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Remediation of PCB contaminated soils in the Canadian Arctic: Excavation and surface PRB technology

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ABSTRACT

The site BAF-5 is 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 military defense system established in the 1950s that became heavily contaminated with PCBs during and subsequent, its operational years. Remediation through excavation of the PCB contaminated soil at Resolution Island began in 1999 and at its completion in 2006 approximately 5 tonnes of pure PCBs in approximately 20,000 m^3 of soil were remediated. Remediation strategies were based on both quantity of soil and level of contamination in the soil. Excavation removed 96% of the PCB contaminated soil on site. In 2003, a surface funnel-and-gate permeable reactive barrier was design and constructed to treat the remaining contamination left in rock crevices and inaccessible areas of the site. Excavation had destabilized contaminated soil in the area, enabling contaminant migration through erosion and runoff pathways. The barrier was designed to maximize sedimentation through settling ponds. This bulk removal enabled the treatment of highly contaminated fines and water through a permeable gate. The increased sediment loading during excavation required both modifications to the funnel and a shift to a more permeable, granular system. Granulated activated charcoal was chosen for its ability to both act as a particle retention filter and adsorptive filter. The reduction in mass of PCB and volume of soils trapped by the funnel of the barrier indicate that soils are re-stabilizing. In 2007, nonwoven geotextiles were re-introduced back into the filtration system as fine filtering could be achieved without clogging. Monitoring sites downstream indicate that the barrier system is effective. This paper describes the field progress of PCB remediation at Resolution Island.

1. Introduction

1.1. Background

Localized PCB contamination in the Arctic has been documented at the Distant Early Warning (DEW Line) sites, a string of 63 military radar stations that were operated across Alaska, northern Canada and Greenland during the 1950s and early 1960 (Bright et al., 1995a,b; Stow et al., 2005).

The radar station on Resolution Island, referred to herein as BAF-5, is located at the southeastern tip of Baffin Island approximately 310 km southeast of Iqaluit and at the end of Frobisher Bay (61° 35′N and 60° 40′W, Fig. 1). The main station site is situated on a summit 360 m above sea level on Cape Warwick at the northeastern end of the island overlooking Brewer Bay. Approaches to the island are by sea at Brewer Bay, and by air using a runway located northwest of the summit.

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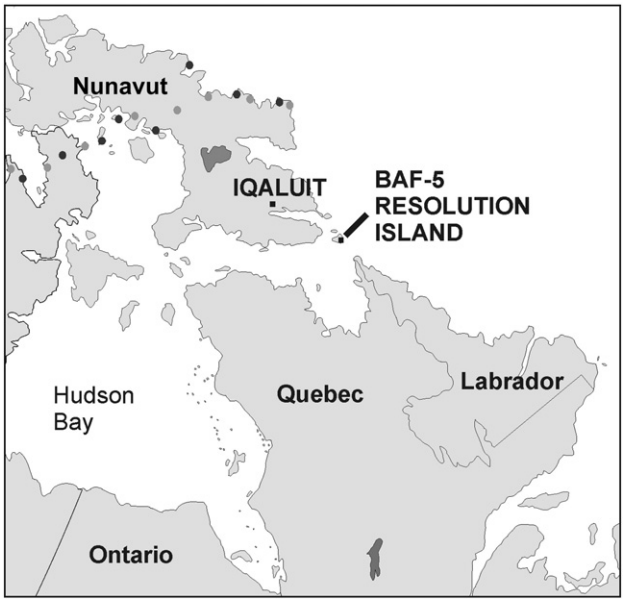

Fig. 1 – Map showing location of BAF-5, Nunavut.

After site abandonment, approximately 8000 kg of pure PCBs (Aroclor 1260) remained on BAF-5, with an estimated 4000 kg (predominately in oil) removed in 1999 (Poland et al., 2001). The remaining 4000 kg of PCBs was distributed in over 20,000 m^3 of soil. The field season at BAF-5 is short and site challenges are amplified by limited access and harsh climatic conditions. Remediation of the PCB contaminated soil under these conditions required the development of a unique cleanup strategy and a novel remediation technology.

Disposal and excavation techniques were adapted to accommodate three different contamination levels that corresponded to three PCB concentration ranges. Different, nonconventional excavation protocols were required for areas which were difficult to access. Several areas were heavily contaminated with PCBs. The area most heavily contaminated with PCBs surrounded the troposcatter dishes and buildings. At Resolution Island, stores of PCB containing oil and equipment were left unattended for several decades during which containers and equipment failed and spilled their contents (Reimer et al., 1993; Poland et al., 2001). Much of the PCB contamination migrated through a drainage pathway that was also used to flush sewage from the camp.

PCBs are known to bioacculumate and biomagnify in fatty tissues (Muir et al., 1999) and are suspected carcinogens (Silberhorn et al., 1990). In the Arctic, there is a narrow food web and Northern inhabitants are susceptible to exposure to contaminants such as PCBs via consumption of local foods (Van Oostdam et al., 1999).

The majority of these PCBs are transported via water runoff, which then enters the surrounding Arctic Ocean ecosystem (Poland et al., 2001). Source removal by soil excavation is often used for remediation of these sites. Unfortunately, much PCB contamination can be left behind during this process in the form of loosened, mobile soils.

The difficult terrain and the fractured bedrock of the site ensured that some PCB contaminated soil would remain on site after the cleanup was complete. Surface funnel-and-gate permeable reactive barriers were designed and constructed on site to mitigate the PCB migration via runoff into the Arctic ecosystem as part of a long-term remediation plan. The localized nature, associated site infrastructure and concentrated nature of the contamination at BAF-5 supported the targeted treatment area of drainage pathways (Poland et al., 2001; Stow et al., 2005).

Three areas were targeted for PCB remediation and eventual barrier construction; the S1/S4 valley, the S1/S4 Beach and the Furniture Dump (Fig. 2). The initial barrier was installed in 2003 and since then, modifications have been added to improve the performance of the barrier. Two additional permanent barriers have since been constructed and monitored. The objective of this paper is to describe the development and implementation of the cleanup strategy, the excavation and disposal of the PCB contaminated soils, and the design, construction and performance of a surface permeable reactive barrier system. This paper will show how permeable reactive barrier design can be modified to remediate surface conditions in cold regions. The application of PRBs has been investigated in cold regions such as the Arctic (Poland et al., 2001; Lindsay and Coulter, 2003) and the Antarctic (Snape et al., 2001; Woinarski et al., 2003; Gore et al., 2006; Woinarski et al., 2006). Only the barriers installed on BAF-5 however are solely surface barriers for PCB remediation. This paper is a substantially expanded version of the conference paper by Kalinovich et al. (2006).

1.2. *Cleanup criteria*

The Canadian Environmental Protection Act (CEPA) regulates the removal and destruction of PCB contaminated materials at concentrations greater than 50 ppm (CEPA, 1999). In this paper, soils containing over 50 ppm PCBs are referred to as CEPA soils. For the DEW Line sites, the CCME (Canadian Council of the Ministers of the Environment) guidelines were

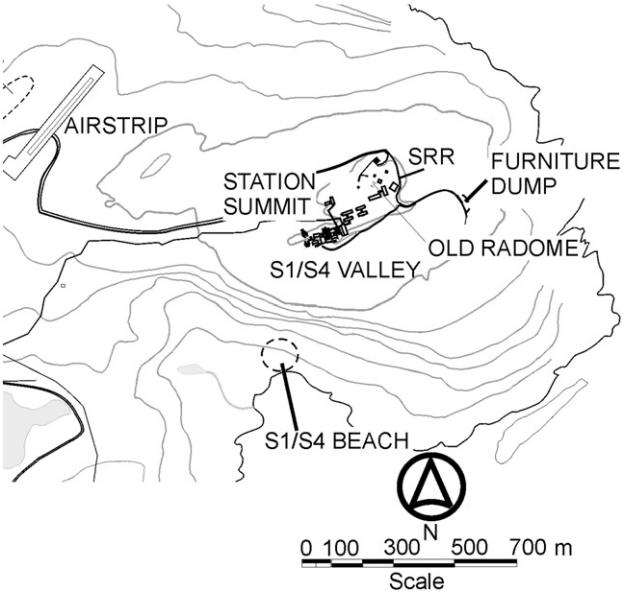

Fig. 2 – Map showing areas of contamination: S1/S4 Valley and Beach, Furniture Dump.