

AGENT ORANGE DIOXIN CONTAMINATION IN THE ENVIRONMENT AND FOOD CHAIN AT KEY HOTSPOTS IN VIET NAM: DA NANG, BIEN HOA and PHU CAT

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Introduction

During the US-Viet Nam War, the American and the ARVN military forces initiated the use of herbicides in Viet Nam through a program codenamed Operation Ranch Hand^{1,2}. The operation, which extended from 1961 to 1971, released over 80 million litres of herbicides into the environment of southern Viet Nam³. Application of herbicides was primarily conducted through cargo aircraft (C-123s), and ground mechanisms (i.e., trucks, backpack sprayers, and river boats); helicopters were also used in certain areas of the country. Sixty-one percent (61%) of the herbicides used in Viet Nam were Agent Orange, intended to destroy forest cover and food crops¹. Vietnamese were exposed to these chemicals during the actual spraying and on a regular basis for the past 50 years, primarily through contact with media such as soils, sediments, dust, and food products near former US military bases.

Elevated levels of dioxins (2,3,7,8-tetrachlorodibenzo-*p*-dioxin, or TCDD), a contaminant in Agent Orange, have been well documented in the environment in and around former US military sites in Viet Nam^{4,5,6,7,8}. The source of contamination was storage, use, and spillage of herbicides by the US military and Army of the Republic of Viet Nam (ARVN) forces during the US-Viet Nam War. Military installations throughout Viet Nam (e.g., Bien Hoa, Da Nang, Phu Cat, and others) served as bulk storage and supply facilities for Agent Orange¹. These storage sites experienced significant contamination due to the spillage of herbicides and improper disposal of empty barrels⁵.

In the past decade, several studies have been undertaken by Vietnamese and international scientists to verify the extent of dioxin contamination at a number of former US bases in southern Viet Nam^{4,5,6,7,8}. The military history and present environmental conditions related to dioxin contamination have been recorded at key hotspots in Viet Nam, including Da Nang, Bien Hoa, Phu Cat, Pleiku, Nha Trang, Can Tho, and Tan Son Nhut^{1,2,7,8}. Installations at Bien Hoa, Da Nang and Phu Cat have been identified as the most contaminated of the Airbases studied; these are the priority areas for remediation of soils and sediments, and for protection of local human populations⁸. A secure landfill has recently been constructed at Bien Hoa Airbase by the Government of Viet Nam (GVN), and remediation work is also being planned for Da Nang Airport through cooperation between the GVN and the US.

Materials and methods

Sampling procedures followed those previously developed and applied by Hatfield in previous Agent Orange dioxin assessment projects in Viet Nam^{5,6,7,8}. Sampling activities were undertaken in cooperation with Office 33 and relevant Vietnamese Government agencies, especially the Ministry of National Defense, Ministry of Health and local Da Nang, Bien Hoa and Phu Cat authorities. All soil and sediment sampling sites were screened for landmines and unexploded ordnance (UXO) in advance of sampling. Sampling locations were selected through pre-field desktop reviews of existing literature, topographic maps and remote sensing information available for the study area, in conjunction with historical sampling results from areas within and surrounding the Airbases. Sampling was conducted on the Da Nang, Bien Hoa and Phu Cat Airbases proper, as well as in surrounding Districts/Wards outside the influence of the Airbase.

Surface soil samples analyzed consisted of 10 composites, and were collected to a maximum of 50 cm depth; core samples were collected to a maximum depth of 3 m. A number of fish species, including Nile Tilapia (*Oreochromis niloticus niloticus*), were sampled from waterbodies on the Da Nang and Bien Hoa Airbases.

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) using a Micromass Ultima high resolution mass spectrometer equipped with an HP 6890 gas chromatograph, a CTC autosampler, and an Alpha workstation running VG software⁹. Standard quality assurance and quality control procedures used for all Hatfield field sampling programs in Viet Nam were applied. Soil and sediment samples were screened against the Vietnamese Dioxin Threshold in Soil and Sediment (National Standard TCVN 8183:2009); the guideline for soil in “dioxin heavily contaminated sites” is 1,000 pg/g TEQ, and for sediment is 150 pg/g TEQ. Health Canada consumption guidelines for edible fish tissue (20 pg/g TEQ) were applied.

Results and discussion:

Results of a number of dioxin sampling programs undertaken in the vicinity of the Da Nang, Bien Hoa and Phu Cat Airbases demonstrated elevated TCDD concentrations in soils, sediments, and fish tissues (Tables 1 and 2), as well as in human blood and breast milk (ref. conference paper by Hang *et al.*). Dioxin concentrations recorded exceeded Vietnamese and international standards, particularly in areas where Agent Orange and other herbicides were stored, loaded onto aircrafts, and/or spilled.

Analytical results demonstrate that soils and sediments have been contaminated for decades, and remain contaminated today. A soil TCDD concentration of >1million pg/g was recorded at Bien Hoa in 2001, although the exact origin of this sample is not known¹⁰. Previous VRTC studies (unpublished data) also found several soil samples exhibiting dioxin concentrations >1 million ppt at Bien Hoa prior to construction of the landfill in 2009.

Elevated concentrations of TCDD were detected in soil samples analysed from Da Nang Airport in December 2006 and January 2009, from Bien Hoa Airbase in 2008-2010, and from Phu Cat Airbase in 2008 (Table 1). Soil and sediment samples analysed from the Former Mixing and Loading and Former Storage Areas in the northern area of the Da Nang Airport exhibited the highest TCDD concentrations of all sites sampled by Hatfield in Viet Nam. The maximum soil TEQ concentration recorded in 2006 was 365,000 ppt from samples collected at the Former Mixing and Loading Area; this is 365 times the Vietnamese and globally acceptable maximum standard of 1,000 ppt. Three soil samples were >100,000 ppt; seventeen (17) of the 23 soil samples (74%) analysed from Da Nang Airport were >1,000 ppt. Dioxin concentrations in sediments of Sen Lake and North Airport drainage ditches exceeded the Vietnamese guideline of 150 ppt TEQ; TEQs from 2006 and 2009 sediment samples from the North Airport sites ranged from 674 to 8,580 ppt. Sampling conducted in 2010 (USAID/GVN collaboration) confirmed the extent and depth of dioxin contamination at the key hotspots on Da Nang Airport.

The highest soil dioxin concentrations at Bien Hoa Airbase were recorded in 2008 from a depth of 60-90 cm in the Z1 Area (former herbicide storage site), and exhibited a TEQ concentration of 262,000 ppt (259,000 ppt TCDD; 99% TCDD of TEQ). Contaminated soils in the Z1 Area have now been contained in a secure landfill; dioxin levels in and around this area have been reduced significantly as a result. Highest sediment dioxin levels were recorded in samples collected from the Pacer Ivy Area (5,970 ppt TEQ) in 2008.

At Phu Cat Airbase, the highest dioxin concentrations were detected in the Former Storage Area (236,000 ppt TCDD; 238,000 TEQ; 99.2% TCDD of TEQ). Dioxin concentrations at Phu Cat Airbase are comparable to those found at Bien Hoa and Da Nang, although the extent of contamination is limited to a small area. The highest sediment TCDD level was recorded to the east of the runway (194 ppt), at a location downstream of the suspected Ranch Hand operational area. Run-off from this site ultimately flows into South Lake, which is used for irrigation purposes, potentially exposing villagers to dioxins during work in paddies, consumption of fish, and perhaps other food items.

Studies conducted between 2006 and 2009 found that Sen Lake A, located in the northern sector of the Da Nang Airport, downstream of the main dioxin hotspot areas, exhibited the highest recorded total TEQ in fish tissue samples collected in Viet Nam to date (Table 2). In 2009, Tilapia fat taken from a composite of 6 large specimens (average weight 439.8 g) exhibited contaminant concentrations as high as 8,350 ppt TEQ and 7,920 ppt TCDD. Muscle (88.2 ppt TEQ), eggs (1,290 ppt TEQ), and liver (1,540 ppt TEQ) tissues analysed from the composite of large Tilapia in Sen Lake all exceeded Health Canada guidelines. In 2006, Tilapia fat tissues analysed from Sen Lake A also exhibited very high TEQ values (3,120 ppt); concentrations appear to be

increasing, due to bioaccumulation in tissues over time. Fish sampled from the rest of the lakes and ponds inside the Da Nang Airport generally remained below the Health Canada guideline.

In Bien Hoa, Tilapia sampled from all lakes and ponds inside and outside the Airbase exhibited very high contaminant concentrations in fat tissue, exceeding the designated Health Canada guideline. In 2010, the highest recorded fish TEQ level in Bien Hoa was found in fat tissue of a Tilapia composite (n=3) in the Pacer Ivy Area (4,040 ppt TEQ; 3,990 ppt TCDD). Muscle samples and whole fish samples analyzed also exceeded Health Canada guidelines. Over 90% of the TEQ was attributed to TCDD from fish samples analyzed.

Overall, Da Nang, Phu Cat and Bien Hoa Airbases exhibited comparable soil and sediment dioxin concentrations. As former Ranch Hand operation sites, these three airbases are confirmed as the most significant dioxin hotspots in the country. As of 2010, dioxin continues to enter the aquatic ecosystem, the general environment, and the food chain in and around Da Nang, Phu Cat and Bien Hoa Airbases. Dioxin levels recorded in soil and sediment samples at all three airbases continue to exceed both Vietnamese and internationally accepted standards and guidelines for these toxic chemicals. Remediation activities at Bien Hoa in the Z1 Area have reduced dioxin levels in the main hotspot area, but other hotspots remain on the Airbase, which need to be treated.

Planning and implementation of remediation measures and clean-up of Da Nang, Bien Hoa and Phu Cat Airbases is urgently required to ensure protection of the local population from ongoing exposure to dioxins from historical Agent Orange use at these sites. Cultivation of Tilapia, other fish species and aquatic animals (e.g., ducks, molluscs, etc.) should be halted immediately on all Airbases. Awareness raising of dioxin exposure pathways (eating contaminated fish and other food items raised on or near Airbases, exposure to contaminated soil and sediment, uncontrolled combustion, etc.) is required to help reduce exposure of local residents, especially nursing mothers. Lessons learned from ongoing cleanup activities at Da Nang Airport (funded by the USG and GVN) will be invaluable for the future remediation of Bien Hoa and Phu Cat Airbases, and at other dioxin hotspots in Viet Nam.

Table 1: Highest recorded concentrations of polychlorinated dibenzo-*p*-dioxins (ppt) in soil and sediment from Da Nang, Phu Cat and Bien Hoa Airbases, Viet Nam.

	Da Nang	Phu Cat	Bien Hoa
Soil	361,000 ppt TCDD	236,000 ppt TCDD	259,000 ppt TCDD
	365, 000 ppt TEQ	238,000 ppt TEQ	262,000 ppt TEQ
	99% TCDD of TEQ	99% TCDD of TEQ	99% TCDD of TEQ
	Mixing and Loading Area	Storage Area	Pacer Ivy Area
Sediment	8,390 ppt TCDD	194 ppt TCDD	5,810 ppt TCDD
	8,580 ppt TEQ	201 ppt TEQ	5,970 ppt TEQ
	98% TCDD of TEQ	96% TCDD of TEQ	97% TCDD of TEQ
	Ditch d/s of Storage Area	East of the Runway	Pacer Ivy Area

Table 2: Highest recorded concentrations of polychlorinated dibenzo-*p*-dioxins (ppt) in Tilapia fish tissue from Da Nang and Bien Hoa Airbases, Viet Nam (2006-2010).

	Tissue	TCDD ppt	TEQ ppt	% TCDD of TEQ
Da Nang (2006)	Fat	3,000	3,120	96%
Da Nang (2006)	Muscle	33.2	34.5	96%
Da Nang (2009)	Fat	7,920	8,350	95%
Da Nang (2009)	Muscle	39.2	40.9	96%
Da Nang (2009)	Liver	1,490	1,540	97%
Da Nang (2009)	Eggs	1,230	1,290	95%
Bien Hoa (2010)	Fat	3,990	4,040	99%
Bien Hoa (2010)	Muscle	31.2	31.5	99%
Bien Hoa (2010)	Whole fish	618	622	99%

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