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THE SUCCESSFUL APPLICATION OF IN-PILE THERMAL DESORPTION TECHNOLOGY FOR ENVIRONMENTAL REMEDIATION OF DIOXIN CONTAMINATION AT DANANG AIRPORT, DANANG, VIETNAM

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Introduction

After the United States and Vietnam normalized diplomatic relations in 1995, discussions and deepened cooperation began in 2000 around the issue of Agent Orange, and since 2006 Vietnamese and American science and health experts have gathered annually to discuss environmental contamination through a Joint Advisory Committee. Through those discussions, the Government of Vietnam (GVN) requested assistance and the U.S. Government (USG) agreed to complete the environmental remediation of the Danang Airport due to high dioxin concentrations in soil and sediment remaining from the use of Agent Orange and other herbicides during the U.S.-Vietnam War. Agent Orange was the most widely used herbicide and was a 50/50 mixture of two individual defoliants, 2,4-Dichlorophenoxyacetic acid (2,4-D) and 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T).[1] Dioxin (i.e., 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD) was a highly toxic contaminant byproduct from the manufacturing process.[1]

In 2010, the United States Agency for International Development (USAID) – the designated implementing agency for the USG – completed an environmental assessment at the Danang Airport in partnership with the GVN's Office of the National Steering Committee 33 of the Ministry of Natural Resources and Environment (Office 33). The environmental assessment built on historical sampling data collected and funded by the Vietnamese Ministry of National Defense (MND), the Vietnamese Ministry of Health Division for Mitigation of Consequences on Human Health of Chemicals Used during the War (10-80 Division), Office 33, and international donors, such as the Ford Foundation and the United Nations Development Program (UNDP).[2] The estimated volume of dioxin-contaminated soil and sediment at the Danang Airport according to the environmental assessment was 61,600 cubic meters (m^3) and 17 ha.[3] This estimate was later modified to 72,900 m3 and 19 ha through additional site characterization completed during the design phase of the Project.[4] The environmental assessment also evaluated multiple containment and treatment strategies and recommended the In-Situ/In-Pile Thermal Desorption® (ISTD/IPTD®) technology. ISTD/IPTD® was determined to be the most effective and scientifically proven technology for destroying dioxin, as well as having the lowest potential impact on human health and the environment given the specific conditions of the Danang Airport.

The GVN's designated project partner for implementation, MND, concurred with the estimated volume and recommended remediation activity, which the GVN evaluated through their own parallel environmental impact assessment. The Prime Minister of Vietnam and MND approved the Environmental Remediation of Dioxin Contamination at Danang Airport Project (the "Project") in 2011, as well as the detailed design plans for excavation and treatment in 2012 and 2013, respectively. The Project is jointly implemented by USAID and MND through a memorandum of understanding signed in May 2011. MND's Air Defense–Air Force Command is the project owner (the project site is located on the military portion of the Danang Airport) and is responsible for ensuring that the Project meets all applicable Vietnamese environmental protection laws and regulations. USAID is responsible for

procurement and oversight of contractors performing the work, as well as compliance with applicable U.S. and GVN regulations. The three prime contractors implementing the project for USAID are CDM Smith – the Project's umbrella Construction Management Contractor (CMC); Tetra Tech Inc. – the Excavation and Construction Contractor (ECC) responsible for all excavation and site restoration work as well as construction of the treatment structure; and TerraTherm, Inc. – the IPTD® Contractor responsible for the installation and operations of the IPTD® technology. The Project was launched in August 2012 and is planned for completion by June 2018.

The remediation strategy involves three major steps: building an enclosed, above ground treatment structure; excavating and placing the dioxin-contaminated soil and sediment into the structure; and heating the contaminated soil and sediment to a high temperature (approximately 335ºC) to destroy the dioxin. Following treatment, the soil and sediment is tested by both USAID and MND scientists to ensure it meets the approved project treatment goal of 150 parts per trillion (ppt) toxic equivalents (TEQ).[5] The treated material is then cooled, removed from the treatment structure, and used as fill material on site. In May 2015, successful treatment of approximately 45,000 cubic meters of dioxin-contaminated material was confirmed – the first of two phases of treatment. Another approximately 45,000 cubic meters of contaminated material will be treated in 2016-2017.

Materials and Methods

Based on an enhanced treatability study conducted by TerraTherm, Inc., thermal conduction heating to a target temperature of 335°C at a residence time of 21 days is required to achieve the Project performance standard of 150 ppt TEQ.[6] These data were consistent with past in situ ISTD/IPTD® projects at which dioxins were treated.[7,8] The treatability study also shaped critical design features including the management of off-gas and condensate of non-target chlorinated organics (e.g., 2,4-D, 2,4,5-T and other contaminants of concern common to military airbases such as hydrocarbons); the potential for shrinkage and subsidence of the soil/sediment in the treatment structure during thermal treatment; corrosion of metals; and changes to arsenic speciation during heating among others. In addition, two supplemental studies were performed as addenda to the enhanced treatability study including an evaluation of the expected loading rates on liquid granular activated carbon (GAC); and an evaluation of the feasibility of steam re-generable synthetic adsorption media for removal of constituents of concern from the liquid condensate. Based on the various results, TerraTherm, Inc. completed the IPTD® system design for the Project in 2012, including the thermal heating array and the combined liquid and vapor treatment plant (LVTP), which was designed to capture and treat prior to discharge any vaporized contaminants and any dioxin not destroyed in-pile.

The insulated treatment structure, designed by CDM Smith and built by TetraTech, Inc., has an internal dimension of 105 meters long, 70 meters wide, and 6 meters deep creating an internal capacity of approximately 45,000 cubic meters. The treatment structure is composed of over 28,000, one-ton concrete masonry unit blocks manufactured in Danang and erected onsite between October 2012 and June 2013 along with an insulated floor and insulated sidewalls supported with sheet pile. Approximately 45,000 m^3 of dioxin-contaminated soil and sediment was subsequently placed and compacted inside the structure between mid-June and mid-September 2013.[9]

[IMAGE 1]

TerraTherm, Inc. then installed the thermal array, which comprised a total of 1,254 vertical heaters with 2.7-m spacing, as well as over 200 air inlet/quench wells and a horizontal vapor extraction system installed in a gravel plenum layer beneath a lightweight insulating concrete cover. Each vertical heater well contains an electrically powered heating element with an operating temperature of approximately 750-800°C (~1400 to 1500°F) connected to substations supplied by MND for the Project and a dedicated power line from the local power grid. In addition, TerraTherm, Inc. constructed a conveyance system that carries off-gas and steam from the heated soil/sediment to the LVTP. The LVTP consists primarily of a quench tower/scrubber, MacroPorous Polymer Extraction (MPPE) media, both liquid- and vapor-phase GAC media vessels, and Granular Ferric Hydroxide (GFH) media for removal of the arsenic.[5] Installation of the IPTD® system and LVTP began in September 2013 and continued to mid-May 2014.[10,11]

Energy/heat was applied to the contaminated soil/sediment through the in-pile array beginning June 1, 2014 and was monitored by 56 vertical thermocouples at 0.3, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 meter below the top of the soil/sediment surface. A vacuum was applied to the treatment structure during thermal treatment operations via the horizontal vapor collection system and three blowers connected to the LVTP. The vacuum was slightly maintained to reduce heat loss and was monitored on-line by eight pressure monitoring points. The system operations were monitored by a supervisory control and data acquisition (SCADA) system 24 hours per day, seven days per week. In addition to monitoring temperature and vacuum of the IPTD®, the liquid and vapor phase influents, interims, and effluents were monitored throughout the LVTP for dioxin, other contaminants of concern, and relevant water quality/ chemistry parameters such as pH and turbidity. Monitoring of the ambient air was also conducted in the LVTP, on top of the treatment structure, and around the Project site perimeter. The monitoring was implemented in accordance with the approved Project Environmental Monitoring and Mitigation Plan to provide for both operational efficiency and environmental compliance with GVN discharge standards. Thermal treatment operations concluded on April 9, 2015 after a total duration of 313 days.[10,11]

[IMAGE 2]

Results and Discussion

A confirmatory sampling program was designed and implemented by CDM Smith between March 16, 2015 and May 11, 2015 to ensure the 150 ppt TEQ treatment goal was achieved throughout the pile using the multi-increment® sampling (MIS) method[12] applied across six horizontal decision units (0-1m, 2-3m, 3-4m, 4-5m, and 5-6m). Samples were analyzed by AXYS Analytical Laboratories in British Columbia, Canada using EPA Method 1613B. The MIS sample from each one-meter layer was comprised of 30 samples. A triplicate sample was collected from the 2-3 meter layer to establish a 95% upper confidence level of the sample collection method.[10] Table 1 below shows that all samples results were well below the treatment goal of 150 ppt TEQ. The 0–1 meter layer, which experienced the lowest treatment temperatures, was 51.5 ppt TEQ. MND's Chemical Command further collected and analyzed 120 discrete samples and conducted an independent laboratory analysis using equipment with a method detection limit of 30 ppt TEQ. All but six results (maximum of 93 ppt TEQ) were below the method detection limit.

This Project has successfully demonstrated the first full-scale application of IPTD® technology that is capable of remediating dioxin to less than 150 ppt TEQ through the joint cooperation of the two governments of Vietnam and the United States. A mass balance was estimated by comparing an estimated starting mass of dioxin in the pre-treatment soil with the sum of the mass of dioxin in: (i) the post-treatment soil, (ii) the liquid influent to the LVTP, (iii) the vapor influent to the LVTP, and (iv) the accumulated non-aqueous phase liquids in the LVTP. The mass balance concluded that at least 90% and possibly up to 97% in-pile destruction of dioxin occurred within the heated soil. However, the pre-treatment soil/sediment was not sampled in-pile prior to thermal operations and the influent sampling locations of the LVTP did not provide a good representation of the effluent of the in-pile thermal treatment; therefore, any estimate of pre-treatment mass is uncertain. Since the Project has the benefit of two thermal treatment phases, USAID is implementing an in-pile, pre-treatment sampling program and relocating the influent sampling locations in the LVTP to more accurately calculate and verify in-pile destruction of dioxin. Further, lessons learned from the first phase of thermal treatment are being incorporated into the second and final phase of treatment operations for the Project.

[IMAGE 3/TABLE 1]

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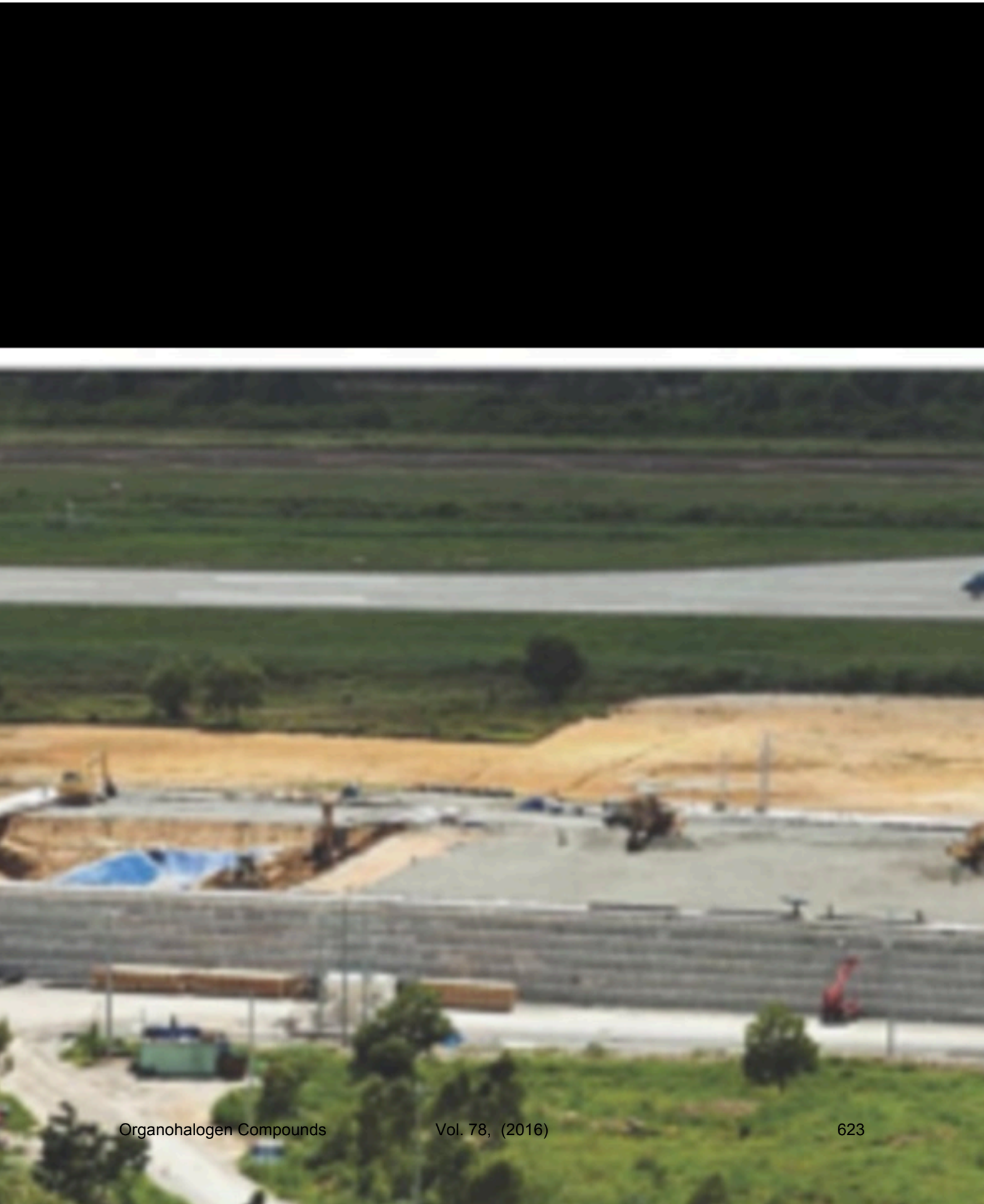
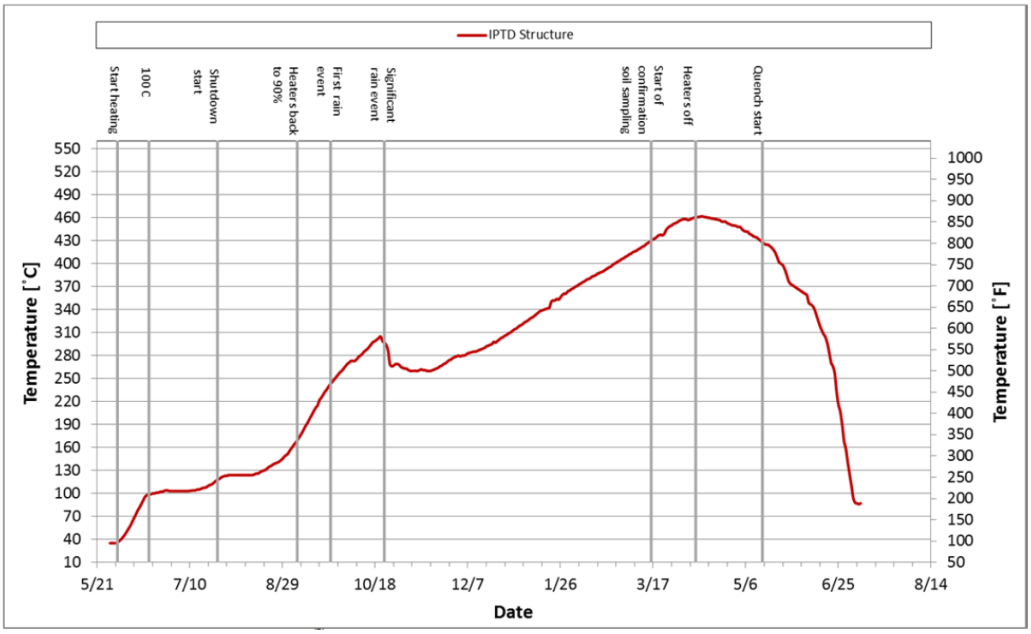


The treatment structure being loaded with contaminated soil and sediment and covered by a gravel plenum layer in Fall 2013 (Photo credit: TetraTech, Inc.)



Average thermal temperature of soils/sediments inside the treatment structure over the duration of IPTD ®operations at Danang Airport (TerraTherm, Inc.)

Table 1: Phase 1 IPTD® Confirmation Sampling Results for Dioxin

Decision Unit Layer (in meters below top of pile)	**Dioxin Concentration (ppt TEQ)***
0-1m	51.5
1-2m	0.332
2-3m, triplicate	0.237 2.34 0.27
95% upper confidence level	2.6
2-3m	0.264 (lab duplicate 0.234)
3-4m	0.304
4-5m	0.0918
5-6m	0.981 (lab duplicate 0.819)
Entire Pile	**8.9**