PCB migration in a 24 year old PCB Storage Facility

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ABSTRACT
In 2009, all Polychlorinated Biphenyl (PCB) contaminated materials in the Pottersburg storage facility were excavated for permanent disposal. Depth profiles of PCB concentrations obtained through the cover and liner system in Cell 2 are reported. The implications with respect to contaminant migration of PCBs over the 24 year period since the waste was placed are discussed. Further project investigations are outlined including the characterization of the geomembrane and clay liner materials by conducting laboratory diffusion tests using benzene, toluene, ethylbenzene and xylenes (BTEX) and PCBs as tracers

RÉSUMÉ
En 2009, tous les matériaux contaminés par le Biphenyl Polychloré (PCB) dans l'ouvrage de stockage de Pottersburg ont été excavés pour une disposition permanent. Des profils de concentration de PCB en fonction de la profondeur obtenus des systèmes de couverture et revêtements de la cellule 2 sont raportés. Les implications relatives à la migration du PCB pendant la période de 24 années depuis le début du stockage des déchets sont discutées. D'autres projets sont des enquêtes sont exposées, y compris la caractérisation complémentaire de la géomembrane et du matériau argileux a été réalisée au moyen d'essais de diffusion en laboratoire de benzène, toluène, ethylbenzène et xylènes (BTEX) et PCB comme traceurs.

1 INTRODUCTION

Historically, a landfill liner would be a clay liner made of either a low-permeability natural clay deposit (e.g. in parts of south western Ontario) or a compacted clay liner. In the last 25 years, there has been a move to add a geomembrane to form a composite liner to further control the advective and diffusive transport of contaminants to negligible levels (Rowe et al, 2004). However there is very limited field data on the long-term performance of these systems for containing contaminants.

Construction of the Pottersburg polychlorinated biphenyl (PCB) storage facility between 1984-1987 bridged the transition from compacted clay to composite liners. The facility was comprised of four separate cells of PCB contaminated soil and waste. Cells 1 and 2 had a compacted clay liner. Cells 3 and 4 had a high density polyethylene (HDPE) geomembrane and compacted clay liner. In 2009, all PCB contaminated materials were excavated for permanent disposal. This exhumation presented a unique opportunity to evaluate the performance of the barrier systems after 22 to 25 years of PCB storage.

The exhumation of the cover and barrier system also offered a unique opportunity to study the effects of aging on the geomembrane. This is the first opportunity of which we are aware where a geomembrane liner could be studied after 22-23 years of use as a base liner in a landfill and certainly the first to have been used as a base liner for storage of PCBs. The movement of PCBs and the performance of the barrier systems in the four cells are presently being studied. To the best of the authors' knowledge, the two oldest previously investigated HDPE geomembranes exhumed from waste containment sites were a 14 year old leachate lagoon liner (Rowe et al. (2003) and a 20 year old liner from a surface impoundment containing power plant ash (Yako et al. 2010). This is the first of several papers dealing with the geomembranes and the PCB migration at this site. The objective of this first paper is to discuss the PCB migration profile through the barrier at Cell 2 (where there was no geomembrane in the base liner) after 24 years in service.

1.1 Site Contamination

PCBs were used extensively in the manufacture of electrical equipment by Westinghouse Canada in London, Ontario, Canada. In 1980, elevated PCB levels were found in fish, sediments and soil downstream from the manufacturing site in the Walkers Drain and Pottersburg Creek (MoE Ontario, 2008). The contaminated soils were removed from the environment downstream of the manufacturer between 1984-1987 and placed in the landfill cells of the Pottersburg PCB storage facility, located on the Westinghouse industrial property. The Ontario Ministry of the Environment (MoE) assumed ownership of the storage site property in 1985. PCBs were to be stored at the Pottersburg site until a method of destroying them became economically viable and was approved by the federal government (Environment Canada, 2009).

Eventually, a federal regulation required the destruction of PCBs by the end of 2009 (MoE Ontario, 2010). The Pottersburg PCB Storage Site was decommissioned, all cells were exhumed and the PCBs were incinerated at a federally approved facility in St-Ambroise, Quebec. All four landfill cells were excavated and PCBs contaminated materials were removed from the site by December 14th, 2009.

1.2 Pottersburg PCB Storage Facility

During the large-scale clean up of PCBs that took place at the Pottersburg site, the waste was separated into four vaults (or cells). One cell was created per year over the four-year clean up period. All of the cells were of comparable size with varying bottom barrier designs. The cells had varying concentrations of PCB contaminated soil. In order to minimize migration of PCBs during excavation, an engineered tarped enclosure was built around the entire site before excavation started. Cell 1 had its own enclosure, and cells 2, 3 and 4 were in a second enclosure.

Each cell had a final cover comprised of top soil, a clay till liner, a geotextile separator, a sand drainage layer, a geomembrane, a sand drainage layer, and a clay cap over the PCB contaminated soil (Figure 1)**.** Below the PCB contaminated soil**,** the bottom barrier system for Cells 1 and 2 (Figure 2) had a geotextile separator, a sand leachate collection system, a compacted clay liner, leak detection system, and a secondary compacted clay liner. Cells 3 and 4 had a leachate collection system, high density polyethylene (HDPE) geomembrane, compacted clay liner, leak detection system and an underlying secondary compacted clay liner (MoE Ontario, 2008).

2 PROJECT INVESTIGATIONS

2.1 PCB migration through barrier

This paper describes the PCB migration through the barrier system for the Cell 2, built 24 years before exhumation. Samples of all layers of the barrier system were collected and PCB concentrations analyzed to give an indication of the extent of PCB migration through the barrier system. Leachate characteristics, collected by the MOE for the lifespan of the landfill, give information about the history of contaminant levels in the cell. Conclusions can be drawn from this leachate data as to the migratory pattern of PCBs through the clay barrier system.

With field data from the site, future work can compare the actual migration with theoretical migration derived from computer modelling using the contaminant transport modelling program such as POLLUTEv.7 (Rowe & Booker, 2005) to assess if the migration is occurring as predicted, using laboratory obtained sorption and diffusion parameters for the clay.

2.2 BTEX Diffusion and Sorption for GM

Geomembranes are the primary advective barrier to contaminant migration in modern landfills. Contaminants moving through the geomembrane travel by diffusion and are governed by the sorption and diffusion coefficients with respect to that particular contaminant. The diffusive properties of the geomembranes, exhumed from the cells of the Pottersburg Creek PCB Storage Facility were evaluated using benzene, toluene, ethylbenzene and xylenes (BTEX) as tracer contaminants in addition to PCBs. BTEXs are used since they diffuse relatively quickly through geomembranes and they can used to compare the diffusive properties of these old geomembranes with those of modern geomembranes.

Geomembranes used in the liners at the Pottersburg PCB Storage Facility were 1.5 mm thick (60 mil) HDPE. The manufacturer of the liners is unknown. The age of each geomembrane was taken to be 24 years (Cell 2) based on the assumption that the geomembrane had been manufactured in the same year it was installed. An unaged 1.5 mm-thick HDPE geomembrane supplied by Solmax International, Quebec is also to be studied as an example of an unaged and relatively modern HDPE geomembrane. Laboratory tests to establish the sorption and diffusion characteristics of the geomembranes recovered from each of the cells are to be performed. Experimental results will establish the diffusion coefficient, D_g, partitioning coefficient, S_{gf}, and permeation coefficient, P_g (Rowe et al, 2004) with respect to BTEX and PCBs. Concentrations in the vials and diffusion cells (source and receptor) are being monitored until equilibrium is reached (defined as 10 days beyond no change in concentration).

2.3 PCB Diffusion and Sorption of GM and Clay

Tests to establish the diffusive properties of the PCBs in water with respect to clay and geomembrane samples are
in progress. PCB sorption tests are being run to equilibrium in the same manner as for BTEX.

2.4 Congener specific migration

PCBs are a group of 209 different congeners, or isomers, which have varying solubility and diffusive properties. Aroclors is the trade name for technical mixtures of specific congeners manufactured by Monsanto, USA.

3 SAMPLING

3.1 Site Sampling

Samples 1m by 2m in size of geomembrane were collected from the cover of each cell. Following excavation of the PCBs, we collected samples of the waste above the barrier, and of the barrier components which included the geotextile separating the waste from the leachate collection layer, the sand drainage layer, the geotextile protection layer, and geomembrane (where present) and the compacted clay liner. Grab samples were taken from the waste and clay samples at varying depths. Samples were taken in the same vertical profile. Whenever feasible, all samples were taken within 6m of sumps where it was expected that the highest concentration of PCBs would be encountered in the

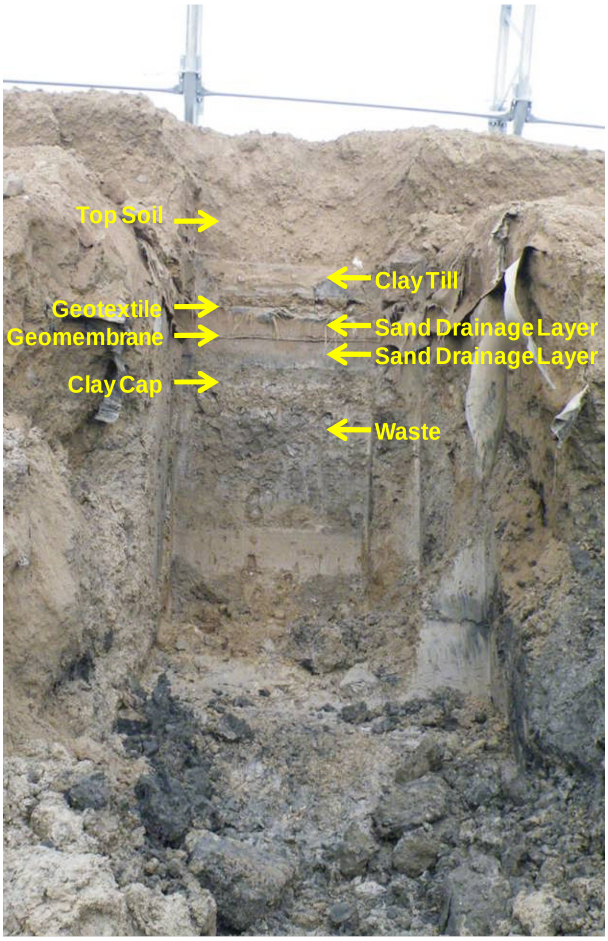

Figure 1. Vertical profile of typical top cover system during excavation at Cell 2. From top down: top soil, clay layer, geotextile, sand drainage layer, geomembrane, sand drainage layer, clay cap and waste soil

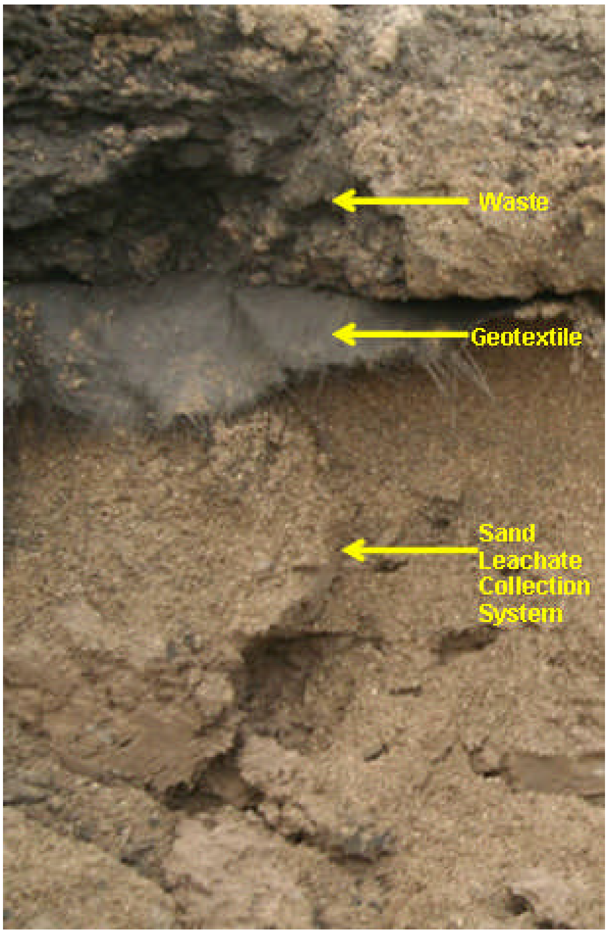

Figure 2. Vertical Profile of the bottom barrier system at Cell 2 during excavation. From the top down: waste soil, geotextile, sand leachate collection system (underlain by clay which is not shown here)

barrier system. Sample depth was recorded, as well as its position in relation to the geomembrane samples and manhole locations.

A 10 cm clay sample from the base liners in Cells 2 and 4 was extracted using a stainless steel core with a modified penetrating tip. PCB diffusion tests will be performed on these undisturbed clay samples.

Clay and sand samples were removed with the use of a core sampler so that a profile of PCB concentrations through a 60 cm section of the barrier could be developed.

3.2 Decommissioning

During the decommissioning samples of the waste were analysed. Significant spatial variability was observed and the waste was composed of multiple different soil types with different PCB concentrations. This arises from the fact as the soil came from multiple different sites and creek beds with different particle size distributions and contaminant levels.

4 PCB CONCENTRATIONS

4.1 Leachate Data

Leachate monitoring data obtained from the MOE over the lifespan of Cell 2 (MoE Ontario, 2010) indicated total PCB concentrations ranging from undetectable to values as high as 95 µg/L (0.1 ppm). Ontario Reg. 153/04: Brownfields standards for industrial land use with potable groundwater suggest that levels must not exceed 0.20 µg/L). Ontario Drinking Water Quality Standards (ODWQS) allows for 3 µg/L total PCBs (Government of Ontario). The detection limit for PCB concentrations in soil was 0.020 µg/L.

Table 1. PCB Concentrations in Cell 2

Cell 2 Sample Collection Strata		PCB Concentrations			
Cover Liner	Depth below Surface cm	Aroclor 1242 µg/g	Aroclor 1254 µg/g	Aroclor 1260 µg/g	Total PCBs µg/g
Grass	0-10	-	-	-	-
Top Soil	10-30	<0.1	0.2	<0.1	0.3
Clay Till	30-90	<0.1	<0.1	<0.1	<0.1
Geotextile		8.0	<0.1	0.2	8.2
Drainage Layer	90-122	<0.1	<0.1	<0.1	<0.1
Geomembrane	(1.5 mm)	1.8	0.55	1.6	4.0
Drainage Layer	122-145	<0.1	<0.1	<0.1	<0.1
Clay Cap		-	-	-	-
Waste	Average	4.0	0.5	0.9	5.4
Base Liner	Depth below Waste cm	Aroclor 1242 µg/g	Aroclor 1254 µg/g	Aroclor 1260 µg/g	Total PCBs µg/g
Geotextile		1.5	0.1	0.1	1.6
Sand LCS	0-5	0.01	<0.01	<0.01	0.01
	5-10	<0.01	<0.01	<0.01	<0.01
	10-15	<0.01	<0.01	<0.01	<0.01
	15-20	<0.01	<0.01	<0.01	<0.01
CCL	0-2	<0.1	<0.1	<0.1	<0.1
	2-7	<0.1	<0.1	<0.1	<0.1
	7-12	<0.1	<0.1	<0.1	<0.1
	12-17	<0.1	<0.1	<0.1	<0.1
	17-22	<0.1	<0.1	<0.1	<0.1
	22-27	<0.1	<0.1	<0.1	<0.1
	27-32	<0.1	<0.1	<0.1	<0.1

"-" indicates unmeasured data

4.2 Soxhlet Analysis

Waste, sand and clay samples were thoroughly mixed before sub-sampling 10 g for analysis. Geomembrane sub-samples (1 g) were cut from larger samples into 1 cm x 1 cm pieces. Geotextile samples (5 g) were also studied. All soil and geosynthetic samples were placed in a glass thimble with Ottawa sand and glass wool as per the Soxhlet method. The samples were spiked with an aliquot of decachlorobiphenyl (DCBP), a surrogate standard, prior to extraction. PCBs were then extracted from the sample by mixing with 250 ml of dichloromethane using the Soxhlet apparatus. A repeated evaporation and condensing process flushes the sample with DCM though the thimble for six hours and allows for the PCBs to be extracted and stored in a round bottom flask. The extracts were concentrated using a rotoevaporator and the solvent was exchanged for hexane. The concentrated sample (10 ml) was filtered through a Florisil column. PCBs were analysed by Gas Chromatography-Electron Capture Detection (GC/ECD) using an Agilent 6890 GC equipped with a ^{63}Ni electron capture detector and an SPB™-1 fused silica capillary column (30 m x 0.25 mm x 0.25 µm). Helium was the carrier gas with a flow rate of 2 mL/min. Nitrogen was used as a makeup gas for the ECD. All values were reported as µg/g (ppm) on a dry-weight basis. A blank, spike and duplicate sample were run with every sample set (n=9). The method detection limit for the samples was 0.1 μg/g). The method detection limit for the low level samples was 0.01 μg/g. Blanks were below the method detections limits for all 13 sampling runs. DCBP recovery was within 80-115%. Preliminary analysis of the cell samples revealed a mixture of Aroclors 1242, 1254 and 1260 present in the samples. Concentrations were calculated by comparison of peak responses in the extracts to those in the 3 individual standards, one for each Aroclor. All samples concentrations were corrected for surrogate recovery (Analytical Services Unit, 2008).

4.3 PCB migration

Since all drinking water and groundwater standards are only concerned with total PCB concentrations, the bulk samples from all cover and base barrier system components of Cell 2 were analysed for the total PCB concentration using the Soxhlet extraction as described above. A profile of total PCB distribution was constructed (Table 1). PCBs also were analysed with respect to specific Aroclors, and it was found that concentrations of Aroclor 1242 were greatest although all were at low levels in the samples tested to date (Table 1).Testing of additional samples is ongoing and the results presented herein should be regarded as preliminary.

PCB concentrations were expected to be higher in the sand layer than in the clay layer, and since no PCBs were detectable in the sand at low levels (<0.01 ppm), the compacted clay liner was not analysed for low levels. The very low (non-detect) concentrations in the drainage layer and compacted clay could be related to the low levels of PCBs in the waste at the section analysed. However, based on the presently available data, after 24 years, there was no significant evidence of PCB migration in Cell 2 and this would suggest that the barrier is performing according to design. It is of note that the geosynthetics appeared to attract/sorb PCBs more than any other material and while the concentrations are low it is also evident that PCBs were present.

5 CONCLUSIONS

A rare opportunity to examine the migration of contaminants through the layers of an exhumed landfill for PCB contaminated soil was provided by the exhumation of four cells at the Pottersburg Creek PCB containment facility 22-25 years after disposal of the waste. Sampling that was conducted in Cell 2 (after 24 years) indicated that PCBs concentrations in the drainage layers and clay line below the waste were below detection limits for Cell 2. Apart from the waste, the highest concentration of PCBs in the base barrier system was in the geotextile filter between the waste and the drainage layer. This make sense since the filter will catch many soil particle to which the PCBs may be attached and prevent them from entering the leachate collection layer. Thus, given the non-detect concentration in the leachate collection sand and the compacted clay liner, it appears that the geotextile was, in its role as a filter, serving as an effective means of controlling the migration of PCBs.

Somewhat more surprising was the concentrations of PCBs at levels near or above 1ppm in the geomembrane, geotextile and top soil above the waste but not in the clay till or the sand drainage layer. It appears that the geosynthetics are good at attracting PCBs from the surrounding material and acting a sink however this unexpected finding needs more investigation. Fortunately all levels of PCB were low. Future work will be conducted to confirm these findings.

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