TECHNOLOGY SELECTION – PRINCIPLES AND PROGRESS – FOR DIOXIN HOTSPOT REMEDIATION IN VIETNAM

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Introduction

Vietnam has a few dioxin contaminated hotspots due to the armed conflict in between 1961 and 1971. Former military airbases where chemical defoliants were loaded/stored/handled have elevated level of dioxin in soil and sediment due to the ignorance of toxicity of dioxin at that time. Dioxin existed as impurity of an herbicide commonly called Agent Orange (AO). Vietnamese Government has adopted the National Action Plan to resolve AO/dioxin issue caused by the War and environmental remediation activities that has started since 2009.

The high-level contamination has been identified and confirmed at 3 former military airbases, i.e. Da Nang, Bien Hoa and Phu Cat, where Vietnamese Government has made significant efforts to resolve the problems. The Vietnamese Government approved 'National Action Plan to Overcome the Consequences of Toxic Chemicals during the War in Vietnam' in 2012, which emphasizes the complete remediation of these 3 hotspots by 2020. This article reviews the status of 3 dioxin hotspots, assesses and compares the progress, and identifies the challenges and follow-on actions.

Materials and methods

Vietnamese Government, in collaboration with international donors, has conducted several dioxin surveys at suspected dioxin hotspots. The contamiation survey and technology selection for Da Nang airprt was reported by USAID (2010)[1)]. Several contamination surveys for Bien Hoa and Phu Cat were conducted by Vietnam-Russia Tropical Center (2008)[2)], Hatfield (2011)[3)], and VEA Dioxin laboratory (2012)[4)], etc. Supplemental analyses were also conducted by various agencies under different initiatives.

The dioxin hotspots are also contaminated with other pollutants. Hang *et. al.* (2012)[5)] reported the elevated level of arsenic in dioxin hotspots, suggesting the artificial pollution by Agent Blue. The levels of VOC, pesticides, heavy metals were surveyed in several reports since it will affect the selection of remediation technology and fate of the treated soil.

USAID has completed the design of the remediation in 2012 and undertake implementation in Da Nang hotspot[6)]. The progress of the remediation activities for Da Nang is reported by USAID monthly[7)]. Those for Bien Hoa and Phu Cat are reported by Office 33 bi-annually[8)].

Results and discussion

The logical flow of dioxin hotspot remediation is described in Figure 1, where all 3 hotspots have at different stage. Key steps are 1) target setting, 2) contamination survey, 3) technology selection, and 4) implementation. As the remediation requires huge investment cost, so-called 'two-stage approach' is also used. In this approach, the contaminated soil is firstly isolated and/or contained to stop diffusion (i.e. exposure risks). The destruction of the dioxin will be done as soon as the fund is secured. Two principal measures of this stage are 'hydraulic isolation' and 'containment landfill'. The former can stop only diffusion through surface water while the latter can completely isolate any means of dioxin transport. Since the chemical substance still remains, a long-term monitoring system needs to be established to ensure sound maintenance of the isolation facilities.

Another important activity is the demonstration of the remediation technologies to evaluate the effectiveness under Vietnamese condition. Very specific local contexts, e.g. climatic conditions, local infrastructures, soil type and co-contaminants, system reliability/robustness, national regulatory values, etc. should be accounted for. A

few technologies have been short-listed for further evaluation. Those are: 1) Thermal desorption, 2) Mechano-chemical destruction, 3) Bio-remediation (with various applications), and 4) Combination of these technologies. The other technologies may also be considered if sufficient information is available.

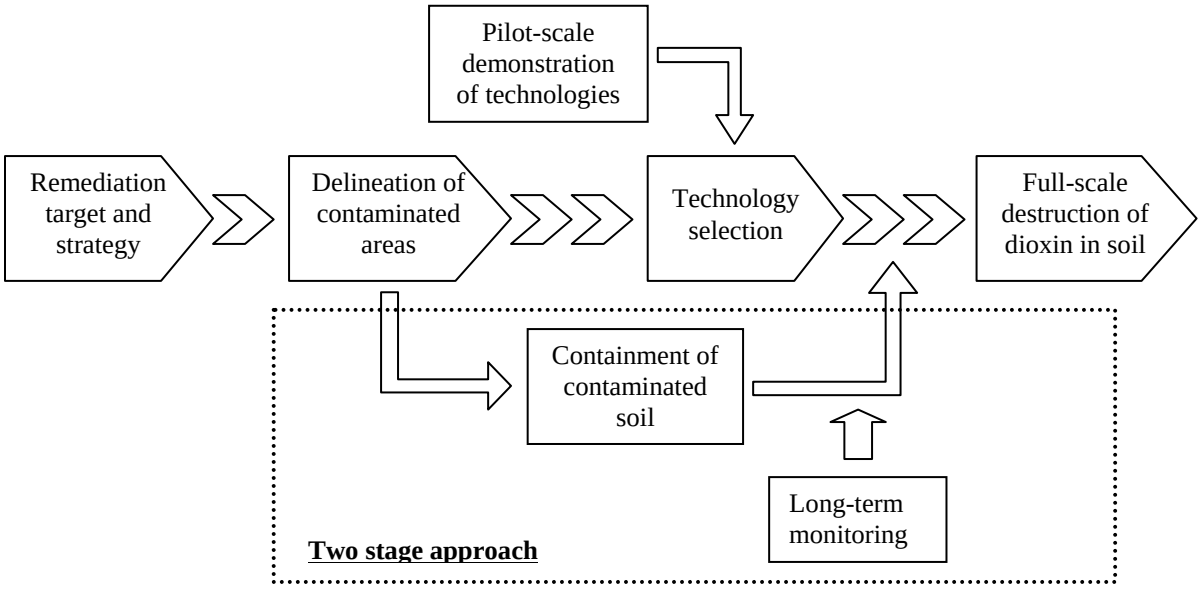

Figure 1 Logical Flow of Dioxin Hotspot Remediation

Contamination survey results in 3 hotspots are summarized in Table 1. Bien Hoa is the most widely contaminated with dioxin. At least 2 large-scale contaminated sub-sites have been identified (i.e. Z1 area and Pacer Ivy area, where the estimated volume reaches as high as 100,000 m3 per site). The contamination in Da Nang is mostly confined at North-east end of the airport premises. The total volume in Da Nang is smaller than that in Bien Hoa but the soil contamination level is actually higher. Some estimation of actual dioxin mass in soil in Da Nang shows the highest among 3 hotspots. The contamination scale in Phu Cat is much smaller than that in other 2 hotspots.

Table 1 Summary of Contamination Status

Hot Spot	Volume of contaminated soil and sediment (m3)	Contamination level			Remarks
		Dioxin* (pg-TEQ/g)	Arsenic (mg/kg)	Others**	
Da Nang	61,600	75,700	129	24-D, 245-T, 24-DCP, 245-TCP	Reported in IPTD design
Bien Hoa	Approx. 200,000 (delineation incomplete)	15,900	299	Cu, Pb, Zn, 24-DCP, 245-TCP	Other contaminants were identified in MCD demonstration
Phu Cat	7,500	26,200	111	-	Dioxin contamination is contained
National Reference	-	1,000 (soil) 150 (sediment)	12		

Note
*: The average at the most contaminated sub-site in each hotspot (not the average of entire volume of contaminated soil).
**: List of chemical substances that the elevated concentration was observed. This is indicative only as no comprehensive contamination surveys for other contaminants have been conducted.

Co-contamination with other chemical substances, especially arsenic, exists in all three hotspots. Substantial portion of the arsenic in highly contaminated soil exists in organic form, suggesting Agent Blue compound (i.e. cacodylic acid salts) as the primary source of such contamination. 24-D and 245-T are the active ingredient of Agent Orange, which were believed to have already been degraded, as reportedly the environmental half-life times are a few weeks. The Chloro-phenol compounds are degradation products of the Agent Orange and also believed to have short life in soil due to its volatility. Some soil samples showed high concentration of heavy metal such as copper, lead and zinc, which may have come from exploded ammunition (shells, bullets) and accidentally included in the sampled soil.

Table 2 shows the progress of the remediation in each hotspot. Bien Hoa and Phu Cat chose 'two-stage approach' while US Government have committed direct and complete remediation at Da Nang hotspot. Da Nang is the only place where full-scale remediation has already started. In-pile thermal desorption (IPTD) has been selected as the remediation technology and the design work has been completed in 2012. It is estimated to be completed in 2016.

Table 2 Progress of Hotspot Remediation

Hot Spot	Target & Strategy	Delineation	Technology Demonstration	Technology Selection	Containment	Long-term Monitoring	Full-scale remediation
Da Nang	Environmental assessment	Completed	Done in USA	Done	N/A	N/A	On-going
Bien Hoa	Strategy under development	Not completed	Undergoing	No	Partially completed	Planning stage	No
Phu Cat	N/A	Completed	No	No	Completed	Implementing stage	No

The contamination in Bien Hoa is most complicated among the three, where full assessment/delineation has not been completed. One main sub-site, Z1 area is former storage area where large container tanks were erected to store and distribute Agent Orange and other herbicides. It was identified in 1990s and the heaviest contamination was put into an on-site landfill (94,000 m3) in 2009. Yet, low-strength contaminated soil and sediment remain uncontrolled. Another large-scale contamination, Pacer Ivy area, was discovered in 2008 where re-drumming operation was conducted to ship out unused chemicals after spraying operation. The hydraulic isolation (construction of separation facility is undertaken in early 2013). In addition, elevated levels of dioxin have been detected at various places in and around Bien Hoa airbase. The Vietnamese Government is currently developing a comprehensive master plan for Bien Hoa hotspot remediation.

Photo 1 Aerial View of Newly Completed Containment Landfill in Phu Cat (45m x 45m)

Phu Cat is the smallest hotspot among the three but still substantial amount of soil is contaminated. The containment landfill has been constructed in 2012, which complies with national regulations and meets internationally acceptable standards (Photo 1). The landfill contains 7,500 m3 of soil in 45m x 45m diamond-shape structure, which is equipped with leachate collection system, leak detection system, maintenance road, and fenced enclosure. The long-term monitoring system that includes groundwater, surface water and ambient air monitoring is under implementation by the development assistance of Czech Republic[9)].

A technology demonstration has been conducted in Bien Hoa under the GEF funded project namely 'Environmental Remediation of Dioxin Contaminated Hotspots in Vietnam'. Approx. 100 m3 of contaminated soil was treated by Mechano-chemical destruction (MCD) system, which was temporarily imported from New Zealand. The demonstration has collected system information, operation parameters and system behaviors, possible environmental and health risks, soil texture after treatment, etc., all of which will be used for the judgment of the suitability of the technology. Another demonstration using biotechnology is under preparation stage and will be implemented in Bien Hoa. These demonstrations will also benefit the technology selection for Phu Cat as well as Bien Hoa.

In overall, the Vietnamese Government is implementing the remediation activities for all three hotspots simultaneously, which has made progresses (though at different stages). Bien Hoa is the first hotspot which has started the interim measure to contain the most contaminated part of the hotspot, while Phu Cat is the first hotspot which has completed containing all dioxin contamination. Da Nang is the only hotspot where the full-scale remediation project has already commenced.

Due to the large scale contamination and diverse local conditions, one technology may not fit to all locations. The best mix of a few technologies, which are proven and have comparative advantages in specific aspects, will be explored to achieve the most effective and efficient remediation.

Acknowledgements
The authors acknowledge the Global Environment Facility to fund for this survey under the project 'Environmental Remediation of Dioxin Contaminated Hotspots in Viet Nam.'

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