DESIGN AND CONSTRUCTION OF IN-PILE THERMAL DESORPTION FOR CLEANUP OF DIOXIN CONTAMINATION AT THE DANANG AIRPORT HOT SPOT, VIETNAM

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Introduction

Large volumes of Agent Orange and other defoliants were handled at former United States (U.S.) military bases during the U.S.-Vietnam War. Agent Orange was contaminated by 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), a toxic chemical that has been associated with a range of health concerns. The airport at Danang had been identified as one of the most contaminated of the former bases, for which the Government of Vietnam (GVN) requested assistance from the U.S. to remediate dioxin-contaminated soil and sediment. The U.S. Agency for International Development (USAID) was designated the lead agency to procure and oversee the remedial design, construction and operation of the Danang Airport remediation, in cooperation with the GVN.

USAID's 2010 Environmental Assessment at Danang Airport, which included sampling of soil and sediment for dioxin analysis, led to the selection of In-Pile Thermal Desorption® (IPTD®) as the most effective and scientifically proven method for destroying dioxin, while having the lowest potential impact on human health and the environment given the specific conditions at the Danang Airport. Treatment of contaminated soil and sediment is being performed in fully-contained soil piles under vacuum extraction. Thermal conduction heating is being carried out to a minimum target temperature of 335°C, over a period of approximately 4-6 months per treatment phase, which has been shown in treatability studies and at previous projects as being capable of achieving the remedial goal established by the GVN of 150 parts per trillion (ppt) TCDD Toxic Equivalency Quotient (TEQ).[1,3]

Materials and methods

Based on the Environmental Assessment, the following areas within the Airport were identified as requiring remediation:

- 1.1 hectare (ha) former Mixing and Loading Area
- 1.8 ha former Storage Area
- 3.3 ha Drainage Ditch
- 1.9 ha Area between Eastern Wetland and Drainage Ditch (including the Eastern Hotspot)
- 10.8 ha Sen Lake and Eastern Wetland, and
- 0.3 ha former Pacer Ivy Storage Area.[2]

As a key part of the IPTD® design effort in 2012, additional samples of soil and sediment were collected and subjected to a set of analytical and treatability tests.[3] The composited pretreatment dioxin concentrations in the soil averaged 64,208 ppt TEQ, while that for the sediment averaged 502 ppt TEQ, both well above the remedial goal of 150 ppt TEQ.

Two treatment phases will occur two years apart, Phase 1 to treat primarily soil, and Phase 2 primarily sediments. Each phase includes treatment of approximately 40,000 m^3 of material inside a pile structure with inside dimensions of 105 m by 70 m by 6 m (length, width, height).

A containment structure or "pile" (Figure 1) was constructed in 2013 in the NE quadrant of the airport to hold the soil and sediment material requiring IPTD® treatment. The floor of the containment structure consists of layers of concrete poured over an impermeable base membrane, resting on sand. The upper floor layer is lightweight, air-entrained concrete for thermal insulation, topped by a gravel drainage layer for removal of any excess water that might enter the pile during the filling process. The walls of the containment structure consist of interlocking free-standing precast concrete blocks, stacked 7-m high. To minimize heat losses during heating, lightweight concrete insulation lines the interior walls of the containment structure. Vertical steel sheeting protects the insulation from earthmoving equipment used to fill and empty the pile structure, and provides a vertical vapor seal along the pile sidewalls.

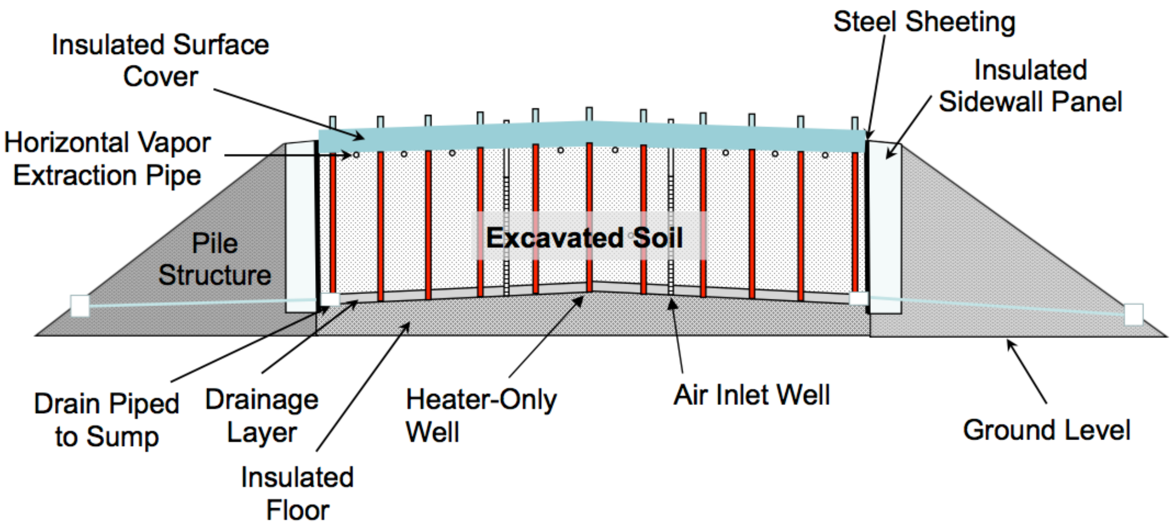

Figure 1. Cross-section of IPTD® treatment pile.

The contaminated soil was placed within the containment structure in 0.3-m lifts at a prescribed density and moisture content, to a height of 6 m. Next a gravel layer was installed over the soil, to serve as a plenum for the extraction of soil vapor and steam during heating. The soil is heated by means of vertical, non-perforated heater pipes (also called "heater wells"), composed of carbon steel, 8.9 cm in diameter, capped at the bottom, and set 2.7 m apart. All 1,254 heater wells, 7 m in length, were direct-pushed into the pile in an equilateral triangular pattern over a period of only 18 days using two rigs. They extend to the bottom of the contaminated soil, and protrude above the top of the pile. Each contains an electrically powered heater element, and is topped by an electrical junction box connecting the heaters to the electrical power/control system.

A total of 202 air inlet wells, 56 temperature monitoring wells and 8 pressure monitoring wells were also installed in the pile. After installation of the various wells, a lightweight, air-entrained concrete surface cover was cast in place, again for thermal insulation, and after curing, a spray-on sealer was applied to the surface cover and a high-density polyethylene (HDPE) membrane was adhered to the vertical sidewall vapor liner. Thus, the IPTD® containment structure is designed to separate the contaminated soil from the environment, such that all gas and steam generated from heating the soil are extracted under vacuum and treated within the liquid/vapor treatment plant. Since a vacuum cannot be pulled on a sealed box, the air inlet wells enable air to enter the treatment cell and replace the extracted gas in a highly controlled manner.

The horizontal vapor extraction system comprises a network of 10-cm diameter slotted vapor extraction pipes, totaling 864-m in length, installed within the 20-cm thick permeable gravel plenum, and connected to a system of piping manifolds above the surface cover to convey the extracted vapors to the treatment plant. The system is designed for a total maximum flow of 18,500 m^3/h of steam at standard conditions and 3,400 m^3/h of air at 100°C, 1 atm. The vapor flow from each horizontal slotted pipe can be monitored and can be controlled independently with a valve. The vapor treatment train consists of a cooling tower/quencher, vapor heat exchangers, knock-out tanks, re-heater, and serial vessels of vapor-phase Granular Activated Carbon (GAC) for adsorption of the organic contaminants, including dioxin (Figure 2).

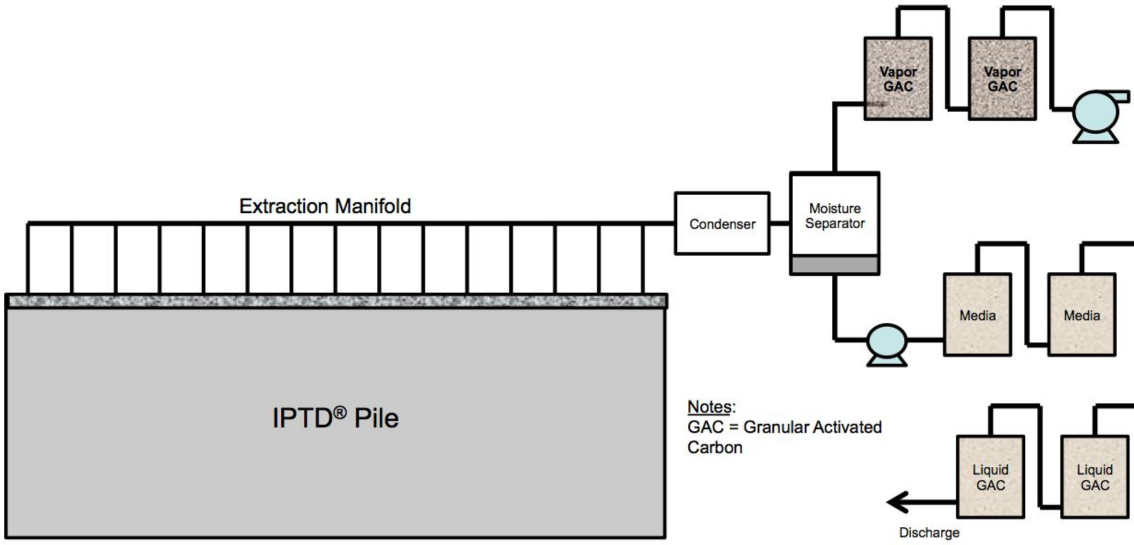

Figure 2. Simplified process flow diagram.

The treatment approach for leachate and vapor condensate streams was based on analytical results for organic and inorganic contaminants from the Enhanced Treatability Study, and supplemental studies.[3] Liquid-liquid extraction within synthetic media that can be steam-regenerated, followed by polishing by adsorption on sacrificial aqueous-phase GAC comprise the selected treatment method for organic materials, including dioxins (Figure 2). The treatment train includes a liquid heat exchanger to decrease the temperature of recovered leachate and condensate streams, phase separation to segregate any non-aqueous phase materials, filtration for particulate removal, synthetic media/GAC adsorption for organic treatment, and Granular Ferric Hydroxide (GFH) for arsenic removal. Both the vapor and liquid effluent streams are sampled by the U.S. and GVN prior to discharge to the environment.

A set of management plans specify the operations, maintenance, monitoring and environmental compliance procedures that are being followed to ensure health and safety of onsite workers, adjacent residents, and protection of the environment.

Results and discussion

Although it had been assumed that the Agent Orange herbicides, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) had naturally decomposed in the soil over the decades after the war, it was discovered during the design studies that 2,4-D and 2,4,5-T residues still remain in the soil and constitute the largest contaminant mass at the site. Furthermore, laboratory thermal tests indicated that during the mid-stage of heating, the 2,4-D and 2,4,5-T are largely converted to chlorophenolic compounds and steam-distilled out of the soil. Thus a major focus of the IPTD® design was the liquid/vapor treatment process. This presentation will convey the major components of the full-scale IPTD® design, and how the full-scale system was constructed. The $37M IPTD® system, construction of which is complete, will be in full operation during the August 2014 Dioxin 2014 conference in Madrid. Heating of Phase 1 will be nearly complete by October 2014 followed by confirmatory soil sampling by both the U.S. and GVN.

After completion of Phase 1, the treated clean soil will be quenched by addition of water via the air injection wells and a network of infiltration pipes installed within the gravel plenum. The steam generated by addition of water to the hot soil will be extracted and released in a controlled manner. Then following removal of the IPTD® wellfield piping and surface cover, the cooled soil will be removed and reused for fill elsewhere within the military portion of the airport property, pending analytical results. Phase 2 sediment and soil will next be placed into the pile structure for Phase 2 treatment, which is scheduled for heating and treatment during late 2015 through mid-2016, in a fashion identical to that described above for Phase 1. Following treatment of Phase 2, the IPTD® system will be dismantled and demobilized from the site.

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