Design and application of surface PRBs for PCB remediation in the Canadian Arctic

Indra K. Kalinovich [a,*], Allison Rutter [b], R. Kerr Rowe [c], John S. Poland [b]

[a] Department of Geology, University at Buffalo, Buffalo, NY 14260, USA
[b] School of Environmental Studies, Analytical Services Unit, Biosciences Complex, Queen's University, Kingston, Ontario, Canada K7L 3N6
[c] Geo-Engineering Centre Queen's-RMC, Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada K7L 3N6

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ABSTRACT

Over the course of three ears, several surface permeable reactive barriers were designed and constructed to deal with leftover site contamination at a site located on the summit of Resolution Island, Nunavut, just southeast of Baffin Island at 61° 35′N and 60° 40′W. The site was part of a North American militar defense s stem established in the 1950s that became heavil contaminated with pol chlorinated biphen ls (PCBs) during and subsequent to, its operational ears. Each of the three barrier designs has a different configuration, to meet the needs of the targeted remediation area, based on their unique contaminant histories. Modifications were made to the barrier designs based on both field observations and laborator results. The comparison of field and laborator results indicated that areas with higher concentrations of PCB contamination behaved differentl than areas with lower concentrations of PCB contaminated soil. Previous laborator studies onl partiall replicated field observations and results. It had previousl been h pothesized that particle retention was the most important factor in trapping and capturing PCBs. However, rinsed filter samples from the field indicated that partitioning of PCBs between contaminated soil and granular activated carbon (GAC) filter particles were occurring at levels of 62 ± 11%, suggesting that sequestration of the PCBs from the environment should be a primar focus of the barrier. This sequestration requires both particle retention (within the granular sorptive filters) as well as maintained contact time between particles for sorption processes to proceed. This mechanism e partitioning of PCB to GAC e was more important in areas with higher PCB concentration. These results suggest that it ma be possible to tailor future barrier designs to their unique site histories and locations.

1. Introduction

1.1. General introduction

Pol chlorinated biphen l (PCB) contamination in the Arctic has been documented at the Distant Earl Warning (DEW) Line sites, a string of 63 militar radar stations that were operated across Alaska, northern Canada and Greenland during the 1950s and earl 1960s (Bright et al., 1995; Stow et al., 2005).

Source removal b soil e cavation is often used for remediation of these sites. Unfortunatel , much PCB contamination can be left behind during this process in the form of mobile soils. PCBs can enter the Arctic ecos stem travelling on these mobile soil particles (Poland et al., 2001). This is particularl important in the Arctic, where there is a narrow food web and PCBs bioaccumulate and biomagnif in fatt tissues (ASTDR, 1997; Fisk et al., 1998).

This paper describes how permeable reactive barriers (PRBs) can be modified from a basic funnel and gate design (

a material such as granular activated carbon (GAC) provides a granular medium for particle retention as well as a sorptive surface to remove PCBs from both water and soil. Field observations and laborator studies of these different barriers provide insight in how to achieve an optimal barrier design.

The initial basic design incorporating of a single funnel (ponding

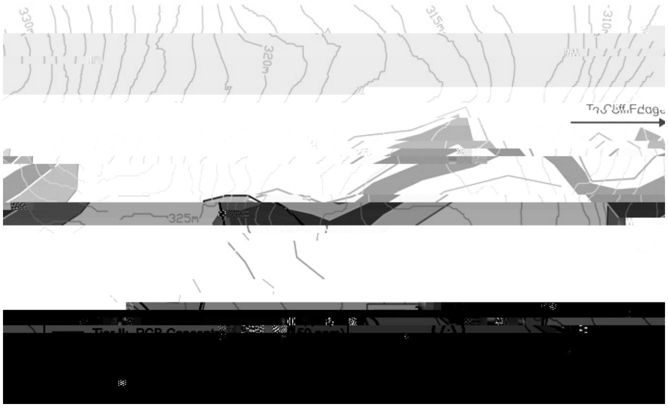

Fig. 3. Map of contamination at furniture dump prior to e cavation.

anal zed to ensure a 'clean' (<1 μg/g PCB) base for construction. Upstream and downstream point samples were taken to establish known prior concentrations. Clean cells were constructed directl behind each barrier gate, in efforts to demonstrate whether contamination was breaking through the barrier s stem or not. Clean cells were constructed and isolated from the surrounding areas using geos nthetic cla liners filled with clean fill obtained from uncontaminated areas of the site. Monitoring schematics for the barrier s stems are illustrated in Figs. 5 and 6.

Fig. 5. Monitoring schematic illustrating monitoring points and clean cells, valle barrier.

2.2. Sampling and analysis

Soil, gravel and GAC samples were collected using plastic scoops and placed in WhirlPak bags. Water samples were collected in 1 L Teflon bottles. Samples were shipped b air freight to Queen's Universit , Kingston, Ontario, Canada for testing. The standard anal tical procedure for the anal sis of PCBs, namel gas chromatograph with an electron capture detector (GC/ECD) was used. These anal ses were performed at the Anal tical Services Unit, Queen's Universit b the procedures described in Kalinovich et al. (2008b). Solvent e traction using dichloromethane b so hlet apparatus or shaker for solids and liquideliquid e traction for liquids was used. After a solvent e change to he anes, the eluent was flushed through a Florisil clean up column with he anes prior

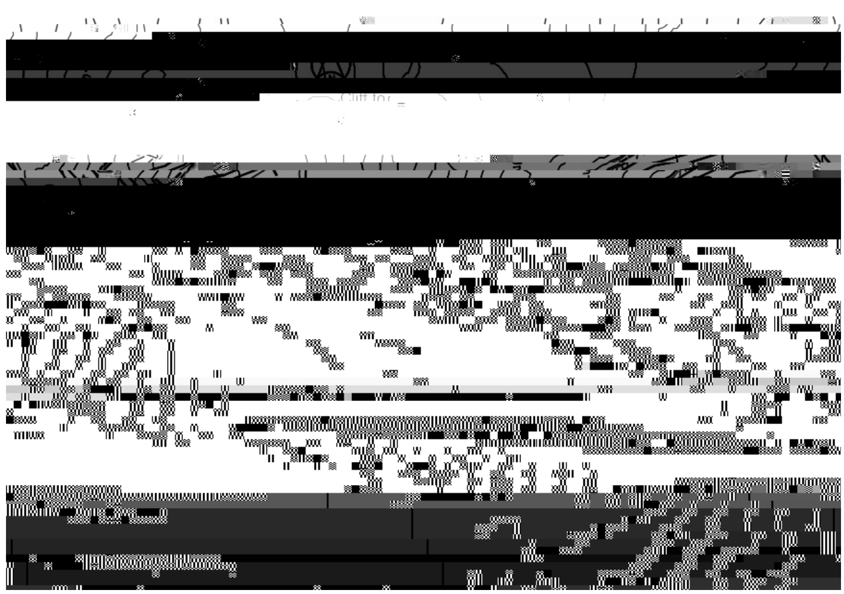

Fig. 4. Map of contamination at furniture dump after e cavation.

to GC/ECD anal sis. Each sample was anal zed using an HP 5890 Series II Plus gas chromatograph equipped with a Ni^{63} electron capture detector (GC/ECD), a SPB™-1 fused capillar column (30 m, 0.25 mm ID × 0.25 μm film thickness) and HPChem station software. A 1260 Aroclor standard was run with the samples, anal tical blank, and control sample (prepared b spiking sand with a separate source standard) along with three DCBP standards, used to calculate percent recov. A he ane blank is also run with the samples. All control samples were within 30% of the e pected value. Rve standard deviations between the samples and their anal tical dupmicate were below 30% for all results. Sample concentrations were corrected for surrogate recover which was between 80% and 120% for all samples. Detection limits for PCBs b liquideliquid e traction and b so hlet e traction were 0.02 μg/L and 0.1 μg/g respectivel .

Standard methods were adopted for soil anal ses of: carbonates (Allison and Moodie, 1965), Cation E change Capacit (Hendershot and Lalande, 2006), particle size distribution and particle densit (Kroetsch and Wang, 2006) Organic Matter as determined b Loss on Ignition (McKeague, 1978) Atterberg Limits (ASTDM D4318-98). Particle size distribution of soil samples from the funnel areas of each barrier are presented in the Supplementar Materials section.

2.3. Column studies

The PCB contaminated soil used for e periments was e cavated from the site and stored at 4 °C. Different PCB concentrations in the soils were combined (rough appro imation of 5 apparatus. The fi

The results from the first field season showed PCB contamina-

If the rising level of contamination (in terms of soil concentration) in the furniture dump barrier is due to this process, surface barriers ma become more relevant for application in cold regions as areas that were previousl in permafrost and are now e periencing freeze-thaw activit (Hugh, 2008; Grossi et al., 2007), thereb potentiall releasing buried contaminants.

3.3.3. *Filters*

soil particles were removed from the GAC material. PCB sorption to GAC in fi

Laborator studies indicated that particle retention was the most important factor in retaining PCBs and that mass transfer mechanisms were occurring in the short duration studied. Rinsed field samples demonstrated that sorption pla s a larger role than had been simulated in the laborator e particularl for areas with highl PCB contaminated soils, as with the furniture dump barrier s stem. The investigation of half-frozen filters and the stressed importance on sedimentation processes are important design challenges that must be considered for surface remediation in cold