2	0.03	0.30	<0.001
PCB 87	26	0.01	0.002	0.01	0.33	<0.001	3.3	3.6	3.0	0.17	1.5	<0.001
PCB 101	58	0.05	0.01	0.02	0.004	0.02	6.2	6.7	0.05	0.33	0.03	<0.004
PCB 105	13	0.02	0.001	0.002	0.01	0.06	2.5	2.2	0.02	0.16	1.0	<0.001
PCB 110	54	0.01	0.01	0.050	0.71	0.005	9.1	11	0.05	0.41	4.2	0.01
PCB 118	37	0.02	0.004	0.01	0.43	0.01	6.0	5.5	3.9	0.34	2.5	<0.001
PCB 128	10	0.006	0.002	0.005	0.10	<0.001	1.7	2.6	1.1	0.06	0.64	<0.001
PCB 138	76	0.07	0.03	0.04	0.87	0.17	8.0	5.0	6.3	0.34	3.1	0.002
PCB 153	93	0.1	0.04	0.03	0.82	0.01	7.3	13	6.2	0.28	2.9	0.001
PCB 170	38	0.02	0.01	0.02	0.34	0.003	0.65	1.8	0.85	0.06	0.33	<0.001
PCB 180	24	0.1	0.04	0.06	1.3	0.01	1.5	4.2	1.4	0.36	0.56	0.02
PCB 187	39	0.02	0.01	0.02	0.20	0.01	0.42	1.1	0.31	0.021	0.23	<0.0004
PCB 195	9.2	0.005	0.002	0.01	0.06	<0.0004	0.1	0.26	0.02	0.003	0.04	0.002
PCB 200	0.029	0.1	0.01	0.001	<0.0004	0.01	0.04	0.38	0.16	<0.0004	<0.0004	<0.0004
PCB 206	4.3	0.002	0.0005	0.02	0.05	0.007	0.03	0.15	0.1	0.003	0.05	0.001
PCB 209	0.24	<0.0006	0.32	0.005	0.05	<0.0006	0.04	0.03	0.02	0.005	0.01	0.001
∑ PCB	**531**	**0.49**	**0.51**	**0.40**	**6.0**	**7.1**	**50**	**145**	**25**	**2.8**	**19**	**0.07**