

# **DIOXIN CONTAMINATION IN CONTAMINATED HOTSPOTS IN VIETNAM: OVERALL ASSESSMENT OF ENVIRONMENTAL CONTAMINATION AND HUMAN EXPOSURE**

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## **Introduction**

The issue of dioxin contamination due to spraying of herbicides during the US - Vietnam War has been of great concern and has received considerable attention by both local and international scientific community over the past three decades. From 1961 to 1971, over 74 millions liters of herbicides were sprayed in the South Vietnam. The sprayed amount of dioxins were estimated about 366 kg<sup>1</sup>. Of particular concern is the former airbases of US Army, where former areas for storage, loading, mixing and washing of herbicides during herbicide spraying and removal mission such as Ranch Hand and Pacer Ivy. Bien Hoa, Da Nang and Phu Cat Airbase have been considered as three hotspots resulting in severe dioxin contamination in the environment and humans. Over the past three decades, a number of investigations have been conducted to understand the status of contamination in soils, sediment, biota and human samples in these hotspots, and results of these programs have provided a basis for subsequent mitigation/rehabilitation measures to prevent potential impacts of dioxins and minimize their risks on ecosystem and human health. These investigations have been coordinated by the Office of National Steering Committee 33, Ministry of Natural Resources and Environment Vietnam with collaboration between various research institutions belonging to Ministry of Defense, Ministry of Health and international organizations and firms such as US Agency for International Development (USAID), Hatfield Consultant, and CDM<sup>2,3,4</sup>.

This article presents a concise summary of the most significant results on the status of dioxin contamination in three hotspots Bien Hoa, Da Nang and Phu Cat Airbase, which are the former airbases of US Army during the war. Results from different investigations from mid 1990s until very recently (in 2010) were compiled and analyzed to provide insights into the dioxin contamination in both spatial and temporal terms, their environmental fate and transport behavior. Recent data on human exposure were also discussed to assess long term accumulation and possible implications for human health.

## **Materials and methods**

Methods and techniques for sampling collection, storage, and chemical analysis were basically followed by US-EPA protocols with necessary modifications. For soils and sediment samples collected from contaminated hotspots (with generally high levels of dioxins) analyzed during surveys in mid 1990s were analyzed by high resolution gas chromatography/low resolution mass spectrometry (HRGC/LRMS) according to US-EPA 8280<sup>5</sup>. While recent investigations conducted in international laboratories employed high resolution GC/MS for dioxin quantification<sup>6</sup>. Quality assurance and quality control was frequently conducted to ensure reliability of the methods. Concentration of PCDD/Fs is the total concentrations of seventeen congeners using WHO-TEF with unit of ppt, unless otherwise specified.

## **Results and discussion**

### *Extent of dioxin contamination in spatial and temporal terms*

The pioneering investigations on dioxin contamination in hotspot areas were conducted by Ministry of Defense Vietnam from early 1995 with extensive surveys throughout three airbases, Bien Hoa, Da Nang and Phu Cat and their nearby areas<sup>2</sup>. In general, elevated dioxin concentrations were found in examined locations inside the

airbases. The areas where the former storage, loading, mixing and washing activities were deployed during the Ranch Hand operation are considered as the heaviest contaminated ones, with concentrations in soils and sediments exceeding many international standard levels. Surveys conducted from 1995 to 2002 examined dioxin levels in over 200 samples of sediments and soils from three hotspots<sup>2,3</sup>. Many of samples exceeding the action value of 1000 pg/g TEQ for soils and 150 pg/g for sediment (Vietnamese standards). The highest dioxin level found in Z1 area of Bien Hoa Airbase in frame of Z1 Project implemented during 1995-1996 (410,000 pg/g TEQ dry wt) while the highest values for were noticed in mixing and loading area of Da Nang Airbase was 365,000 pg/g TEQ during survey in 2005-2006 (conducted by Hatfield Consultant and Office 33). In Phu Cat Airbase, the highest concentrations in soils were encountered in the storage area (238,000 pg/g TEQ dry wt) during 2008 survey. Elevated contamination were also revealed in sediment samples, with elevated levels found in lakes and ponds in three airbases. For example, Sen Lake, the largest lake in Da Nang Airbase, a reservoir for run-offs within the airbase, is considered as final sink for toxic contaminants including dioxins. Elevated levels of dioxins in biological (including plant and animals) and sediment samples. For example, lotus roots and bulbs in Sen Lake accumulate up to 490 ppt TEQ of dioxin. Recent investigations in Sen Lake in 2010 releaed that levels of dioxins in sediment were still relatively high (mean: 1145, range: 5.3 - 5370 pg/g dry wt.)<sup>2,4</sup>.

Figure 1 illustrates the spatial distribution of dioxins in soils and sediment from the most recent surveys (during 2008 - 2010) in three hotspots. In general, the extent of contamination follow the order: Bien Hoa > Da Nang > Phu Cat. In general, residue concentrations in soils and sediments in recent surveys have decreased compared to the previous ones. For example, surveys in Sen Lake sediment, Da Nang Airbase in 2002-2004 reported elevated dioxin levels, ranged from 282 - 12,390 pg/g TEQ dry wt. Subsequent investigations implemented during 2005 - 2006 exhibited considerably lower levels (68.6 - 6820 pg/g TEQ dry wt), as well as in recent survey in 2010 (5 - 5370 pg/g TEQ dry wt)<sup>2,3,4</sup>. Although sampling sites may be different among studies, these results indicate relatively rapid reduction of dioxin contamination, thus underlining the improvement in environmental quality over the years. Nevertheless, dioxin concentrations in a considerable number of soil and sediment samples still exceeded the guideline values, particularly in Bien Hoa and Da Nang Airbase. Former storage area in Phu Cat and Da Nang Airbase, Z1 area in Bien Hoa Airbase, Sen Lake and nearby areas are still the contaminated areas with elevated dioxin concentrations (Fig. 1). These areas deserve further monitoring surveys and remediation measures.

#### *Human expsoure and human health implications*

Human blood and breast milk samples were often used as bio-indicators for understanding contamination status and human health implications posed by persistent toxic contaminants including dioxins. In general, available data indicate that there are clear differences in dioxin levels in human blood from hotspots, sprayed areas and reference areas, with much higher levels in hotspots areas. In particular, mean TEQ concentration of TCDD in human blood from Sen Lake was 359 ppt TEQ lipid wt ( $n = 11$ , survey in 2006), which was higher than those in Bien Hoa city (93.8 ppt TCDD,  $n = 43$ , survey in 1999-2001) and the average level of those collected from sprayed areas in South Vietnam (32 ppt TEQ,  $n = 233$ , survey in 1993). This result highlights the importance of the hotspots areas to pose greater risks for human health. To gain a better understanding on the recent contamination status, dioxin residue levels in human blood in Da Nang Airbase and polulation living in nearby areas have been examined during 2010 survey (Fig. 2). TCDD concentrations in workers in Sen Lake and West Airbase area were significantly higher than those in other areas such as Thuan Tay and Khue Trung<sup>4</sup>. The typical range of TCDD in general population of industrialized countries are reported from 3 to 7 pg/g lipid wt. (ATSDR 1998)<sup>7</sup>. ATSDR also indicated that TCDD in human blood rarely exceeds 10 pg/g, and lower levels of this contaminant are usually recorded in less industrialized countries. A large proportion of blood samples from Sen Lake and West Airbase workers contained TCDD levels greater than 10 pg/g lipit wt.<sup>4</sup> This suggest dioxin contamination largely results from direct exposure and working on the Airbase. In addition, higher dioxin blood levels in Sen Lake group suggest the consumption of contaminated food items such as fish and aquatic organisms, and dermal contact with soils and sediments from the lake are major cause for such elevated exposure. This also highlights the role of the Sen Lake as potential sink for dioxins, and pose a considerable risk for ecosystem and biodiversity of the lake.

As for human breast milk, a compilation of available data indicates breast milk from nursing women collected in Da Nang Airbase (mean: 39 pg/g TEQ lipid wt) were comparable to those reported in industrialized countries such as Japan, Germany, Norway, the Netherlands, and higher than those in Asian countries such as China, India, Philippines, Cambodia and Malaysia<sup>4,8</sup>. Elevated dioxin contamination in breast milk from Da Nang Airbase is of concern, and suggests an urgent need for raising public awareness on potential contaminated food items originating from Da Nang Airbase.

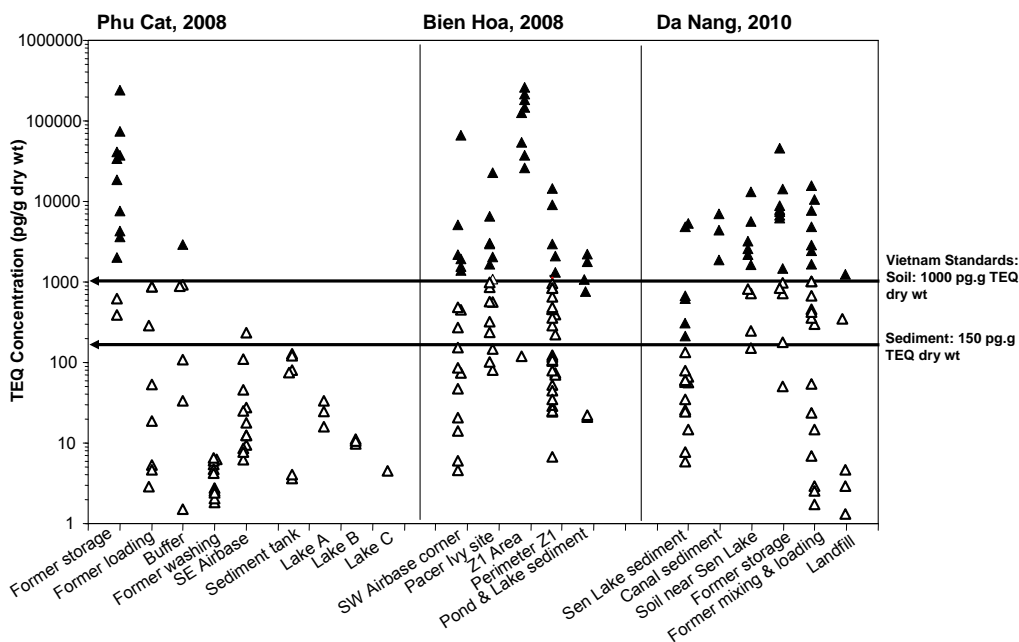


Fig. 1. Results of recent investigations on spatial distribution of dioxins in soils and sediments from three hotspots: Bien Hoa, Da Nang and Phu Cat Airbase. Black triangles represent samples with dioxins concentrations exceeding Vietnamese standards (1000 pg/g TEQ dry wt or soils and 150 pg/g dry wt for sediment)

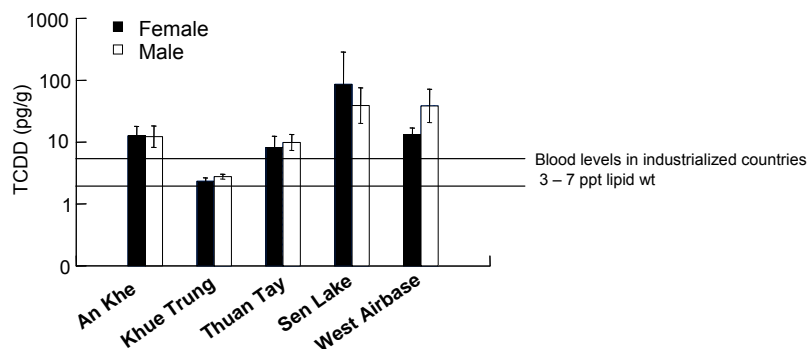


Fig. 2. Results of recent investigations on TCDD levels in human blood samples from Da Nang Airbase in comparison with normal TCDD blood levels industrialized countries.

Overall, results from various investigations over the last three decades in three hotspots in Vietnam indicate that while dioxin contamination has showed relatively rapid decline, the present status is still relatively high in the former storage and loading areas, and some lakes and ponds in the airbases, with concentrations exceeding the Vietnamese standards for soils and sediments. Elevated human exposure was found in certain groups who are workers near Sen Lake and in western area of Da Nang Airbase, suggesting potential risks due to consumption of contaminated food items and direct ingestion of contaminated soils, sediments and aquatic organisms/plants. These areas deserve further scientific attention and remediation measures, such as excavation and removal of contaminated soil and sediment and disposal in a landfill areas, as well as advanced chemical technology for pilot treatment of contaminated soils.

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