TECHNOLOGY SELECTION AND CONCEPTUAL DESIGN FOR CLEANUP OF DIOXIN CONTAMINATION AT THE DA NANG AIRPORT HOT SPOT, VIET NAM

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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.-Viet Nam 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[2]. The airports at Da Nang, Bien Hoa, and Phu Cat have been identified as the most contaminated of the installations studied, and are the Government of Vietnam (GVN) priority areas for remediation of soils and sediments to eliminate the risk of human exposure to TCDD[1]. The GVN has requested assistance from the U.S. to remediate dioxin-contaminated soil and sediment at the Da Nang Airport (Airport), where studies conducted to date show that TCDD concentrations within certain areas substantially exceed international and Vietnamese standards for dioxin[3a,b]. These studies have also shown that TCDD comprises greater than 90% of the toxicity equivalent (TEQ), implying that Agent Orange was the source of contamination.

Since 2007, the U.S. Congress has appropriated approximately $41 million to carry out environmental health and remediation activities in Da Nang. A portion of this funding has been programmed to support health and social services for people with disabilities in the Greater Da Nang area, no matter the cause of the disability. The remainder has been allocated for environmental remediation at the Airport. The U.S. Agency for International Development (USAID) was designated as the lead U.S. agency to implement remediation assistance programs in Da Nang. USAID's GVN counterpart for the Da Nang project is the Ministry of National Defense in coordination with Office 33, which was established by the GVN in 1999 for coordination of dioxin-related matters and for development of dioxin implementation and research plans. This paper provides an overview of the work funded by USAID, beginning in late 2009, to collect additional site characterization data required for site remediation, evaluate the environmental impacts of potential remediation strategies, select the most appropriate technology for long-term cleanup at the Airport, and begin remediation design and planning.

Materials and Methods

Site Characterization – In 2010, USAID began a sampling program to augment existing data from previous studies at the Airport, to provide the necessary data to delineate the areas in need of remediation, and to support the design of a long-term remediation strategy. During this program, more than 120 soil and sediment samples were collected and analyzed. All samples were kept cool (4°C), or frozen within 2 hours of collection and shipped to Canada immediately after completion of the field program. Samples were analyzed by AXYS Analytical Laboratories in Sidney (British Columbia, Canada) using a Micromass Ultima high resolution mass spectrometer equipped with an HP 6890 gas chromatograph, a CTC autosampler and an Alpha workstation running VG software. Measured soil and sediment concentrations were compared to the national cleanup standards established by the GVN for dioxin of 1,000 ppt TEQ in soil and 150 ppt TEQ in sediment[4].

Technology Selection – Selection of the most appropriate and effective technology for remediation of TCDD-contaminated soil and sediment at the Airport capitalized on the efforts of several organizations and agencies, including not only the GVN and the U.S. government, but also the United Nations Development Program (UNDP) and the Ford Foundation. The U.S. Environmental Protection Agency (USEPA) and the GVN's Ministry of Natural Resources and Environment (MoNRE) have co-chaired the bilateral Joint Advisory Committee to coordinate collaborative research on issues related to Agent Orange and dioxins since 2000. This work has included a survey of technologies potentially applicable for remediation of TCDD-contaminated soil and sediment in Viet Nam, as well as a field pilot study of bioremediation approaches at the Airport by USEPA. The Ford Foundation not only supported detailed site characterization of TCDD contamination at the Airport, it also financed interim mitigation measures[1] to help reduce potential exposure of residents and workers there. The UNDP and Office 33 co-sponsored a workshop in February 2009 to build consensus among the GVN and

donors on a national approach for dioxin remediation. The UNDP also funded a separate survey and ranking of technologies that might be applicable for remediation of the dioxin contamination in Viet Nam[5].

A number of technologies and/or management strategies have potential applicability for treatment of dioxin contamination in soil and sediments. A two-step evaluation process was utilized comprising an initial screening to develop a short list of alternatives, followed by a more detailed evaluation of the short list. Criteria considered for the screening process included environmental impact, effectiveness, feasibility, and cost. The screening process built upon previous studies performed to review technologies potentially applicable to dioxins associated with Agent Orange in Vietnam[5,6]. The technologies that received unfavorable assessments in these reports were not considered further in this evaluation. Further, the highest scoring technologies presented in the UNDP (2009) report were considered for evaluation. If a technology/strategy was determined to be effective for containment, it was retained for further consideration even if it was not considered effective for treatment.

Following the screening process, four strategies were retained for a more detailed evaluation. In the detailed evaluation of the four retained alternatives, the criteria considered were once again effectiveness, implementability, cost, and environmental impact. In this case, however, conceptual designs were developed for each of the alternatives in order to provide a more detailed assessment of each of the criteria. In particular, a rigorous Environmental Assessment (EA) of the alternatives was performed that took into account the site-specific conditions at the Airport.

Treatability Study – One of the technologies considered for treating TCDD-contaminated soils and sediments at the Airport was In-Pile Thermal Desorption (IPTD). Although results from studies at other sites indicated that IPTD was capable of achieving target cleanup goals at the Airport, a laboratory treatability study was performed to confirm treatment with site-specific soil and sediment, and to estimate the required time for TCDD destruction in the treatment pile at the minimum design temperature of 335^{o}C. The treatability study was performed by KEMRON Environmental Services (Atlanta, Georgia, USA). Soil and sediment samples were collected in August 2010 from areas expected to have some of the highest TCDD concentrations at the Airport. Upon receipt, the soil and sediment were maintained at 4^{o}C, and were homogenized prior to analysis of baseline contaminant concentrations and treatment. Triplicate aliquots of the soil and the sediment were analyzed for total dioxins/furans using a modified version of EPA Method 8290.

The two test materials, sediment and soil, were subjected to thermal desorption treatment performed at a temperature of 335^{o}C, plus or minus 5^{o}C, for a treatment duration of 7 days for sediment, and 21 days for soil at the target temperature. Treatment simulations were performed using stainless steel box reactors measuring approximately 30 cm in length, 15 cm in width, and 7.5 cm in depth. The untreated materials were placed loose inside the box reactor and then covered with a stainless steel lid and carbon gasket material. The lid was fitted with Swagelok ports to allow the introduction of breathing quality air into the reactor chamber, and the insertion of a thermocouple probe for monitoring and recording the soil temperatures during treatment. An additional port allowed the removal of off-gas from the reactor during testing. Finally, a condensate collection system was utilized to remove and condense vaporized water and any organics in the off-gas during treatment. The reactors were heated to temperature using a Fisher Isotemp Muffle Furnace. Once inside the furnace, the appropriate air inlet and off-gas lines as well as the temperature thermocouples were connected.

Results

Site Characterization – The results of the soil and sediment sample analysis were used to determine the areas and volumes of contaminated material requiring treatment at the Airport. Six different areas were determined to have concentrations requiring remediation. Based on these results, the remediation will address a volume of contaminated material at the Airport estimated in 2010 to be 61,700 m^3. It is important to note that the area and volume estimates are likely to increase based on the analysis of new data and on conditions observed in the field during remediation. Table 1 provides the estimated excavation volume and footprint for each area.

Technology Selection – The four remediation strategies retained after the initial screening included: no action (required by U.S. regulations as a baseline for comparison), passive landfill, active landfill, and IPTD. In many cases, technologies that were otherwise promising were eliminated in the screening process because of a lack of data to demonstrate that they could meet cleanup targets in a full-scale application (e.g., Geo-Melt™, ball milling, etc.). The passive landfill alternative was retained because it would provide containment of the contaminated materials, although it would not provide treatment. The active landfill alternative essentially added bioremediation to a passive landfill option. IPTD and its companion technology, In Situ Thermal

Table 1. Volume and area of TCDD-contaminated material at the Da Nang Airport.

Area Designation	Volume (m^3)	Area (m^2)
Mixing and Loading Area	19,500	19,600
Storage Area	8,900	16,200
Drainage Ditch	8,500	35,600
Eastern Hotspot	500	7,700
Sen Lake and Eastern Wetland	22,800	85,400
Pacer Ivy Storage Area	1,400	3,200
Total	**61,600**	**167,700**

Desorption (ISTD), have been applied to several dioxin sites in the U.S. in recent years, as well as in a small scale demonstration in Japan[7,8]. This alternative requires construction of a temporary stockpile of contaminated soil and sediment, and utilizes 700°C to 800°C heater wells to achieve and maintain a minimum soil temperature of 335°C for several days. This has been documented to reduce TCDD concentrations in soil to well below the cleanup targets at the Airport[7,8].

The EA report fully documents the assessment and the complete technology evaluation process[9]. A summary of the results is provided in Table 2. The preferred alternative was IPTD, which was the only alternative currently demonstrated to be capable of achieving permanent treatment of the contaminated soil and sediment to below cleanup goals, determined to have the lowest overall environmental impact, and similar in cost to the other two remediation alternatives.

Table 2. Summary of EA findings for remediation at the Da Nang Airport.

Alternative	**Effectiveness (i.e., dioxin ≤ cleanup goals/"final remedy")?**	**Implementable**	**Environmental Assessment**	**Estimated Cost (in Millions) -30%+50%**
No Action	No	Yes	Highest overall potential environmental impact	Externalized
Passive Landfill	No	Yes with challenges	Third-highest overall potential environmental impact	$35.8M
Active Landfill (Bioremediation)	Uncertain	Yes with challenges	Second-highest overall potential environmental impact	$30.7M
IPTD	Yes	Yes with challenges	Lowest overall potential environmental impact	$33.7M

Treatability Study – A summary of the treatability study results is presented in Table 3. As for baseline samples, triplicate aliquots of the treated sediment and soil were analyzed for dioxins using modified EPA Method 8290. Within 7 days at approximately 335°C, the sediment samples were treated to concentrations approximately two orders of magnitude below the target cleanup goal of 150 ppt TEQ. The soil on the other hand, while decreasing in concentration by an order of magnitude from baseline, was still well above the target cleanup goal for soil of 1,000 ppt TEQ after 7 days. At 10 days, the soil was approximately at the cleanup goal, and was well below the goal at 14 days in two of the three samples. One sample result was above the goal, which appeared to be a spurious result. Nevertheless, the test was extended to 21 days, at which point the dioxins in all three soil samples were treated not only below the soil cleanup goal, but also below the sediment goal.

Conceptual Design – Based on the work performed as part of the USAID EA and supported by the successful treatability study results, a conceptual design for the IPTD application at the Da Nang Airport was developed. The conceptual design includes building a treatment stockpile large enough to treat all of the contaminated material in two batches. The approximate dimensions would be 70 m by 90 m by 6 m tall, not including insulation and structural support. Heater wells will be placed throughout the pile in a grid pattern at a spacing of about 3 m between wells. Some of the heater wells will also be vacuum wells that extract hot air and water

Table 3. Summary of IPTD treatability study results (TEQ; ppt) for Da Nang airport sediment and soil.

	Sediment A TEQ (ppt)	Sediment B TEQ (ppt)	Sediment C TEQ (ppt)	Soil A TEQ (ppt)	Soil B TEQ (ppt)	Soil C TEQ (ppt)
Baseline	6350	6630	7850	158,000	163,000	153,000
7 days	2.45	3.35	4.27	11,300	19,500	17,500
10 days	-	-	-	937	984	1,050
14 days	-	-	-	392	2,910	367
21 days	-	-	-	81.1	113	134

vapor, along with any contaminants in the vapor phase. The gas and liquid may be separated in a condenser and treated independently prior to discharge. Based on the treatability study, the soil in the pile should be held at a minimum of 335^{o}C for between 10 and 21 days to achieve the cleanup goals. It is estimated that about four to five months of heating will be required to bring the contaminated soil up to the minimum temperature throughout the pile. Thermocouples will be placed throughout the pile in order to monitor the temperature in three dimensions. After temperature data indicate that the treatment time at minimum temperature has been reached, sampling will be conducted in order to confirm treatment goals have been achieved. The treatment pile will only be disassembled when confirmation sampling indicates no further treatment is required.

Project Status and Timeline – The Environmental Remediation at Da Nang Airport Project is now in the procurement phase for the IPTD design and construction, as well as the excavation and construction contracts. USAID and the Ministry of National Defense anticipate mobilization on the site occurring in December 2011, pending final project approvals and successful procurements.

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