Comprehensive Assessment of Dioxin Contamination in Da Nang Airport, Viet Nam: Environmental Levels, Human Exposure and Options for Mitigating Impacts

Final Report

November 2009

Prepared by:

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North Vancouver, British Columbia, Canada

and

Office of the National Steering Committee 33, MONRE
Ha Noi, Viet Nam

Funded by:

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New York, USA

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SUMMARY OF FINDINGS

This report presents the results, conclusions and recommendations of three recent studies conducted to determine the extent and level of dioxin contamination in the environment and the exposed human populations in and around the airport in Da Nang, Viet Nam. The 10-80 Division of Viet Nam's Ministry of Health conducted the first of these studies in 2003-2005, while the second and third studies (in 2006 and 2009, respectively) were the responsibility of the Office of the National Steering Committee 33 of the Ministry of Natural Resources and Environment. Hatfield Consultants (West Vancouver, Canada) collaborated closely with the Vietnamese agencies on the three studies, all of which were funded by the Ford Foundation.

Da Nang was one of the key U.S. Department of Defense (DOD) Operation Ranch Hand sites in Viet Nam, and was second only to Bien Hoa in terms of number of C-123 aircraft sorties and volume of herbicides stored and used. Dioxin contamination at Da Nang Airport is the result of the storage, loading, spillage and handling of Agent Orange and other toxic herbicides during the US-Viet Nam war, especially between 1965 and 1971.

A total of 410 environmental samples, including 198 soil/sediment, 41 fish/vegetation and 171 human blood and breast milk were collected and analyzed for dioxin[1] and furan concentrations over the course of the Hatfield/10-80/Office 33 studies. Human tissue sampling was performed on a volunteer basis and followed internationally-accepted protocols to ensure consent of donors. All samples were analyzed at AXYS Analytical Laboratories (Sidney, BC, Canada), a WHO-accredited independent laboratory for dioxin and furan analyses. The 2005 data, consisting of soil and sediment samples, were part of a larger reconnaissance survey of former US military bases and suspected Agent Orange dioxin hot spots in southern Viet Nam. The 2006 sampling focused on soils/sediments and biosamples from the most highly contaminated areas in the northern part of the Da Nang Airport. These earlier studies confirmed the northern area of Da Nang Airport to be a significant dioxin hot spot.

Following the 2006 study, interim mitigation measures were implemented in 2007-2008 to protect the local population from continued exposure to dioxins from the Airport. Mitigation measures implemented with funding provided by Ford Foundation included: cessation of all fishing and agricultural activities on Sen Lake; construction of a permanent fence at the northern boundary of the Airport; capping of soils at the Former Mixing and Loading Area; and construction of interim water treatment and sediment containment facilities.

The 2009 environmental and human population studies at Da Nang Airport and in surrounding communities have provided a more complete picture of the overall dioxin contamination issue in the Da Nang area, including suspected Pacer Ivy sites in the south of the Airport. As a result of these studies, we now have a clearer understanding of dioxin contaminated areas, exposure pathways and affected populations in Da Nang. These data

[1] In this report, dioxin or TCDD refers specifically to 2,3,7,8-tetrachlorodibenzo-p-dioxin; TEQ is based on 2005 WHO TCDD Toxic Equivalent factors (using one-half of the detection limit). PCDD and PCDF are general terms for all dioxin or furan congeners, respectively. Note that "ppt" is the same as "pg/g".

will help facilitate planned remediation efforts for Da Nang Airport, which are currently being discussed between the Governments of Viet Nam and the United States.

Dioxins and furans in soils and sediments[2]:

- Significant quantities of TCDD, the dioxin contaminant in Agent Orange, were detected in soil samples analyzed from the north end of the Da Nang Airport in December 2006, and again in January 2009. Dioxin levels at this location continue to exceed Vietnamese and international standards and guidelines for these toxic chemicals. TCDD concentrations ranged from 858 pg/g dry weight to 361,000 pg/g dry weight in samples collected from the Former Mixing and Loading Area and the Former Storage Area.

- Dioxin concentrations in sediments of Sen Lake and North Airport drainage ditches exceeded the Vietnamese guideline of 150 pg/g TEQ; TEQs from 2006 and 2009 sediment samples from North Airport sites ranged from 674 to 8,580 pg/g dry weight. Sediments for other lakes near the perimeter of the Airport ranged from 0.54 to 146 pg/g TEQ in 2009.

- Dioxin congener profiles confirmed that the main source of dioxin contamination in the northern area of the Da Nang Airport was Agent Orange and other dioxin-containing herbicides. TCDD contributed over 90% of the TEQ (TCDD toxic equivalents) in soil and sediment samples collected from the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake.

- TCDD levels measured in soil samples in January 2009, in the central and southern areas of the Da Nang Airport, were generally lower than contaminant levels detected in the north. TCDD concentrations ranged from 0.388 pg/g dry weight to 145 pg/g dry weight.

- One soil sample in the Pacer Ivy Storage Area (PISA), and one surface sample adjacent to the PISA in the southern area of the Airport, exceeded Vietnamese and international standards and guidelines for TCDD (1,180 and 13,400 pg/g dry weight, respectively). At the Pacer Ivy Re-Drumming Area (PIRA), all samples exhibited low TCDD levels (1.21 to 79.9 pg/g dry weight). The proportion of TCDD to TEQ concentrations at, and adjacent to, the Pacer Ivy sites was generally low.

- All samples analyzed from the west and east of the Da Nang Airport exhibited low TCDD concentrations (non-detect to 46.1 pg/g dry weight).

- The present study (and previous work by Hatfield/10-80 Division/Office 33) has verified that the highest concentrations of dioxins by Agent Orange and related herbicides in contaminated soils/sediments in Viet Nam are found in the top 10 cm layer; some contamination is found at deeper strata (e.g., >30 cm), but only in limited areas in the former Mixing and Loading Area, former Storage Area, and PISA at Da Nang Airport.

[2] WHO-TEQ guidelines are typically in the range of 4 to 40 pg/g TEQ for soils used for agriculture, and approximately 1,000 pg/g for residential and recreational areas.

- Other contaminants which contribute to total PCDD/PCDF load (including polychlorinated biphenyls, organochlorine pesticides and hydrocarbons) are also present in the environment, both inside and outside the perimeter of Da Nang Airport. Potential dioxin sources need to be determined and quantified in order to verify the total dioxin load to the environment and human population in Da Nang.

- Collectively, the concentrations of total dioxins and furans indicate extremely high contamination, and confirm the northern end of Da Nang Airport as a significant dioxin hot spot. The southern, eastern and western areas of Da Nang Airport exhibit less dioxin contamination than is recorded in the northern hot spot areas.

Dioxin exposure pathways:

- The existing evidence indicates dioxin moves from the former Mixing and Loading and Storage Areas into Sen Lake, and ultimately into humans (via ingestion of contaminated fish, direct dermal contact with soils and sediments, and likely via inhalation of dust), and is directly linked to historical Agent Orange use on the Da Nang Airport. The Sen Lake ecosystem, located on the Da Nang Airport property, has recently (2007) been restricted from public access, which has resulted in a reduction of dioxin exposure to the local human population of Da Nang.

- Tilapia, the most common fish captured and analyzed on Da Nang Airport property, exhibited TEQ concentrations ranging from 5.64 to 8,350 pg/g wet weight in fat tissues; the median TEQ value was 64.4 pg/g. Health Canada consumption guidelines for edible fish tissue is 20 pg/g TEQ wet weight.

- The maximum TEQ concentration recorded in Tilapia fat from Sen Lake in 2009 (8,350 pg/g wet weight basis) is more than 400 times the acceptable level established by Health Canada. In 2006, Tilapia fat levels were 3,120 pg/g TEQ (wet weight basis). Possible explanations for increased dioxin concentrations in Sen Lake Tilapia between 2006 and 2009 include higher bioconcentration in larger fish over time. Since cessation of fishing practices at Sen Lake in 2007, average fish sizes (and average age) appear to have increased over time, resulting in increased bioaccumulation of dioxins in biological tissues.

- Muscle samples analyzed from Tilapia and other fish species from 12 other lakes on the Da Nang Airport property in 2009 generally exhibited low dioxin levels, ranging from 0.0786 to 1.38 pg/g TEQ wet weight.

- Dioxin levels recorded in vegetation (i.e., lotus, sweet potato) collected at Sen Lake in 2006 were generally low, although potential for contamination exists through contact with soil and sediments used for growing these food items on the Airport property.

Dioxins and furans in humans:[3]

- Summary statistics for TCDD concentrations for each group analyzed during the 2009 study are presented below:

Group	TCDD Minimum (pg/g lipid basis)	TCDD Median (pg/g lipid basis)	TCDD Maximum (pg/g lipid basis)
Khue Trung, Cam Le (n=45)	1.66	5.26	15.0
Thuan Tay, Hai Chau (n=24)	2.41	21.3	96
Anh Khe, Thanh Khe (n=15)	5.94	31.3	251
Sen Lake Workers (n=11)	9.64	157	1340
West Airbase Workers (n=6)	24.7	47.8	212

- TCDD concentrations in human blood from donors of Khue Trung Ward in Cam Le District south of the Airport, which exhibited the statistically lowest TCDD and TEQ levels, were ≤15 pg/g. The low percentage of TCDD in these TEQ values (none exceeded 40%) indicates that it is unlikely that these participants are directly exposed to Agent Orange from soils, sediment, water or food supplies. This was also true for individuals sampled in 2006 from the reference area, Thuan Phuoc Ward in Hai Chau District.

- Analysis of 2009 blood dioxin/furan levels from communities surrounding the Airport confirmed elevated concentrations in people living north (Sen Lake and West Airbase Workers), east (Thuan Tay, Hai Chau) and west (Anh Khe, Thanh Khe) of the Airport. Although contamination levels in people living around the Airport are likely from a variety of sources, working on the Airport significantly increases blood TCDD and TEQ above the background levels generated from other sources. Sources of dioxin other than Agent Orange are conjectured given the presence of several dioxin and furan congeners in blood profiles.

- Blood dioxin (TCDD) levels recorded in the 2006 study (n=55 blood donors sampled) ranged from 2.77 to 1,150 pg/g lipid basis. The maximum TCDD concentration of 1,150 pg/g lipid basis (1,220 pg/g TEQ; 94% TCDD) was recorded in a 42-year old male who actively harvested fish and plants from the Da Nang Airport. In 2009, TCDD in the same individual's blood was 1,340 pg/g lipid basis (1,410 pg/g TEQ; 95% TCDD).

- West Airbase and Sen Lake Workers that were retested in 2009 demonstrated no statistical differences in blood TCDD or TEQ levels from those recorded in 2006. Sen Lake Workers were relocated and all fishing and agricultural activities in the north Airport area were halted in 2007 (with the exception of the West Airport Ponds, which are still in operation).

[3] The typical range of TCDD in the general population of industrialized countries has been reported as 3 to 7 pg/g (lipid-based) (ATSDR 1998). ATSDR also indicated that TCDD in human blood rarely exceeds 10 pg/g and that typically, lower levels of this contaminant are recorded in less industrialized countries.

- The people most exposed to dioxins from the Da Nang Airport hot spot are members of an extended family who previously fished and harvested lotus from Sen Lake, and gardened along its banks. Others may also have been affected by eating fish and other aquatic animals harvested from the Airport lakes, although exact numbers are presently unknown.

- The analysis of blood dioxin levels in people randomly selected in the wards surrounding the Airport (Anh Khe Ward in Thanh Khe District, Khue Trung Ward in Cam Le District, and Thuan Tay Ward in Hai Chau District) shows that working on the Airport is the strongest predictor of blood dioxin levels in these people. Eating fish from Sen Lake was also deemed a significant factor in blood dioxin levels recorded.

- Some, but not all, individuals sampled from other wards surrounding the Airport exhibited TCDD concentrations greater than 10 pg/g. These include residents from Anh Khe Ward in Thanh Khe District, Thuan Tay Ward in Hai Chau District, and Chinh Gian Ward in Hai Chau District. These wards are located on the west, east and north sides of the Airport, respectively, within 1 km of the boundary.

- Dioxins and furans were recorded in all breast milk samples analyzed in 2009 (N=14). Maximum levels were recorded in a young primaparous female (232 pg/g lipid basis TCDD) who previously consumed fish from Sen Lake. Average Daily Intake of breast milk per infant was calculated based on WHO/Euro (1989); Total TEQ ingested by infants ranged from 23.4 to 2,320 pg TEQ/kg bw/d.

- All breast milk samples analyzed exhibited TEQs exceeding the WHO Tolerable Daily Intake guideline of 4 pg TEQ/kg bw/d. High dioxin and furan levels in breast milk are cause for concern, and emphasize the need for raising awareness of potential contaminated food items originating from Da Nang Airport.

- Results from the 2009 study suggest that the interim mitigation measures implemented in 2007 have reduced the potential dioxin exposure pathways for the human population residing in the north end of Da Nang Airport, and that there is minimal dioxin exposure risk for people residing in the southern Airport area.

Recommendations:

- Implementation of final mitigation measures and clean-up of Da Nang Airport is required immediately to ensure protection of the local population from future exposure to dioxins from historical Agent Orange use at the site. Time is of the essence to implement final clean-up, as the Governments of Viet Nam and Da Nang City have plans to expand the current Airport runway as early as 2010.

- Final remediation and clean-up efforts should focus on mitigating dioxin and furan contamination at the northern end of the Airport. Current plans being considered include construction of a secure onsite landfill in the south of the Airport, near the former Pacer Ivy site. Remediation options need to carefully assess the risk of re-mobilization of contaminated soils and sediments from the Former Mixing and Loading Area, Former Storage Area and Sen Lake during excavation and transport.

- Other potential dioxin and furan contamination sources, particularly uncontrolled combustion and industrial emissions, need to be identified.

- Awareness raising of dioxin exposure pathways (eating contaminated fish, access to the northern Airport area, uncontrolled combustion, etc.) is required to help reduce dioxin loads in local Da Nang residents, especially nursing mothers.

- Other major dioxin hot spots in Viet Nam, particularly Bien Hoa and Phu Cat, also require remediation and clean-up, to protect the local populations from continued exposure to Agent Orange and other herbicides used over 40 years ago during the US-Viet Nam war.

1.0 INTRODUCTION AND BACKGROUND

This report summarizes work completed during investigations conducted in January and April 2009 for the project entitled *Comprehensive Assessment of Dioxin Contamination in Da Nang Airport, Viet Nam: Environmental Levels, Human Exposure and Options for Mitigating Impacts* (hereafter referred to as the *Da Nang 2009 Study*). The report was prepared by Hatfield Consultants (hereafter referred to as "Hatfield") and the Office of the National Steering Committee 33 (hereafter referred to as "Office 33"), and was funded through a grant from the Ford Foundation Special Initiative on Agent Orange/Dioxin.

Results of environmental investigations on the Agent Orange (AO) dioxin issue at Da Nang are presented from field sampling conducted at Da Nang Airport and in Da Nang City in January 2009 (Phase I) and follow-up environmental sampling and human blood and breast milk sampling conducted in April 2009 (Phase II). Historical environmental sampling conducted from 2005 to 2006 is included to provide a complete picture of the status of dioxin contamination at Da Nang Airport and in the City of Da Nang.

Previous reports investigating the Agent Orange dioxin issue in and around the Da Nang Airport were prepared by Hatfield, 10-80 Division of the Ministry of Health and Office 33 in 2006 and 2007 (Hatfield/10-80 2006; Hatfield/Office 33 2007). Extensive surveys of the northern area of Da Nang Airport were conducted in December 2006 to determine the extent and level of dioxin contamination in the environment and human population (Hatfield/Office 33 2007). Final results were presented at a workshop in Ha Noi in April 2007 by Hatfield and Office 33, and interim mitigation measures were recommended for immediate implementation to protect Da Nang residents most at risk from exposure to dioxin-contaminated soils and dust in the northern Airport, as well as sediments and fish from the Sen Lake. Interim mitigation measures were implemented in 2007-2008, through funding provided by Ford Foundation, and included: cessation of all fishing and agricultural activities on Sen Lake; construction of a permanent fence at the northern boundary of the Airport; capping of soils at the Former Mixing and Loading Area; and, construction of interim water treatment and sediment containment facilities.

In June 2007, a workshop was organized in Ha Noi by the Viet Nam Ministry of Defense (MOD) and the US Department of Defense (DOD) to discuss dioxin contamination and, additionally, the "Pacer Ivy" mission. In logistics operations, the word "Pacer" refers to the movement of material, and the word "Ivy" is a short-form of "Inventory" (Young 2007). On April 17, 1970 all uses of Agent Orange were halted in the Republic of Viet Nam and all remaining materials were put into storage. The Pacer Ivy mission was launched on September 15, 1971 to consolidate, re-drum and ship all remaining Agent Orange material in South Viet Nam to Johnston Island in the Central Pacific Ocean.

Consolidation of contaminated materials occurred at Bien Hoa Airbase, Tuy Hoa Airbase and Da Nang Airport. On December 23, 1971 clean-up, re-labeling and re-packaging of Agent Orange for shipment began at the Da Nang Airport. The

ARVN Commander was responsible for designating sites for the operations area and storage area as well as the transportation routes to the port of Da Nang (Young 2009). About half of the 8,220 drums of Agent Orange were re-drummed, and on March 7, 1972 drums were loaded onto the M/T Trans Pacific ship in Da Nang Harbor. The ship travelled to Cam Rhan Bay where 6,000 drums from Tuy Hoa were loaded, and then on to the Port of Saigon where a further 11,000 drums were added from Bien Hoa before heading to Johnston Island. Final inspection of the Agent Orange storage areas was completed by April 3, 1972.

Because of the war-time conditions, clean-up of former Ranch Hand sites (including Da Nang) was not always undertaken with consideration of human and environmental health; there are concerns that herbicides and waste water used for cleaning was dumped directly to the ground or possibly into groundwater wells, particularly in the southern area of Da Nang Airport.

In October 2007, the VN-MOD undertook a survey trip and verified the location of suspected Pacer Ivy sites at the south of Da Nang Airport: the Pacer Ivy Re-Drumming Area (PIRA) and the Pacer Ivy Storage Area (PISA). The total area of the two Pacer Ivy sites is approximately 21,000 m^2, and both are located near residential areas in Thanh Khe and Cam Le Districts. Because of the proximity of these sites to the general population and the potential for human exposure, these sites were investigated by Hatfield/ Office 33 as part of the current study.

This 2009 study included 2 components: Phase I focused on the PIRA and PISA areas, and included monitoring of areas in the north of the Airport that were identified as being highly contaminated in the 2006 study (Hatfield/Office 33 2007). Although the sampling focus was on the two Pacer Ivy sites, an assessment of the entire Airport and the city surrounding the perimeter of the Airport was also conducted in January 2009 to determine if there are additional contaminated sites not yet identified.

Phase II was conducted in April 2009 to determine potential human exposure to dioxins and furans in communities surrounding the Da Nang Airport. Blood and breast milk were collected from randomly selected participants and from individuals who had been tested in 2006 to determine any temporal trends in dioxin levels. A detailed questionnaire survey was also implemented for all blood/milk donors. As part of the Phase II study, additional environmental samples were collected from the PISA to better delineate the extent of contamination based on Phase I results.

1.1 PROJECT OBJECTIVES

The main objectives of the 2009 study were to:

1. Assess dioxin contamination in the environment in and near Pacer Ivy sites and monitor the effectiveness of interim mitigation measures implemented in the north of Da Nang Airport in 2007/2008;
2. Assess the levels of dioxins and furans in soil, sediment and fish in areas not previously sampled in the vicinity of the Da Nang Airport;

3. Better understand bio-accumulation pathways of dioxin in the local food chain and human populations;

4. Assist with protection of human health and development of mitigation measures for the contaminated areas; and

5. Enhance public awareness, strengthen governmental management at central and local levels, and increase scientific exchanges to improve prevention/protection of people from dioxin exposure.

The primary focus of the Hatfield/Office 33 studies was to identify dioxin exposure pathways to protect the human population of Da Nang from future dioxin contamination (i.e., "positive human health outcomes"). Protection of local people from current and future dioxin exposure in Da Nang City is the ultimate objective of this study.

Primary project activities included determining the linkage between potential dioxin contamination in the soils and sediments in Da Nang Airport and its movement into aquatic ecosystems, and into the human food chain. The identification and assessment of potential dioxin pathways into the human population allows recommendations to be made for immediate and longer-term mitigation measures to protect people working on the Airport, as well as local communities downstream of the Airport.

Important issues considered in the assessment of dioxin contamination at Da Nang Airport included the following:

1. Numerous dioxin hot spots with contamination levels exceeding Vietnamese and international standards and guidelines were identified on the Airport in the 2006 study (Hatfield/Office 33 2007). The Pacer Ivy sites were only identified following completion of the 2006 study. Therefore, the potential for additional hot spots in other areas of the Airport was deemed high;

2. As of January 2009, people were continuing to earn livelihoods from harvesting fish and lotus from wetlands and fishponds on the Airport. Based on our field observations, some city residents continue to enter the Airport perimeter to harvest fish and timber (and likely lotus, other edible plants, fish and aquatic organisms) for subsistence use. In Sen Lake A, fishing and the collection of lotus were banned following the Hatfield/ Office 33 (2007) study, which is enforced by mitigation measures such as warning signs and guard posts;

3. Given the likelihood that dioxin continues to enter the food web and human population through consumption of fish and vegetation, and from direct exposure to highly-contaminated soil and sediments, the implementation of mitigation measures to protect the human population is of high priority. Based on field surveys conducted in December 2006, recommendations were made that public access to the Airport should be prohibited, and all fishing for subsistence or commercial purposes should be banned immediately (Hatfield/ Office 33 2007);

4. Human exposure to contamination outside the Airport along the east, south and west perimeters was unknown prior to the human surveys conducted under this study in April 2009. Blood and breast milk analysis were used to determine to what extent dioxins are bioaccumulating in the human food chain; and

5. For the current study, all dioxin samples were analyzed at AXYS Analytical Laboratories (AXYS, Sidney BC, Canada), an internationally accredited independent laboratory which has analyzed all samples collected in previous Hatfield/10-80/Office 33 Viet Nam studies.

Selecting sampling locations in Thanh Khe District (Anh Khe Ward), outside the Da Nang Airport (2009).

1.2 AGENT ORANGE USE AT DA NANG AND SUSPECTED HOT SPOTS

In 1962, the US military initiated use of herbicides in Viet Nam for general defoliation and crop destruction through a program codenamed Operation Ranch Hand (Young 2009). The presence of dioxin in the environment in and around former US military sites in Viet Nam is a direct result of storage and use of herbicides by the US forces, spillage, and from improper disposal of empty herbicide barrels (Dwernychuk *et al*. 2002). Since the US-Viet Nam war, Vietnamese living in the vicinity of key former Ranch Hand sites (Bien Hoa, Da Nang, Phu Cat and others) have been exposed to contaminated soils, sediments and foods; these contaminated areas are often referred to as dioxin hot spots. Herbicide applications ceased in 1971. However, due to the chemical

stability of dioxins, contaminated lands have potential to expose the general population to dioxin for many decades, well beyond initial aerial applications and spillages during wartime Ranch Hand operations.

Da Nang was one of the key Ranch Hand sites in Viet Nam, and was second only to Bien Hoa in terms of number of C-123 aircraft sorties (US Army documents 1969, Cecil 1986). Dioxin contamination at Da Nang Airport is the result of the storage, loading, spillage and handling of Agent Orange and other toxic herbicides during the US-Viet Nam war (1968/69 US military memoranda). Agent Orange and other herbicides were used at Da Nang primarily between 1965 and 1971. A detailed history of AO use at Da Nang Airport is provided in Hatfield /Office 33 (2007) and Young (2009).

A number of dioxin sampling programs have been undertaken in Da Nang to assess the status of historical and current contamination. Extensive sampling and dioxin laboratory analysis was undertaken by MOD (in 1997) and MOD/VAST/EPA (in 2005) on Da Nang Airport, and by Hatfield/10-80 (2006) for areas outside the base (summarized in Table 1.1). In 2006, Hatfield/Office 33 conducted a comprehensive assessment of the north Airport, and included sampling of blood and breast milk in local residents (summarized in Hatfield/Office 33 2007). To date, MOD/VAST/EPA analytical data have not been published in the international scientific literature. EPA (2005) CALUX data are available in an unpublished summary report (Xenobiotic Detection Systems Inc. 2006).

Historical sampling in the north of the Airport by Hatfield/Office 33 (2007) focused on three suspected hot spot locations (Figure 1.1):

1. **Former Mixing and Loading Area (MLA) –** Located to the northeast of the main runway, approximately 150 m from the current international airport. At this site, Agent Orange and other herbicides were loaded on C-123 airplanes, helicopters and other aircraft, as well as other distribution devices (e.g., backpack sprayers). Planes returning from spray missions were also washed and serviced in this area, leading to spills of herbicides into the surrounding lands and drainage ditches, and ultimately into Sen Lake and other local waterbodies;

2. **Former Storage Area (SA) ("Bai Doc") –** According to MOD, 105,400 barrels of herbicide (208 L or 45 gallons/barrel) were stored at the Storage Area on the Da Nang Airport during the US-Viet Nam war (Dr. Tran Ngoc Tam, MOD *pers. comm.*). Herbicides were transported from the Storage Area to the MLA for loading onto aircraft or other dispersal mechanisms. The former Storage Area substrate currently consists of hard-packed sand, with no vegetation growing on the site; and

3. **Sen Lakes ('Ho Sen") –** Includes a series of three lakes, referred to in this report as Sen Lake (sometimes also referred to as "Sen Lake A"), Lake B and Lake C. The Sen Lakes form a large (7 ha) wetland situated

at the northern border of the Airport, within the boundaries of the Airport. A drainage ditch carries run-off waters from the former MLA and former SA to Sen Lake. The area between the former Storage Area and Sen Lakes has been used as a waste dump area for decades, and it is therefore possible that the Sen Lakes received direct dumping of herbicide, and/or empty herbicide barrels during the 1960s. Drainage from Sen Lake flows north into the Da Nang City storm sewer system.

Table 1.1 Da Nang dioxin data analyses completed between 1997 and 2009.

Agency	Year	Number of Samples	Sample Type	Analytical Technique	Laboratory
1) Ministry of National Defense	1997-98	~ 330	Soil & Biological	GCMS (low resolution)	Viet Nam (some in Russia and Japan)
2) Ministry of National Defense & Medical University	2000-05	200	Biological	GCMS (low resolution)	Viet Nam (some in Japan)
3) Viet Nam Academy of Science and Technology, Environment Protection Agency, Ministry of National Defense, and US EPA	2005	109/179	Soil & Biological	Calux	USA
4) Hatfield/10-80	2005	21	Soil & Sediment	GCMS (high resolution)	Canada (AXYS)
5) Hatfield/ Office 33	2006	147	Soil, Sediment, Fish, Vegetation, Blood and Breast Milk	GCMS (high resolution)	Canada (AXYS)
6) Hatfield/ Office 33	2009	127 environ/ 115 human	Soil, Sediment, Fish/Blood and Breast Milk	GCMS (high resolution)	Canada (AXYS)

For potential health risks to be present, a contaminated site must exhibit at least three conditions or risk factors:

- Chemical Hazard – one or more chemical contaminants at concentrations capable of causing human or ecological health impacts;
- Receptors – humans, animals or plants at the site; and
- Exposure Pathway – a way for chemical contaminants to reach the receptors.

Given all scientific evidence from previous studies concerning Da Nang Airport (Hatfield/Office 33 2007), it is evident that all of these potential risk factors co-exist as a result of historic handling, storage and disposal activities of Agent Orange and other herbicides. Although various contaminants have been identified at the site, the focus is on polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) as the chemical hazards of interest.

Drainage patterns from the Da Nang Airport into the city of Da Nang were determined based on field investigations by Hatfield and BEM Systems Inc., and also from a 1968 Airport drainage map of Da Nang obtained by Hatfield from the US Archives in Washington, DC (Hatfield/Office 33 2007). The Phu Loc River is found to the north and east of the Airport, and is regarded as one of the main recipients of drainage from Da Nang Airport. Low dioxin levels were found in the Phu Loc River by Hatfield/ Office 33 (2007). Drainage in the central and southern areas of the Airport flows south towards the Han River, a separate watershed.

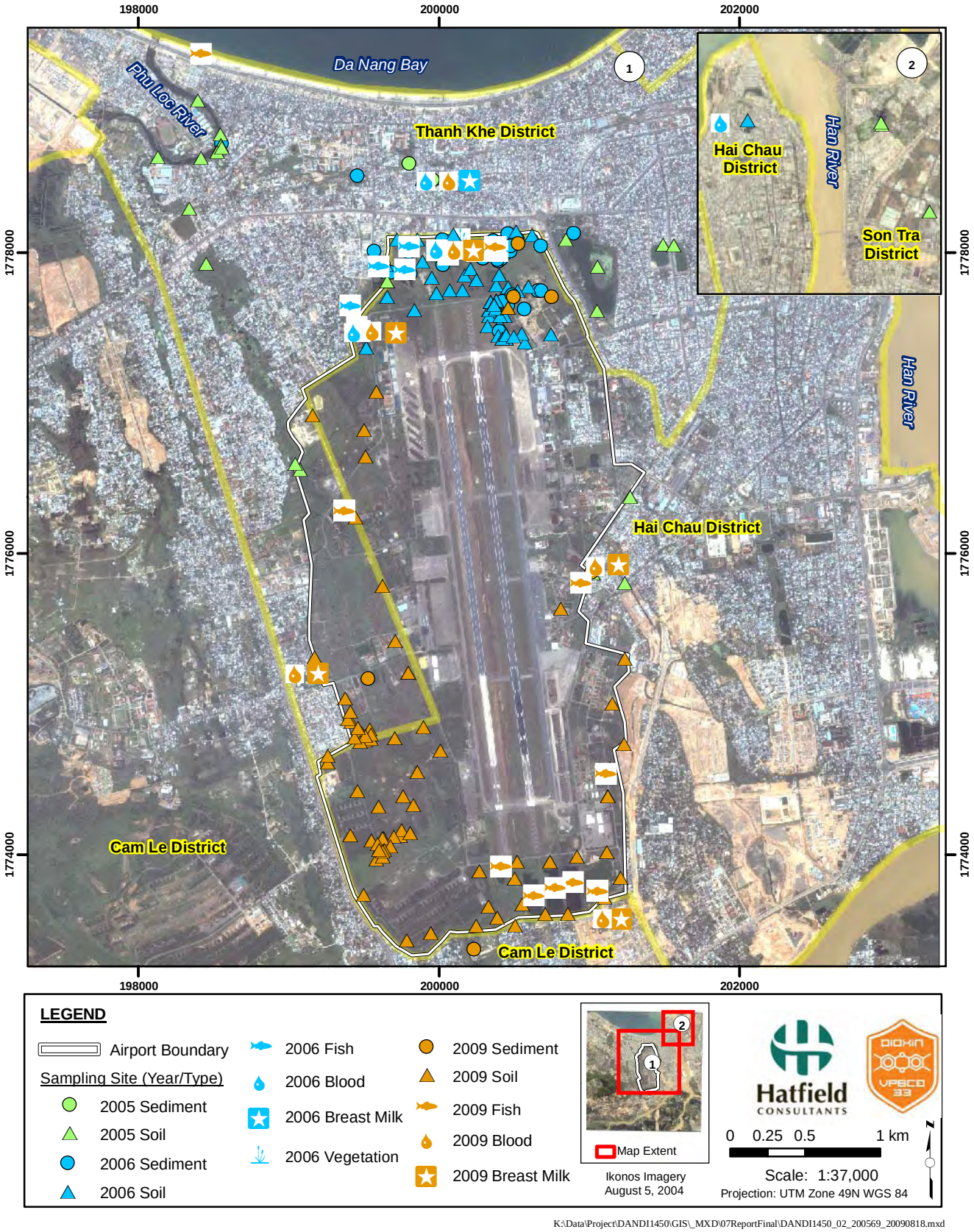
A summary of dioxin/furan analyses completed in Da Nang City and on the Airport by Hatfield/10-80 (2006) and Hatfield/ Office 33 (2007), and in the current study, is presented in Table 1.1; sampling locations are presented in Figure 1.1. In the 2005 (Hatfield/10-80 2006) study, elevated levels of dioxin were recorded in soil and sediments in Thanh Khe District, particularly near "Site 18" (227 ppt TCDD); over 80% of the TCDD in the TEQ was TCDD, suggesting Agent Orange as the primary source of dioxin contamination at this site (Table 1.2; Figure 1.2).

In the 2006 study (Hatfield/Office 33 2007), elevated levels of dioxin were recorded at the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake, all of which are located on Da Nang Airport. The maximum soil TEQ concentration recorded was 365,000 ppt, 365 times Vietnamese and international recommended guidelines, from samples collected from the former Mixing and Loading Area (Table 1.3; Figure 1.3). Fish collected and analyzed in 2006 are presented on Table 1.4; the highest dioxin concentration (3,000 pg/g wet weight) was found in fat tissues from a Sen Lake Tilapia. Human blood and breast milk samples from 2006 are summarized on Table 1.5; elevated TCDD TEQ levels (maximum 1,220 ppt) were recorded in people who consumed fish from Sen Lake. Discussion of these levels in comparison with 2009 samples is presented in detail in Section 3.

The current study included further investigation of soil, sediment and fish tissue dioxin levels in areas previously not sampled on the Da Nang Airport and in Da Nang city adjacent to the Airport, to assess possible impacts to local residents from dioxin exposure. The 2009 study focused on delineation of dioxin contamination near suspected Pacer Ivy sites (PISA and PIRA), and on collection of additional human tissue dioxin data from communities surrounding Da Nang Airport.

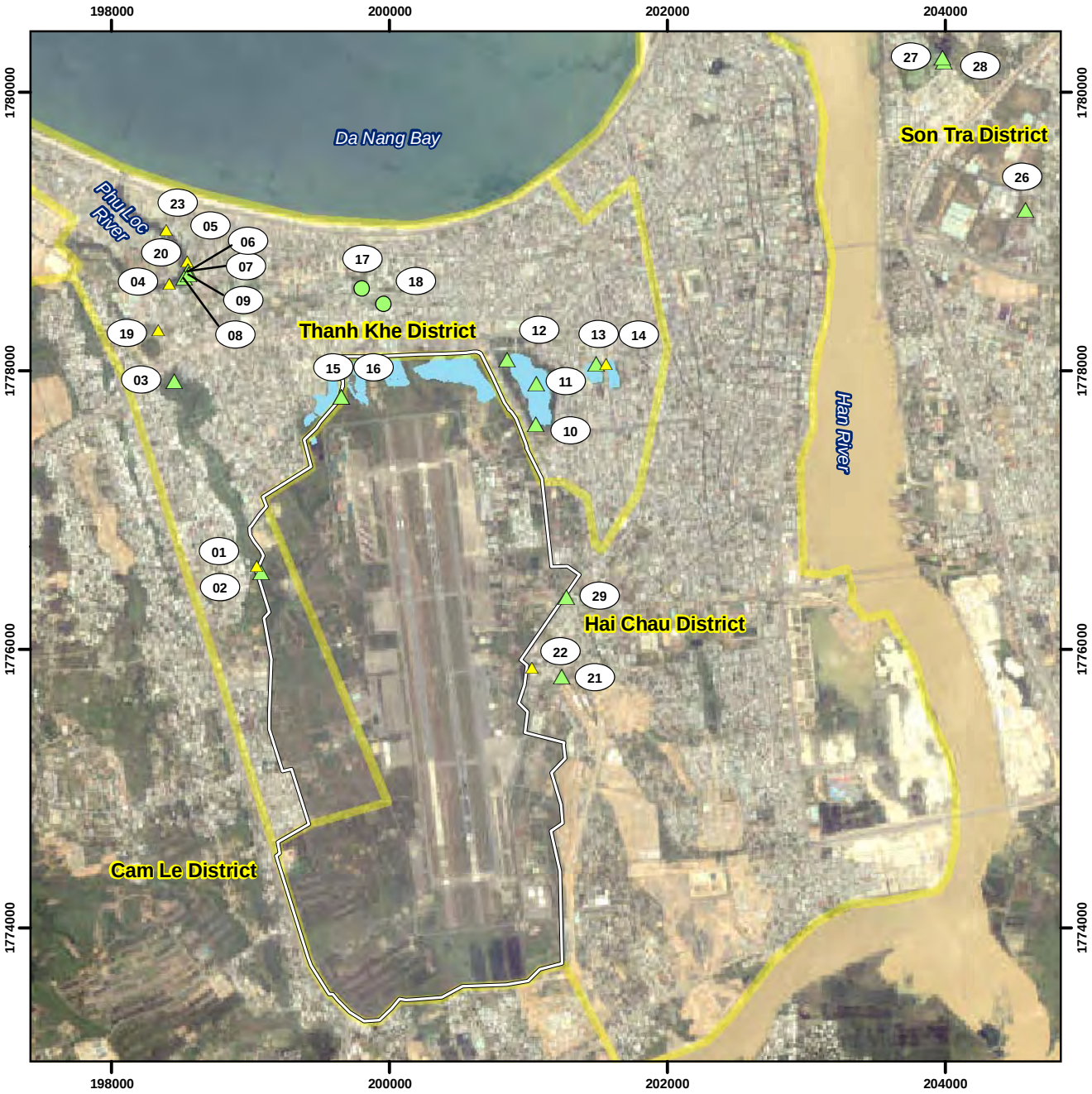
Figure 1.1 identifies the location of all sampling sites for fish, soil and sediment conducted in 2005, 2006 and 2009 in and around Da Nang Airport by Hatfield/10-80 and Office 33.

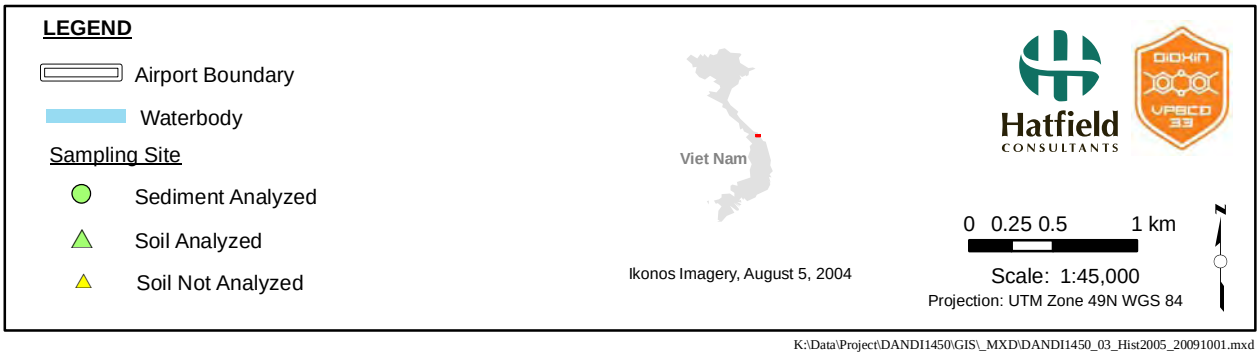
Figure 1.1 Overview of all dioxin sampling locations in Da Nang, Viet Nam by Hatfield/ 10-80 Division/ Office 33 in 2005, 2006, and 2009.



K:\Data\Project\DANDI1450\GIS_MXD\07ReportFinal\DANDI1450_02_200569_20090818.mxd

Figure 1.2 Historical sampling locations, outside the Da Nang Airport, Viet Nam, 2005 (Hatfield/ 10-80 2006).





K:\Data\Project\DANDI1450\GIS_MXD\DANDI1450_03_Hist2005_20091001.mxd

Figure 1.3 Historical sampling locations, Da Nang Airport, Viet Nam, December 2006 (Hatfield/Office 33 2007).

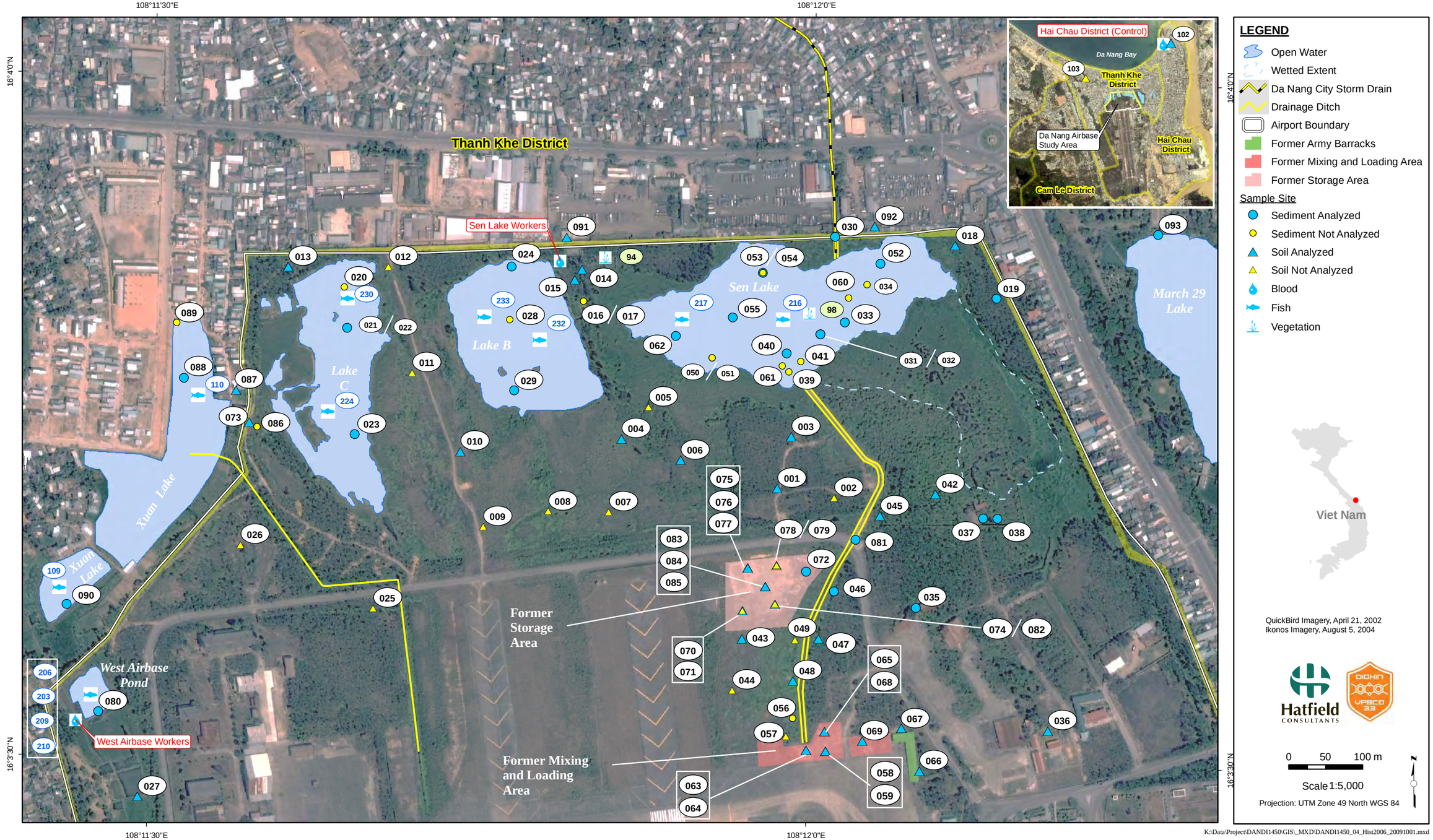


Table 1.2 2,3,7,8-TCDD (pg/g dry weight), TEQ (pg/g), and percent TCDD of the TEQ concentration for soil and sediment samples from Da Nang (outside the Airport), Viet Nam, 2005 (Hatfield/10-80 2006).

Sample ID	Sample Type	Location	TCDD	TEQ	% TCDD of TEQ
05VN018	Soil	Cultivated land	227	269	84
05VN022	Sediment	Ditch	130	191	68
05VN001	Sediment	Ditch	27	34.3	79
05VN012	Sediment	March 29 Lake (Ho 29.3)	22.6	154	15
05VN015	Sediment	Xuan Lake (Ho Xuan Ha)	11.7	29.9	39
05VN003	Sediment	Ditch	11	34	32
05VN021	Sediment	Ditch	10.8	16.4	66
05VN017	Soil	Cultivated land	9.06	24.7	37
05VN009	Sediment	Ditch	6.84	13.7	50
05VN007	Sediment	Phu Loc River	6.46	11.9	54
05VN029	Sediment	Ditch	5.14	10.5	49
05VN016	Sediment	Xuan Lake (Ho Xuan Ha)	3.23	32.9	10
05VN013	Sediment	Thac Gian Lake	2.28	33.6	7
05VN026	Sediment	An Don ditch	1.64	20.2	8
05VN011	Sediment	March 29 Lake (Ho 29.3)	1.61	8.69	19
05VN011 (Duplicate)	Sediment	March 29 Lake (Ho 29.3)	1.46	8.47	17
05VN010	Sediment	March 29 Lake (Ho 29.3)	0.415	2.34	18
05VN028	Sediment	An Don pond	0.262	1.42	18
05VN008	Sediment	Phu Loc River	0.175	0.449	39
05VN027	Sediment	An Don ditch	0.07	0.44	16
05VN027 (Duplicate)	Sediment	An Don ditch	0.07	0.42	17

Table 1.3 2,3,7,8-TCDD (pg/g dry weight), TEQ (pg/g), and percent TCDD of the TEQ concentration for soil and sediment samples from Da Nang Airport, Viet Nam, 2006 (Hatfield/ Office 33 2007).

Sample ID	Location	Media	Depth	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
Former Mixing and Loading Area (MLA)						
06VN058	Site 2 - Centre	Soil	0-10 cm	361000	365000	99
06VN059	Site 2 - Centre	Soil	10-30 cm	330000	333000	99
06VN063	Site 1 - West	Soil	0-10 cm	1190	1200	99
06VN064	Site 1 - West	Soil	10-30 cm	8730	8770	100
06VN065	Site 3 - NE	Soil	0-10 cm	27700	27900	99
06VN068	Site 3 - NE	Soil	10-30 cm	36800	37000	99
06VN066	Perimeter - S of Former Barracks	Soil	0-10 cm	858	899	95
06VN067	Perimeter - N of Former Barracks	Soil	0-10 cm	4820	4980	97
06VN069	Perimeter - W of Former Barracks	Soil	0-10 cm	165000	167000	99
Former Storage Area (SA)						
06VN075	Site 1 - NW	Soil	0-10 cm	5100	5200	98
06VN076	Site 1 - NW	Soil	10-30 cm	773	787	98
06VN077	Site 1 - NW	Soil	30-50 cm	9.12	24.5	37
06VN078	Site 2 - NE	Soil	0-10 cm	106000	106000	100
06VN083	Site 3 - Centre	Soil	0-10 cm	61500	62200	99
06VN084	Site 3 - Centre	Soil	10-30 cm	336	347	97
06VN085	Site 3 - Centre	Soil	30-50 cm	136	143	95
06VN070	Site 4 - SW	Soil	0-10 cm	3350	3520	95
06VN074	Site 5 - SE	Soil	0-10 cm	63200	64600	98
Between Storage Area and Mixing and Loading Area						
06VN043	S of SA / W of Ditch	Soil	0-10 cm	136	170	80
06VN047	SE of SA / E of Ditch	Soil	0-10 cm	6080	6520	93
06VN048	N of MLA / W of Ditch	Soil	0-10 cm	3840	4150	93
Drainage System						
06VN072	Water Treatment Basin	Sediment	grab	25700	27700	93
06VN081	Ditch d/s of Storage Area	Sediment	grab	8390	8580	98
Airbase Perimeter						
06VN036	Military Garden	Soil	0-10 cm	16.9	31	55
06VN035	Old Munitions Dump	Soil	0-10 cm	103	149	69
06VN046	5m E of Ditch, Near Main Road	Soil	0-10 cm	5400	5690	95
06VN042	N of Airline Staff Residence	Soil	0-10 cm	1700	1830	93
06VN045	NE of SA / E of Ditch	Soil	0-10 cm	598	674	89
06VN037	S of Airlines Staff Residence	Soil	0-10 cm	165	270	61
06VN038	S of Airlines Staff Res. (Dup)	Soil	0-10 cm	150	253	59
06VN019	NE Corner Airbase (2)	Soil	0-10 cm	7.91	17.1	46
06VN018	NE Corner Airbase (1)	Soil	0-10 cm	43.6	72.9	60
06VN001	Btwn SA and Sen Lake (1)	Soil	0-10 cm	9.66	16.4	59
06VN003	Btwn SA and Sen Lake (2)	Soil	0-10 cm	6.44	12.2	53
06VN004	Btwn SA and Lake B (1)	Soil	0-10 cm	219	232	94
06VN006	Btwn SA and Lake B (2)	Soil	0-10 cm	14	26	54
06VN010	Btwn Lakes B & C	Soil	0-10 cm	25.4	49.2	52
06VN014	Sen Lake Garden	Soil	0-10 cm	12.5	18	69
06VN015	Sen Lake Residence	Soil	0-10 cm	1.72	4.34	40
06VN013	NW Corner Airbase	Soil	0-10 cm	53.1	68.2	78
06VN073	Footpath W Airbase	Soil	0-10 cm	0.212	0.643	33
06VN027	Garden SW Airbase	Soil	0-10 cm	2.29	15	15

Table 1.3 (Cont'd.)

Sample ID	Location	Media	Depth	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
Da Nang City						
06VN093	March 29 Lake	Sediment	Grab	4.57	26.9	17
06VN091	N of Airbase / Dien Bien Phu Street	Soil	0-10 cm	1.26	5.91	21
06VN092	NE of Airbase / Dien Bien Phu Street	Soil	0-10 cm	0.649	7.36	9
06VN087	Garden near Xuan Lake	Sediment	Grab	2.58	6.66	39
06VN088	Xuan Lake (N)	Sediment	Grab	8.21	17.8	46
06VN090	Xuan Lake (S)	Sediment	Grab	2.63	16.7	16
06VN099	Thanh Khe Garden (1)	Soil	0-10 cm	26	36.1	72
06VN100	Thanh Khe Garden (2)	Soil	0-10 cm	1.28	3.94	32
06VN101	Thanh Khe Garden (3)	Soil	0-10 cm	0.616	5.34	12
06VN102	Hai Chau Garden	Soil	0-10 cm	0.644	3.14	21
Sen Lake						
06VN030	Outlet to Da Nang City	Sediment	Grab	253	292	87
06VN030**	Outlet to Da Nang City	Sediment	Grab	232	244	95
06VN031	Centre	Sediment	Grab	191	198	96
06VN031**	Centre	Sediment	Grab	184	192	96
06VN032	Centre	Sediment	Grab	2750	2980	92
06VN032**	Centre	Sediment	Grab	1140	1230	93
06VN033	SE	Sediment	Grab	61.4	68.6	90
06VN033**	SE	Sediment	Grab	63.6	69.2	92
06VN052	NE	Sediment	Grab	5440	5950	91
06VN053	NW	Sediment	Grab	6240	6820	91
06VN055	Centre-West	Sediment	Grab	3190	3520	91
06VN040	Inlet from Ditch	Sediment	Grab	1160	1290	90
Core Sample from Sen Lake						
06VN062-1	West	Sediment	0-2 cm	3730	4050	92
06VN062-2	West	Sediment	2-4 cm	674	750	90
06VN062-3	West	Sediment	4-6 cm	22.3	39.4	57
06VN062-4	West	Sediment	6-8 cm	6.15	18.9	33
06VN062-5	West	Sediment	8-10 cm	6.45	19.8	33
06VN062-6	West	Sediment	10-14 cm	4.4	20.2	22
06VN062-11	West	Sediment	30-32 cm	5.91	23.1	26
Lake B						
06VN024	North	Sediment	Grab	30.4	39.4	77
06VN029	South	Sediment	Grab	57.1	70.5	81
Lake C						
06VN021	North	Sediment	Grab	11.7	20.1	58
06VN022	North (Dup)	Sediment	Grab	8.89	16	56
06VN023	South	Sediment	Grab	4.54	7.99	57
West Airbase Pond						
06VN080	Centre	Sediment	Grab	3.35	7.14	47

** Sample analyses were repeated; these data are not illustrated on figure in Hatfield/Office 33 (2007).

Table 1.4 2,3,7,8-TCDD (pg/g wet weight), TEQ (pg/g), and percent TCDD of the TEQ concentration for fish samples from Da Nang Airport, Viet Nam, 2006 (Hatfield/Office 33 2007).

Sample ID	Location	Common Name	Latin Name	Sample Type	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	as % of TEQ (2005)
Fish							
06VN216	Sen Lake	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Fat	3000	3120	96
06VN217	Sen Lake	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Muscle	33.2	34.5	96
06VN232	Lake B	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Fat	68.4	72.6	94
06VN233	Lake B	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Muscle	0.898	0.967	93
06VN224	Lake C	Carp	*Osteocheilus melanopleurus*	Fish Fat	6.61	8.22	80
06VN230	Lake C	Carp	*Osteocheilus melanopleurus*	Fish Muscle	0.163	0.22	74
06VN206	Pond W Airbase	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Fat	45.8	56.1	82
06VN203	Pond W Airbase	Nile Tilapia	*Oreochromis niloticus niloticus*	Fish Muscle	1.14	1.38	83
06VN209	Pond W Airbase	Catfish (Whitespotted clarias)	*Clarias fuscus*	Fish Fat	33.6	53	63
06VN210	Pond W Airbase	Catfish (Whitespotted clarias)	*Clarias fuscus*	Fish Muscle	0.943	1.39	68
06VN110	Xuan Lake	Snakehead Murrell	*Channa striata*	Fish Liver	3.21	6.37	50
06VN109	Xuan Lake	Snakehead Murrell	*Channa striata*	Fish Muscle	0.171	0.223	77
Vegetation							
06VN094	Sen Lake Garden	Sweet Potato	*Ipomoea*	Sweet Potato Root	NDR 0.280	0.332	42
06VN098	Sen Lake	Lotus	*Lotus*	Lotus Stem	6.91	7.25	95

Table 1.5 Summary of concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood and breast milk (pg/g [ppt], lipid basis), Da Nang, Viet Nam, December 2006.

Sample ID	Sex	Age	% Lipid	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
Sen Lake Workers						
06VNB001	F	72	0.28	567	662	86
06VNB002	M	42	0.28	1150	1220	94
06VNB003	F	44	0.37	430	501	86
06VNB004	F	17	0.23	294	331	89
06VNB005	M	54	0.22	366	427	86
06VNB006	M	28	0.28	9.42	18.4	51
06VNB007	F	52	0.31	6.36	52.2	12
06VNB008	M	20	0.28	62.1	91.1	68
06VNB009	M	24	0.21	19.7	40.9	48
06VNB010	M	22	0.15	343	444	77
06VNB011	M	23	0.23	70.8	107	66
West Airbase Workers						
06VNB051[1]	M	39	0.24	357	491	73
06VNB052	M	29	0.26	33.4	62.9	53
06VNB053	F	23	0.26	14	39.3	36
06VNB058	F	35	0.29	25.5	57.5	44
06VNB060	F	34	0.24	36	79.3	45
06VNB050	M	39	0.45	20.3	34.7	59
06VNB054	M	27	0.26	41.8	78	54
06VNB055	F	24	0.26	41.1	93.6	44
06VNB056	F	52	0.33	71.4	165	43
06VNB057	F	35	0.31	6.71	15.9	42
06VNB059	M	42	0.19	77.7	142	55
Chinh Gian Ward, Thanh Khe District						
06VNB012	M	58	0.23	43.7	122	36
06VNB013	F	57	0.18	68.1	152	45
06VNB014	M	57	0.19	8.24	37.6	22
06VNB015	M	26	0.14	23.6	79.3	30
06VNB016	M	61	0.22	5.14	40.4	13
06VNB031	F	54	0.2	12.5	79.1	16
06VNB034	M	18	0.17	< 5.89	9.31	-
06VNB035	M	32	0.21	6.68	44.6	15
06VNB037	M	30	0.28	40	73.4	54
06VNB041	M	52	0.2	16.6	96.8	17
06VNB042	F	43	0.31	6.99	44.9	16
06VNB043	F	57	0.29	15.1	73.4	21
06VNB044	M	33	0.27	7.13	56.1	13
06VNB045	F	21	0.19	5.46	44.2	12
06VNB046	F	35	0.17	6.6	60.4	11
06VNB048	F	23	0.26	4.8	40.7	12

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for “Total TEQ” calculations, NDR was treated as ND.

[1] TCDD and TEQ values for 06VNB051 have been corrected as of August 2009.

Table 1.5 (Cont'd.)

Sample ID	Sex	Age	% Lipid	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
Thuan Phuoc Ward, Hai Chau District						
06VNB017	M	47	0.19	< 8.54	36.4	-
06VNB018	F	42	0.43	3.93	39.9	10
06VNB019	M	36	0.22	5.92	33	18
06VNB020	F	36	0.2	3.5	40.4	9
06VNB021	M	54	0.14	< 6.37	33	-
06VNB022	F	55	0.26	6.15	46.3	13
06VNB023	M	57	0.28	4.97	60.9	8
06VNB024	M	22	0.16	3.76	48.1	8
06VNB026	F	49	0.37	4.36	32.3	13
06VNB027	M	58	0.27	< 7.38	28.7	-
06VNB028	F	54	0.27	4.89	61.1	8
06VNB049	F	20	0.26	2.77	32.6	8
Non-Random, Chinh Gian Ward, Thanh Khe District						
06VNB036	F	51	0.25	20.8	96.2	22
06VNB038	F	19	0.27	8.4	46.6	18
06VNB039	M	28	0.23	15.3	63.4	24
06VNB040	M	52	0.25	42.8	115	37
Non-Random, Thuon Phuoc Ward, Hai Chau District						
06VNB061	F	44	0.35	44.2	77.7	57
Breast Milk, Chinh Gian Ward, Thanh Khe District						
06VN201M	*F*	*30*	*3.24*	*6.76*	*42.4*	*16*

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for "Total TEQ" calculations, NDR was treated as ND.

1.3 DIOXIN GUIDELINES TO LIMIT HUMAN EXPOSURE

Polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), biphenyls (PCBs) and related compounds, collectively known as dioxins, have never been intentionally manufactured but are instead an unintentional byproduct of combustion processes, metallurgical processes, chemicals manufacturing and pulp and paper processing (AEA Technology plc, 1999). There are 210 congeners of PCDD/Fs, of which only 17 have chlorine substitutions in at least the 2,3,7,8 positions making them toxic, stable and persistent in the environment. Because of the large number of congeners, each individual congener is assigned a toxic equivalency factor (TEF) that relates their toxicity to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). 2,3,7,8-TCDD is the most toxic of all of the congeners and is classified as a carcinogen by the WHO (Abad *et al.* 2000; Srogi 2008). The concentration of each individual congener in its mixture is multiplied by its TEF to give a commonly used WHO endorsed TCDD Toxic Equivalent (WHO-TEQ) (Srogi 2008). Before the WHO-TEF and WHO-TEQ were established, the older International Toxic Equivalent (I-TEQ) was used. Generally, the I-TEQ gives a value about 10% higher than the WHO-TEQ. In this report, 2005 WHO-TEQ is the most commonly referenced TEQ; however, there are instances where I-TEQ is referred to in past reports.

Dioxins have a high affinity for organic materials and low water solubility, and exhibit lipophilic properties (a tendency to combine with lipids). As Persistent Organic Pollutants (POPs), dioxins are considered to be relatively non-mobile; however, they will migrate from their source of origin through the air, water and soil over time. Throughout history, the intentional and non-intentional introduction of PCDD/Fs into our environment has resulted in PCDD/Fs being present in most areas of the world. In Japan, pesticide use accounted for 460 kg TEQ released into the environment between 1950 and 1998 (Masunaga *et al.* 2001; Seike *et al.* 2003; Weber and Masunaga 2005; Weber *et al.* 2008). An estimated 366 to 600 kg TEQ was released over Viet Nam in the form of herbicides during the US-Viet Nam war (Allen 2004; Stellman *et al.* 2003; Young 2006, Young *et al.* 2008; Weber *et al.* 2008). In Hamburg, 378 kg TEQ was released from a single factory in Hamburg producing hexachlorocyclohexane (HCH) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (University of Bayreuth 1995; Weber *et al.* 2008). A study of 55 countries set contemporary releases of dioxins at 20 kg TEQ/year (Fiedler 2007; Weber *et al.* 2008).

To limit the presence and spread of dioxins, regulatory agencies responsible for human health protection have employed various protocols to address the issue of dioxin contamination. One method of protection is the establishment of guidelines for the protection of the environment and human health in various media such as soils, sediments and food.

1.3.1 PCDD/F in Soils

In EU Member Countries, typical PCDD/F soil concentrations range between <1 and 100 ng I-TEQ/kg of dry matter with a maximum recorded concentration of 100,000 pg I-TEQ/g (AEA Technology, 1999). In the United States, the Agency for Toxic Substance and Disease Registry ATSDR (ATSDR, 1998) reports that TCDD is not generally detected in rural soils; however, in industrialized regions of the US, TCDD levels typically range from 1.0 pg/g to 10 pg/g.

The International Agency for Research on Cancer (IARC 1997) provided a detailed summary of 42 studies in 18 industrialized countries, presenting over 150 TCDD data points. TCDD concentrations presented in this overview ranged from non-detected (ND) to 9.6 x 10^9 pg/g; the highest concentrations recorded in the IARC (1997) summary were found in highly contaminated soils from Missouri (a horse arena and farm soil, Kimbrough *et al.* 1997 and Viswanthan *et al.* 1995, both *cited in* IARC 1997). Other very high TCDD levels (i.e., >1,000 pg/g) were recorded in soils collected from heavily industrialized sites; these sites included manufacturing plants for tetrachlorophenol, pentachlorophenol, chlorophenolics and herbicides (e.g., 2,4,5-T) and incineration facilities.

In Canada, soils that have been affected by pulp and paper mills exhibited PCDD/F WHO-TEQ levels of 255pg/g. In the province of Quebec, at the site of a warehouse fire, a PCDD/F WHO-TEQ level of 1,124 pg/g was measured in soils (Environment Canada 2004). Paustenbach *et al.* (1992) has indicated that the half-life of dioxins in subsurface soils can extend to 100 years making them a persistent problem long after their initial release.

As shown in Table 1.6, a number of industrialized nations have established TEQ guidelines for soils contaminated with polychlorinated dioxins and polychlorinated furans (PCDD and PCDF), which if exceeded, would designate a site to be a "contaminated site". WHO-TEQ guidelines (and I-TEQ for older guidelines) for dioxin contamination in soil vary with target soil use but are typically in the range of 4 to 40 pg/g TEQ for agricultural use and approximately 1,000 pg/g TEQ for residential/recreational areas. Higher dioxin concentrations (up to 10,000 pg/g TEQ) are tolerated in industrial areas in a number of industrialized nations.

In August 2009, Viet Nam adopted a dioxin threshold of 1,000 pg/g TEQ for soils in “dioxin heavily contaminated sites” (National Standard TCVN 8183:2009). This level provides a base for restricting site access and treating dioxin in sites that are heavily contaminated by dioxin.

Table 1.6 Summary of dioxin (TCDD and TEQ) criteria for soil (dry weight basis).

Country/Jurisdiction	Guideline	Comments
Viet Nam[1]	1,000 pg/g TEQ	Dioxin heavily contaminated sites (soils)
Germany[2,3]	5-40 pg/g TEQ	Agricultural soils – target concentration
	100 pg/g TEQ	Playground soils
	1,000 pg/g TEQ	Residential soils
	10,000pg/g TEQ	Industrial soils
Japan[3]	250 pg/g TEQ	If exceeded, research studies required
	1,000 pg/g TEQ	If exceeded, removal required
British Columbia, Canada[4] (Provincial)	10 pg/g TEQ	Agricultural – human health protection
	350 pg/g TEQ	Residential – human health protection
Alberta, Canada[5] (Provincial)	250 pg/g TEQ	Natural area remediation guideline
	4 pg/g TEQ	Agricultural, residential/parkland, commercial, industrial remediation guideline
Canada (Federal)[6]	4 pg/g TEQ	Agricultural (provisional Soil Quality Guideline) Residential/Parkland (provisional Soil Quality Guideline) Commercial (Soil Quality Guideline) Industrial (provisional Soil Quality Guideline)
Canada (Interim soil quality criterion)[6]	10 pg/g TEQ	Agricultural soils
	1,000 pg/g TEQ	Residential/park land soils
Czech Republic[7]	1 pg/g TEQ	Background
	100 pg/g TEQ	Pollution Limit
	500 pg/g TEQ	Action limit- living area
	1,000 pg/g TEQ	Action limit- recreational area
	10,000 pg/g TEQ	Action limit- industrial
Denmark[7]	<5 pg/g TEQ	Target concentration soil used for agricultural purpose
	>100 pg/g TEQ	Soil exchange on children's playgrounds
	>1,000 pg/g TEQ	Soil exchange in residential areas
	>10,000 pg/g TEQ	Soil exchange independent of the location
USEPA (Federal)[3]	1,000 pg/g TEQ	Residential
*USEPA (Regional)[8]	4.5 pg/g TCDD	Residential soils, if exceeded, risk assessment required
	18.0 pg/g TCDD	Industrial soils, if exceeded, risk assessment required
USEPA Region 5[9]	11 pg/g	PCDD soil guideline level
	38.6pg/g	PCDF soil guideline level
California [10]	50 pg/g TEQ	Residential
	200-1,000 pg/g TEQ	Commercial/ Industrial
	<40 pg/g TEQ	Agricultural
New Zealand Interim Accepted Criteria [7]	10 pg/g TEQ	Agricultural
	1,500 pg/g TEQ	Residential
	18,000 pg/g TEQ	Industrial
	90,000 pg/g TEQ	Industrial – Paved, with a management plan
	21 pg/g TEQ	Maintenance
ATSDR[11]	≤50 pg/g TEQ	Screening level
	>50 - <1,000 pg/g TEQ	Evaluation level
	≥1,000 pg/g TEQ	Action level

Table 1.6 (Cont'd.)

Country/Jurisdiction	Guideline	Comments
Sweden[3]	10 pg/g TEQ	Residential soils
	250 pg/g TEQ	Industrial soils
Netherlands[3]	10 pg/g TEQ	Dairy farming and land with sensitive use
	1,000 pg/g TEQ	Residential and agricultural
Finland[2,3]	2 pg/g TEQ	Protection of humans
	500 pg/g TEQ	Limit for contaminated soils

* In May of 2009 the USEPA released the Regional Screening table to replace the previous RBC table for Region 3, the Region 6 Screening Level table and the Region 9 PRG table. Region 4 also recommends the use of this table for screening in certain projects (USEPA 2009).

[1] Viet Nam National Standard TCVN 8183:2009.

[2] AEA Technology 1999.

[3] NZMOE 2002.

[4] BC- Queen's Printer 2009.

[5] Alberta Environment 1994, 2009.

[6] CCME 2001.

[7] IPEN 2009.

[8] USEPA 2009.

[9] USEPA 2003.

[10] HHRA 2009.

[11] ATSDR 1997, 2006.

These guidelines are only one method of protecting the environment and human health from dioxin contamination. The ATSDR (1997) guideline recommends that an area with a soil concentration of >50 pg/g to <1,000 pg/g T-TEQ should be evaluated further based on the following criteria:

- Bioavailability;
- Ingestion rates;
- Pathway analyses;
- Soil cover;
- Climate;
- Other contaminants;
- Community concerns;
- Demographics; and
- Background exposures.

ATSDR (1997) also recommends that if soil levels are ≥1000 pg/g T-TEQ, public health actions should be considered, such as:

- Surveillance;
- Research;
- Health studies;

- Community;
- Education, and
- Exposure investigations.

Essentially, health assessors should obtain a sufficiently detailed database to enable a judgment regarding assessment of the site as a public health hazard, thereby facilitating implementation of public health recommendations to prevent human exposure, which includes clean-up of the contaminated site.

1.3.2 PCDD/F in Sediments

Dioxins are characterized by their tendency to be strongly absorbed onto the surface of particulate matter and for their low water solubility (Srogi 2008). In aquatic systems, PCDD/Fs tend to accumulate in suspended sediments, the organic-rich fraction of the bed and with the lipid-rich tissues of aquatic organisms (CCME 2001). Sediments are soils found in freshwater and marine environments and can act as sinks and secondary sources for dioxins and other POPs (Weber *et al.* 2008). Historically deposited POPs can become buried in sediments making them not bioavailable. Dredging, floods and construction activities can expose these contaminated sediments, releasing them into the food chain. In a study by Mai *et al*. (2007), sediment samples were taken from Bien Hung Lake in Bien Hoa at different layers. It was found that the highest concentrations of PCDD/F contamination were within the first 30 cm where organic debris had settled, facilitating dioxin absorption. This observation was also confirmed in a Hatfield study from a core sample from Sen Lake (Hatfield/ Office 33 2007).

In Canada, sediment tested from sites upstream of pulp mills exhibited non-detectable levels of PCDD/Fs, while sites below mills exhibited levels to 158 pg/g TEQ (dry weight) (Environment Canada 2009). In EU Member countries, sediment concentrations typically ranged from <1 to 200 pg /g I-TEQ with a maximum concentration of 80,000 pg/g I-TEQ at contaminated sites (AEA Technology 1999).

In August 2009, Viet Nam adopted a dioxin threshold of 150 pg/g TEQ for sediments in "dioxin heavily contaminated sites" (National Standard TCVN 8183:2009). This level provides a base for restricting site access and treating dioxin in sites that are heavily contaminated by dioxin.

Table 1.7 outlines the proposed dioxin guidelines in sediments designed for the protection of human health and ecological receptors in various industrialized countries. The guideline used in this report is 150 pg/g TEQ.

Table 1.7 Proposed dioxin guidelines (TCDD TEQ) in sediments (dry weight basis).

Country/Jurisdiction	Guideline	Comments
Viet Nam[1]	150 pg/g TEQ	Dioxin heavily contaminated sites (sediments)
USEPA, Region 10[2]	4 pg/g TEQ	Protection of human and ecological receptors
USEPA, Region 3[3]	0.85 pg/g TEQ	Freshwater Sediment Screening Benchmarks
USEPA, Region 5[4]	1.2 pg/g TEQ	Sediment ecological screening levels
New York State Dept. of Environmental Conservation[2]	10-100 pg/g TEQ	Protection of human and ecological receptors
Wisconsin Dept. of Natural Resources[2]	1 pg/g TEQ	Protection of human receptors
Int. Joint Comm., Great Lakes Science Advisory Board[2]	10 pg/g TEQ	Protection of human and ecological receptors
Canada[5]	21.5 pg/g TEQ (PEL) 0.85 pg/g TEQ (ISQG)	Provisional maximum expressed on a toxic equivalency basis using toxic equivalent factors for fish
Environment Canada, Pacific Yukon Region[2]	10 pg/g TEQ	Protection of ecological receptors
British Columbia, Canada[6]	130 pg/g TEQ 260 pg/g TEQ	Criteria at sensitive sites Criteria at typical sites
Germany – Hamburg Dept. of Environment[2]	5-10 pg/g TEQ	Protection of human receptors
Netherlands[2]	100 pg/g TEQ	Protection of human receptors (threshold for remediation)

[1] Viet Nam National Standard TCVN 8183:2009.

[2] AEA Technology 1999.

[3] USEPA Region III BTAG Freshwater Sediment Screening Benchmarks. 8/2006.

[4] USEPA 2003.

[5] CCME 2001. PEL= Probable Effect Level; ISQG= Interim Sediment Quality Guidelines.

[6] MacDonald 2003.

1.3.3 PCDD/F in Food Sources and Tolerable Daily Intakes

Because of their persistent nature, PCDD/Fs tend to bioaccumulate and are found in the tissues of high trophic level organisms and humans (Michell 1997; Schecter *et al.* 2006; Park *et al*. 2009). Food consumption contributes to more than 90% of human exposure to dioxins in the general population (AEA 1999; Srogi 2008). A dietary exposure assessment for EU Member States revealed that the average total human exposure was up to 210 pg I-TEQ/day in Spain. This translates to an average of 3.0 pg I-TEQ/kg body weight/day assuming an average body weight of 70 kg. Because this amount of PCDD/Fs and dioxin-like PCBs is only assumed to contribute about 50% of the total dietary TEQ, many individuals are probably exceeding the WHO recommended daily value (Tolerable Daily Intake of 1 to 4 pg TEQ/kg body weight/day).

Background concentrations for foodstuffs in the EU revealed that fruits and vegetables generally have the lowest concentrations of dioxins (I-TEQ of 0.01 to 0.2 pg /g fresh weight) while fish fat has the highest concentration (I-TEQ of 2.4 to 214.3 pg/g wet weight). A study in Finland of 228 food items collected from a market is an example of where fish had the highest dioxin and PCB concentrations. The contribution of fish to the intake of PCDD/F and PCBs to the general population in Finland was estimated to be between 72 and 94% (Kiviranta *et al*. 2004; Srogi 2008). In Western Canada, PCDD/F levels in the fat-rich hepatopancreas (digestive gland) of Dungeness crab are good indicators of contamination. Because of their sedentary nature and preference for sandy substrates, crabs are susceptible to contaminant build-up and bioconcentrate contaminants at a higher level than finfish and many other shellfish (Environment Canada 2009). In 2007, the Canadian closure threshold for the crab fishery was reduced from 30 pg/g TEQ to 22.5 pg TEQ/g wet weight in crab hepatopancreas.

Table 1.8 Maximum Allowable PCDD/F Concentration in Fish.

Country/ Jurisdiction	Maximum allowable concentration – wet weight (pg/g)	Reference
EU	4 pg/g TEQ	Bellona 2009
Canada	20 pg/g TEQ in fish (edible portions) 22.5 pg/g TEQ in crab hepatopancreas	Health Canada 1990 Environment Canada 2007
Ontario, Canada	2.7 pg/g TEQ – consumption restriction	Queen's Printer Ontario 2009
	21.6 pg/g TEQ – total restriction	Queen's Printer Ontario 2009
US FDA	50 pg/g TEQ	The Food and Drug Administration (FDA) (ATSDR 2008)
WHO (JECFA)	5 pg/g TEQ	Government of Canada- website accessed 2009

Tolerable daily intake (TDI) values and minimal risk levels (MRL) have been recommended to ensure that human populations are not exposed to dioxin levels that could result in adverse health effects (AEA 1999; Smith and Lopipero 2001). In 1998, the WHO European Centre for Environment and Health and the International Programme on Chemical Safety conducted a detailed assessment of health risks associated with dioxin-like compounds. Based on their assessment, a TDI of 1 to 4 pg TEQ/kg body weight/day was recommended as a safe limit. In 2007, the Canadian TDI for crab hepatopancreas was revised to 2.33 pg TEQ/kg body weight.

Table 1.9 International Tolerable Daily Intake PCDD/F Exposure Guidelines.

COUNTRY / AGENCY	YEAR	GUIDELINE (pg-TEQ/kg-bw/day)	DERIVATION	REFERENCE
USEPA	2003	*RfD = 0.001	Range of effects from biochemical to adverse	USEPA 2003
European Commission	2001	TDI = 2 (day)	Extrapolated from a 14 pg-TEQ/kg-bw/week. The Tolerable weekly intake was derived using the lowest-observed-adverse-effect levels from a study showing developmental effects in male rat offspring following repeated subcutaneous administration of TCDD; applied uncertainty factor of 9.6	European Commission 2001
WHO	1998	TDI = 1-4	Human daily intakes corresponding with body burdens similar to those associated with reproductive and developmental toxicity in animals estimated in the range of 14-37 pg/kg-bw/day. A composite uncertainty factor of 10 was recommended to achieve the TDI.	van Leeuwen *et al.* 2000
JECFA	2001	TDI = 2.3	Based on developmental and reproductive effects in rodents and monkeys (4 studies), and endometriosis in monkeys; applied uncertainty factor of 9.6	JECFA 2001
Health Canada	2005	TDI = 2.3	Based on JECFA/WHO TDI	Health Canada 2005
Japan	1999	TDI = 4	Based on WHO TDI	Japan Environmental Health Committee of the Central Environmental Council 1999
United Kingdom	2000	TDI = 2	Based on European Commission TDI	UK Committee on Toxicity 2000
Australia	2002	TDI = 2.3	Based on JECFA/WHO TDI	Australian NHMRC 2002
Nordic countries	2000	TDI = 5		Johansson and Hanberg 2000; IARC 1997; IOM 2003
Netherlands		TDI = 1		IARC 1997; IOM 2003
Sweden		TDI = 5		IARC 1997; IOM 2003
AEA Technology	1999	TDI = 1-4		IOM 2003
Fiedler *et al.*	2000	TDI = 1-4		IOM 2003

* The USEPA has not established a reference dose for dioxin, but predicts that it would be 100-1,000 times lower than current background exposure levels. That theoretical reference dose is represented here as 0.001 pg-TEQ/kg-bw/day.

Uncertainty factors are applied when accounting for inter- and intra-species variations.

Adapted from: ARCC 2009.

The ATSDR has established a minimal risk level for oral exposure as opposed to the tolerable daily intake. The Acute level is 200 pg/kg bw/day, the Intermediate level is 20 pg/kg bw/day and the Chronic level is 1 pg/kg bw/day.

1.3.4 PCDD/F Levels in Human Tissue

Human tissue concentrations of PCDD/Fs are on average higher in industrialized countries (around 15 pg/g TEQ lipid) than in non-industrialized countries (below 10 pg/g TEQ lipid).

Schecter *et al.* (2006) compared human tissue levels and toxic equivalents of dioxins and dibenzofurans from different countries and exposure scenarios; the following is a summary of key findings. In the US, fat tissues from the general population had an average TEQ of 22.8 pg/g with TCDD contributions of 3.6 pg/g TEQ. Pentachlorophenol-exposed people in the US exhibited higher TEQ levels (609 pg/g), mostly comprised of Penta-CDD, Hexa-CDDs and PCDFs. In a pooled sample of blood of people tested in Viet Nam, the TEQ was 13 pg/g (2.2 pg/g TCDD). TEQ from Agent Orange-exposed people in Viet Nam was higher (111 pg/g) with TCDD contributing to the majority of the TEQ (101 pg/g). In Japan, the general population exhibited TEQ levels of 24.6 pg/g in blood with TCDD contributions of 2.6 pg/g TEQ. Incinerator workers in Japan had higher levels, with TEQ averaging 1,467 pg/g and TCDD levels were 6.4 pg/g. PCDFs contributed to the majority of the TEQ (1,365 pg/g). In Austria, men with no or low occupational exposure to 2,3,7,8-TCDD had blood concentrations of <5 to 23 pg/g (IARC 1997). From these and other studies, it is evident that occupational or accidental exposure can result in PCDD/F concentrations in humans above normal or background levels (Domingo *et al.* 2001; Hansson *et al.* 1995, 1997; Iida *et al.* 1999; Papke *et al.* 1992; Schecter *et al.* 1991; Park *et al.* 2009).

The half life of 2,3,7,8-TCDD in human tissue is estimated at 7 to 11 years with wide individual variation (IARC 1997; Srogi 2008). When the source of dioxin is removed from the human exposure pathway, dioxin contamination decreases over time. PCDD/Fs dropped from an average of (lipid-based) 45,800 pg/g to 16,100 pg I-TEQ/kg from 1989 to 1996 according to a summary of blood samples in Germany (IARC 1997). The rate of decrease was slightly higher in rural areas than industrial areas. The dioxin intake of 2 month-old infants breast feeding was 106 pg I-TEQ/kg/day in rural areas and 144 pg I-TEQ/kg/day in industrial areas.

Breastfed babies have a daily dioxin intake 1 to 2 orders of magnitude higher (10 to 20 times higher) than adults (Jodicke *et al.* 1992; McLachlan 1993; Srogi 2008). These levels are generally higher in industrialized areas (10-35 pg I-TEQ/g milk fat) than in developing countries (<10 pg I-TEQ/g milk fat).

The tendency for dioxins to be stored in fatty tissues results in the chemical build-up of PCDD/F in breast tissue and milk during lactation (Jensen 1991; Srogi 2008). Breast feeding is predicted to contribute to a higher body burden of dioxin early in life, but not to contribute to an increased steady-state body

burden when compared to the ingestion of 10 pg/kg bw/day from birth (Srogi 2008). The levels of PCDD/Fs in breast milk are lower when a mother is nursing her second child compared to when nursing the first child (Fürst *et al.* 1989; Kiviranta *et al*. 1998; Srogi 2008).

Studies have shown a significant correlation between smoking and PCDD/F levels. Mothers who smoke actively or even passively have lower PCDD/F levels in their breast milk than mothers who do not smoke (Fürst *et al.* 1992; Srogi 2008). Therefore, age, smoking history, dietary habits and other factors must be considered when drawing conclusions about the influence of smoking on PCDD/F levels in breast milk (Uehara *et al.* 2006). Smoking is a source of carcinogens in its own right and therefore causes alternative health risks.

2.0 MATERIALS AND METHODS

2.1 GENERAL

All sampling activities were undertaken in close cooperation with Office 33 and relevant Vietnamese authorities. Office 33 and other Vietnamese Government agencies, especially the Vietnam-Russia Tropical Centre (VRTC) of the Ministry of Defense (MOD) and local Da Nang authorities, played critical roles in the sampling program, data collection, and in all aspects of project implementation.

MOD supervised all sampling activities on Da Nang Airport, and provided assistance to Hatfield/Office 33 with sampling design, sample collection, demining, and security clearance. Hatfield followed the direction of MOD personnel at all stages of the Airport sampling program, and provided technical training on-site to assist Office 33 and MOD with future dioxin sampling and mitigation programs.

Health and Safety (H&S) of the Hatfield/Office 33/MOD and other personnel working on the project was a critical component of all sampling activities, given the expected high levels of dioxin contamination and potential for unexploded ordnance (UXO) and landmines in the area. A deminer (from MOD) screened all sampling areas for UXO and landmines prior to sample collection. This included pre-screening of sampling sites on land, and in aquatic ecosystems (e.g., Sen Lake).

All sampling equipment was transported from Canada, including sampling jars, soil coring devices used for collecting samples, and the Ekman dredge; the only exception was acetone and hexane and stainless steel pans. All environmental samples collected in Da Nang were split into two: one set of samples was taken to Canada for analysis at AXYS Laboratory, and the other was left in Viet Nam for Office 33/MOD.

All field sampling activities, both on Da Nang Airport and in the general Da Nang City population outside of the Airport, were conducted in January and April 2009. The human health and exposure sampling program and additional environmental sampling at the Pacer Ivy Storage Area and Da Nang Bay were conducted in April 2009.

Soil and sediment sampling on the Da Nang Airport focused on the two main suspected hot spots: i) Pacer Ivy Storage Area (PISA); and ii) Pacer Ivy Re-Drumming Area (PIRA). Fish sampling concentrated on lakes found in the south and central areas of the Airport; as these lakes were unnamed, they are referred to as lakes D, E, F, G, H, I, J, K, L and M. Samples were also collected from lakes sampled during the 2006 study: Sen Lake A and the West Airport fishponds, and from Da Nang Bay.

In general, sampling procedures follow those previously developed and applied by Hatfield for Agent Orange dioxin assessment projects in Viet Nam (Hatfield/10-80 1998, 2000, 2006 and Hatfield/Office 33 2007). Standard operating procedures for all Hatfield field sampling programs were applied.

An IKONOS image at a 1m resolution of Da Nang area, acquired on August 5, 2004, was purchased in November 2008 by Hatfield to support data collection and mapping activities.

2.2 NUMBER AND TYPES OF ANALYSES PERFORMED

Summaries of samples analyzed are presented in Table 2.1 to Table 2.3 inclusive. All samples collected were split into two batches at the time of collection, one for archiving in Viet Nam, and one for transport to Canada for analyses and archiving. A complete list of all samples analyzed by AXYS is presented in Appendix A1.

Sediment, soil, fish, and human blood and breast milk samples were analyzed for dioxins/furans (all samples) using HR-GCMS.

2.3 SAMPLING SITE SELECTION

The location of 2009 sampling sites is presented in Figure 2.1. All samples were analyzed by AXYS in Canada. Analytical methods are provided in Appendix A1.5. Soil and sediment sampling locations were determined during a pre-field desktop review of existing topographic maps and remote sensing information available for the study area, in conjunction with historical sampling results and information provided by the US-DOD and VN-MOD.

Environmental sampling density was highest in the Pacer Ivy Storage Area and Pacer Ivy Re-Drumming Area sites, to provide sufficient data to allow dioxin concentration mapping of surface conditions. Dioxin concentration mapping was based on final environmental sample distribution and post-processing of analytical results, with sampling focus placed in the following order:

- South Area of the Da Nang Airport including Pacer Ivy sites + surrounding residential area;
- North Area (for monitoring purposes);
- West Area + surrounding residential area;
- East Area + surrounding residential area; and
- Da Nang Bay.

The study design included sampling sequentially on the Airport from the suspected hot spots (Pacer Ivy Sites) to the least contaminated sites (soils in the east and west of the Airport), ending with known hot spots in the north of the Airport. Sampling outside the Airport was conducted on the last day of the program.

Figure 2.1 Dioxin sampling locations, Da Nang Airport, Viet Nam, January and April 2009.

LEGEND

- Airport Boundary
- Sampling Site
  - Sediment Analyzed
  - Soil Analyzed
  - Soil Not Analyzed
- Fish
- Blood
- Breast Milk

Ikonos Imagery
August 5, 2004

Hatfield CONSULTANTS

0 0.25 0.5 1 km

Scale: 1:36,000

Projection: UTM Zone 49N WGS 84

K:\Data\Project\DANDI1450\GIS_MXD\07ReportFinal\DANDI1450_05_Overview2009_20091001.mxd

Table 2.1 Soil and sediment samples analyzed for dioxins and furans, Da Nang, Viet Nam, January 2009 and April 2009.

Sample ID	Location	Media	Coordinates		Analysis
			Easting	Northing	PCDD/F
Pacer Ivy Re-Drumming Area					
215A	Pacer Ivy Re-Drumming Area	Soil	199537	1774835	X
216A	Pacer Ivy Re-Drumming Area	Soil	199544	1774772	X
218A	Pacer Ivy Re-Drumming Area	Soil	199546	1774803	X
219A	Pacer Ivy Re-Drumming Area	Soil	199484	1774812	X
221A	Pacer Ivy Re-Drumming Area	Soil	199474	1774751	X
222A	Pacer Ivy Re-Drumming Area	Soil	199507	1774790	X
223A	Pacer Ivy Re-Drumming Area	Soil	199437	1774779	X
224A	Pacer Ivy Re-Drumming Area	Soil	199458	1774843	X
226A	Pacer Ivy Re-Drumming Area	Soil	199392	1774902	X
227A	Pacer Ivy Re-Drumming Area	Soil	199406	1774953	X
228A	Pacer Ivy Re-Drumming Area	Soil	199373	1775041	X
Pacer Ivy Storage Area					
202A	Pacer Ivy Storage Area	Soil	199639	1774076	X
203A	Pacer Ivy Storage Area	Soil	199739	1774125	X
204A	Pacer Ivy Storage Area	Soil	199748	1774167	X
206A	Pacer Ivy Storage Area	Soil	199696	1774121	X
207A	Pacer Ivy Storage Area	Soil	199806	1774145	X
213A	Pacer Ivy Storage Area	Soil	199549	1774095	X
214A	Pacer Ivy Storage Area	Soil	199581	1773969	X
321A*	Pacer Ivy Storage Area	Soil	199599	1774034	X
322A*	Pacer Ivy Storage Area	Soil	199623	1774024	X
323A*	Pacer Ivy Storage Area	Soil	199634	1774032	X
324A*	Pacer Ivy Storage Area	Soil	199673	1774056	X
325A*	Pacer Ivy Storage Area	Soil	199625	1773988	X
326A*	Pacer Ivy Storage Area	Soil	199590	1774073	X
327A*	Pacer Ivy Storage Area	Soil	199620	1774109	X
Depth Profile					
208A	Pacer Ivy Storage Area	Soil (1-10 cm)	199608	1774054	X
209A	Pacer Ivy Storage Area	Soil (10-30 cm)	199608	1774054	X
210A	Pacer Ivy Storage Area	Soil (30-60 cm)	199608	1774054	X
211A	Pacer Ivy Storage Area	Soil (60-90 cm)	199608	1774054	X
212A	Pacer Ivy Storage Area	Soil (90-115 cm)	199608	1774054	X
South Airport Perimeter					
229A	South Airport Perimeter	Soil	200858	1773610	X
230A	South Airport Perimeter	Soil	201104	1773718	X
231A	South Airport Perimeter	Soil	201208	1773851	X
232A	South Airport Perimeter	Soil	201118	1774020	X
233A	South Airport Perimeter	Soil	200708	1773608	X
234A	South Airport Perimeter	Soil	200551	1773673	X
237A	South Airport Perimeter	Soil	200244	1773529	X
238A	South Airport Perimeter	Soil	200919	1773987	X
239A	South Airport Perimeter	Soil	200739	1773953	X
240A	South Airport Perimeter	Soil	200516	1773952	X
241A	South Airport Perimeter	Soil	200265	1773893	X
242A	South Airport Perimeter	Soil	200324	1773657	X
243A	South Airport Perimeter	Soil	199944	1773479	X
244A	South Airport Perimeter	Soil	199785	1773434	X
315A	South Airport (Outside Airport)	Soil	200504	1773534	X

* Samples collected in April 2009. All other samples collected in January 2009.

Table 2.1 (Cont'd.)

Sample ID	Location	Media	Coordinates		Analysis
			Easting	Northing	PCDD/F
South Airport Perimeter (Cont'd.)					
249A	Lake D	Sediment	201054	1773762	X
250A	Lake E	Sediment	200893	1773821	X
251A	Lake F	Sediment	200772	1773785	X
252A	Lake G	Sediment	200631	1773735	X
245A	Lake H	Sediment	200411	1773923	X
316A	Outside Airport	Sediment	200233	1773371	X
West Airbase Locations					
248A	West Airport Perimeter	Soil	200005	1774696	X
261A	West Airport Perimeter	Soil	199851	1774552	X
263A	West Airport Perimeter	Soil	199826	1774331	X
264A	West Airport Perimeter	Soil	199595	1774319	X
265A	West Airport Perimeter	Soil	199408	1774133	X
266A	West Airport Perimeter	Soil	199494	1773736	X
267A	West Airport Perimeter	Soil	199455	1774426	X
268A	West Airport Perimeter	Soil	199257	1774614	X
269A	West Airport Perimeter	Soil	199702	1774778	X
270A	West Airport Perimeter	Soil	199894	1774850	X
271A	West Airport Perimeter	Soil	199792	1775213	X
273A	West Airport Perimeter	Soil	199792	1775213	X
274A	West Airport Perimeter	Soil	199704	1775423	X
275A	West Airport Perimeter	Soil	199622	1775789	X
276A	West Airport Perimeter	Soil	199441	1776240	X
278A	West Airport Perimeter	Soil	199509	1776646	X
279A	West Airport Perimeter	Soil	199579	1777078	X
317A	West Airport (Outside Airport)	Soil	199158	1776921	X
318A	West Airport (Outside Airport)	Soil	199168	1775313	X
Lakes West of Airport					
246A	Lake I	Sediment	199525	1775170	X
247A	Lake J	Sediment	199367	1776287	X
East of Airport					
308A	East Base (Outside Airport)	Soil	201232	1774736	X
297A	East Base Perimeter	Soil	201124	1774387	X
298A	East Base Perimeter	Soil	201136	1774574	X
299A	East Base Perimeter	Soil	201153	1775004	X
300A	East Base Perimeter	Soil	201238	1775303	X
301A	East Base Perimeter	Soil	200810	1775637	X
307A	East Base (Outside Airport)	Sediment	201014	1775877	X
Lakes East of Airport					
280A	Lake L	Sediment	200947	1775812	X
281A	Lake M	Sediment	201112	1774538	X
North Airport					
304A	North Base Perimeter	Soil	200456	1777636	X
286A	Sen Lake East	Sediment	200525	1778061	X
287A	Sen Lake West	Sediment	200372	1778040	X
302A	North Base Perimeter	Sediment	200495	1777706	X
306A	North Base Perimeter	Sediment	200747	1777705	X
285A	West Airport Lake	Sediment	199470	1777480	X

* Samples collected in April 2009. All other samples collected in January 2009.

Table 2.2 Fish samples analyzed for dioxins and furans from Da Nang, Viet Nam, January 2009 and April 2009.

Sample ID	Location	Species**	Tissue Type (for fish)	Coordinates		Analysis	
				Easting	Northing	PCDD/F	Lipid
South Airport							
253A	Lake D	Tilapia	Muscle	201054	1773762	X	X
254A	Lake D	Tilapia	Fat	201054	1773762	X	X
254B	Lake D	Tilapia	Liver	201054	1773762	X	X
328AB*	Lake D	Tilapia	Muscle	201054	1773762	X	X
329A	Lake D	Tilapia	Fat	201054	1773762	X	X
255A	Lake E	Tilapia	Muscle	200893	1773821	X	X
257A	Lake F	Tilapia	Muscle	200772	1773785	X	X
288A	Lake G	Tilapia	Muscle	200631	1773735	X	X
259A	Lake H	Snakehead (1 fish)	Muscle	200411	1773923	X	X
260B	Lake H	Snakehead (1 fish)	Liver	200411	1773923	X	X
Central Airport							
292A	Lake J	Grass Carp (2 fish)	Muscle	199367	1776287	X	X
293A	Lake J	Grass Carp (2 fish)	Fat	199367	1776287	X	X
294A	Lake J	Tilapia	Muscle	199367	1776287	X	X
296A	Lake J	Tilapia	Eggs	199367	1776287	X	X
312A	Lake M	Tilapia	Muscle	201112	1774538	X	X
313A	Lake M	Tilapia	Fat	201112	1774538	X	X
314A	Lake L	Tilapia	Muscle	200947	1775812	X	X
North Airport							
282A	Sen Lake A	Tilapia (large)	Muscle	200372	1778040	X	X
283A	Sen Lake A	Tilapia (large)	Fat	200372	1778040	X	X
283B	Sen Lake A	Tilapia (large)	Liver	200372	1778040	X	X
284A	Sen Lake A	Tilapia (large)	Eggs	200372	1778040	X	X
309A	Sen Lake A	Tilapia (small)	Muscle	200372	1778040	X	X
311A	Sen Lake A	Tilapia (small)	Fat	200372	1778040	X	X
311B	Sen Lake A	Tilapia (small)	Liver	200372	1778040	X	X
290A	West Airport Lake	Tilapia	Muscle	199470	1777480	X	X
291B	West Airport Lake	Tilapia	Liver	199470	1777480	X	X
Da Nang Bay							
333A*	Da Nang Bay	Crab	Hepatopancreas	198417	1779326	X	X

* Samples collected in April 2009. All other samples collected in January 2009.

** All Tilapia samples were composites of 6 fish for each site, except where indicated. Eggs were composites of a portion of the 6 fish, as not all 6 were female.

Table 2.3 Additional analyses (rinseate water), Da Nang, Viet Nam, January 2009.

Sample ID	Comments	Media	Analysis PCDD/F
Rinseate 1	Taken at the start of the program	Water	X
Rinseate 3	Taken after completion of sampling on the Airbase	Water	X

Where possible, stations corresponded with historical dioxin/furan sampling locations (MOD, EPA, Hatfield/10-80 and Hatfield/Office 33 and other studies).

2.4 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Quality assurance sample collections were undertaken at a generally accepted rate of 5-10% of total samples. Water rinseate samples consisted of analyte-free water passed through/over a pre-cleaned/decontaminated sampling device; these samples provided information of potential cross-contamination related to field sampling equipment.

Field blanks provide information on sample handling, storage, and shipment procedures. These analyte-free water sample bottles are opened in the field to assess ambient conditions and/or equipment conditions that may affect the quality of the samples. In addition to field blanks, trip blanks were carried into the field but unopened during the entire program.

To ensure samples are not contaminated during the collection process, a number of sampling procedures were incorporated:

- Disposable latex gloves were used to handle all samples and specimens; gloves were changed between samples and specimens;
- All sampling equipments that comes in direct contact with samples was constructed of stainless steel;
- All stainless steel equipment (dissection trays, scalpels, forceps, calipers, etc.) was rinsed in ambient water, triple rinsed with reagent grade acetone and triple rinsed with reagent grade hexane, before each use and between sample collections (see equipment decontamination below);
- All dioxin samples were collected to 125 mL heat treated, wide-mouth jars provided to AXYS and transported to Viet Nam by Hatfield;
- Sample jars were pre-labeled, cross-referenced to field sheets, stored in a cool/dark area, and where feasible, transported to freezer facilities within two hours of collection;

- Any tools or gloved areas that came in direct contact with skin or external organs of sampled animals were not permitted to touch internal tissues; any tissue suspected of being contaminated in this manner was discarded;

- Duplicate samples were collected at all sampling stations. Duplicates were provided to Office 33;

- The location of each sampling station was recorded using a hand-held GPS and still photography to ensure repeatability in future sampling programs;

- Detailed records of the name of the owners of local farms, fields, fish ponds and animals sampled was collected where possible. This information was collected through interviews with local residents; and

- Smoking was not permitted in the vicinity of sampling activities.

Collecting a rinseate sample as part of Hatfield's QA/QC (2009)

2.5 SAMPLING METHODOLOGY

All soil and sediment sampling was conducted in a similar manner to previous Hatfield programs in Viet Nam (Hatfield/10-80 1998, 2000, 2003, 2006; Hatfield/Office 33 2007; Dwernychuk *et al.* 2002). All soil and sediment sampling sites were screened for UXO in advance of samples being collected. A permit for importing samples to Canada was required from the Canadian Food Inspection Agency; a permit was also required to export samples from Viet Nam (see Appendix A2).

2.5.1 Surface Sediment Sampling Protocol

Surface sediment samples were collected using a 6x6″ stainless steel Ekman grab. Each sample consisted of a single grab. The top 5-10 cm of sediments were collected at each site. Photos were taken at each station to record sampling procedure, sediments and shoreline.

Detailed Ekman sample collection procedure:

1. Clean sampling equipment as described in Section 2.4;
2. Bring sampler grab up and set in the cleaned stainless steel sampling tray;
3. Lift lids to reveal top of sample;
4. Drain excess overlying water in dredge;
5. Spoon top layer (5-10 cm) into stainless pan and set aside;
6. Discard remainder of grab;
7. Complete soil observations + photograph sample;
8. Thoroughly mix sample in stainless steel pan;
9. Spoon sample directly from Ekman to sample containers;
10. Fill appropriate sample jars (dioxin + total organic carbon + particle size); and
11. Fill out station details on sediment data sheet (Appendix A2).

2.5.2 Soil Sampling Protocol

All soil sampling was conducted in a similar manner to previous Hatfield programs in Viet Nam (e.g., Hatfield/Office 33 2007). Soil sampling to a maximum of 10 cm depth was conducted with the exception of one depth profile (Samples 208A-212A) conducted to a maximum depth of 115 cm.

Soil samples were collected using a stainless steel soil corer in softer ground, and stainless steel digging instruments (e.g., spade, chisel) in harder ground.

Each soil sample consisted of a composite of 10 sub-samples. Each sample utilized a standardized area coverage and spacing system, as follows:

- 5 x 5 m square plot; and
- 10 spaced sampling points identified to be UXO free by the VN-MOD.

All ten sub-samples were transferred to a clean stainless steel tray, homogenized with a clean stainless steel spoon, and transferred to a laboratory-supplied sample jar. The soil data sheet was filled in with details about the site (Appendix A2).

Samples collected from underneath cement aprons (e.g., former Mixing and Loading Area or PISA) did not use the composite procedures outlined above. A 50 cm X 50 cm area of the apron was removed by MOD personnel, following procedures agreed by all project stakeholders (manual removal, to ensure external contaminants were not introduced). Extreme care was taken to not disturb the soils beneath the apron. All surface soils (0-10 cm) in the 50 cm X 50 cm area below the apron were removed using a spade, transferred to a stainless steel pan for compositing and placed into glass jars.

2.5.3 Fish Tissue Sampling Protocol

Nile Tilapia (*Oreochromis niloticus niloticus;* cà rô phi), Grass Carp (*Ctenopharyngodon idella;* cà chép), and Snakehead Murrell *(Channa striata;* cà lóc*),* were sampled from lakes D, E, F, G, H, J, L and M, Sen Lake and the West Airport Ponds. A sample of crab hepatopancreas was taken in Da Nang Bay and followed the same general protocols as for fish tissue sampling.

Only fish visually certified as being captured in target waterbodies were collected and analyzed. Fish were captured by local residents using traditional fishing techniques (i.e., netting or hook and line). Captured fish were dissected within 24 hours of capture; fish were kept cool on ice packs, or frozen in cases where dissection took place more than 6 hours after capture.

Muscle tissues (skin removed) were collected from the left side of each fish, above the lateral line, and between the dorsal and caudal fins. Liver tissue samples (entire livers removed from each specimen), fish fat (collected from the viscera), and on occasion fish roe (eggs) were collected. Tilapia samples were a composite of 6 fish; Grass Carp samples were a composite of 2 fish; Snakehead were individual samples. Tissue samples were placed in individual jars for each type of tissue and frozen immediately after dissections were completed.

Hepatopancreas was collected from a total of 10 crabs from Da Nang Bay near the outlet of the Phu Loc River. The carapace of the crab was removed and the hepatopancreas collected out of the underside of the carapace and within the body cavity of the crab. One tissue sample was collected from a composite of all 10 crabs.

A fish sampling field data sheet was filled out for each specimen. This record documented fork length (mm), whole weight (g), sex (visual inspection of gonads), liver weight (g), and tissue sample weights (g); any abnormalities were also noted (Appendix A2).

2.5.4 Human Blood and Breast Milk Sampling Protocol

Human blood and breast milk sampling was undertaken according to protocols employed in previous Hatfield/10-80 Division/Office 33 investigations in Viet Nam (Hatfield/10-80 1998, 2000, 2003, 2006; Hatfield/Office 33 2007). Hatfield personnel supervised all sample collections, and consent forms were obtained in advance from all donors (Appendix A1). A total of 100 blood samples were collected and analyzed from 114 eligible donors (the remainder refused to provide a sample, or did not appear at the medical clinic to provide samples on the date prescribed).

Department of Health professionals in Da Nang City collected individual blood samples using multiple 7-mL glass Vacutainers with a target volume of 80 mL, and also assisted with collection of breast milk samples.

Breast milk samples were collected from 14 volunteer donors: 2 from Khue Trung in Cam Le District, 7 from Thuan Tay in Hai Chau District and 5 from Anh Khe Ward in Thanh Khe District. Breast milk sampling was conducted at the same time as the blood sampling program. Volunteer patients were asked to donate 15 to 50 cc of breast milk; milk was manually extruded by each individual mother, with assistance of a medical professional from Thanh Khe, Hai chau or Cam Le Medical Centres (if needed), directly into the sample jar.

2.5.5 Questionnaire and Consent Form Protocol

Human tissue sampling was performed on a volunteer basis and followed internationally-accepted protocols to ensure consent of donors. Prior to human tissue sampling, a detailed survey of each potential donor was conducted. All donors signed consent forms in advance of completing detailed questionnaires (see sample form in Appendix A3); both consent forms and questionnaires were translated into Vietnamese language, and were presented through Vietnamese translators.

Socioeconomic data collection, completion of questionnaire surveys and human donor screening was conducted by MOH, Office 33, and Hatfield in April 2009.

Questionnaire design was adapted from the format used for the University of Michigan Dioxin Study; pre-approval to use the Michigan questionnaire as a model was provided by Dr. Alfred Fransblau. Review of the questionnaire was provided by Prof. Dr. Nguyen Van Tuong (Hanoi Medical University) who has extensive experience working on dioxin exposure in Da Nang. Dr. Nguyen My Hang (MOH) supervised the human health component of the program, and worked with Hatfield to implement the socio-economic survey and blood/milk

sampling program. Extensive information was collected from each patient in advance of blood/milk sampling, including age, sex, family history, general health, work history, smoking habits, food consumption patterns, and awareness on the dioxin issue (Appendix A4).

Each volunteer donor was interviewed by the Hatfield/Office 33/MOH/ Da Nang Health Department staff to determine name, age and personal medical history. Between 30 and 80 mL of blood was collected from each patient. Samples were collected by the District Medical Centre professionals using a syringe and 7 mL or 10 mL glass Vacutainers with a pre-added sodium heparin preservative, and was supervised by Thomas Boivin of Hatfield. All blood collection equipment was imported from Canada. Whole blood samples were kept cool on ice packs during the sampling procedure, and frozen within one hour of collection.

Blood samples were collected from the following groups of people (F = female, M = male):

1. **Anh Khe Ward, Thanh Khe District, 2009 (F=5, M=10**): representing people living outside the Airport, close to the Pacer Ivy area, and within 1 km of its western boundary. The sampling area selected consisted of a densely populated urban community in an established area to the West of the Airport. Individual blood donors were selected randomly within the ward, lived near the Airport Wall, and were of legal age. Many of the residents were military personnel and their families, who had lived in the area since the mid 1990's.

2. **Khue Trung Ward, Cam Le District, 2009 (F=24, M=21)**: representing people living outside the Airport, but within 1 km of its southern boundary. The sampling area selected consisted of a densely populated urban community situated on a low-lying former wetland area located to the South of the Airport. During flood season, the agricultural area located immediately outside the Airport wall and adjacent residential properties becomes flooded. Local residents stated that water can rise up to a meter in their yards and fish were sometimes present. Because of the Airport drainage patterns, there was concern that people living in Khue Trung could be susceptible to any contaminants carried from the Pacer Ivy sites during flood season. Individuals living in this area were therefore considered to be a potentially exposed group. Some residents in Khue Trung had previously worked or lived on Da Nang Airport, and were therefore more physically influenced by the presence of the Airport. Individual blood donors were selected randomly within the ward.

3. **Thuan Tay Ward, Hai Chau District, 2009 (F=15, M=9)**: representing people living outside the Airport, but within 1 km of its eastern boundary. The sampling area selected consisted of a densely populated urban community in a developing area of Da Nang to the east of the Airport. Individual blood donors were selected randomly within the ward.

4. **Thuan Phuoc Ward, Hai Chau District, 2006 (F=6, M=6)**: represented the control individuals for the 2006 study. This area is located approximately 5 km northeast of the Airport. Individual blood donors were selected randomly within the ward (Hatfield/Office 33 2007).

5. **Sen Lake (A, B and C) Workers and their families, 2006 and 2009 (F=4, M=7):** non-random individuals sampled in the Hatfield 2006 site investigation and re-sampled in 2009 to monitor trends in blood dioxin levels. This population represents people known to have been exposed to and had direct contact with, and/or consumed/ingested Sen Lake water, sediments, fish, other aquatic organisms, lotus or other vegetation. These individuals were considered to be in a highly exposed group, given the previously reported high dioxin concentrations in Sen Lake, and were relocated away from the source of contamination following the 2006 study.

6. **West Airbase Workers and their families, 2006 and 2009 (F=3, M=3)**: non-random individuals sampled in the Hatfield 2006 site investigation; some were re-sampled in 2009. This population represents people known to have been exposed to, had direct contact with, and/or consumed/ingested water, sediments, fish, other aquatic organisms, lotus and other vegetation from aquaculture ponds located on the western perimeter of the Airport. These individuals were considered to be in an exposed group, given that the fishponds are located within the perimeter of the Da Nang Airport.

7. **Chinh Gian Ward, Thanh Khe District, 2006 (F=7, M=9)**: represented people living north of the Airport in the 2006 study. Residents lived within 1 km of the Airport in a former wetland area which was originally connected to the Sen Lake wetland ecosystem. Individual blood donors were selected randomly within the ward (Hatfield/Office 33 2007).

2.6 LABORATORY HANDLING REQUIREMENTS

Table 2.4 provides a summary of laboratory sample requirements for the Da Nang dioxin sampling program.

Table 2.4 Typical sample sizes, sample storage, and sample receipt requirements for PCDD/F analysis.

Matrix	Sample Size (per analysis)	Sample Container	Condition Upon Receipt	Storage Conditions
Solid (Sed/Soil)	10 g dry	Glass	<4°C, dark	<-10°C, dark
Fish (& Crab) Tissue	10 g wet	Glass or foil wrapped	<4°C, dark	<-10°C, dark
Aqueous (water)	1 L	Amber Glass	0 - 4°C	0 - 4°C, dark
Blood	5-20 g	Glass	<4°C	<-10°C, dark
Milk	50-150 g	Glass	<4°C	<-10°C, dark

Source: AXYS

All samples were kept cool (4°C), or frozen (for sediments, sufficient airspace was left in the jars to prevent breakage upon freezing). Samples were exported to Canada immediately after completion of the field program. Canadian and international shipping/handling protocols for samples were employed. Hatfield personnel transported the samples back to Canada with them upon departure from Ho Chi Minh City. This was essential to ensure QA/QC and proper chain-of-custody of the samples. Samples were transferred immediately to freezer facilities at Hatfield upon arrival in Vancouver, and then shipped to AXYS Analytical Laboratories in Sidney (British Columbia), within 48 hours of arrival in Canada. Laboratory analytical methods used in this study are provided in Appendix A1.4.

2.7 HEALTH AND SAFETY

Health, safety, and security of Hatfield and Vietnamese personnel working on the project were top priorities. Extensive measures were taken to protect our workers from exposure to toxic contamination, landmines and UXO, and to ensure safety of all day-to-day fieldwork activities.

Demining personnel from MOD accompanied Hatfield staff to all sites and screened all sampling sites prior to collection of soils/sediments on Da Nang Airport.

Utmost caution was taken to protect sampling personnel from direct exposure to highly contaminated soils present on the base. Protective clothing, gloves, soap, and water were kept on hand to limit direct skin contact with sediment and soil.

Field sampling in lakes in the south Airport area (2009)

2.8 STATISTICAL METHODS

Several statistical analyses were used to determine relationships among variables, among congener profiles among groups, and differences among TCDD and TEQ levels between areas. Different levels of α (*alpha* = significance) were used in different statistical tests during the analysis of 2009 blood congener levels because of the nature of statistical testing done, to account for possible inflation of the Type I error rate, and based on sample size. The different levels are noted in the descriptions below.

2.8.1 Testing Assumptions

Testing of assumptions was completed using visual methods. Probability plots and residuals in Systat were used to estimate normality and homogeneity of variance, respectively. Testing of these assumptions, however, was completed following Rank transformation of all data. The presence of non-detectable values in several analytes creates anomalous statistical properties. For the statistical analyses of analytes, values below detection were set to the detection limit because of the fewer assumptions versus setting non-detects to half of the detection limit.

The rank transformed data were found to be normally distributed and have equal variance among sites.

2.8.2 Area Comparisons in 2006 and 2009

Area comparisons within the 2006 and 2009 data were completed using a ranked one-way ANOVA with a Tukey HSD post-hoc test. Due to the decreased likelihood of Type I errors with a Tukey test, α was set for 0.05 for these comparisons. Prior to testing of differences between areas, sex-related differences were tested using a non-parametric Kruskal-Wallis test with α set to 0.01.

Comparisons of the proportion of TEQ that is from TCDD was compared using untransformed data in a one-way ANOVA with a Tukey HSD post-hoc test.

2.8.3 Temporal Analyses in Sen Lake and West Airbase Workers

Comparisons of individuals measured in both 2006 and 2009 were made using a Wilcoxon signed rank test. TCDD and TEQ were tested within areas (Sen Lake and West Airbase) between years.

2.8.4 Congener Profiles – Principal Components Analysis (PCA) and Discriminant Functional Analysis (DFA)

2.8.4.1 PCA

Principal components analysis (PCA) was used to determine underlying patterns in the analytes, create summary variables, and determine if these summary variables would provide any insight into the distribution of dioxin and furan compounds in the blood of individuals. The PCA used a correlation matrix and no rotation of factors. PCA was used as a descriptive tool during the congener analyses.

2.8.4.2 DFA

Discriminant function analysis (DFA) was used to determine if the analytes measured in the blood of the residents of Da Nang could be used to discriminate among the various areas selected for sampling. A stepwise forward discriminant analysis was used with an alpha-to-enter of 0.1. Stepwise forward discriminant analyses select single factors, in our case congeners, at a time and build models to describe the groups. Only the congeners selected by the stepwise forward model are presented.

Classification and jackknifed classification matrices were produced during the analyses and are presented. Classification matrices use the models developed from the data to determine group membership and then compare these predicted memberships versus the predetermined groupings. In jackknife classification matrices, the individual used for prediction is omitted from the assignment prediction; the jackknife analysis uses all values except the one being predicted to determine the group membership.

The contribution of each compound to the discriminant models were evaluated using the standardized canonical discriminant function values. Larger relative values indicate a strong contribution to a given discriminant function.

Assumptions of discriminant analysis include normality, homogeneity of variance and covariance, and non-multicollinearity. Ranked data were used in the analysis which fit the assumptions of homogeneity of variance and normal distributions. Multi-collinearity among the input variables was assessed through scatterplot matrices. Several variables likely had strong correlations, but few were collinear. No summed variables were included in the analyses to limit collinearity issues.

2.8.5 Demographics and Human Health Survey

Survey data obtained through interviews of participants were included in the analyses as possible explanatory factors. Many of the questions included binary (e.g., "yes/no") data which limited their utility in statistical analysis. As well, questionnaire data were collected incidentally with blood samples and therefore lack statistical power. The present study was not designed to detect the influence of, for instance, smoking on dioxin/furan concentrations in blood. Analyses using the demographic/lifestyle data are therefore limited to general conclusions regarding potential exposure routes and pathways.

The demographic/lifestyle data were included as grouping variables within the Khue Trung, Thuan Tay, and Anh Khe groups when they were pooled to determine if any relationships existed with the survey data. Sen Lake and West Airbase worker samples were excluded from these analyses because of the likelihood of their biasing the analyses; Sen Lake and West Airbase workers were sampled because they are a high risk group within the Da Nang Airport study area. They were, however, included in a separate analysis examining the relationships of the explanatory variables and the blood TCDD and TEQ values within a high risk group. An additional analysis of demographic factors was completed for all participants that reported working on the Airport.

Each variable, such as working on the base, or fishing on the base, was analyzed separately as a grouping variable with a ranked one-way ANOVA. Multi-way ANOVAs (beyond a two-way comparison) could not be used because of the loss of interaction factors due to the partitioning of the sample sizes when multiple grouping variables are used. Two-way ANOVAs, however, were used to determine if interactions existed between specific grouping variables. Because of the high number of separate ANOVAs during these analyses, α was set at 0.01.

3.0 RESULTS AND DISCUSSION

3.1 SOIL AND SEDIMENT

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; the sediment guideline is 150 pg/g TEQ. Soil and sediment samples analyzed from the 2009 sampling locations in the south, east and west of the Da Nang Airport generally exhibited lower levels of dioxin contamination than those collected from the north of the Airport in 2006. Only one sediment sample and three soil samples collected in the southern and central Airport areas in 2009 exceeded the 1,000 ppg/g TEQ guideline.

3.1.1 Pacer Ivy Storage Area (PISA)

- **Figure 3.1; Table 3.1**

Nineteen (19) soil samples were analyzed from the PISA in January and April 2009 (Figure 3.1; Table 3.1). The highest soil TEQ concentration recorded was 20,600 ppt (208A) in the 0-10 cm fraction; 65% of the TEQ was attributed to TCDD. Deeper soils (10-30 cm) at the same site also exhibited relatively high dioxin concentrations (3,500 ppt TCDD; 5,120 ppt TEQ; TCDD accounted for 68.4% of the TEQ). Samples from 30 cm to 115 cm in the same depth profile had lower TEQ concentrations, decreasing with depth from 123 ppt to 4.15 ppt, respectively.

Other soil samples analyzed from the top 10 cm from the PISA had lower levels of contamination, ranging between 1.25 ppt TCDD with a TEQ concentration of 6.61 ppt (325A) and 1,180 ppt TCDD (TEQ of 1,420 ppt [202A]). Agent Orange was the likely source of contamination at site 202A as evident from the high proportion of TCDD in the TEQ (80.1%). The soil depth profile samples (208A to 212A) indicated high TCDD levels in the 0 to 10 cm (13,400 ppt) and 10 to 30 cm (3,500 ppt) layers, but much lower contamination >30 cm in depth. Samples immediately north of the PISA (261A, 263A, 264A and 269A) had low TCDD concentrations (non-detectable to 0.623 ppt). A sample taken to the south of the PISA (266A) had a slightly higher level of TCDD (46.1 ppt TCDD; 115 ppt TEQ).

Overall, the proportion of TCDD to total TEQ concentration was moderate (range: 18.9% to 80.1%) indicating that Agent Orange was not the only contaminant contributing to the TEQ. A number of different dioxin and furan congeners contributed to the total TEQ of samples, including penta-, hexa-, hepta- and octa-chlorinated congeners.

3.1.2 Pacer Ivy Re-Drumming Area (PIRA)

- **Figure 3.1; Table 3.1**

A total of eleven (11) surface soil samples (0-10 cm) were analyzed from the Pacer Ivy Re-Drumming Area (PIRA) (Figure 3.1; Table 3.1). Concentrations were all below international guidelines (1,000 ppt TEQ) ranging from 5.2 ppt TEQ to 99.7 ppt TEQ. Samples 223A (73.7 ppt TCDD; 85.2 ppt TEQ) and 226A (79.9 ppt TCDD; 99.7 ppt TEQ) were the only samples with a proportion of TCDD to TEQ concentration higher than 80% (86.5% and 80.1%, respectively).

Table 3.1 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in the Pacer Ivy Storage and Pacer Ivy Re-Drumming soil samples (pg/g [ppt] dry weight), Da Nang Airport, Viet Nam, January 2009 and April 2009. All samples collected at the surface (0 to 10 cm) except where noted.

Sample ID	Location	Media	PCDD (pg/g dry weight)						PCDF (pg/g dry weight)						TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
Pacer Ivy Re-Drumming Area																	
215A	Pacer Ivy Re-Drumming Area	Soil	NDR 1.21	< 0.273	0.537	12.6	77.9	679	0.915	0.915	1.56	2.44	2.87	3.96	1.11	1.21	NC
216A	Pacer Ivy Re-Drumming Area	Soil	5.14	7.79	15.1	82	364	1600	6.04	21.4	39.5	64.5	103	59.6	16.7	16.1	31.9
218A	Pacer Ivy Re-Drumming Area	Soil	NDR 1.82	0.35	1.06	30	157	1200	NDR 0.313	1.5	6.85	16.1	19	NDR 10.7	2.65	2.85	NC
219A	Pacer Ivy Re-Drumming Area	Soil	12	14.5	14.4	132	948	7370	4.1	10.6	44.1	144	212	63.8	29.6	30.5	39.3
221A	Pacer Ivy Re-Drumming Area	Soil	2.48	2.48	7.01	166	1270	4150	3.87	15.8	24.3	64.1	91.9	56.2	11.5	11.9	20.8
222A	Pacer Ivy Re-Drumming Area	Soil	5.63	5.63	2.65	46.3	375	2380	NDR 1.12	1.55	15.8	47.6	72.8	35.2	11.8	12	46.9
223A	Pacer Ivy Re-Drumming Area	Soil	73.7	84.6	28.8	91.9	377	9220	5.47	19.8	27.2	18.3	27.7	19.2	83.5	85.2	86.5
224A	Pacer Ivy Re-Drumming Area	Soil	2.55	3.29	0.833	37.1	153	938	1.27	5.34	9.22	18.2	25	14.2	5.03	5.2	49.0
226A	Pacer Ivy Re-Drumming Area	Soil	79.9	93.6	47.8	179	728	4370	8.41	32.6	46.5	59.2	109	72.6	98.8	99.7	80.1
227A	Pacer Ivy Re-Drumming Area	Soil	3.39	5.09	8.88	59.9	267	3050	1.88	6.03	18	65.9	72.6	26.5	10.2	10.8	31.4
228A	Pacer Ivy Re-Drumming Area	Soil	11.1	312	273	796	1840	9190	76.4	509	352	307	290	129	66.3	62.8	17.7
Pacer Ivy Storage Area																	
202A	Pacer Ivy Storage Area	Soil	1180	1910	1150	2300	2500	6290	167	1130	1540	598	147	103	1430	1420	83.1
203A	Pacer Ivy Storage Area	Soil	54.5	67.8	60	196	370	4300	8.54	33.9	57.3	44.6	28.2	18.8	72.5	73.3	74.4
204A	Pacer Ivy Storage Area	Soil	6.81	8.35	19.9	128	660	5080	1.62	7.34	17.8	83.9	185	166	21.4	22.2	30.7
206A	Pacer Ivy Storage Area	Soil	2.99	2.99	< 0.244	22.9	121	1610	NDR 0.424	< 0.223	< 0.174	< 0.153	< 0.118	NDR 1.13	4.09	4.4	68.0
207A	Pacer Ivy Storage Area	Soil	30.2	31.5	16.7	68	201	5470	2.37	9.27	16.5	15	17.8	18.7	33.7	34.7	87.0
213A	Pacer Ivy Storage Area	Soil	5.4	6.5	6.32	55.5	310	3480	1.45	3.96	9.71	17.2	48.8	29.6	12	12.5	43.2
214A	Pacer Ivy Storage Area	Soil	NDR 0.774	< 0.291	0.954	20.4	97.3	1530	NDR 0.507	< 0.304	0.922	0.759	4.34	3.57	1.45	1.72	NC
321A*	Pacer Ivy Storage Area	Soil	46.1	105	248	508	659	1910	16.6	128	201	72.2	30.7	21.4	124	124	37.2
322A*	Pacer Ivy Storage Area	Soil	NDR 1.62	3.33	< 0.232	19.1	103	1980	< 0.622	2.79	1.12	3.03	6	3.88	1.42	1.79	NC
323A*	Pacer Ivy Storage Area	Soil	NDR 1.22	5.97	11.1	44.4	201	3510	< 0.483	7.79	6.74	10.1	11.3	9.44	3.93	4.6	NC
324A*	Pacer Ivy Storage Area	Soil	1.97	5.52	2.74	64.7	257	4980	1.17	7.03	10.8	10.9	16.1	14.2	6.06	6.93	28.4
325A*	Pacer Ivy Storage Area	Soil	1.25	17.1	5.13	53.8	310	4260	NDR 0.755	0.7	1.38	12.4	23	19.4	5.93	6.61	18.9
326A*	Pacer Ivy Storage Area	Soil	44	64.7	103	295	433	2860	16.2	96.1	107	45.2	20.3	12.5	75.1	75.3	58.4
327A*	Pacer Ivy Storage Area	Soil	18.7	30.4	83.7	288	599	3180	NDR 3.76	15	38.2	58.5	110	76.8	39.8	40.3	46.4
Depth Profile																	
208A	Pacer Ivy Storage Area	Soil (1-10 cm)	13400	25800	19500	23700	31200	47600	NDR 6460	61200	42000	4310	1820	1700	20700	20600	65.0
209A	Pacer Ivy Storage Area	Soil (10-30 cm)	3500	6530	4860	5280	6900	12200	1810	15200	9130	1110	509	620	5140	5120	68.4
210A	Pacer Ivy Storage Area	Soil (30-60 cm)	123	239	168	206	355	2200	NDR 67.0	583	336	39.1	22.8	27.4	189	189	65.1
211A	Pacer Ivy Storage Area	Soil (60-90 cm)	13.1	23.3	13.8	36.3	100	1950	NDR 5.88	51.6	29	3.87	1.42	3.9	21.3	21.6	60.6
212A	Pacer Ivy Storage Area	Soil (90-115 cm)	4.15	4.63	4.54	10.1	30	784	2.15	14.3	9.58	0.834	< 0.306	0.678	6.92	6.96	59.6

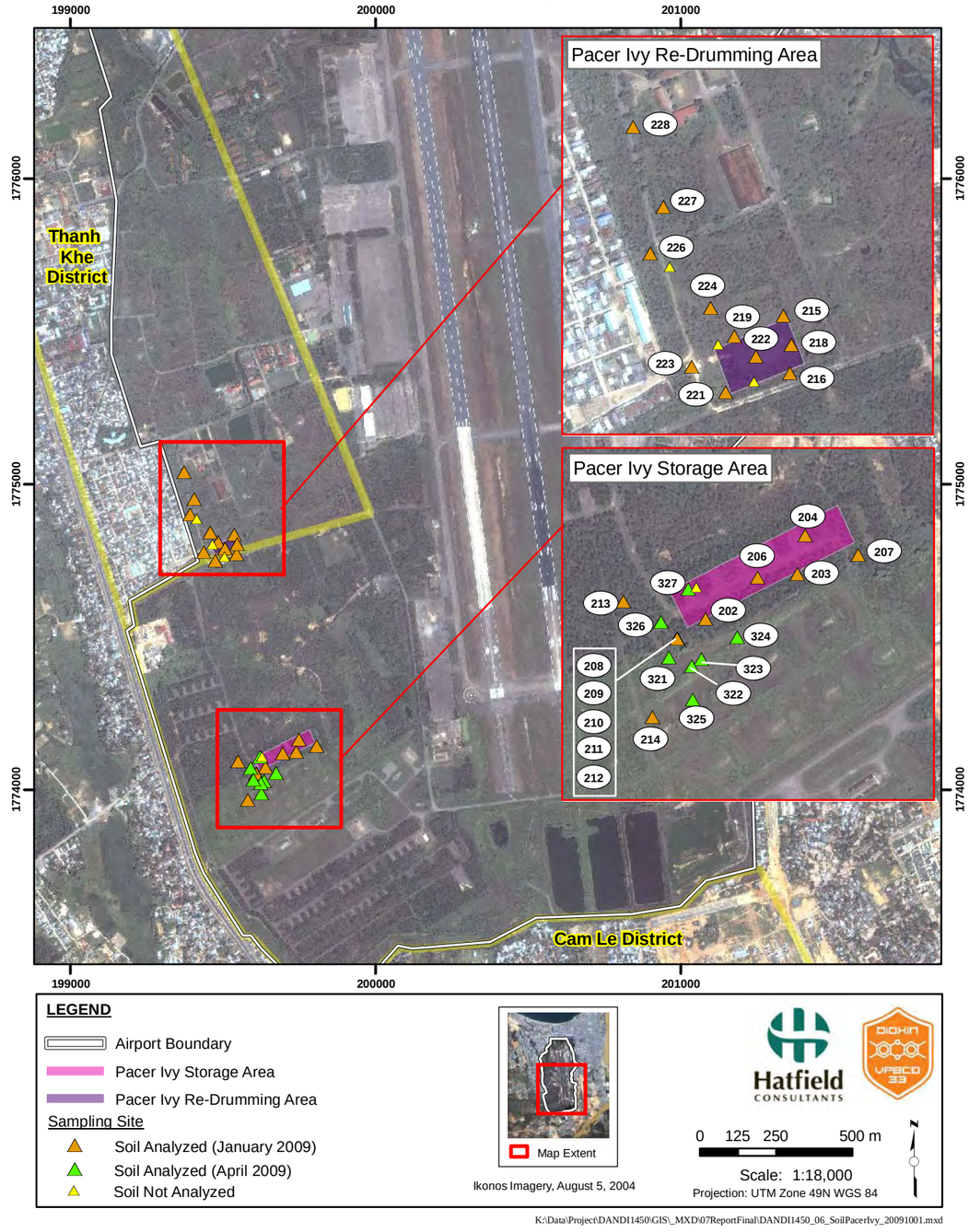
NC = Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

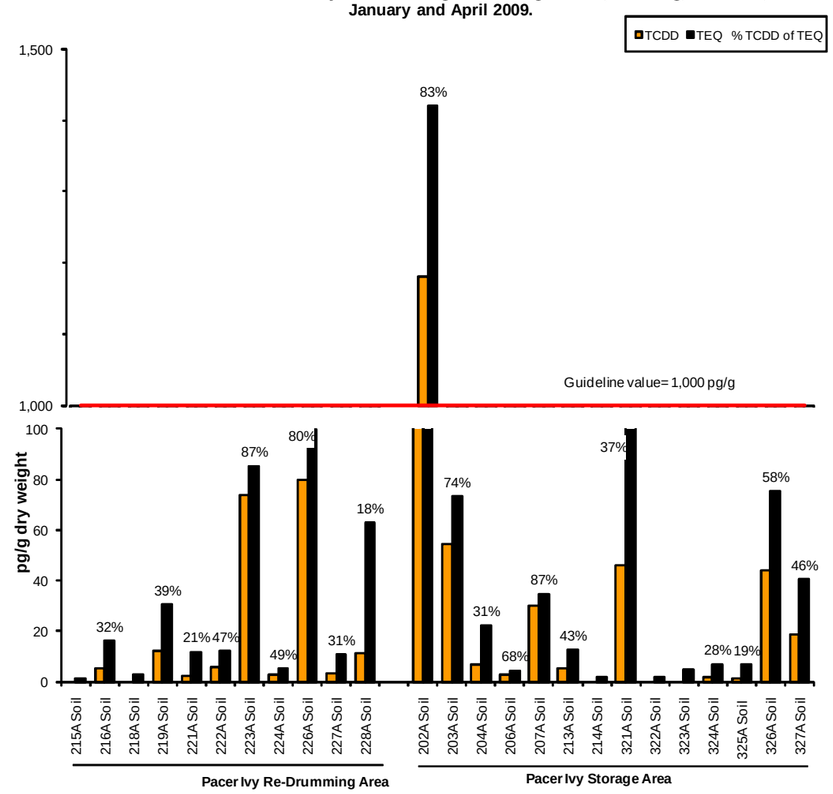
NDR = Non-detect ratio; peak detected but did not meet quantification criteria; for “Total TEQ” calculations, NDR was treated as ND ("0").

* = Samples collected in April 2009. All other samples collected in January 2009.

Figure 3.1 Soil and sediment sampling locations in the Pacer Ivy Storage Area and Pacer Ivy Re-Drumming Area, Da Nang, Viet Nam, January and April 2009.

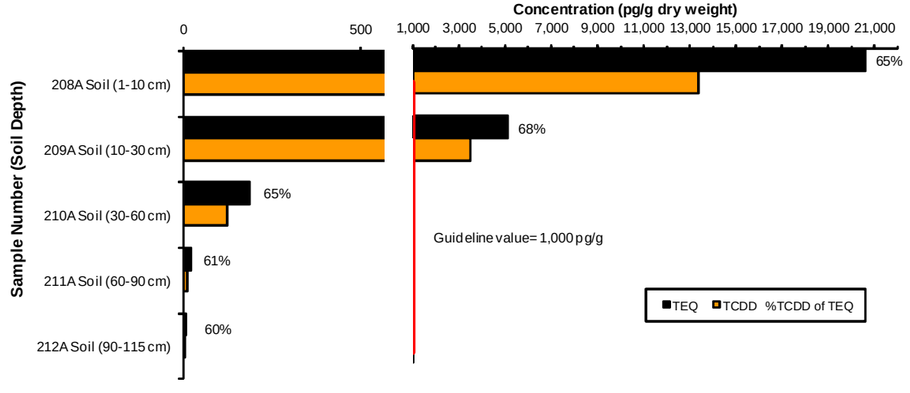


TCDD (pg/g dry weight), TEQ (pg/g) and Percent TCDD of TEQ in Soil Samples Collected from the Pacer Ivy Re-Drumming and Storage Areas, Da Nang, Viet Nam, January and April 2009.



No % TCDD of TEQ is shown when 2,3,7,8-TCDD concentrations were NDR (peak detected, but did not meet quantification criteria).

TCDD (pg/g dry weight), TEQ (pg/g) and Percent TCDD of TEQ in Soil Samples Collected from a Depth Profile at the Pacer Ivy Storage Area, Da Nang, Viet Nam, January 2009.



3.1.3 South Airport Perimeter

- **Figure 3.2; Table 3.2**

A number of samples were collected along the south of the Airport (both inside and outside the Airport perimeter) in January 2009 to identify any potential contaminant pathways leading to the general population in Da Nang City.

Most soil samples collected at the south of the Airport had TCDD concentrations of less than 2 ppt and TEQ concentrations ranging from 1.14 ppt to 11.2 ppt. The maximum recorded TEQ concentration was 161 ppt (238A); the proportion of TCDD to the TEQ concentration was 90.1%; suggesting that Agent Orange was the source of contamination at this site. Site 237A (98.2 ppt TEQ) was the only other site to have a TCDD concentration suggesting Agent Orange as the primary source of contamination (87.1% of the TEQ).

One soil sample was analyzed from outside of the wall south of the Airport (315A). This sample was collected from a garden south-west of Lake F. The garden is prone to flooding and can be inundated up to half a meter during large floods in the rainy season. The TCDD level at this site was low (0.388 ppt) with a TEQ of 3.87 ppt.

Sediment samples were collected from Lakes D, E, F, G and H inside the Airport and from a wetland outside the Airport wall that is channeled into a large culvert. All sediment samples collected on the Airport had low TCDD concentrations ranging from non-detectable (Lake D) to 15.6 ppt (Lake E). The wetland area outside the Airport wall (316A) had a TEQ concentration of 30.8 ppt (44% TCDD). As seen with the soil samples, sediment sample results suggest that historical Agent Orange handling did not result in significant contamination in the south of Da Nang Airport.

Table 3.2 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in the south Airport perimeter soil and sediment samples (pg/g [ppt] dry weight), Da Nang Airport, Viet Nam, January 2009. All samples collected at the surface (0 to 10 cm).

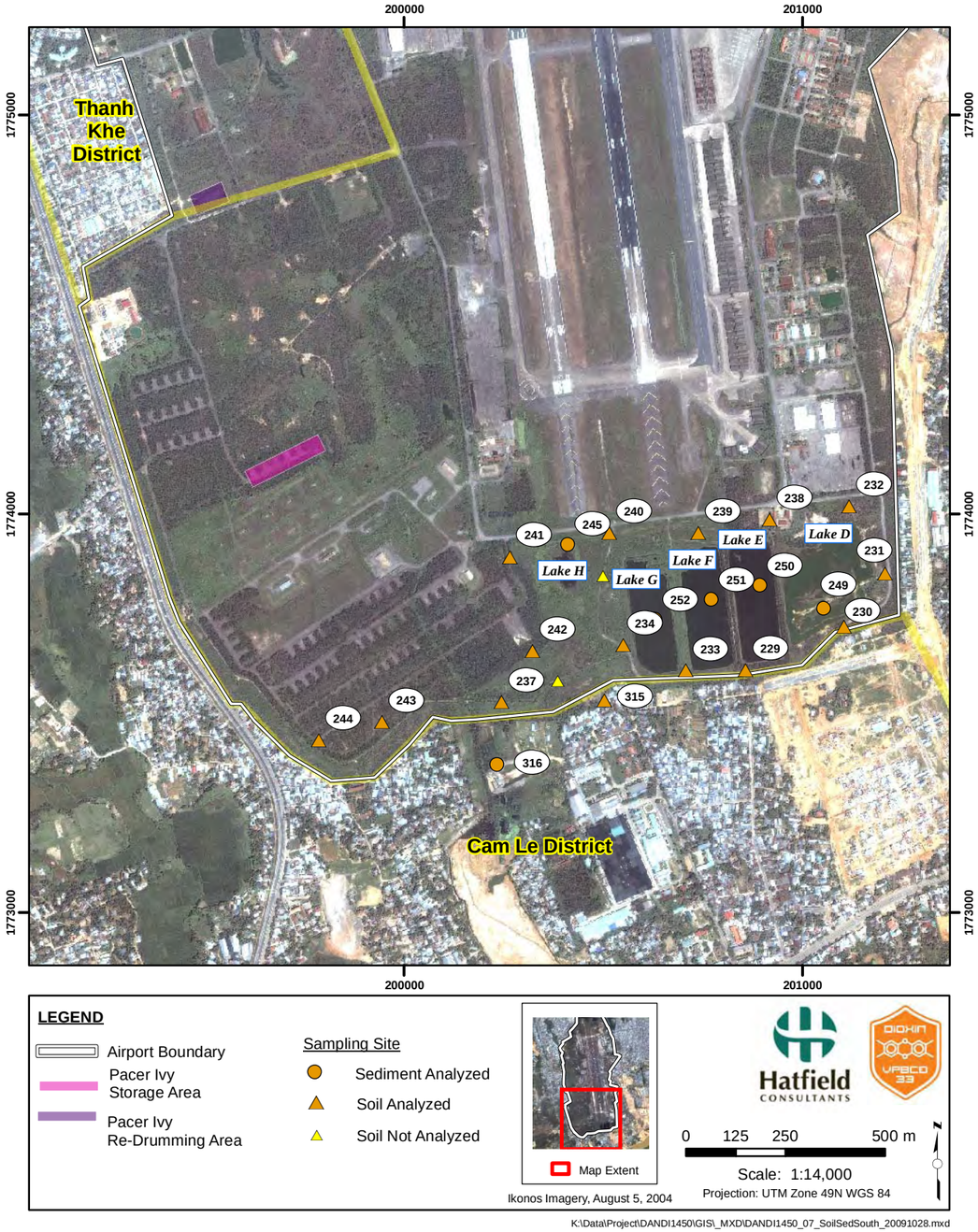
Sample ID	Location	Media	PCDD (pg/g dry weight)						PCDF (pg/g dry weight)						TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
South Airbase Perimeter																	
229A	South Airbase Perimeter	Soil	1.05	1.05	1.17	7.5	48.3	749	NDR 0.547	< 0.305	0.461	3.3	4.5	NDR 2.35	1.94	2.06	51.0
230A	South Airbase Perimeter	Soil	4.14	4.78	7.44	94.6	725	7530	0.712	2.11	18.3	119	288	352	15.9	17.1	24.2
231A	South Airbase Perimeter	Soil	1.29	1.29	1.01	12.3	75.7	1200	0.643	1.09	1.53	1.66	< 0.283	2.81	3.33	3.44	37.5
232A	South Airbase Perimeter	Soil	NDR 1.37	< 0.465	< 0.870	14.4	279	1710	< 0.435	0.515	5.68	24.6	46.7	25.5	2.67	2.96	NC
233A	South Airbase Perimeter	Soil	0.875	1.35	4.84	44.2	387	2890	1.21	3.24	16.3	73.6	68.2	16.7	8.1	8.2	10.7
234A	South Airbase Perimeter	Soil	9.61	10.6	7.1	36.6	176	3640	1.5	5.48	7.12	13.5	17.1	16	14.1	14.8	64.9
237A	South Airbase Perimeter	Soil	85.5	103	28.7	87.2	415	5400	3.01	11.4	27.6	40.7	60.7	63	97.4	98.2	87.1
238A	South Airbase Perimeter	Soil	145	153	26.4	149	897	4730	5.67	17.3	36	76	107	75	160	161	90.1
239A	South Airbase Perimeter	Soil	NDR 0.620	< 0.239	1.05	4.05	43.9	1090	0.494	0.771	0.439	1.53	1.61	2.14	1.02	1.14	NC
240A	South Airbase Perimeter	Soil	1.69	2.31	1.81	42	295	3760	0.84	1.69	7	27.9	52.4	44.8	5.49	6.13	27.6
241A	South Airbase Perimeter	Soil	1.65	3.75	10.1	71.8	359	1960	1.32	7.45	26.4	104	119	61.2	10.8	11.2	14.7
242A	South Airbase Perimeter	Soil	18.3	33.3	137	846	3400	17000	6.74	36.5	174	568	809	487	101	103	17.8
243A	South Airbase Perimeter	Soil	NDR 1.05	< 0.299	6.99	92.4	548	6770	NDR 0.514	1.75	8	42.4	94.1	71.8	9.54	10.9	NC
244A	South Airbase Perimeter	Soil	NDR 0.617	< 0.212	4.93	63.8	384	6460	0.221	1.76	1.78	18.5	40	39.2	5.75	6.94	NC
315A	South Airbase (Outside Airbase)	Soil	0.388	4.05	7.11	39.5	182	2370	2.75	16.4	8.48	6.75	5.54	2.8	3.56	3.87	10.0
Lakes South Airbase																	
249A	Lake D	Sediment	NDR 0.639	0.196	0.493	4.08	22.1	554	0.136	0.187	0.261	0.248	0.226	0.706	0.439	0.538	NC
250A	Lake E	Sediment	15.6	27.5	21.6	90.2	404	3900	4.13	27.3	26	34.9	39.6	23.7	23.4	23.8	65.5
251A	Lake F	Sediment	2.11	9.16	9.22	48.7	214	1840	3.5	25.8	19.9	20.8	21.1	12.2	6.82	6.89	30.6
252A	Lake G	Sediment	0.911	6.63	4.71	25.9	118	1510	2	11	8.45	9.76	10.4	7.23	3.37	3.54	25.7
245A	Lake H	Sediment	1.04	5.46	10.5	56.5	337	12500	0.711	4.34	2.89	5.37	7.09	9.39	5.38	7.86	13.2
316A	Outside Airbase	Sediment	13.7	98.6	122	617	1330	6840	1.25	7.83	8.45	15.3	22.9	15.8	29.5	30.8	44.5

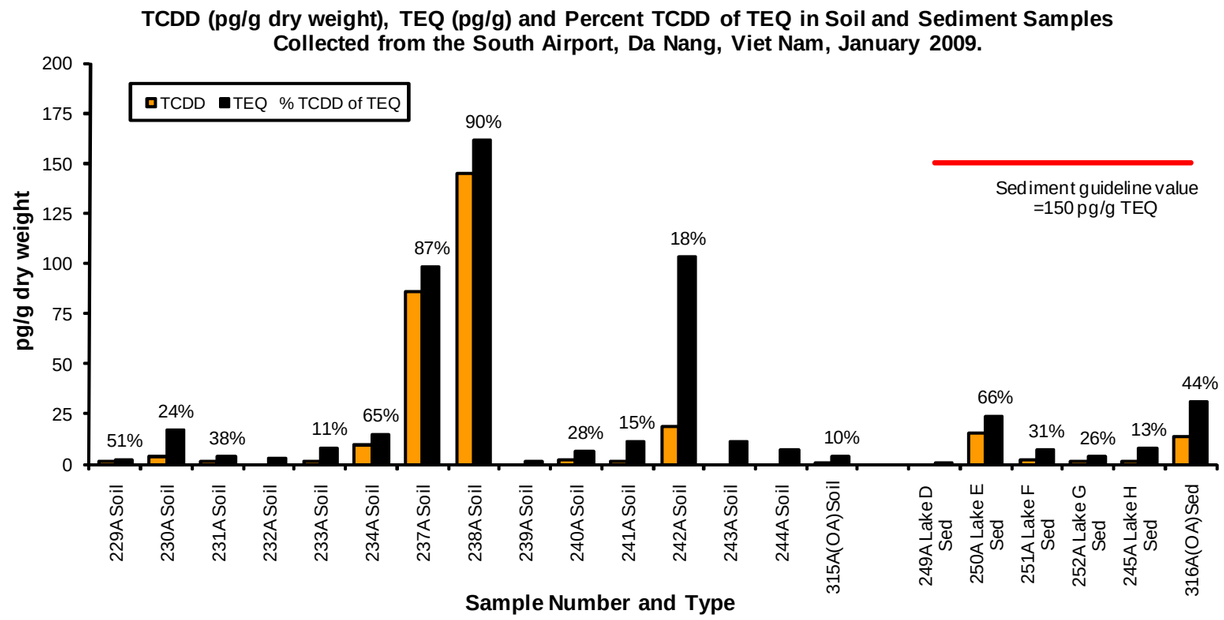
NC= Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Non-detect ratio; peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND ("0").

Figure 3.2 **Soil and sediment sampling locations in the south of Da Nang Airport, Viet Nam, January 2009.**





No % TCDD of TEQ is shown when 2,3,7,8-TCDD concentrations were NDR (peak detected, but did not meet quantification criteria).
OA= Outside Airbase Wall.

3.1.4 East and West of the Central Airport

- **Figure 3.3; Table 3.3**

A number of soil and sediment samples were analyzed in the central Airport area, and outside the Airport walls, along the west and east sides of the runway in January 2009.

TCDD concentrations in soil samples collected in the west Airport area ranged from non-detectable to 46.1 ppt; TEQ concentrations ranged from 1.67 ppt to 115 ppt. Two (2) soil samples were collected outside the central-west of the Airport. Sample 317A was taken in An Khe Ward in a garden that is not subject to flooding. The sample had a TCDD concentration of 4.06 ppt and a TEQ of 15.3 ppt. Sample 318A was collected from a garden directly west of the Pacer Ivy Re-Drumming site. This site is not prone to flooding and had a TEQ of 37 ppt.

Two (2) sediment samples were collected west of the Airport from Lakes I and J. TCDD concentrations were very low (1.32 ppt in Lake I and 0.597 ppt in Lake J), as were TEQs (11.9 ppt in Lake I and 9 ppt in Lake J). Dioxin levels are likely not a significant concern in these lakes.

Soil samples collected from the east Airport area were primarily from small garden plots, with the exception of sample 300A which was collected from a vacant lot. All samples had low TCDD concentrations, ranging from 1.04 ppt to 21.4 ppt. TEQs ranged from 7.6 ppt to 38.5 ppt, and the proportion of TCDD to the TEQ concentration ranged from 6.6% to 59.3%. Sample 308A was taken outside the Airport adjacent to the wall and exhibited a TCDD concentration of 3 ppt (8.95 ppt TEQ).

Sediment samples were analyzed from Lakes L and M in the east Airport. In Lake M, the TCDD concentration was very low (0.2 ppt; 2.28 ppt TEQ). Lake L had a TCDD concentration of 93.8 ppt, and a corresponding TEQ concentration of 146 ppt (64.2% TCDD); this sample (280A) was slightly less than the sediment TEQ guideline (150 ppt) in the central and southern Airport areas.

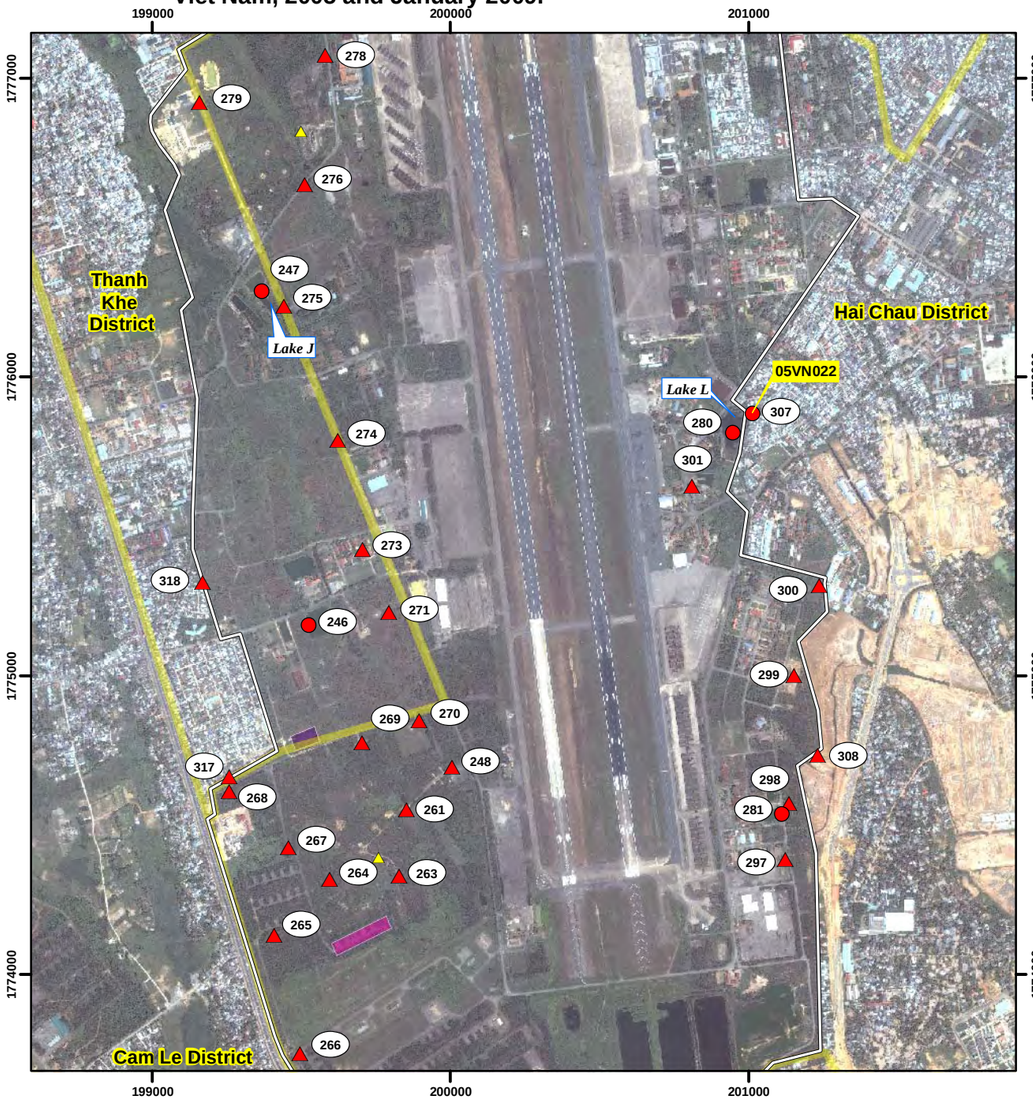
Sediment sample 307A was collected at the same site as sample 05VN22, analyzed as part of the Hatfield/10-80 2005 study (Hatfield/10-80 2006). The site is located in a large drainage canal running through a residential area. In 2009, TCDD concentrations were 24.8 ppt, which was lower than the 130 ppt measured in 2005. TEQ concentrations were also lower (35.1 ppt) than recorded in 2005 (191 ppt). However, the proportion of TCDD to the TEQ concentrations was similar: 70% in 2009 and 68% in 2005.

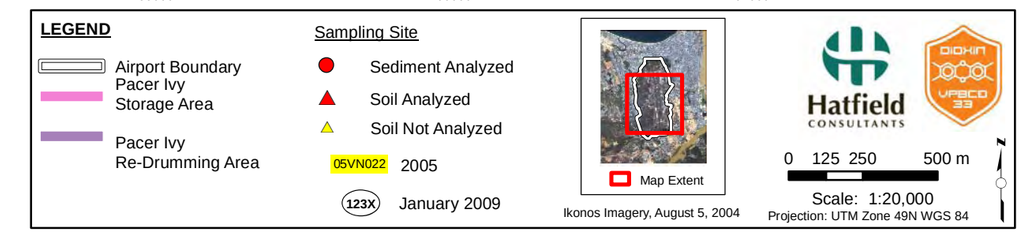
Table 3.3 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in the central Airport area soil and sediment samples (pg/g [ppt] dry weight), Da Nang Airport, Viet Nam, 2005 and January 2009. All samples collected at the surface (0 to 10 cm).

Sample ID	Location	Media	PCDD (pg/g dry weight)						PCDF (pg/g dry weight)						TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
West Airbase Locations																	
248A	West Airbase Perimeter	Soil	17.5	20.8	23.7	127	622	3950	2.97	15.6	36.3	102	152	109	30.5	30.9	56.6
261A	West Airbase Perimeter	Soil	0.497	2.62	3.67	38.3	204	6320	3.32	18	27.6	38.6	36.1	22.8	7.93	8.61	5.8
263A	West Airbase Perimeter	Soil	< 0.256	< 0.256	< 0.259	1.2	90.8	2650	< 0.188	< 0.188	< 0.174	2.38	2.32	NDR 3.70	1.16	1.67	7.7
264A	West Airbase Perimeter	Soil	NDR 0.580	0.334	1.28	18.3	161	1410	NDR 0.703	1.33	3.63	21.1	39.6	24.9	3.73	3.89	NC
265A	West Airbase Perimeter	Soil	NDR 0.682	< 0.261	1.56	18.1	109	2150	0.582	0.931	1.26	1.63	6.3	6.11	1.79	2.21	NC
266A	West Airbase Perimeter	Soil	46.1	50.3	59.5	529	3970	26000	NDR 2.50	12.1	108	634	1290	1030	111	115	40.1
267A	West Airbase Perimeter	Soil	0.623	2.29	1.38	27.1	159	3910	7.53	12	8.64	5.3	18.4	17.8	3.62	4.29	14.5
268A	West Airbase Perimeter	Soil	2.55	5.05	8.07	62.2	330	3910	NDR 1.13	3.84	9.7	32.7	59.7	47.8	9.35	9.98	25.6
269A	West Airbase Perimeter	Soil	1.65	1.65	< 0.252	3.11	27.3	292	NDR 0.253	< 0.234	0.451	4.2	4.23	NDR 6.15	2.23	2.24	73.7
270A	West Airbase Perimeter	Soil	NDR 0.869	< 0.680	21.2	297	2100	10700	1	7.03	69.2	378	1020	1160	36.5	38.8	NC
271A	West Airbase Perimeter	Soil	1.61	1.99	1.78	23	104	863	0.503	0.503	1.71	< 0.185	6.42	5.15	2.71	2.85	56.5
273A	West Airbase Perimeter	Soil	30.2	47.7	36	170	674	3950	6.06	36.6	43.3	71.9	81.3	43.9	46.4	46.5	64.9
274A	West Airbase Perimeter	Soil	5.51	10.6	22.7	124	552	4350	4.01	29.6	26.1	51.8	76.5	60.7	13.7	14.3	38.5
275A	West Airbase Perimeter	Soil	3.93	6.28	17	114	737	13000	4.4	19.6	20.1	51.4	141	181	16.4	18.6	21.1
276A	West Airbase Perimeter	Soil	3.09	3.09	1.01	13.7	109	6800	0.679	1.34	0.272	3.7	8.02	7.89	5.13	6.47	47.8
278A	West Airbase Perimeter	Soil	NDR 1.01	< 0.468	6.25	34.6	182	5140	NDR 0.670	< 0.390	0.986	7.76	12	8.39	3.74	4.72	NC
279A	West Airbase Perimeter	Soil	1.48	3.39	6.78	126	684	7860	2.95	10.9	109	378	311	71.6	23.2	23	6.4
317A	West Airbase (Outside Airbase)	Soil	4.06	13.1	21	83.4	442	4570	5.58	29.9	41.7	96.1	101	47.5	15.2	15.3	26.5
318A	West Airbase (Outside Airbase)	Soil	1.91	23.3	55	297	2060	13200	20.2	119	107	178	290	252	36.1	37	5.2
Lakes West of Airbase																	
246A	Lake I	Sediment	1.32	4.73	11.8	94.4	564	14200	1.41	8.49	11.5	20.2	31	19.1	9.21	11.9	11.1
247A	Lake J	Sediment	0.597	3.33	7	66.7	553	9040	2.08	13.7	7.69	14.9	26.3	21.2	7.34	9	6.6
East of Airbase																	
308A	East Base (Outside Airbase)	Soil	3	4.9	2	52.2	204	12100	< 0.232	< 0.232	< 0.242	4.32	3.43	4.79	6.56	8.95	33.5
297A	East Base Perimeter	Soil	1.05	5.23	17.3	138	1050	4800	2.01	12.1	36.6	73.8	66	22.8	15.8	16	6.6
298A	East Base Perimeter	Soil	14.4	18.1	11.4	77.6	422	4390	1.48	9.17	18.7	48.3	77.8	50.9	23.5	24.3	59.3
299A	East Base Perimeter	Soil	21.4	30.3	19.2	125	830	6620	5.58	28	58.9	129	116	28.3	38.3	38.5	55.6
300A	East Base Perimeter	Soil	3.96	12.7	22	74.3	268	2890	4.11	22.9	31.4	39.1	33.2	14.7	11.6	11.8	33.6
301A	East Base Perimeter	Soil	1.04	6.89	12.7	59.2	306	5270	2.93	18.3	17.4	30.7	29.8	12.6	6.85	7.6	13.7
307A	East Base (Outside Airbase)	Sediment	24.8	36.4	25	113	630	5420	4.21	24	23.6	35.7	56.7	33.4	34.3	35.1	70.7
Lakes East of Airbase																	
280A	Lake L	Sediment	93.8	143	108	580	2780	38400	34.2	175	153	187	222	129	140	146	64.2
281A	Lake M	Sediment	0.2	0.992	2.48	12.4	82.9	2780	0.723	4.06	3.82	4.83	6.28	4.68	1.8	2.28	8.8
Central Airbase - Selected Site from 2005																	
05VN022	East Base (Outside Airbase) (307A)	Sediment	130	187	125	660	3550	42100	29.8	204	212	277	340	203	191	-	68.0

NC= Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).
ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.
NDR = Non-detect ratio; peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND ("0").

Figure 3.3 Soil and sediment sampling locations in the central Airport area, Da Nang, Viet Nam, 2005 and January 2009.





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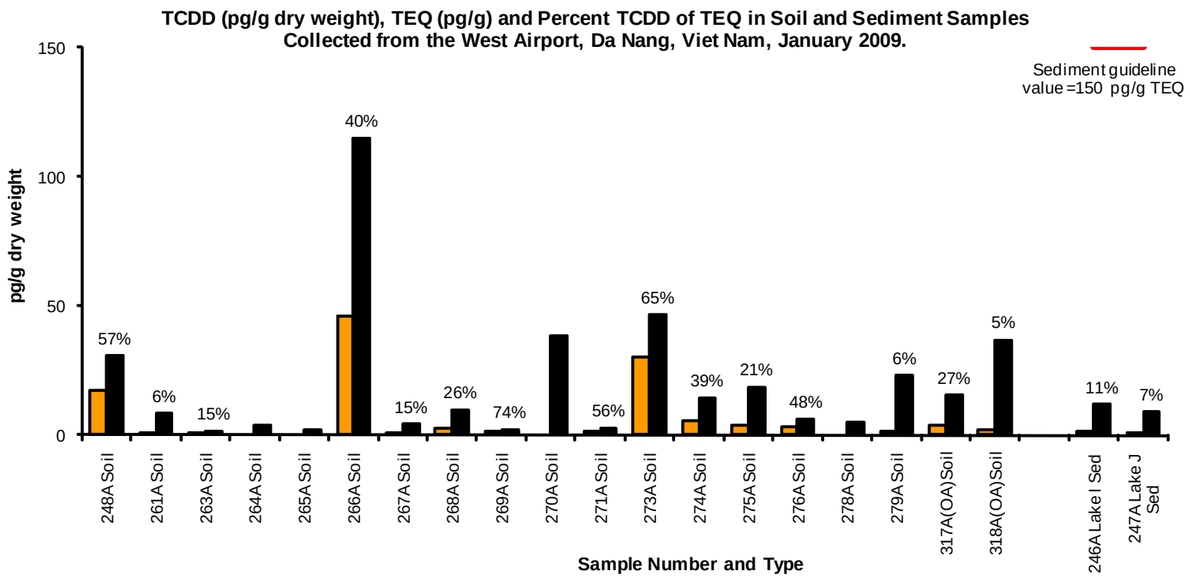
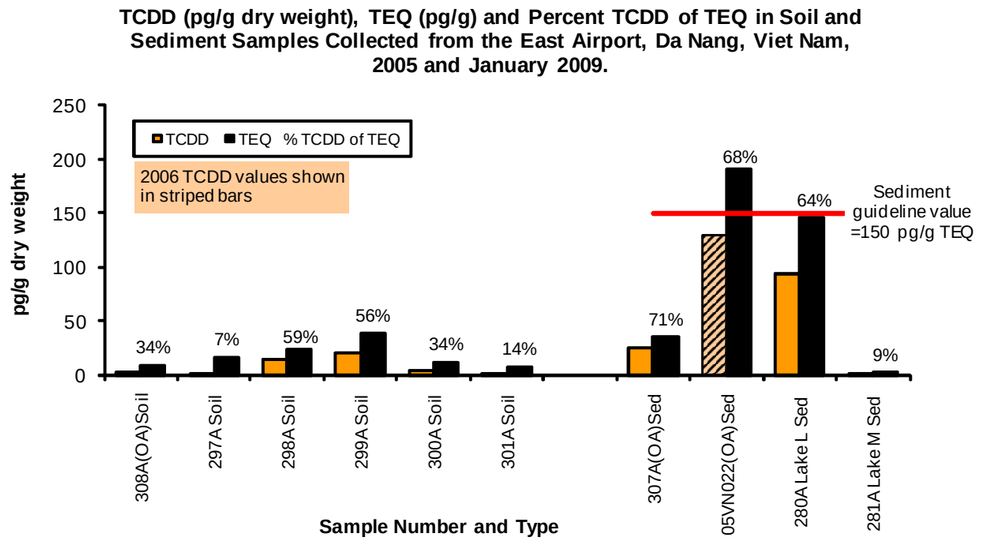


No % TCDD of TEQ is shown when 2,3,7,8-TCDD concentrations were NDR (peak detected, but did not meet quantification criteria).
OA= Outside Airbase Wall



OA= Outside Airbase Wall

3.1.5 North Airport

- **Figure 3.4; Table 3.4**

Extensive sampling was conducted in the north Airport area in 2006 (Hatfield/Office 33 2007), and follow-up monitoring was performed in 2009. Six (6) soil and sediment samples were collected in January 2009 for comparison with results from the December 2006 sampling program. The north Airport remains highly contaminated: four of the six samples collected exceeded international guidelines; TEQ concentrations ranged from 64 ppt to 11,700 ppt.

One soil sample (304A) was collected adjacent to the Former Storage Area for comparison with a sample from the same site in 2006 (06VN046). TEQ concentrations were 11,700 ppt and 5,690 ppt for the 2009 and 2006 samples, respectively; the percent TCDD in the TEQ was high for both (95.7% and 94.9%, respectively).

Sediment samples were collected from five (5) sites. Two sediment samples were collected from Sen Lake A, from the same locations sampled in 2006. The east Sen Lake sample (286A) exhibited a TEQ concentration of 2,740 ppt, which was lower than recorded in 2006 (sample 06VN052; 5,960 ppt TEQ). The proportion of TCDD in both years was almost identical (91.6% in 2009 and 91.4% in 2006). The west Sen Lake sample (287A) had a higher TEQ concentration (4,540 ppt) than the east Sen Lake sample; however the TEQ concentration was lower than a sample collected at the same location in 2006 (06VN053; 6,820 ppt TEQ). The proportion of TCDD to TEQ was greater than 90% for all samples, indicating that Agent Orange was the source of contamination. These results confirm that Sen Lake continues to be a sink for historical Agent Orange contamination at the north end of the Airport.

Two (2) sediment samples were collected along the north Airport perimeter. Sample 302A was collected from a drainage ditch for comparison with a 2006 sample, 06VN081. The 2009 sample (302A) had a TEQ concentration of 4,200 ppt, which was half the 2006 concentration (8,580 ppt). Residual Agent Orange contamination continues at this sampling location, exceeding the Vietnamese sediment guideline by 28 times (guideline= 150 ppt).

Sample 306A was collected from a ditch draining the airport to the north of the Airport near Sen Lake. The initial intention was to replicate a 2006 sampling site, 06VN042 (located between the Former Mixing and Loading and Former Storage Area). However, land change had disrupted the top meter of soil; therefore a nearby site was sampled. Sample 306A had a TEQ concentration of 674 ppt and a TCDD proportion of 79.2% indicating lower levels of contamination relative to 302A.

The West Airport Pond (Lake) was sampled in 2006 (06VN080), and exhibited a TEQ concentration of 7.14 ppt (3.35 ppt TCDD). The 2009 sample (285A), collected from the same site, exhibited higher concentrations (64 ppt TEQ; 24.2 ppt TCDD); these sediments remain below the guideline.

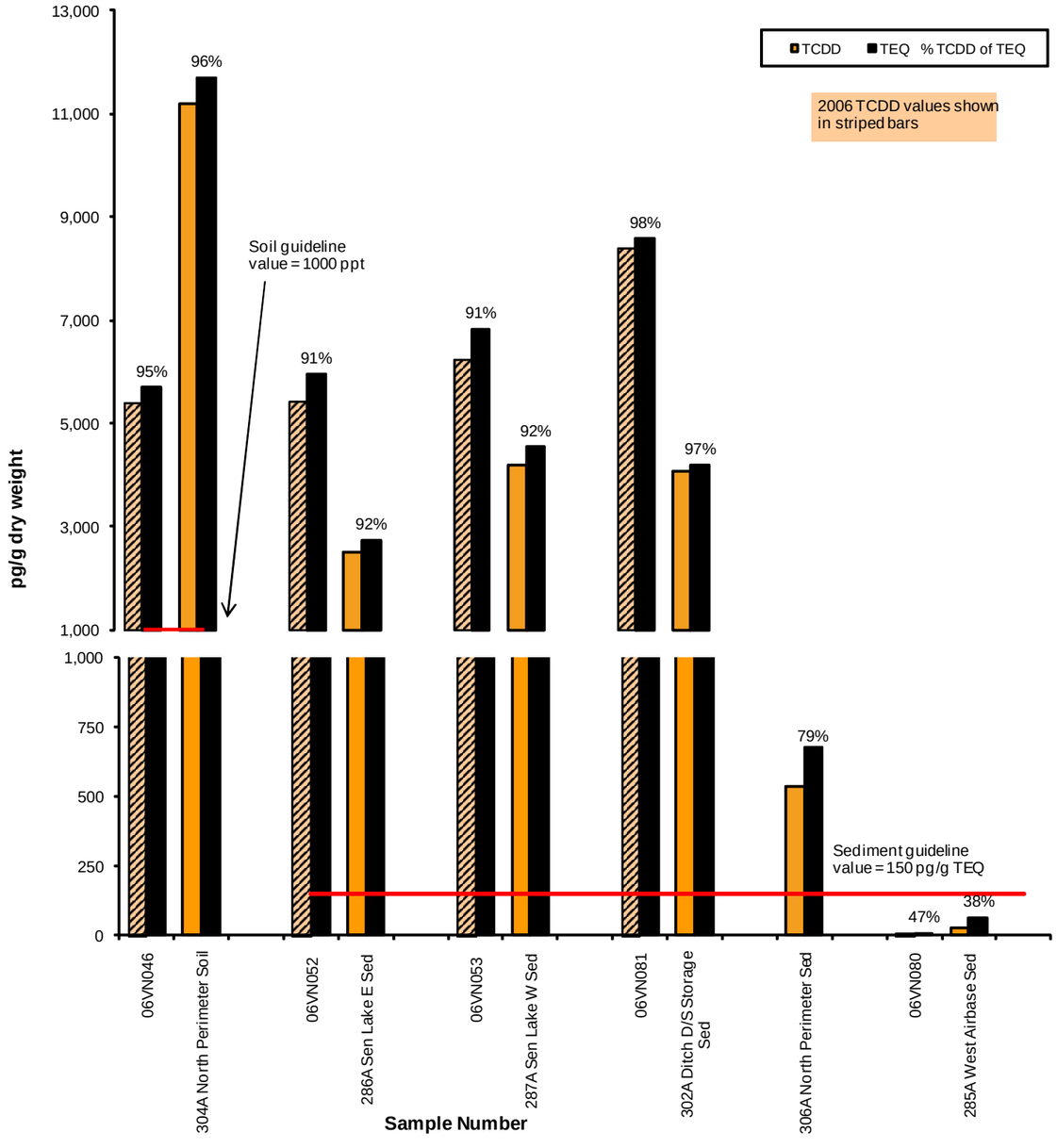
Table 3.4 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in the north Airport area soil and sediment samples (pg/g [ppt] dry weight), Da Nang Airport, Viet Nam, December 2006 and January 2009. All samples collected at the surface (0 to 10 cm).

Sample ID	Location	Media	PCDD (pg/g dry weight)						PCDF (pg/g dry weight)						TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
North Airbase																	
304A	North Base Perimeter	Soil	11200	12000	1750	3090	3320	5060	449	2350	3190	700	178	42	11700	11700	95.7
286A	Sen Lake East	Sediment	2510	2810	669	1600	4790	30000	906	1680	939	690	863	753	2730	2740	91.6
287A	Sen Lake West	Sediment	4180	4720	1120	2310	5890	32500	1480	2850	1510	817	979	834	4540	4540	92.1
302A	North Base Perimeter	Sediment	4080	4390	426	792	1010	4380	198	795	903	211	70.2	41.4	4200	4200	97.1
306A	North Base Perimeter	Sediment	534	831	481	1490	4950	29500	138	852	839	958	949	571	679	674	79.2
285A	West Airbase Lake	Sediment	24.2	82.7	112	522	2100	20500	13.7	105	129	159	151	76	61.4	64	37.8
North Airbase - Selected Sites from 2006																	
06VN046	North Base (304A)	Soil	5400	5780	1110	1800	2110	3570	333	1740	2240	502	113	57	5690	5690	94.9
06VN052	Sen Lake East (286A)	Sediment	5440	6160	1370	3340	14900	72200	1850	3550	2310	1770	2480	1940	5950	5950	91.4
06VN053	Sen Lake West (287A)	Sediment	6240	7160	1540	3190	10200	43300	2330	4370	2710	1270	1400	999	6820	6820	91.5
06VN081	North Base (302A)	Sediment	8390	8880	811	1280	1760	4280	340	1370	1480	327	153	99.7	8580	8580	97.8
06VN080	West Airbase Lake (285A)	Sediment	3.35	8.09	10	47.1	225	1790	0.991	8.29	11.3	14.9	14.4	7.47	6.92	7.14	46.9

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Non-detect ratio; peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND ("0").

Figure 3.4 **Soil and sediment sampling locations in the north of Da Nang Airport, Viet Nam, December 2006 and January 2009.**



3.1.6 Summary Discussion – Soil and Sediment

- **Figure 3.5**

Soil and sediment samples analyzed in 2009 in and around Da Nang Airport (i.e., Pacer Ivy Areas Figure 3.1, southern and central Airport Figure 3.3), generally exhibited lower levels of dioxin contamination than those collected from the north of the Airport in 2006 and 2009 (Figure 3.4). None of the twelve sediment samples taken in the southern and central Airport (208A; Lake L) exceeded the TEQ guideline of 150 ppt. Only three soil samples (all from the PISA) exceeded the guideline of 1,000 ppt (Table 3.1).

In the Hatfield/10-80 (2006) study of dioxin concentrations in Da Nang City (outside of the Airport), the highest concentration of TCDD was recorded at Site 18 in Thanh Khe District (227 pg/g TCDD; 269 pg/g TEQ). The highest concentration of TCDD recorded outside the Airport during the 2009 study was a sediment sample from east of the base at site 307A (24.8 ppt TCDD; 70.7% of the TEQ); the same site in 2005 (05VN022) exhibited a concentration of 130 ppt TCDD (68% of the TEQ). All other 2009 samples analyzed from the east, south and west of the Airport perimeter had relatively low TCDD concentrations (0.388 ppt to 13.7 ppt TCDD) and low to moderate proportions of TCDD to the TEQ concentrations (5.2% to 44.5% of the TEQ).

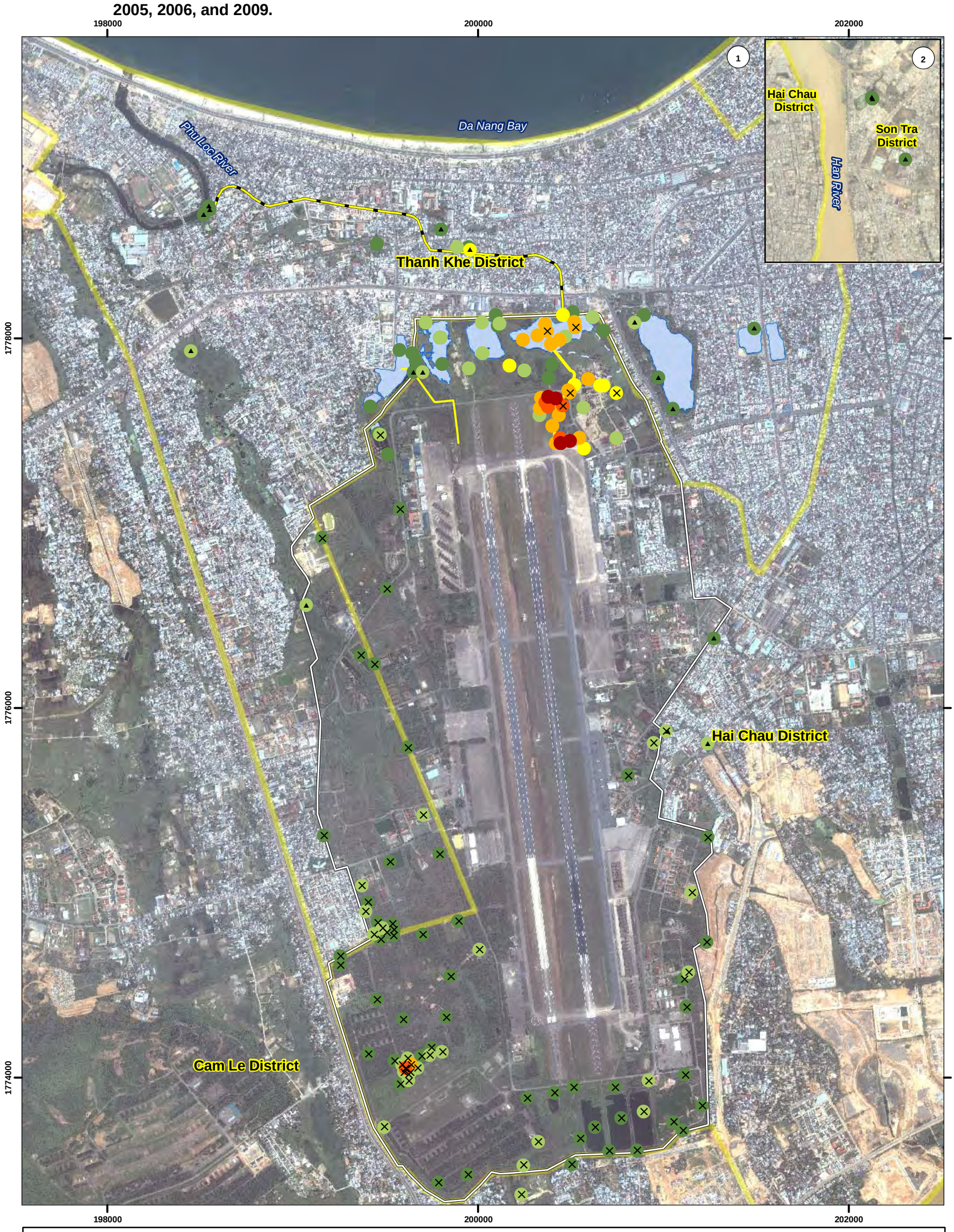
Agent Orange continues to contribute to the high concentrations of TCDD in soil and sediment samples in the north area of the Da Nang Airport (Table 3.4; Figure 3.4). Soil and sediment samples analyzed from near the Former Mixing and Loading and Former Storage Areas exhibited extremely high TCDD levels in soil in both 2006 and 2009. Site 304A exhibited the highest recorded TEQ concentrations in the north of the Airport in 2009 (11,700 ppt); this site was equivalent to site 06VB046 sampled in 2006 (5,690 ppt). It is important to note that soil samples were not collected from the Former Mixing and Loading and Storage Areas in 2009, so no comparative data between years are available. Sediment samples collected from Sen Lake also exhibit extremely high levels of TCDD (2,510 ppt and 4,180 ppt); however, these were lower than 2006 concentrations (5,440 ppt and 6,240 TCDD). The northern area of Da Nang Airport and the PISA site exceed Vietnamese and international guidelines by significant margins. Guideline levels set in Canada, the US EPA and Finland are the most conservative and were exceeded by the greatest margin.

Sediment samples taken from the West Airport Fishponds (Lakes) did not exceed the guideline (150 ppt TEQ) in either the 2009 or 2006 studies (samples 285A and 06VN080, respectively).

Soil depth profile sampling at the Pacer Ivy Storage Area (2009).

Sampling in the north Airport drainage ditch (2009).

Figure 3.5 Summary of TEQ values (pg/g dry weight) for soil and sediment samples analyzed in Da Nang, Viet Nam, 2005, 2006, and 2009.



3.2 FISH

- **Figure 3.6, Table 3.5**

Dioxin/furan concentrations in fish tissues collected from several lakes (N = 13) on Da Nang Airport and from Da Nang Bay were significantly lower than in Sen Lake. All fish tissue samples analyzed from lakes in 2009 in the south and central Airport, the West Airport Pond, and from Da Nang Bay were within Health Canada consumption guidelines (20 ppt for edible fish tissue and 22.5 ppt for crab hepatopancreas). All tissue samples from Sen Lake in 2009 continue to exceed Health Canada consumption guidelines. Results from 2009 sampling locations, and a comparison with historical studies, are discussed below.

3.2.1 South Airport

In January 2009, Tilapia were collected from Lakes D, E, F and G in the south of the Airport, while Snakehead were collected from Lake H. All muscle tissue samples (wet weight) for both species had very low TEQ concentrations (< 1 ppt). Fat tissue taken from a Tilapia composite (6) from Lake D had a TEQ concentration of 25.1 ppt and a proportion of TCCD to the TEQ concentration of 95.6%, indicating Agent Orange as the source of the contamination. Liver taken from the same Tilapia composite had a TEQ of 3.49 ppt. A liver sample was also analyzed from a Snakehead (1 fish) in Lake H; this sample had a TEQ of 12.4 ppt (54.5% of the TEQ).

3.2.2 Central Airport

Fish muscle, fat and egg tissue were sampled from Lakes J, L and M in the central Airport in 2009. In Lake J, a composite of Tilapia (n=6) and a composite of Grass Carp (n=2) were analyzed; in Lakes L and M, composites of Tilapia (n=6) were analyzed. As seen with fish collected from the south end of the Airport, all muscle samples had TEQ concentrations <1 ppt. Fat tissue samples for Grass Carp in Lake J exhibited a similar TEQ (4.03 ppt) to Tilapia eggs sampled in Lake J (5.63 ppt) and fat tissue sampled in Lake L (5.64 ppt). The highest proportion of TCDD to TEQ concentration was in the Lake L fat tissue sample (88.9%); all other samples had TCDD proportions ranging between 0% (ND) and 68.8%.

3.2.3 North Airport

Sen Lake A

Dioxin levels and Total TEQ in fish fat from Sen Lake A continue to be the highest recorded in Viet Nam to date. In 2009, Tilapia fat taken from a composite of 6 large Tilapia (283A; average weight 439.8 g) had higher contaminant concentrations (8,350 ppt TEQ; 7,920 ppt TCDD) than similar-sized fish sampled in 2006. Muscle (84 ppt TEQ), egg (1,230 ppt TEQ) and liver (1,490 ppt TEQ) tissues analyzed from the composite of large Tilapia in Sen Lake all exceeded Health Canada guidelines. A composite of 6 small Tilapia (average weight 149.4 g, which was similar to fish sampled in 2006) was also taken from Sen Lake. Fat tissue samples from the small fish had a lower TEQ (2,680 ppt) with similar TCDD proportions (95.5%). Muscle (39.2 ppt TEQ) and liver (682 ppt TEQ)

tissues also exceeded guidelines and represent significant levels of contamination in fish tissues from Sen Lake. In 2006, Tilapia fat (06VN216; 3,120 ppt TEQ) and muscle (06VN217; 34.5 ppt TEQ) from Sen Lake were found to be significantly contaminated with dioxins and furans; in both fat and muscle tissues, TCDD (3,000 ppt and 33.2 ppt, respectively) accounted for 96% of the total TEQ concentration, confirming Agent Orange was the source of the contamination (Hatfield/Office 33 2007). In both 2006 and 2009 samples, over 90% of the TEQ was attributed to TCDD.

Lake B, Lake C and Xuan Lake (2006)

In 2006, fish samples were collected from Lake B, Lake C and Xuan Lake west of Sen Lake A. TEQs in Tilapia fat from Lake B (72.6 ppt) exceeded Canadian guidelines; TCDD comprised 94% of TEQ, indicating Agent Orange was the contaminant source. Other muscle and fat tissues analyzed in 2006 from Tilapia muscle, carp fat and muscle, and snakehead liver and muscle had TCDD and TEQ concentrations less than the 20 ppt TEQ guideline.

West Airport Ponds (Lakes)

The TEQ for Tilapia muscle analyzed in 2009 from a composite of 6 fish (0.464 ppt; 290A) was similar to levels in 2006 (1.38 ppt; 06VN203); liver samples had a higher TEQ (4.24 ppt). In 2006, Tilapia fat tissues had concentrations exceeding Canadian guidelines (34.5 TEQ; 33.2 TCDD); fat tissues from the West Airport Ponds were not analyzed in 2009, as sufficient fat samples were not available. Both the liver and muscle tissue samples were within the acceptable limit of Health Canada consumption guidelines in 2009.

3.2.4 Da Nang Bay

The hepatopancreas of a crab sample taken from Da Nang Bay exhibited a low TEQ concentration of 1.42 ppt (sample 333A).

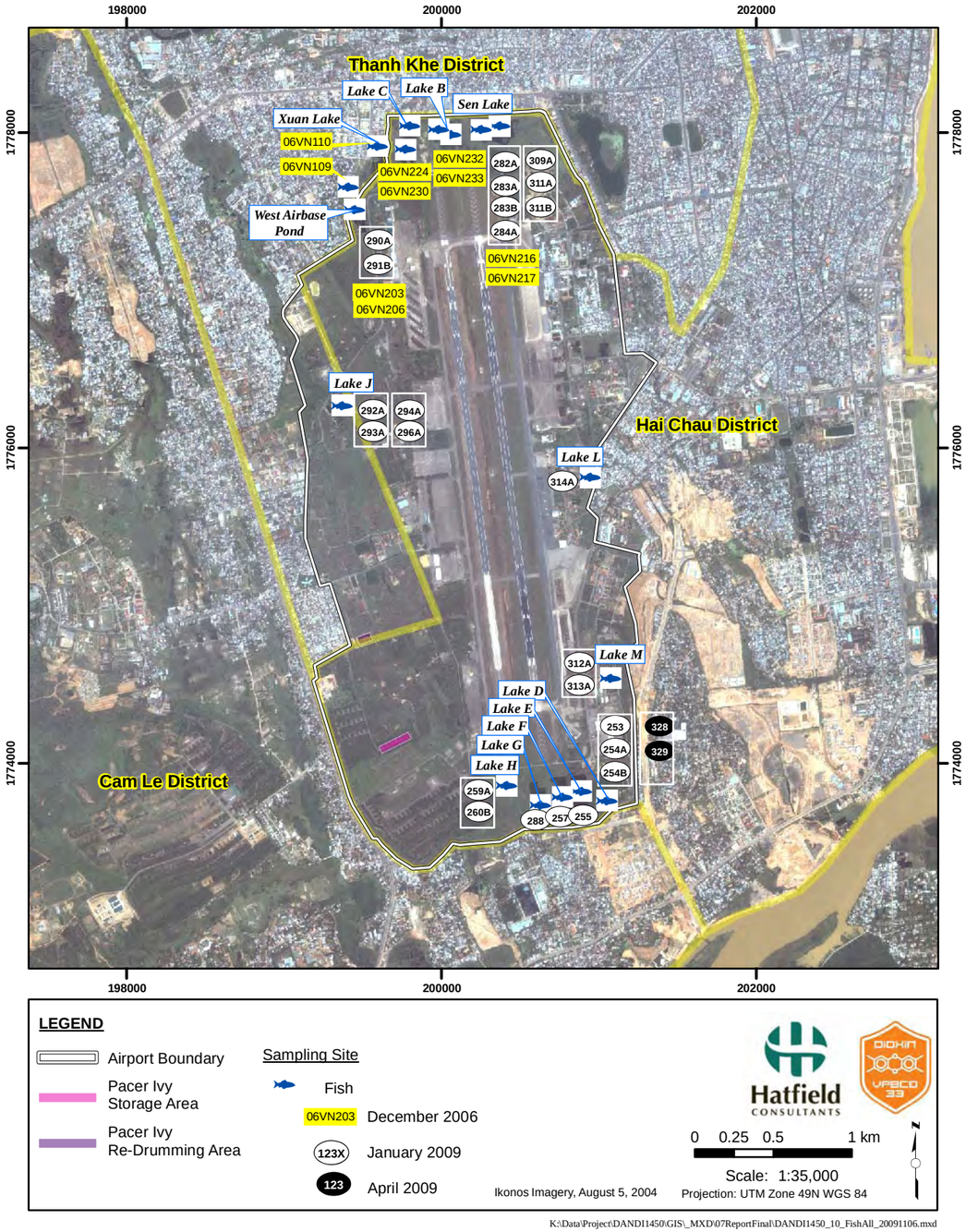
A composite of 6 Tilapia from Lake L for analysis (2009).

Table 3.5 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in fish tissue samples (pg/g [ppt] wet weight), Da Nang, Viet Nam, January 2009 and April 2009.

Sample ID	Location	Fish Species	Tissue Type	PCDD (pg/g wet weight)						PCDF (pg/g wet weight)						TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
				2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
Da Nang Bay																		
333A*	Da Nang Bay	Crab	Hepatopancreas	NDR 1.31	8.65	7.67	28.9	14.8	20.7	2.38	8.48	7.84	3.99	1.28	< 0.424	1.46	1.42	NC
South Airport																		
253A	Lake D	Tilapia	Muscle	0.551	0.551	< 0.0495	< 0.0495	0.05	0.234	0.145	0.145	0.075	< 0.0495	< 0.0495	< 0.0495	0.635	0.62	88.9
254A	Lake D	Tilapia	Fat	24	25.2	< 0.456	1.12	2.69	21.7	6.73	9.79	2.77	0.854	1.23	< 0.758	25.4	25.1	95.6
254B	Lake D	Tilapia	Liver	2.99	3.28	0.274	< 0.214	< 0.278	2.01	1.05	1.05	0.4	< 0.277	< 0.315	< 0.497	3.57	3.49	85.7
328AB*	Lake D	Tilapia	Muscle	NDR 0.149	< 0.0479	< 0.0479	< 0.0479	< 0.0479	0.172	0.056	0.056	< 0.0479	< 0.0479	< 0.0479	0.055	0.081	0.0758	NC
329A*	Lake D	Tilapia	Fat	17.7	18.8	< 0.472	< 0.472	< 0.472	5.11	9.49	14.5	1.95	< 0.472	< 0.472	< 0.472	19.7	19.5	90.8
255A	Lake E	Tilapia	Muscle	NDR 0.148	< 0.0482	< 0.0482	< 0.0482	< 0.0482	0.17	0.113	0.113	< 0.0482	< 0.0482	< 0.0482	< 0.0482	0.0815	0.0762	0.0
257A	Lake F	Tilapia	Muscle	NDR 0.069	< 0.0497	< 0.0497	< 0.0497	< 0.0497	0.225	0.134	0.134	< 0.0497	< 0.0497	< 0.0497	< 0.0497	0.084	0.0786	0.0
288A	Lake G	Tilapia	Muscle	NDR 0.111	< 0.0495	< 0.0495	0.058	< 0.0495	0.29	0.119	0.119	0.065	< 0.0495	0.057	0.093	0.107	0.094	0.0
259A	Lake H	Snake Head (1 fish)	Muscle	NDR 0.511	< 0.0492	< 0.0492	0.431	0.67	2.19	< 0.0492	< 0.0492	< 0.0492	0.059	< 0.0492	0.096	0.131	0.126	0.0
260B	Lake H	Snake Head (1 fish)	Liver	6.96	7.32	3	13.6	52	237	< 0.254	< 0.254	2.13	2.69	0.868	< 0.298	13.1	12.8	54.4
Central Airport																		
292A	Lake J	Grass Carp (2 fish)	Muscle	NDR 0.088	0.055	< 0.0472	< 0.0472	0.147	1.04	0.133	0.411	0.198	< 0.0472	< 0.0472	< 0.0472	0.106	0.0907	0.0
293A	Lake J	Grass Carp (2 fish)	Fat	1.32	5.19	1.25	3.81	2.22	NDR 13.6	7.96	30.7	12.9	2.47	< 0.989	< 1.22	4.63	4.03	32.8
294A	Lake J	Tilapia	Muscle	NDR 0.111	< 0.0484	< 0.0484	< 0.0484	0.315	3.26	0.167	0.167	< 0.0484	< 0.0484	< 0.0484	< 0.0484	0.0836	0.0789	0.0
296A	Lake J	Tilapia	Eggs	3.59	3.77	0.613	1.12	3.9	25.8	11.9	12.7	0.708	< 0.0963	0.367	NDR 0.255	5.77	5.63	63.8
312A	Lake M	Tilapia	Muscle	0.161	0.161	< 0.0495	< 0.0495	0.219	2.08	0.384	0.384	0.081	< 0.0495	< 0.0495	0.113	0.25	0.234	68.8
313A	Lake M	Tilapia	Fat	3.79	3.79	< 0.429	0.821	6.31	47.2	10.5	11.9	2.84	< 0.659	1.07	NDR 0.823	5.82	5.64	67.2
314A	Lake L	Tilapia	Muscle	0.755	0.755	< 0.0495	< 0.0495	< 0.0495	NDR 0.138	0.394	0.394	0.055	< 0.0495	< 0.0495	< 0.0495	0.861	0.849	88.9
North Airport																		
282A	Sen Lake A	Tilapia (large comp.)	Muscle	84	84	0.251	< 0.0479	< 0.0479	0.382	39.9	39.9	0.186	< 0.0479	< 0.0479	< 0.0479	88.3	88.2	95.2
283A	Sen Lake A	Tilapia (large comp.)	Fat	7920	7940	43.7	13.7	15.2	29.8	3810	3830	18.6	< 2.16	< 2.90	< 1.80	8350	8350	94.9
283B	Sen Lake A	Tilapia (large comp.)	Liver	1490	1500	8.72	5.04	9.86	37.9	400	403	4	0.286	< 0.167	< 0.396	1540	1540	96.8
284A	Sen Lake A	Tilapia (large comp.)	Eggs	1230	1250	4.73	1.49	2.48	12.4	572	578	3.35	0.129	0.257	NDR 0.119	1290	1290	95.3
309A	Sen Lake A	Tilapia (small comp.)	Muscle	39.2	39.2	< 0.0499	< 0.0499	< 0.0499	0.454	16.6	16.6	< 0.0499	< 0.0499	< 0.0499	< 0.0499	40.9	40.9	95.8
311A	Sen Lake A	Tilapia (small comp.)	Fat	2560	2570	11.2	< 3.28	33.2	NDR 107	1230	1230	13.4	< 2.93	< 4.61	< 3.21	2690	2680	95.5
311B	Sen Lake A	Tilapia (small comp.)	Liver	682	685	6.27	4.01	9.53	39.7	187	192	5.53	< 0.387	1.7	NDR 0.613	704	703	97.0
290A	West Airport Lake	Tilapia	Muscle	0.359	0.359	< 0.0477	< 0.0477	0.132	0.671	0.373	0.373	0.084	< 0.0477	< 0.0477	< 0.0477	0.481	0.464	77.4
291B	West Airport Lake	Tilapia	Liver	3.48	3.48	< 0.431	1.36	2.41	14.8	2.73	2.74	3.32	< 0.401	0.682	< 0.676	4.46	4.24	82.1
2006 North Airport																		
06VN216	Sen Lake	Tilapia	Fat	3000	3000	17.5	7.74	10.9	29	1060	1080	19.6	3.96	1.99	1.04	3120	3120	96
06VN217	Sen Lake	Tilapia	Muscle	33.2	33.2	0.12	< 0.0497	< 0.0497	0.464	11.6	11.7	0.069	0.055	< 0.0497	< 0.0497	34.5	34.5	96
06VN232	Lake B	Nile Tilapia	Fish Fat	68.4	69.7	1.69	0.631	0.855	3.36	27.1	34.6	3.32	< 0.114	< 0.114	0.2	72.6	72.6	94
06VN233	Lake B	Nile Tilapia	Fish Muscle	0.898	0.898	< 0.0501	< 0.0501	0.072	0.167	0.349	0.349	0.067	< 0.0501	< 0.0501	< 0.0501	0.98	0.967	93
06VN224	Lake C	Carp	Fish Fat	6.61	8.81	1.54	0.749	1.19	4.08	6.01	23	7.35	0.753	< 0.0517	NDR 0.058	8.47	8.22	80
06VN230	Lake C	Carp	Fish Muscle	0.163	0.163	< 0.0500	< 0.0500	< 0.0500	NDR 0.067	0.056	0.056	< 0.0500	< 0.0500	< 0.0500	< 0.0500	0.226	0.22	74
06VN206	W Airport Pond	Tilapia	Fat	45.8	50.2	6.42	6.9	5.91	13.7	36.1	56.9	22	2.41	0.305	NDR 0.118	57.5	56.1	82
06VN203	W Airport Pond	Tilapia	Muscle	1.14	1.14	0.1	< 0.0492	< 0.0492	0.354	0.82	1.36	0.231	< 0.0492	< 0.0492	NDR 0.052	1.42	1.38	83
06VN209	W Airport Pond	Catfish	Fish Fat	33.6	34.7	8.19	32.8	63	112	7.43	13.9	34.8	28.6	10.6	0.89	56.5	53	63
06VN210	W Airport Pond	Catfish	Fish Muscle	0.943	0.943	0.198	0.599	1.24	2.3	0.155	0.155	0.525	0.538	0.196	0.091	1.47	1.39	68
06VN110	Xuan Lake	Snakehead Murrell	Fish Liver	3.21	3.21	1.51	5.9	21	58.5	0.578	0.578	2.61	1.81	0.881	0.173	6.75	6.37	50
06VN109	Xuan Lake	Snakehead Murrell	Fish Muscle	0.171	0.171	< 0.0480	< 0.0480	< 0.0480	0.178	< 0.0480	< 0.0480	< 0.0480	< 0.0480	< 0.0480	< 0.0480	0.228	0.223	77

NC= Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).
ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.
NDR = Non-detect ratio; peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND ("0").
Large comp. = A composite sample of the 6 largest Tilapia collected
Small comp. = A composite sample of the 6 smallest Tilapia collected
*= Samples collected in April 2009. All other samples collected in January 2009.

Figure 3.6 Fish sampling locations and TCDD and TEQ values in fish tissues, Da Nang Airport, Viet Nam, December 2006 and 2009.



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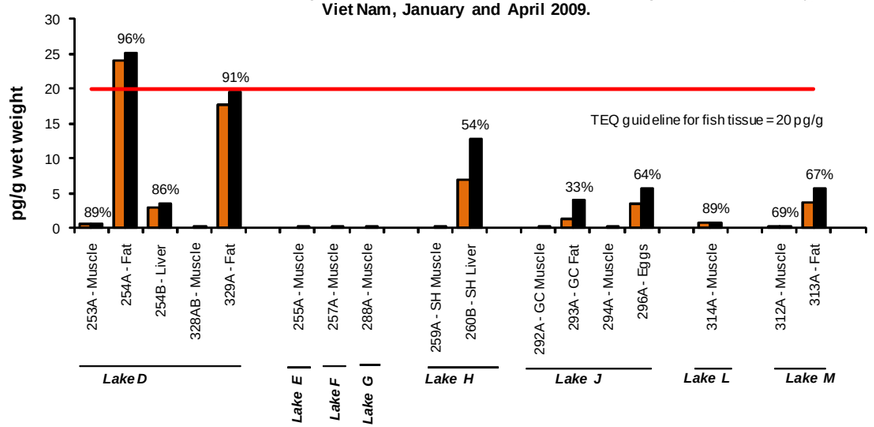
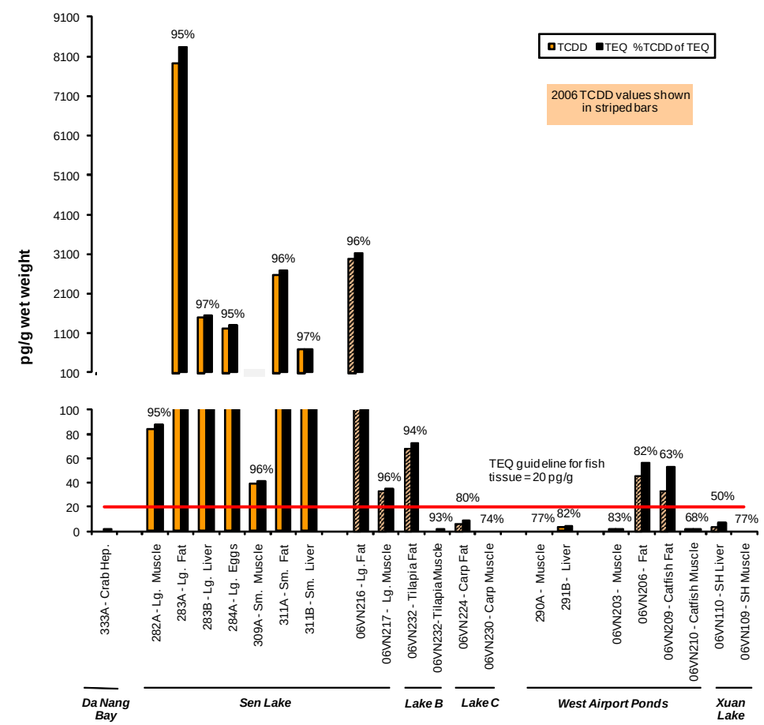
TCDD (pg/g wet weight), TEQ (pg/g) and Percent TCDD of TEQ in Fish Samples (Tilapia, unless otherwise indicated) Collected from the Central and South Airport Areas, Da Nang, Viet Nam, January and April 2009.



Abbreviations: SH = Snakehead; GC = Grass Carp
No % TCDD of TEQ is shown when 2,3,7,8-TCDD concentrations were NDR (peak detected, but did not meet quantification criteria).

TCDD (pg/g wet weight), TEQ (pg/g) and Percent TCDD in TEQ in Tilapia and Other Fish Samples Collected from the North Airport and a Crab Sample Collected from Da Nang Bay North of the Airport, Da Nang, Viet Nam, 2006 and 2009.



No % TCDD of TEQ is shown when 2,3,7,8-TCDD concentrations were NDR (peak detected, but did not meet quantification criteria).
SH = Snakehead.

3.2.5 Summary of Fish Data

Sen Lake A continues to have the highest level of dioxin contamination in bottom sediments of all water bodies sampled, both inside and outside of Da Nang Airport. Consequently, fish captured in Sen Lake also contained the highest level of TCDD recorded in biological tissues (fat 7,920 ppt; liver 1,490 ppt; eggs 1,230 ppt; and muscle 84 ppt; Table 3.5). Fish sampled from the West Airport Ponds in the north of the Airport had comparatively low TEQ concentrations in 2009 (4.24 ppt for liver and 0.464 ppt for muscle). High levels were recorded in fish fat from the West Airport Ponds in 2006; no fish fat samples were collected at this location in 2009.

Health Canada has specific guidelines for consumable tissues. If, for example, fat tissue exceeds 20 ppt TEQ, an assessment of consumption and probable restrictions on intake would be determined for the species of fish involved. Given the data presented above, Sen Lake should continue to be assigned total fishing/consumption bans.

Fish sampled from lakes in the Central Airport (J, M and L) all had muscle TEQ concentrations <1 ppt. Fat and egg samples exhibited low TEQ concentrations ranging from 4.03 ppt for Grass Carp fat to 5.64 ppt for Tilapia fat; Tilapia eggs in Lake J had a TEQ of 5.63 ppt.

In the southern Airport lakes, fish tissue exhibited slightly higher TEQ concentrations than fish tissue analyzed in the central Airport. Muscle TEQ concentrations were low (<1 ppt) in all samples; however, fat and liver concentrations were higher, ranging from 3.57 ppt in Tilapia liver to 25.4 ppt in Tilapia fat (both from Lake D). Snakehead liver samples analyzed from Lake H had a slightly higher TEQ concentration (12.8 ppt) than the Tilapia samples from Lake D.

North of the Airport in Da Nang Bay, a sample taken from crab hepatopancreas tissue indicates that contaminant exposure is low (TEQ 1.42 ppt). More samples are required before definitive conclusions may be reached, as the crab sampled in 2009 were of small size.

Dai *et al*. (1994b) and Cau *et al*. (1994) reported that by 1998, dioxins had decreased significantly in southern Viet Nam and levels in foodstuffs were considered comparable to those for other nations. However, both authors offered the generalization that residual dioxin contamination nonetheless remained a threat to human health in Viet Nam. Hatfield and 10-80 (2000) also confirmed high TCDD levels in fish fat from Aluoi District, in former bomb craters used as aquaculture ponds.

Our data confirm extremely elevated levels of TCDD for fish from Sen Lake, but generally lower levels in all other Da Nang Airport Lakes.

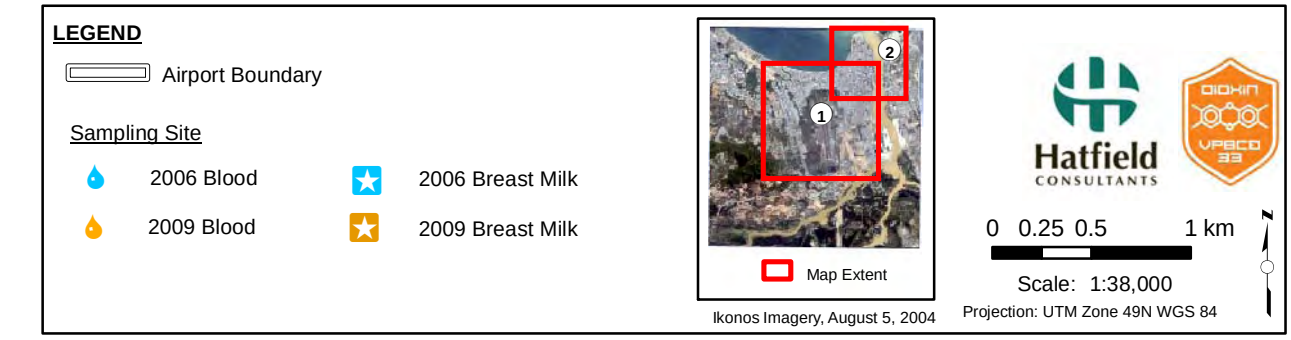
3.3 HUMAN BLOOD

- **Figure 3.7**

In 2009, dioxins and furans were analyzed from a total of 111 residents of Da Nang (persons living to the east, south and west of the Airport). Blood data were obtained from random samples of residents in Anh Khe Ward, Thanh Khe District (n=15) west of the Airport; Khue Trung Ward, Cam Le District (n=45) south of the Airport; and Thuan Tay Ward, Hai Chau District (n=34) east of the Airport. In addition, several highly exposed residents from the 2006 study were retested in January 2009. These included 10 of the 11 Sen Lake Workers and 5 of the 11 West Airbase Workers, plus two additional male donors in 2009. In addition, 2006 results from Thuan Phuoc Ward, Hai Chau District (n=12) and Chinh Gian Ward, Thanh Khe District (n=16) are included in the discussion of blood data.

Tables 3.6 through 3.12, and Figures 3.8 to 3.14, summarize dioxin/furan concentrations in human blood samples collected from various locations in the vicinity of Da Nang Airport. Unless otherwise indicated, all blood data are presented on a lipid basis.

Figure 3.7 Overview of blood and breast milk sampling areas for 2006 and 2009, Da Nang Airport, Viet Nam.



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3.3.1 Anh Khe Ward, Thanh Khe District

- **Table 3.6; Figure 3.8**

Anh Khe Ward in Thanh Khe District is located immediately west of the Pacer Ivy site on the Da Nang Airport. Dioxins and furans were present in all human blood samples analyzed from this ward. The two highest concentrations of TCDD measured in blood samples were 251 pg/g and 220 pg/g; TEQs were 326 pg/g and 302 pg/g, respectively. TCDD represented 77% and 73% of the TEQ for these two samples, respectively. The highest blood sample from a female (09VNB195; aged 44 years) exhibited a TCDD concentration of 43.0 pg/g and a TEQ of 78.6 pg/g. The percent TCDD of TEQ in this case was 55%.

TCDD concentrations in the remaining samples for males and females aged 21 to 51 ranged from 5.94 to 41.8 pg/g; TEQs ranged from 39.2 pg/g to 103 pg/g. The percentage of TCDD in the TEQ was relatively low (15 to 71%), indicating that sources other than Agent Orange may be influencing the total TEQ of individuals sampled.

Table 3.6 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) from residents of Anh Khe Ward, Thanh Khe District, Da Nang, Viet Nam, April 2009.

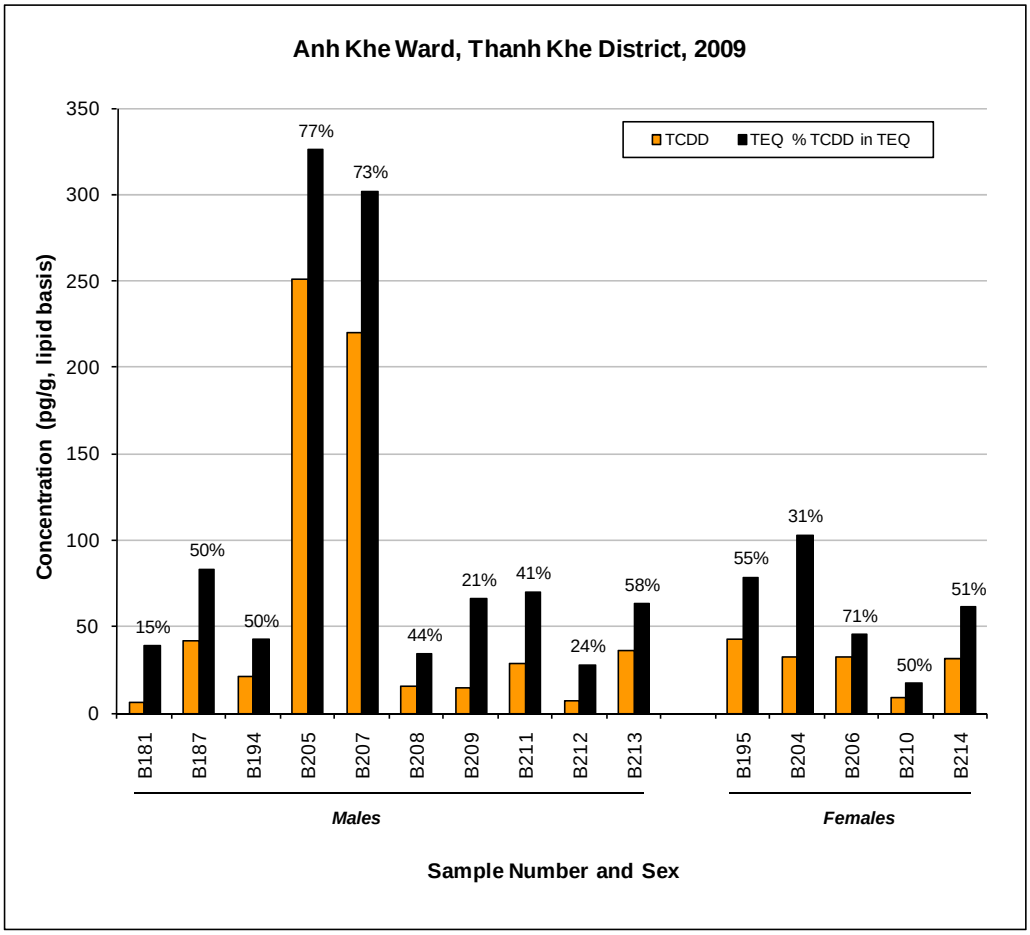
Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
09VNB-181	M	45	5.94	6	15	60.6	61.2	571	< 2.16	< 2.16	15.6	62.4	55.8	NDR 3.42	0.17	42.3	39.2	15
09VNB-187	M	22	41.8	42	18.6	72.7	56.5	532	2.59	< 2.50	25	59.8	46.9	NDR 3.31	0.12	88.1	83.2	50
09VNB-194	M	51	21.4	21.4	10.4	35.8	19.9	231	< 2.04	< 2.04	12.9	25.9	12.4	NDR 2.29	0.2	45	42.4	50
09VNB-195	F	44	43	42.8	15	61.2	72.1	618	< 2.72	< 2.72	19	71.4	41.5	< 2.72	0.15	82.4	78.6	55
09VNB-204	F	50	32.3	32.3	38.2	137	168	1300	2.36	4.51	29.1	81.2	45.8	2.57	0.29	108	103	31
09VNB-205	M	44	251	251	34.9	146	93.6	1410	4.79	4.74	42.7	119	35.4	< 1.42	0.23	334	326	77
09VNB-206	F	33	32	32	6.05	22.2	34.6	325	1.61	1.68	7.06	20.2	16.5	< 1.21	0.3	46.6	45.2	71
09VNB-207	M	42	220	220	38.8	141	239	1320	9.49	9.18	48	111	57.1	< 3.57	0.098	310	302	73
09VNB-208	M	21	15.1	15.4	8.87	30.8	27.8	344	< 1.95	< 1.95	11.2	30.2	20.7	< 1.95	0.17	36.4	34.2	44
09VNB-209	M	23	14.1	13.9	22.8	91.9	160	896	2.62	2.78	23.4	107	81.8	2.73	0.18	70.3	66.3	21
09VNB-210	F	37	8.51	8.41	3.46	10.9	18.8	111	1.93	1.98	6.43	13.4	9.4	< 1.63	0.2	18.1	16.9	50
09VNB-211	M	42	29	28.8	18	75	55.8	449	3.06	3	27.6	63	45.6	< 2.10	0.17	75	70.1	41
09VNB-212	M	34	6.62	6.83	7.36	31	38.4	851	< 1.79	< 1.79	16.8	54.1	52	3.94	0.19	31	28.1	24
09VNB-213	M	42	36.4	36.3	11.7	50.4	60.9	379	2.15	2.46	14.1	41.2	26.5	< 2.09	0.16	65.9	63.1	58
09VNB-214	F	37	31.3	31.4	11.4	49.8	73.4	447	< 3.23	3.49	20.1	63.8	79.5	< 3.23	0.11	64.2	61	51

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND.

Lipid calculations based on "independent" or "factored" analysis (see Appendix A1).

Figure 3.8 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Anh Khe Ward, Thanh Khe District, Da Nang, Viet Nam, April 2009.



The percentage of TCDD present in the TEQ is given above each bar.

3.3.2 Khue Trung Ward, Cam Le District

- **Table 3.7, Figure 3.9**

Khue Trung Ward of Cam Le District is located immediately south of the Da Nang Airport. In all blood samples analyzed, dioxin and furan concentrations were low or not quantified (non-detected or NDR - peak detected but did not meet quantification criteria). The maximum TCDD level was 15 pg/g; the highest TEQ was 104 pg/g. Other dioxin congeners, such as penta- and hexa- dioxins and furans, contributed to the TEQ in all samples. The maximum contribution of TCDD in the TEQ was 39% (09VNB124), which corresponded to one of the highest TCDD concentrations (14.7 pg/g; TEQ = 37.5 pg/g). The highest TCDD concentration (09VNB139, 15.0 pg/g TCDD; TEQ = 72.6 pg/g) only represented 21% of the TEQ. These data suggest that the influence of contamination from the Da Nang Airport does not extend to residents living south of the Airport in Cam Le District, and that other sources of dioxin are the main contributors to the total TEQ.

Table 3.7 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) from residents of Khue Trung Ward, Cam Le District, Da Nang, Viet Nam, April 2009.

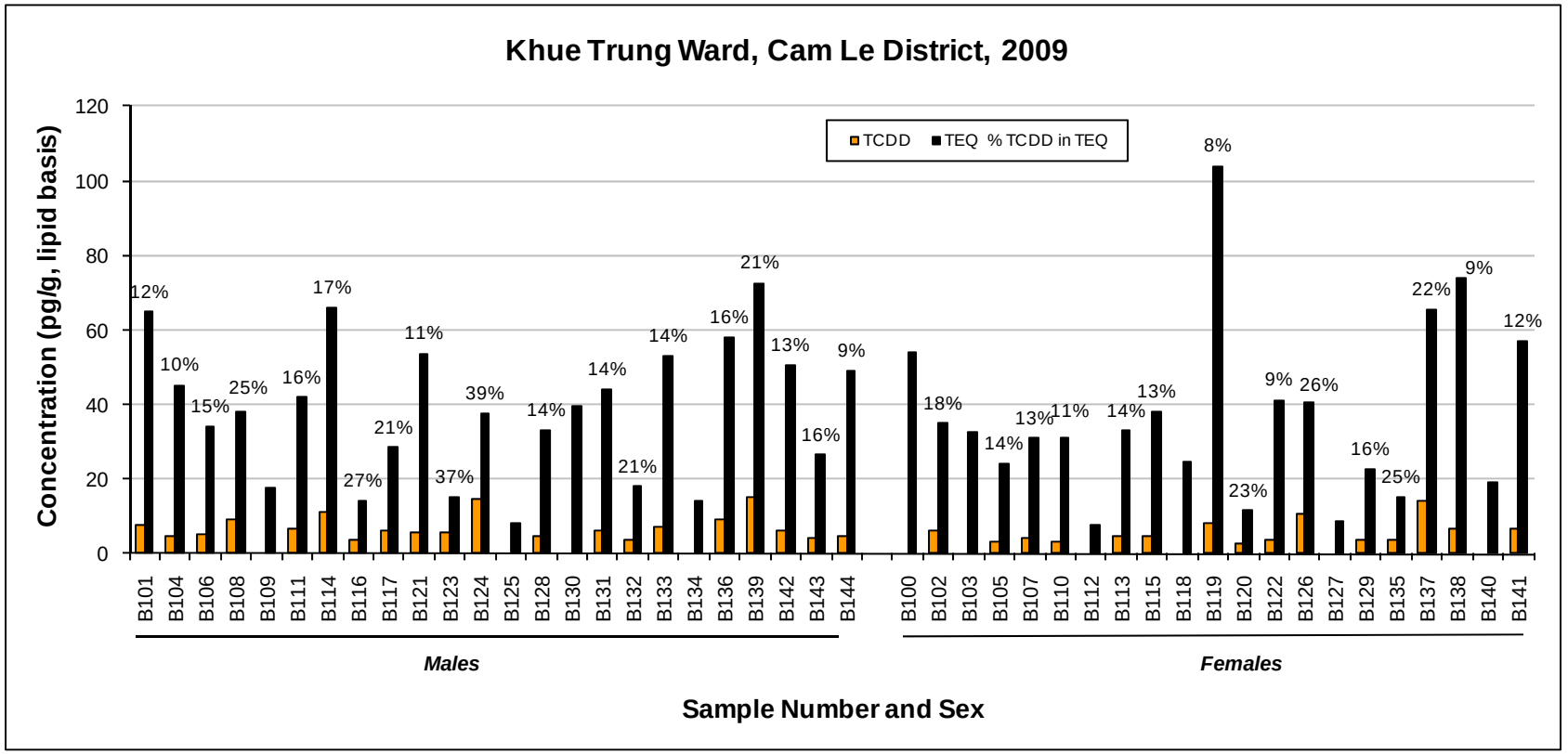
Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
09VNB-100	F	38	< 12.3	< 12.3	21.5	54.9	< 12.3	2650	< 12.3	113	< 12.3	129	141	NDR 15.8	0.12	54.7	53.9	-
09VNB-101	M	39	7.55	7.62	< 2.77	99.8	132	1790	< 2.77	2.77	25.6	132	81.1	NDR 3.60	0.14	69.6	64.8	12
09VNB-102	F	56	6.28	6.06	11	37.5	82.1	551	< 1.82	< 1.82	14.9	74.9	55.1	NDR 1.87	0.18	37.8	34.9	18
09VNB-103	F	42	NDR 4.21	< 2.49	12.8	51.7	87.4	740	< 2.49	< 2.49	14.7	70.8	61.2	3.76	0.16	35.7	32.8	-
09VNB-104	M	44	4.74	4.59	14.3	75.5	97.4	1020	2.24	2.04	< 1.68	156	163	7.7	0.2	45.3	45.3	10
09VNB-105	F	37	3.47	3.65	7.31	27.4	47.5	587	< 2.01	< 2.01	12.2	56.7	49.9	3.84	0.16	26.6	24.2	14
09VNB-106	M	50	5.26	5.44	11.3	39.9	34.9	580	1.72	1.81	17.2	70.3	47.6	< 1.50	0.22	37.5	34.1	15
09VNB-107	F	52	4.14	4.02	10.9	32.6	30.1	393	< 1.33	< 3.34	15.3	69.9	49.8	< 1.33	0.25	33.9	30.9	13
09VNB-108	M	23	9.29	9.41	13.5	48.8	42.9	412	< 2.18	< 2.18	16.5	42.3	28.8	< 2.18	0.17	41.2	37.9	25
09VNB-109	M	47	NDR 6.88	< 1.85	11.8	24	21.7	342	2.99	9.05	< 1.49	13.1	2.71	NDR 4.79	0.22	17.7	17.7	-
09VNB-110	F	45	3.26	3.3	8.24	63.9	180	1120	NDR 1.40	< 1.40	12.8	68.8	48.6	< 1.40	0.24	33.3	31	11
09VNB-111	M	22	6.87	6.51	17.4	76.7	68	1070	< 2.75	< 2.75	< 2.75	78.1	62.9	11.6	0.14	42	41.9	16
09VNB-112	F	37	NDR 1.80	< 1.65	3.5	9.5	17.5	206	< 1.65	< 1.65	< 1.65	15	12.5	1.75	0.2	7.89	7.75	-
09VNB-113	F	28	4.67	4.42	11.4	29	32.2	482	< 2.46	< 2.46	17	68.8	66.3	NDR 4.10	0.16	36.3	32.9	14
09VNB-114	M	41	11.2	11.2	20.7	68	51.4	554	2.48	2.36	27.2	167	100	4.61	0.17	71.4	66	17
09VNB-115	F	56	4.9	4.96	12.7	52.4	55.7	522	< 1.76	< 1.76	19.8	79.4	56.8	< 1.76	0.18	42	38.2	13
09VNB-116	M	23	3.87	3.87	< 2.72	6.59	35.7	489	NDR 2.88	< 2.72	< 2.72	63.6	36.6	NDR 4.37	0.12	14.5	14.3	27
09VNB-117	M	31	6.12	6.12	< 2.51	41	68.3	640	< 2.51	< 2.51	19.7	91.4	61.8	< 2.51	0.16	32.4	28.5	21
09VNB-118	F	34	< 2.59	< 2.59	12.6	37.6	108	581	< 2.59	< 2.59	< 2.59	46.4	30.7	3.77	0.13	24.9	24.7	-
09VNB-119	F	30	8.44	8.44	30.3	233	326	2680	8.17	8.17	46.9	214	166	11.3	0.11	113	104	8
09VNB-120	F	33	2.61	2.61	3.75	15.1	35.2	484	< 1.67	< 1.67	2.34	19	44.8	NDR 3.70	0.19	11.6	11.5	23
09VNB-121	M	38	5.77	5.77	17.7	85.7	80.5	596	4.26	4.26	23.7	126	78.1	NDR 2.22	0.21	58.4	53.7	11
09VNB-122	F	39	3.71	3.71	12	33.9	65.4	730	< 2.53	< 2.53	22.1	134	73.6	NDR 2.89	0.17	45.6	41.3	9
09VNB-123	M	20	5.61	5.61	< 2.24	< 2.24	37.2	640	< 2.24	< 2.24	< 2.24	64.5	49.6	< 3.30	0.14	15.4	15.3	37
09VNB-124	M	32	14.7	14.7	< 1.86	48.4	49.6	513	< 1.86	< 1.86	21.8	88.2	62.2	NDR 3.22	0.18	41.8	37.5	39
09VNB-125	M	20	NDR 4.02	< 1.34	< 1.34	11.9	19.2	294	< 1.34	< 1.34	10.1	17	19.9	< 1.34	0.25	10.1	8.17	-
09VNB-126	F	46	10.5	10.5	10.7	47.5	62.6	528	2.38	2.38	15.6	82	58.8	2.72	0.18	43.6	40.6	26
09VNB-127	F	43	< 1.66	< 1.66	< 1.66	4.42	43.2	502	< 1.66	< 1.66	4.77	34.6	73.3	NDR 3.11	0.2	9.62	8.75	-
09VNB-128	M	41	4.62	4.62	10.4	46.3	57.4	695	2.69	2.69	17.1	67	47.7	4.62	0.2	36.4	33.1	14
09VNB-129	F	39	3.66	3.66	7.1	30.9	42.9	440	< 1.75	< 1.75	10.4	44.9	40.7	2.83	0.19	24.7	22.7	16
09VNB-130	M	40	NDR 5.27	< 2.07	14.1	84.1	98.6	848	2.95	2.95	24.3	66.6	37.8	NDR 4.08	0.16	44.2	39.4	-
09VNB-131	M	30	6.36	6.36	18.4	53.5	40.3	664	< 1.76	< 1.76	19.6	69.1	38.6	2.74	0.18	47.9	44	14
09VNB-132	M	18	3.83	3.4	< 2.81	26.1	23	414	< 2.81	< 2.81	14.5	47.7	< 2.81	< 2.81	0.12	20.9	18	21
09VNB-133	M	43	7.32	7.23	18.3	61.7	35.6	531	< 1.58	< 1.58	29.3	112	95.7	NDR 4.35	0.21	58.6	53.1	14
09VNB-134	M	28	NDR 4.08	< 2.70	< 2.70	11.8	32.5	508	3.6	3.46	15.2	40.8	33.9	< 2.70	0.15	17.3	14.3	-
09VNB-135	F	37	3.79	3.64	< 3.02	30.2	< 3.02	723	NDR 3.22	< 3.02	< 3.02	50.9	49.4	NDR 3.79	0.19	15.4	15.3	25
09VNB-136	M	37	8.99	8.99	23.2	72.7	66.2	759	2.96	2.96	23	94.8	60.8	NDR 3.28	0.19	62.4	57.9	16
09VNB-137	F	46	14.2	14.5	< 2.67	160	229	1970	3.96	3.96	< 2.67	275	239	9.29	0.12	65.3	65.4	22
09VNB-138	F	41	6.61	6.92	18.5	108	157	2090	NDR 2.84	< 2.54	29.2	238	258	NDR 9.23	0.13	79.3	73.8	9
09VNB-139	M	52	15	15	26.8	79.5	50	530	3.28	3.31	35.8	106	41.2	NDR 2.17	0.33	79.6	72.6	21
09VNB-140	F	38	NDR 4.42	< 2.08	< 2.08	10.4	87.1	561	3.25	3.25	16.9	85.2	69.6	2.21	0.15	22.3	19	-
09VNB-141	F	62	6.79	6.79	19.7	74.8	70.7	542	3.74	3.74	32.8	119	49.9	< 2.29	0.14	62.8	56.9	12
09VNB-142	M	39	6.4	6.4	15.3	71	86	1230	NDR 2.45	< 1.60	28.8	115	85.5	NDR 2.60	0.2	55.6	50.5	13
09VNB-143	M	46	4.24	4	< 2.56	43.2	106	1090	NDR 2.56	< 2.56	21.6	77.7	57.6	NDR 3.60	0.13	30.6	26.5	16
09VNB-144	M	23	4.56	4.43	13.9	65.9	102	1340	3.61	3.8	26	130	98.8	3.61	0.16	54.2	49.2	9

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND.

Lipid calculations based on "independent" or "factored" analysis (see Appendix A1).

Figure 3.9 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Khue Trung Ward, Cam Le District, Da Nang, Viet Nam, April 2009.



The percentage of TCDD present in the TEQ is given above each bar.
No % TCDD is shown when 2,3,7,8-TCDD concentrations were ND or NDR (peak detected but did not meet quantification criteria).

3.3.3 Thuan Tay Ward, Hai Chau District

- **Table 3.8, Figure 3.10**

Thuan Tay Ward, Hai Chau District, is located east of the Da Nang Airport near the entrance to the main passenger terminal. Dioxin and furan concentrations in blood samples from Thuan Tay Ward were slightly higher than in samples collected south of the Airport in Cam Le District. The two highest TCDD levels were recorded in a 48-year-old female (09VNB146; 96 pg/g TCDD) and a 69-year-old male (09VNB177; 93.7 pg/g TCDD), with TEQs of 126 pg/g and 137 pg/g, respectively. TCDD concentrations in the remaining samples ranged from 2.41 pg/g to 83.6 pg/g; TEQ levels of these samples ranged from 12.1 pg/g to 140 pg/g. TCDD as a percentage of TEQ ranged from 9% to 80% for samples collected from the Thuan Tay Ward of Hai Chau.

Table 3.8 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) from residents of Thuan Tay Ward, Hai Chau District, Da Nang, Viet Nam, April 2009.

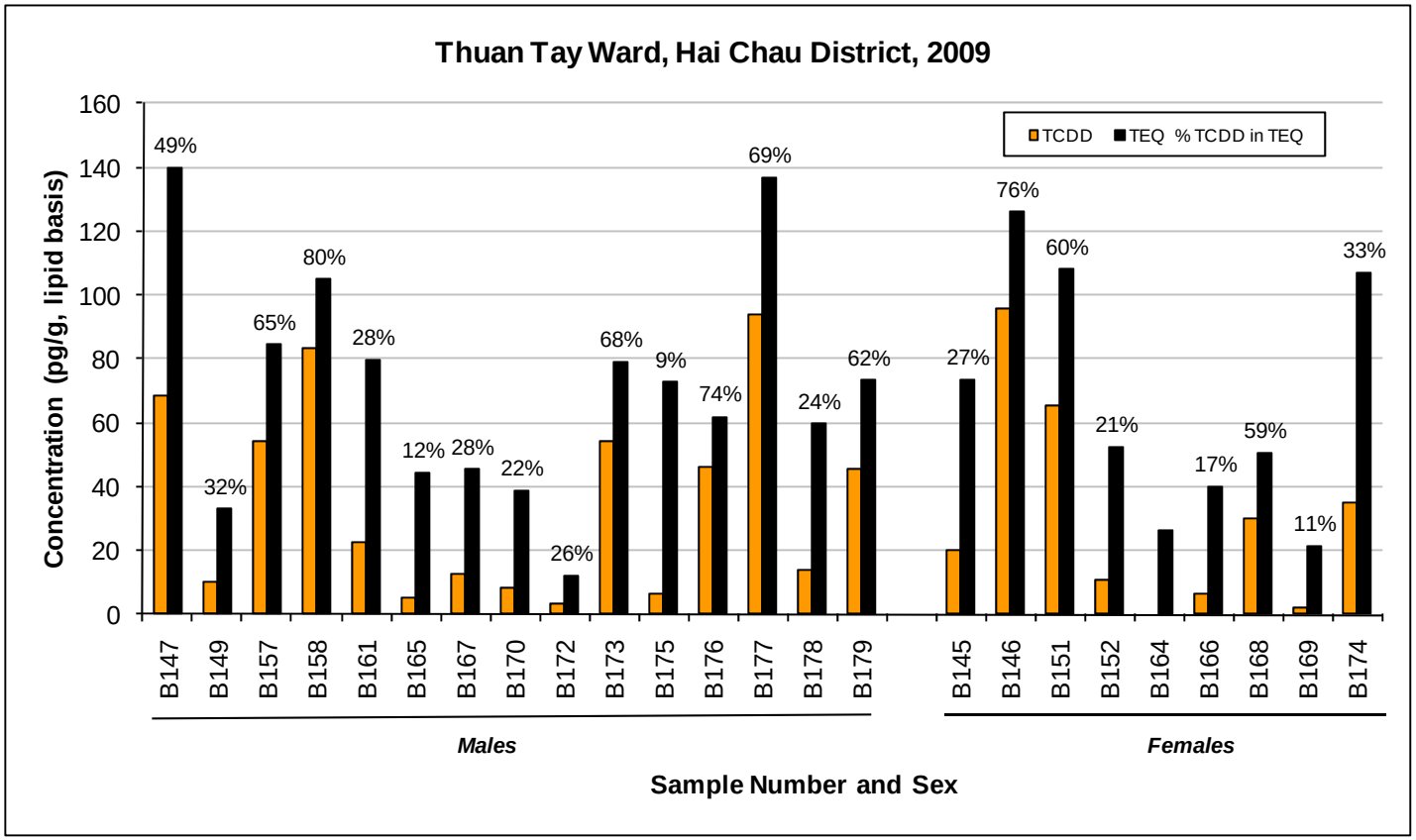
Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
09VNB-145	F	47	20.2	20.4	21.6	77.6	70.6	1370	< 2.39	< 2.39	28	133	86.3	NDR 3.85	0.17	78.9	73.5	27
09VNB-146	F	48	96	96	12.6	37	91.7	515	< 3.95	< 3.95	17.6	58.7	70.2	18.9	0.18	129	126	76
09VNB-147	M	54	68.8	68.6	28.4	112	107	887	4.43	4.16	47.8	159	110	3.53	0.14	148	140	49
09VNB-149	M	27	10.4	10.6	8.9	36	39.8	421	< 3.22	< 3.22	11.9	48.3	50.8	NDR 5.08	0.24	35.2	32.9	32
09VNB-151	F	49	65.2	65.2	19.4	72.3	67	485	< 2.60	6.17	24.7	82.4	38.8	< 2.60	0.23	112	108	60
09VNB-152	F	50	10.8	11	13	60.5	55.2	301	< 2.78	< 2.78	23.5	143	68.2	< 2.78	0.21	57.2	52.6	21
09VNB-157	M	51	54.5	54.5	13.1	40.4	67.2	495	< 5.96	8.08	18.7	48	31.3	< 5.96	0.2	88.1	84.4	65
09VNB-158	M	22	83.6	83.6	10.1	26.9	39.8	578	< 3.31	3.36	12.9	30.3	27.5	< 3.31	0.18	107	105	80
09VNB-161	M	44	22.4	22.6	24.2	139	152	2200	< 2.34	< 2.34	27.9	88.7	60	< 2.34	0.24	84.5	79.9	28
09VNB-164	F	19	NDR 7.55	< 1.90	11	42	90.2	1160	< 1.90	2.46	9.39	49.1	55.9	2.52	0.16	27.7	26.1	-
09VNB-165	M	26	5.47	5.47	14	62.5	67.6	1150	2.73	4.44	28.4	90.2	75.5	NDR 3.76	0.29	49.3	44.4	12
09VNB-166	F	57	6.69	6.57	12.7	43.1	45.1	277	1.64	1.64	25	82.5	34.9	NDR 1.52	0.24	44.6	40	17
09VNB-167	M	34	12.5	12.3	15.7	56.6	27.5	303	NDR 2.41	< 1.96	20.7	44.3	28.6	2.13	0.18	49.6	45.5	27
09VNB-168	F	48	29.8	29.8	8.59	30.3	27.3	464	< 4.30	< 4.30	13.1	38.4	25.8	< 4.30	0.2	53.3	50.7	59
09VNB-169	F	33	2.41	6.79	6.17	25.9	37.6	521	8.14	21	16	50.6	66	5.86	0.16	23.7	21.5	11
09VNB-170	M	47	8.53	8.39	13.5	30.8	42.9	440	1.77	1.86	21	61.5	38.2	NDR 4.52	0.21	42.9	38.8	22
09VNB-172	M	19	3.14	3.23	< 1.52	15.7	29.6	327	1.52	< 1.52	7.39	33.3	35.1	NDR 4.71	0.22	13.5	12.1	26
09VNB-173	M	54	54.1	54.3	12.2	40	40	452	NDR 2.98	< 2.17	14.9	35.3	25.8	< 2.17	0.15	82.3	79.3	68
09VNB-174	F	53	35.3	35.1	36.1	128	109	922	< 1.61	< 1.61	26.8	125	81.4	NDR 5.85	0.21	112	107	33
09VNB-175	M	53	6.3	6.07	22	112	109	1150	< 3.87	< 3.87	37.2	187	126	NDR 4.10	0.13	80	72.8	9
09VNB-176	M	24	45.9	46	6.88	26.4	36.5	332	4.92	4.76	8.99	25.9	23.3	< 2.38	0.19	63.8	62	74
09VNB-177	M	69	93.7	93.7	20.3	80.6	86.5	658	8.51	8.56	18.9	67.1	23.9	2.25	0.22	140	137	68
09VNB-178	M	43	14.1	14	18.1	75.7	77.3	783	NDR 2.80	< 1.05	27	109	72.9	2.51	0.31	64.1	59.6	24
09VNB-179	M	39	45.6	45.6	14.9	29.4	49	266	3.24	3.38	20.6	36.5	18.6	< 1.08	0.3	76.8	73.3	62

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND.

Lipid calculations based on "independent" or "factored" analysis (see Appendix A1).

Figure 3.10 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Thuan Tay Ward, Hai Chau District, Da Nang, Viet Nam, April 2009.



The percentage of TCDD present in the TEQ is given above each bar.
No % TCDD is shown when 2,3,7,8-TCDD concentrations were ND or NDR (peak detected but did not meet quantification criteria).

3.3.4 Thuan Phuoc Ward, Hai Chau District – Reference 2006

- **Table 3.9, Figure 3.11**

Thuan Phuoc Ward, Hai Chau District, represents a reference group of residents in Da Nang City, as it is located more than 5 km northeast of the Airport; residents do not come into direct regular contact with the Airport. Blood dioxin levels exhibited the lowest TCDD and TEQ levels of areas sampled in 2006; however, these levels were not as low as was seen in Cam Le District in 2009. In 2006, TCDD levels for residents of Thuan Phuoc Ward ranged from 2.77 pg/g to 6.15 pg/g; TEQ levels ranged from 28.7 pg/g to 61.1 pg/g. Other dioxin congeners, including hexa- (H6) dioxins and furans, contributed to the TEQ in all samples, suggesting other possible sources of contamination in these individuals. The maximum contribution of TCDD in TEQ was 18%, which indicates that Agent Orange does not appear to be the main contaminant source in this area of Hai Chau District.

Table 3.9 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) from residents of Thuan Phuoc Ward, Hai Chau District, Da Nang, Viet Nam, December 2006.

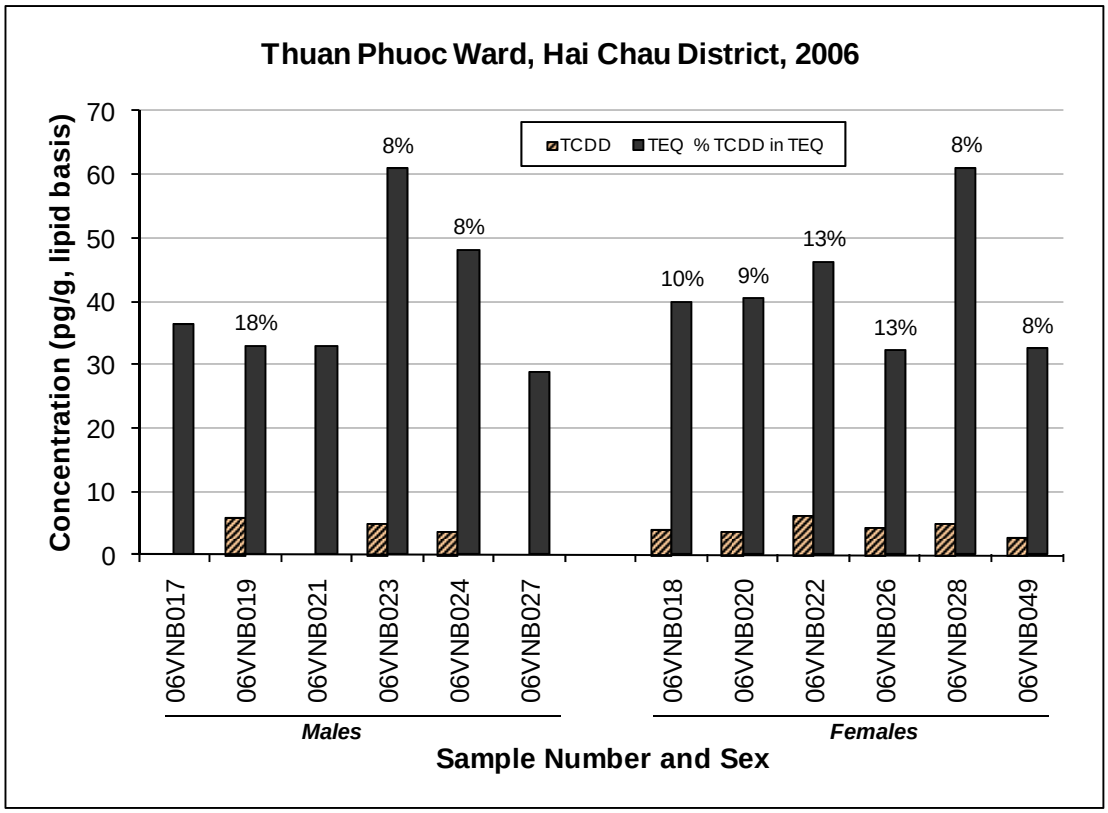
Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
06VNB017	M	47	< 8.54	< 8.54	< 8.54	39	62.5	499	< 8.54	< 8.54	25.6	124	127	13.3	0.19	41.5	36.4	-
06VNB018	F	42	3.93	3.93	10.4	45.7	71.1	446	0.924	0.924	24.9	135	109	3.93	0.43	43.6	39.9	10
06VNB019	M	36	5.92	5.92	10.5	41.4	42.8	298	2.73	2.73	19.1	54.7	31.9	NDR 3.64	0.22	36.8	33	18
06VNB020	F	36	3.5	3.5	< 1.50	53	174	1040	1.5	1.5	20	216	236	16.5	0.2	44.2	40.4	9
06VNB021	M	54	< 6.37	< 6.37	8.58	30.8	42.9	NR	< 4.51	< 4.51	20.7	70.8	50.1	NR	0.14	37.2	33	-
06VNB022	F	55	6.15	6.15	15	49.2	95	484	< 3.84	< 3.84	27.3	96.9	75.3	16.5	0.26	51.7	46.3	13
06VNB023	M	57	4.97	4.97	17.8	83.8	61.4	621	< 1.42	< 1.42	32.7	190	98.3	2.49	0.28	66.7	60.9	8
06VNB024	M	22	3.76	3.76	13.8	52	62.7	586	< 3.13	< 3.13	28.8	152	117	NDR 3.13	0.16	53.2	48.1	8
06VNB026	F	49	4.36	4.36	9.27	43.9	69.3	472	0.818	0.818	19.1	81.3	56.5	5.73	0.37	35.4	32.3	13
06VNB027	M	58	< 7.38	< 7.38	< 7.38	29.1	54.6	764	< 7.38	< 7.38	18.4	95.5	80	NDR 10.7	0.27	32.3	28.7	-
06VNB028	F	54	4.89	4.89	14.3	73	102	689	1.13	1.13	32.7	239	172	1.88	0.27	66.3	61.1	8
06VNB049	F	20	2.77	2.77	8.72	35.7	51.9	281	< 1.58	< 1.58	18.2	111	69.7	3.17	0.26	35.9	32.6	8

NR = not reported.

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for “Total TEQ” calculations, NDR was treated as ND.

Figure 3.11 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Thuan Phuoc Ward, Hai Chau District, Da Nang, Viet Nam, December 2006.



No % TCDD is shown when 2,3,7,8-TCDD concentrations were ND or NDR (peak detected but did not meet quantification criteria).

3.3.5 Sen Lake Workers

- **Table 3.10, Figure 3.12**

Most Sen Lake Workers were retested in 2009 and again exhibited the highest blood dioxin levels of all groups sampled in the Da Nang area. TCDD concentrations ranged from 9.64 to 1,340 pg/g in 2009; TEQs ranged from 39.6 to 1,410 pg/g. The highest dioxin level (09VNB199; 1,340 pg/g TCDD) was recorded in the same male who had the highest levels in 2006 (06VNB002, 1150 pg/g TCDD), and indicated an increase in lipid-basis TCDD concentrations. Immediate family members exhibited the second and third highest TCDD levels in 2006 (567 and 430 pg/g TCDD, respectively); they also exhibited an increase in lipid-basis TCDD concentrations in 2009 (589 and 785 pg/g, respectively).

Remaining Sen Lake Workers' TCDD concentrations in blood samples ranged from 9.64 pg/g to 369 pg/g in 2009 (relative to 6.36 to 366 pg/g in 2006). On average, TCDD and TEQ lipid-basis values increased slightly between 2006 and 2009.

The percent TCDD of the TEQ remained approximately the same in 2009 compared to 2006 (ranging from 12 to 95%). Sen Lake Workers with lower concentrations of TCDD usually exhibited a lower percent TCDD of TEQ in both studies.

Other dioxin congeners were present in all blood samples, primarily penta- and hexa-dioxins and furans, as was seen in 2006. However, percent TCDD of TEQ remained relatively high for five Sen Lake Workers (TCDD ≥85% of TEQ), indicating that Agent Orange remains the primary source of contamination for these individuals.

Table 3.10 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) of Sen Lake Workers, Da Nang, Viet Nam. Results for individuals sampled in December 2006 and April 2009 are paired for comparison.

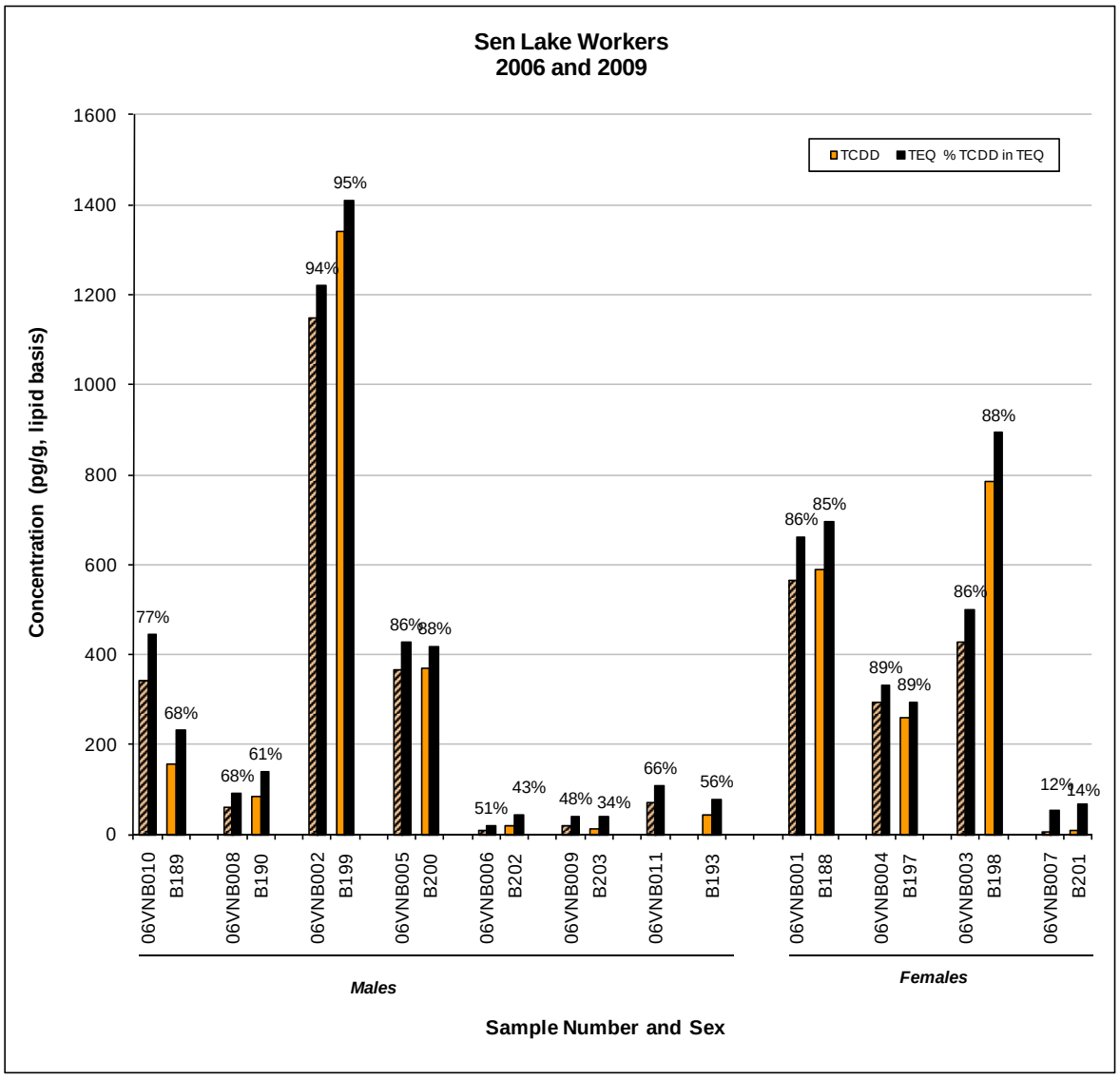
Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
06VNB001	*F*	*72*	*567*	*567*	*45.7*	*153*	*92.5*	*688*	*< 1.06*	*< 1.06*	*49.3*	*173*	*88.3*	*1.42*	*0.28*	*671*	*662*	*86*
09VNB-188	F	75	589	589	51.6	165	76	703	3.28	3.12	54.2	209	84.9	4.22	0.19	707	696	85
06VNB002	*M*	*42*	*1150*	*1150*	*38.2*	*99.2*	*94.9*	*864*	*22.3*	*22.3*	*29.4*	*103*	*93.5*	*NDR 2.48*	*0.28*	*1230*	*1220*	*94*
09VNB-199	M	45	1340	1340	39	103	92.5	1140	19.4	19.5	28	111	94.5	3.8	0.2	1420	1410	95
06VNB003	*F*	*44*	*430*	*430*	*30.7*	*116*	*155*	*1120*	*10.4*	*10.4*	*33.4*	*159*	*82.2*	*3.01*	*0.37*	*506*	*501*	*86*
09VNB-198	F	47	785	785	50.3	186	153	1670	5.74	5.83	47.5	221	67.8	5.06	0.33	901	893	88
06VNB004	*F*	*17*	*294*	*294*	*17.6*	*58.7*	*50.9*	*425*	*7.4*	*7.4*	*15.7*	*71.2*	*74*	*3.7*	*0.23*	*334*	*331*	*89*
09VNB-197	F	20	260	260	16.2	50.6	41.5	474	< 4.51	< 4.51	14.9	59.6	< 4.51	4.87	0.22	296	293	89
06VNB005	*M*	*54*	*366*	*366*	*23.8*	*63.3*	*108*	*550*	*37.7*	*37.7*	*34.5*	*147*	*129*	*6.06*	*0.22*	*433*	*427*	*86*
09VNB-200	M	57	369	369	20.2	70.3	82.7	703	1.91	2.07	30.5	116	72.4	4.29	0.19	424	418	88
06VNB006	*M*	*28*	*9.42*	*9.42*	*< 1.09*	*17.4*	*42.4*	*267*	*2.17*	*2.17*	*11.6*	*31.1*	*42.4*	*4.71*	*0.28*	*20.1*	*18.4*	*51*
09VNB-202	M	31	18.2	18	8.68	37.8	90.5	2130	< 2.11	< 2.11	13.6	53.9	42.8	2.98	0.16	44.6	42.3	43
06VNB007	*F*	*52*	*6.36*	*6.36*	*16.2*	*66.4*	*94.7*	*601*	*NDR 1.27*	*< 1.27*	*21.6*	*145*	*101*	*NDR 9.22*	*0.31*	*56.4*	*52.2*	*12*
09VNB-201	F	55	9.64	9.88	19.3	95	84.2	912	< 1.60	< 1.60	31	185	93.6	3.15	0.21	73.4	67.7	14
06VNB008	*M*	*20*	*62.1*	*62.1*	*11.1*	*34.1*	*47*	*725*	*NDR 3.95*	*< 1.44*	*16.5*	*77.2*	*101*	*NDR 6.82*	*0.28*	*94.2*	*91.1*	*68*
09VNB-190	M	23	85.2	85	19	97	52	1420	< 3.20	< 3.20	27	144	144	7.1	0.1	144	139	61
06VNB009	*M*	*24*	*19.7*	*19.7*	*< 1.97*	*30.6*	*59.7*	*486*	*NDR 4.44*	*< 1.97*	*19.7*	*96.1*	*81.8*	*NDR 4.93*	*0.21*	*44.8*	*40.9*	*48*
09VNB-203	M	26	13.3	13.1	9.54	34.2	33.7	489	< 1.66	< 1.66	16.6	73.3	60.8	2.41	0.2	42.8	39.6	34
06VNB010	*M*	*22*	*343*	*343*	*39.8*	*170*	*103*	*1780*	*< 2.65*	*< 2.65*	*49.7*	*242*	*349*	*14.6*	*0.15*	*453*	*444*	*77*
09VNB-189	M	25	157	157	29.9	114	49.2	1360	< 2.99	< 2.99	40.4	174	224	8.64	0.12	239	231	68
06VNB011	*M*	*23*	*70.8*	*70.8*	*11.2*	*55.8*	*62.2*	*802*	*< 1.72*	*< 1.72*	*21*	*110*	*94.4*	*3.86*	*0.23*	*111*	*107*	*66*
09VNB-193	M	29	43.6	43.7	14.8	54.8	51.1	548	< 2.22	< 2.22	28.9	41.2	36.9	< 2.22	0.16	84	78.4	56

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND.

Lipid calculations based on "independent" or "factored" analysis (see Appendix A1).

Figure 3.12 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Sen Lake Workers, Da Nang, Viet Nam, December 2006 and April 2009. [Note: shaded TCDD bars and the associated TEQ represent results from 2006.]



The percentage of TCDD present in the TEQ is given above each bar.

3.3.6 West Airbase Workers

- **Table 3.11, Figure 3.13**

West Airbase Workers exhibited TCDD levels in blood ranging from 24.7 to 212 pg/g; TEQs ranged from 60.9 to 296 pg/g. These levels are lower than Sen Lake Workers that were resampled in 2009, but higher than TCDD and TEQ values in blood samples collected from residents of other wards in Da Nang City.

The male with the highest TCDD and TEQ levels in 2009 also exhibited the highest levels in 2006. [Note: the 2006 2,3,7,8-TCDD and TEQ values for sample 06VNB051 have been corrected as of August 2009]. The 2006 TCDD concentration for 06VNB051 was 357 pg/g; the WHO 2005 TEQ has been revised to 491 pg/g. The 2009 concentrations for this individual indicate a decrease in TCDD concentrations, from 357 pg/g in 2006 to 212 pg/g in 2009. Other West Airbase Workers that were retested in 2009 exhibited slightly higher TCDD concentrations in blood relative to 2006. For example, lipid-basis TCDD concentrations in the youngest female donor (06VNB053/09VNB-186) were 14 pg/g in 2006 and 24.7 pg/g in 2009; TEQ values were 39.3 and 60.9 pg/g, respectively.

The TCDD percentage of the TEQ remained approximately the same from 2006 to 2009, ranging from 36 to 73% for both surveys.

Table 3.11 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) of West Airbase Workers, Da Nang, Viet Nam. Results for individuals sampled in December 2006 and April 2009 are paired for comparison.

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
06VNB051	*M*	*39*	*357* [1]	*357*	*75.9*	*265*	*174*	*1620*	*NDR 6.09*	*< 1.62*	*56.4*	*139*	*89.2*	*14.2*	*0.24*	*500* [1]	*491* [1]	*73*
09VNB-183	M	42	212	212	48.4	173	99.1	1210	2.45	2.29	32.1	74.2	45.1	2.81	0.31	301	296	72
06VNB052	*M*	*29*	*33.4*	*33.4*	*12.3*	*43.4*	*76*	*339*	*2.3*	*2.3*	*25.3*	*42.6*	*27.6*	*< 1.92*	*0.26*	*67.9*	*62.9*	*53*
09VNB-184	M	32	58.3	58.3	15.4	51.7	56.1	296	< 1.81	< 1.81	26.9	35.7	18.7	< 1.81	0.18	96.9	91.6	64
06VNB053	*F*	*23*	*14*	*14*	*12.8*	*44*	*44*	*383*	*< 2.00*	*< 2.00*	*13.2*	*30.4*	*26*	*2*	*0.26*	*41.8*	*39.3*	*36*
09VNB-186	F	25	24.7	25	17.7	67.6	60.9	743	< 2.25	< 2.25	19.5	42.6	45.1	2.68	0.16	64.7	60.9	41
06VNB058	*F*	*35*	*25.5*	*25.5*	*14.3*	*55.8*	*127*	*911*	*2.44*	*2.44*	*18.5*	*59*	*55.5*	*8.03*	*0.29*	*60.1*	*57.5*	*44*
09VNB-192	F	38	26.3	26.3	14.3	72.2	126	1160	1.86	1.91	17.7	83.2	74.6	5.5	0.21	66.4	63.5	41
06VNB060	*F*	*34*	*36*	*36*	*23.2*	*79.5*	*89.8*	*608*	*2.48*	*2.48*	*21.1*	*42.2*	*24*	*2.48*	*0.24*	*83.5*	*79.3*	*45*
09VNB-191	F	37	47.4	47.4	25.8	94.3	85.1	665	1.75	< 1.60	25.3	57.2	35.6	< 1.60	0.19	102	97.6	49
06VNB050	*M*	*39*	*20.3*	*20.3*	*6.17*	*28.4*	*62.8*	*379*	*2.42*	*2.42*	*11.5*	*12.3*	*17.6*	*NDR 2.42*	*0.45*	*36.6*	*34.7*	*59*
06VNB054	*M*	*27*	*41.8*	*41.8*	*14.3*	*58.8*	*67.3*	*538*	*4.64*	*4.64*	*34.1*	*47.2*	*47.2*	*5.03*	*0.26*	*84.2*	*78*	*54*
06VNB055	*F*	*24*	*41.1*	*41.1*	*30.1*	*89.7*	*76.1*	*535*	*1.88*	*1.88*	*24.5*	*49.4*	*43.3*	*4.14*	*0.26*	*98*	*93.6*	*44*
06VNB056	*F*	*52*	*71.4*	*71.4*	*56.7*	*176*	*108*	*676*	*3.12*	*3.12*	*43*	*57.1*	*20.3*	*1.25*	*0.33*	*173*	*165*	*43*
06VNB057	*F*	*35*	*6.71*	*6.71*	*3.52*	*15.7*	*49.9*	*299*	*1.92*	*1.92*	*6.07*	*13.7*	*15*	*NDR 1.60*	*0.31*	*17.1*	*15.9*	*42*
06VNB059	*M*	*42*	*77.7*	*77.7*	*31.2*	*123*	*161*	*1160*	*5.47*	*5.47*	*36.6*	*75.5*	*52*	*4.92*	*0.19*	*150*	*142*	*55*
09VNB-196	M	61	48.1	47.9	23.5	89.1	34.4	371	< 1.88	< 1.88	32.3	32.3	15.6	< 1.88	0.19	101	94.6	51

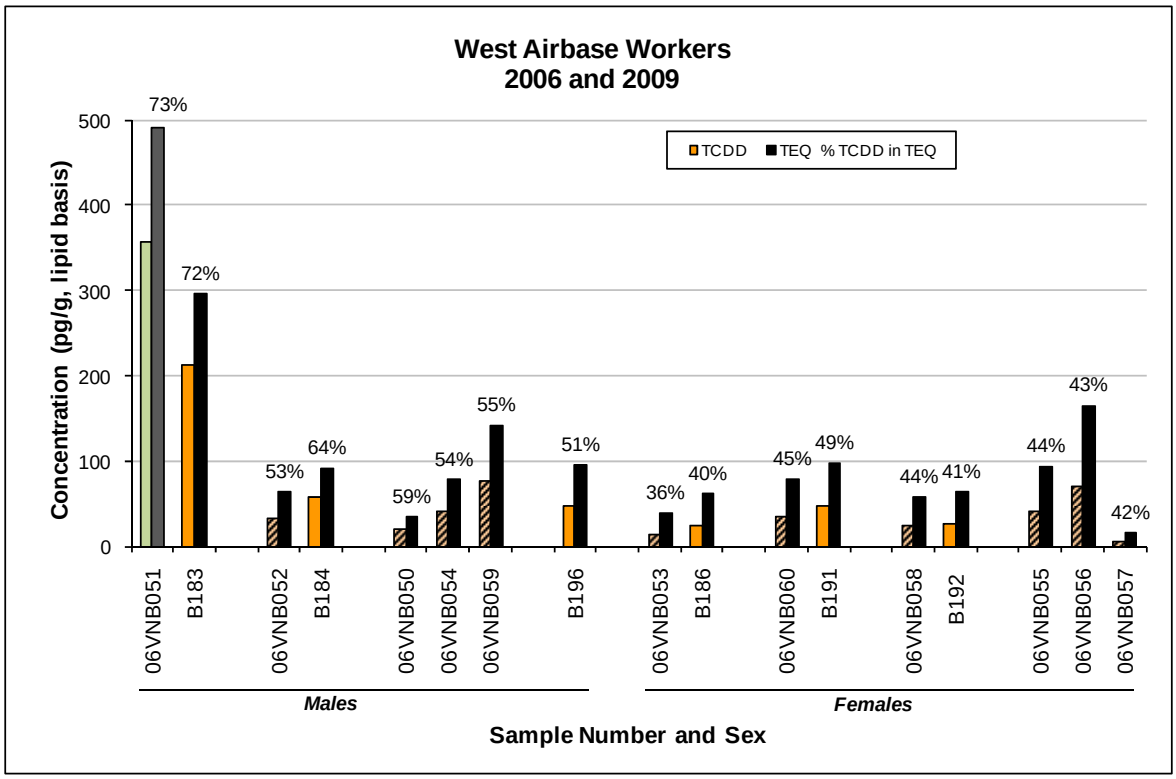
[1] 2,3,7,8-TCDD and TEQ values were corrected in August 2009.

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND.

Lipid calculations based on "independent" or "factored" analysis (see Appendix A1).

Figure 3.13 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, West Airbase Workers, Da Nang, Viet Nam, December 2006 and April 2009. [Note: shaded TCDD bars and the associated TEQ represent results from 2006.]



The percentage of TCDD present in the TEQ is given above each bar.

No % TCDD of TEQ is provided if 2,3,7,8-TCDD is ND or NDR (peak detected, but did not meet quantification criteria).

Note: TCDD and TEQ values for 06VNB051 have been corrected as of August 2009.

3.3.7 Chinh Gian Ward, Thanh Khe District (2006)

- **Table 3.12, Figure 3.14**

In 2006, 16 individuals from this ward were randomly selected to provide an indication of contamination levels in the general population north of the Airport, and for comparison with highly exposed workers from Sen Lake and West Airport. None of these individuals were retested in 2009. TCDD concentrations in 2006 ranged from non-detect (<5.89 pg/g) to 68.1 pg/g; TEQs ranged from 9.31 to 152 pg/g. TCDD comprised 54% of one sample and 11% to 45% of the remaining samples, indicating that Agent Orange was not a high contributing source of dioxin exposure to the majority of individuals tested.

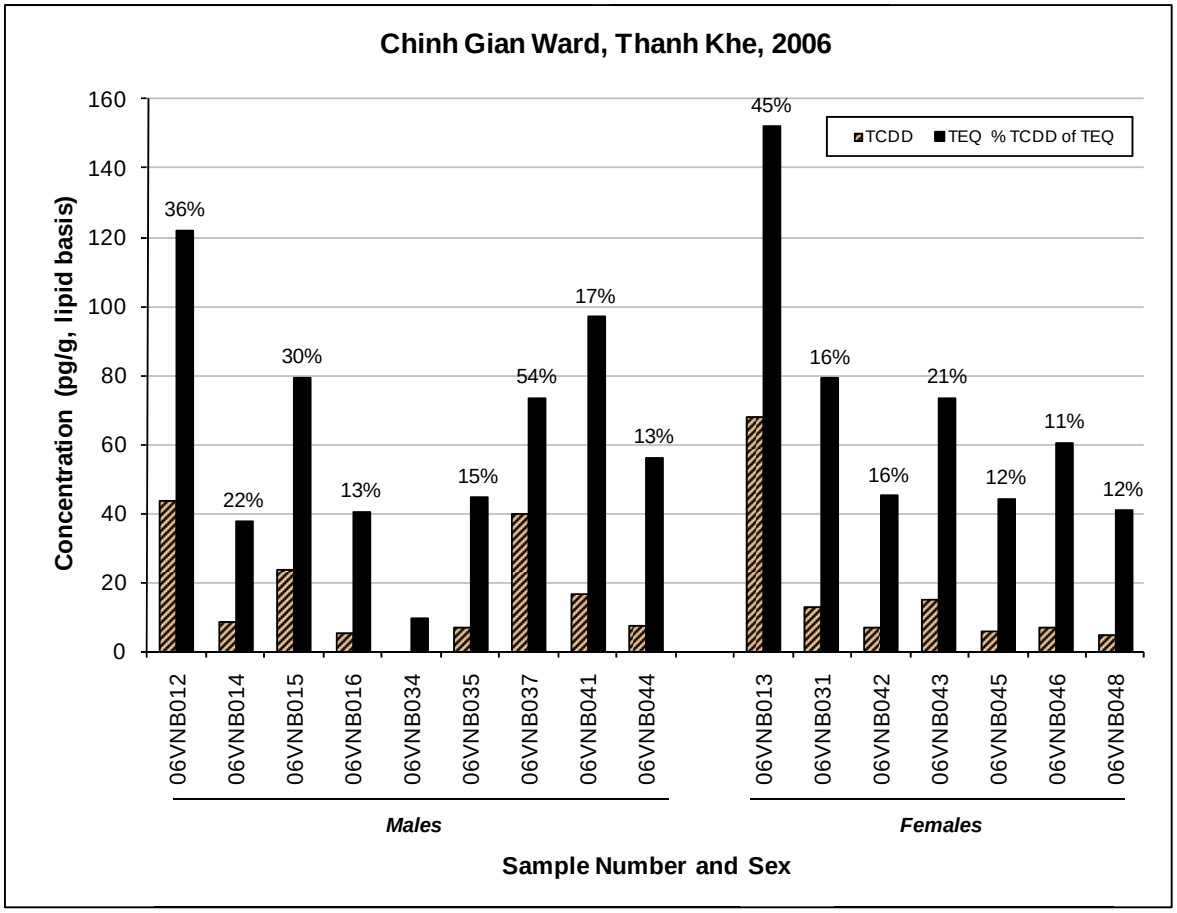
Table 3.12 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human blood (pg/g [ppt], lipid basis) from residents of Chinh Gian Ward, Thanh Khe District (random samples), Da Nang, Viet Nam, December 2006.

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
06VNB012	M	58	43.7	43.7	25.1	145	163	1560	1.3	1.3	45.4	230	154	12.1	0.23	129	122	36
06VNB013	F	57	68.1	68.1	< 2.79	171	226	1890	< 2.79	< 2.79	53.6	439	281	11.2	0.18	163	152	45
06VNB014	M	57	8.24	8.24	9.33	43.4	60.9	543	< 1.65	< 1.65	16.5	92.2	107	NDR 2.75	0.19	40.5	37.6	22
06VNB015	M	26	23.6	23.6	17.9	101	71.5	1000	< 2.86	< 2.86	33.6	154	108	6.43	0.14	85.9	79.3	30
06VNB016	M	61	5.14	5.14	10.8	50.5	107	519	< 1.87	< 1.87	21.5	124	112	22	0.22	44.3	40.4	13
06VNB031	F	54	12.5	12.5	19.6	108	62.2	868	< 1.51	< 1.51	33.6	243	191	6.52	0.2	84.9	79.1	16
06VNB034	M	18	< 5.89	< 5.89	< 5.89	< 5.89	< 5.89	23	< 5.89	< 5.89	< 5.89	< 5.89	< 5.89	< 5.89	0.17	9.96	9.31	-
06VNB035	M	32	6.68	6.68	12.4	57.3	72	759	1.91	1.91	24.3	113	126	NDR 6.68	0.21	48.8	44.6	15
06VNB037	M	30	40	40	11.8	60	56	692	< 2.14	< 2.14	20.3	78.2	59.6	NDR 4.28	0.28	77.3	73.4	54
06VNB041	M	52	16.6	16.6	30.2	109	84.6	730	< 5.04	< 5.04	44.8	223	138	11.6	0.2	106	96.8	17
06VNB042	F	43	6.99	11	11.7	59.9	108	609	2	2	25	120	108	9.99	0.31	49.2	44.9	16
06VNB043	F	57	15.1	15.1	15.5	93.4	111	831	1.72	1.72	34	219	134	3.78	0.29	78.9	73.4	21
06VNB044	M	33	7.13	7.13	12.8	70.5	126	664	2.25	2.25	33.4	182	172	6	0.27	61.1	56.1	13
06VNB045	F	21	5.46	5.46	10.4	53	86.8	520	< 1.64	< 1.64	24	141	181	7.1	0.19	48.1	44.2	12
06VNB046	F	35	6.6	6.6	12	78.6	115	684	1.8	< 1.80	27.6	226	279	7.2	0.17	65.1	60.4	11
06VNB048	F	23	4.8	4.8	9.99	43.6	81.1	536	< 1.60	< 1.60	16	143	171	9.59	0.26	43.8	40.7	12

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for “Total TEQ” calculations, NDR was treated as ND.

Figure 3.14 TCDD and Total TEQ (pg/g [ppt], lipid basis) for whole human blood, Chinh Gian Ward, Thanh Khe District, Da Nang, Viet Nam, December 2006.



The percentage of TCDD present in the TEQ is given above each bar.

No % TCDD of TEQ is provided if 2,3,7,8-TCDD is ND or NDR (peak detected, but did not meet quantification criteria).

3.3.8 Statistical Analyses of Blood Data

3.3.8.1 2006 Sex-related Effects

Differences in sex were tested for the 2006 blood dioxin data. These tests were included only on TCDD and TEQ because they were the only variables tested in later analyses. No sex differences were found in any areas in either blood TCDD or blood TEQ ($p>0.057$; data not shown).

3.3.8.2 2006 Area Effects

Blood TCDD and TEQ values were tested for differences between areas for data collected in 2006. Several significant differences were found between areas in 2006 in both TCDD and TEQ (Figure 3.15 and Figure 3.16). For TCDD, Thuan Phuoc Ward in Hai Chau (reference area) was statistically lower than all other areas ($p<0.007$). Sen Lake Workers were statistically similar to West Airbase Workers ($p=0.258$), but were significantly higher than Chinh Gian Ward in Thanh Khe District ($p=0.001$).

As was seen with the TCDD analyses, TEQs in Thuan Phuoc Ward were statistically lower than all other areas ($p<0.023$). All other areas were statistically similar ($p>0.112$).

Figure 3.15 Mean whole human blood TCDD (lipid basis; ± 1SE) for Da Nang residents sampled in 2006; different letters show significance between areas.

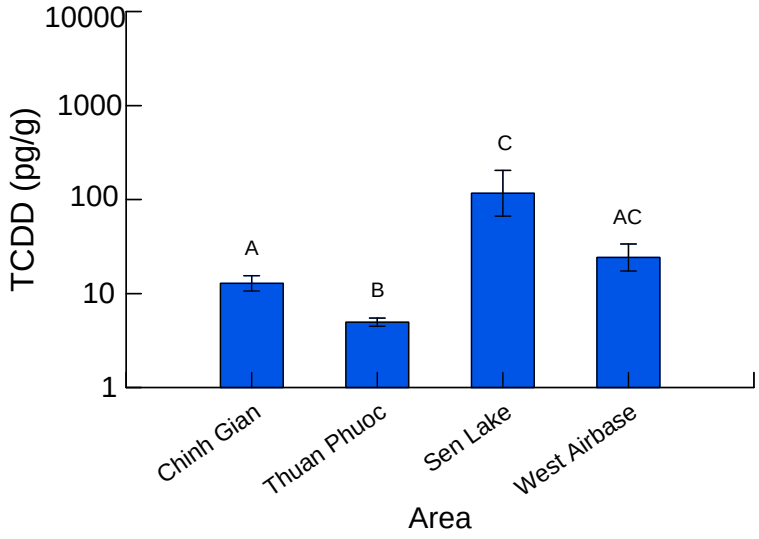
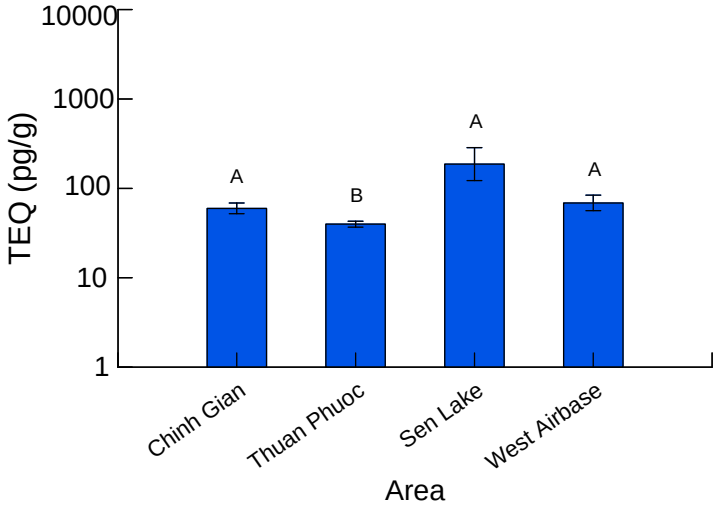


Figure 3.16 Mean whole human blood TEQ (lipid basis; ± 1SE) for Da Nang residents sampled in 2006; different letters show significance between areas.



3.3.8.3 2009 Sex-related Effects

Differences in sex were tested within areas for all dioxin and furan congeners measured in the blood of individuals. No differences were detected between sexes in any congener in Anh Khe Ward, Thuan Tay Ward, Khue Trung Ward, and Sen Lake and West Airbase Workers ($p>0.03$). In TCDD and TEQ sex-related comparisons, no differences were detected at $\alpha=0.01$. For all further analyses, sexes were pooled within areas.

3.3.8.4 2009 Area Comparisons

Blood TCDD concentrations were compared between areas in 2009 (Figure 3.17) and were found to be significantly different ($p<0.0001$). Khue Trung Ward TCDD was significantly lower than all other sites ($p<0.0001$) and Sen Lake was significantly higher than Thuan Tay Ward ($p=0.016$). No statistical differences in blood TCDD were found between Sen Lake and West Airbase workers ($p=0.994$).

Blood TEQ values were also tested for differences between areas (Figure 3.18). Similar to the TCDD values, TEQ was significantly different between areas ($p<0.0001$). Khue Trung Ward blood TEQ was significantly lower than all other areas ($p<0.0052$); no other comparisons between areas were significantly different in the blood TEQ values ($p>0.09$).

The proportion of blood TEQ comprised of TCDD was also tested between areas (Figure 3.19); the proportion of TEQ from TCDD was significantly different between areas ($p<0.00001$). Khue Trung Ward was significantly lower than all other areas ($p<0.0002$) and Sen Lake was significantly higher than Thuan Tay ($p=0.0015$); no other comparisons were statistically significant ($p>0.07$).

Figure 3.17 Mean whole human blood dioxin (TCDD, lipid basis) ± 1SE in areas surrounding the Da Nang Airport, not separated by sex.

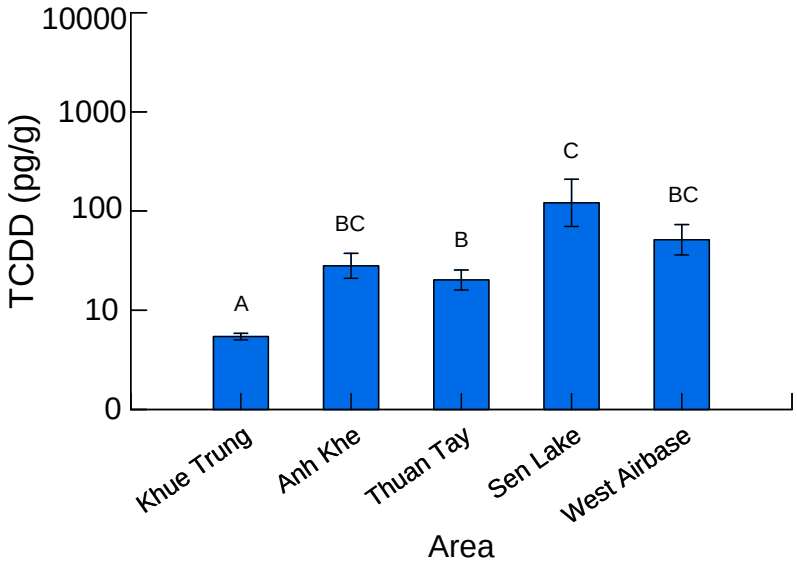


Figure 3.18 Mean whole human blood Toxic Equivalence (TEQ; lipid basis) ± 1SE in areas surrounding the Da Nang Airport; sexes pooled within area; different letters indicate statistical differences.

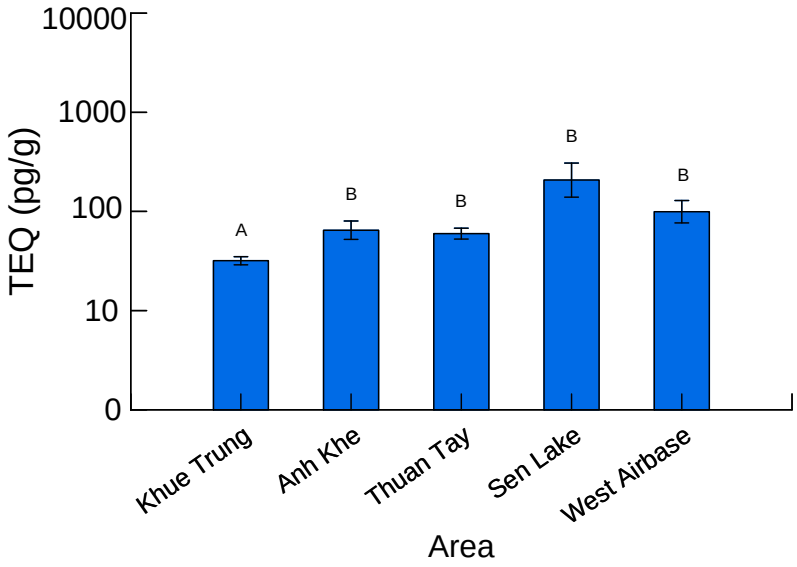
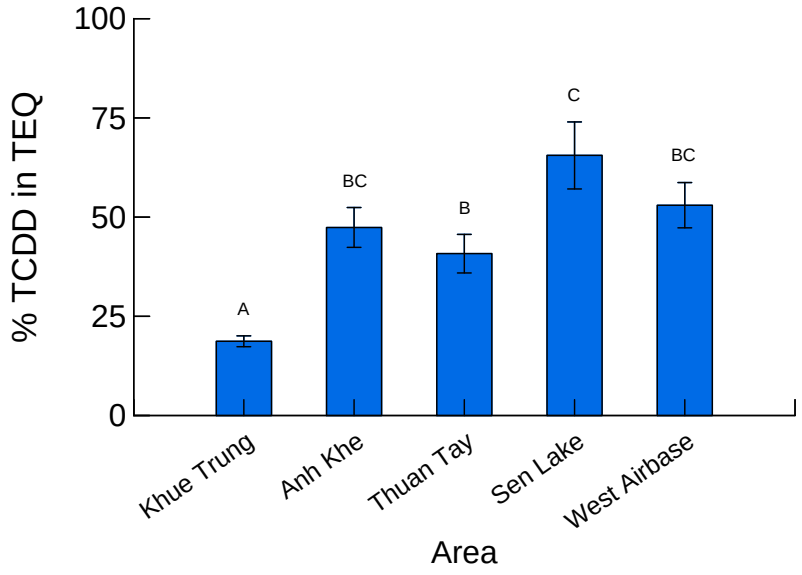


Figure 3.19 Mean Proportion of TEQ composed of TCDD in whole human blood (lipid basis; % ± 1SE) by area; Da Nang Airport, Viet Nam, 2009; different letters indicate statistical differences.



3.3.8.5 Temporal Analyses in Sen Lake and West Airbase Workers

2006 vs. 2009

Ten Sen Lake and five West Airbase workers that were sampled in 2006 (Hatfield/ Office 33 2007) were sampled again in 2009 for dioxin/furan congeners. Using a Wilcoxon signed rank test, no statistical differences were found from 2006 to 2009 in TCDD or TEQ in West Airbase workers ($p>0.077$) or Sen Lake Workers ($p>0.351$) (Figure 3.20 and Figure 3.21).

Figure 3.20 **Mean whole human blood TCDD (lipid basis; ± SE) between years for Sen Lake and West Airbase workers; Da Nang Airport, Viet Nam, 2006 and 2009.**

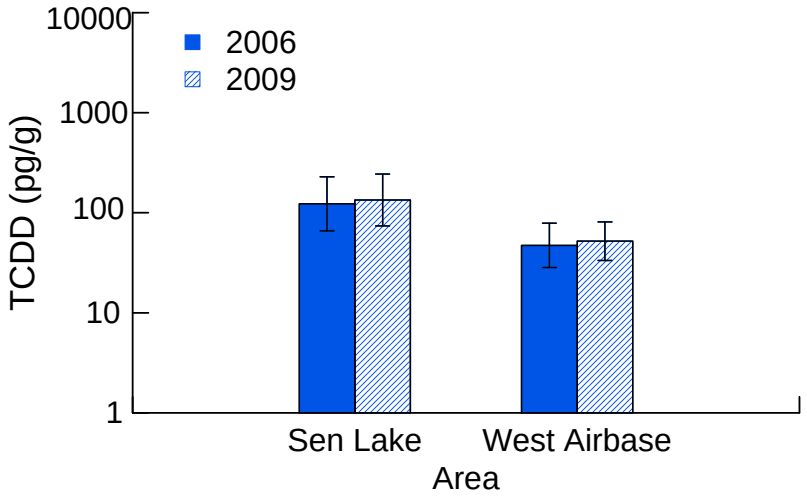
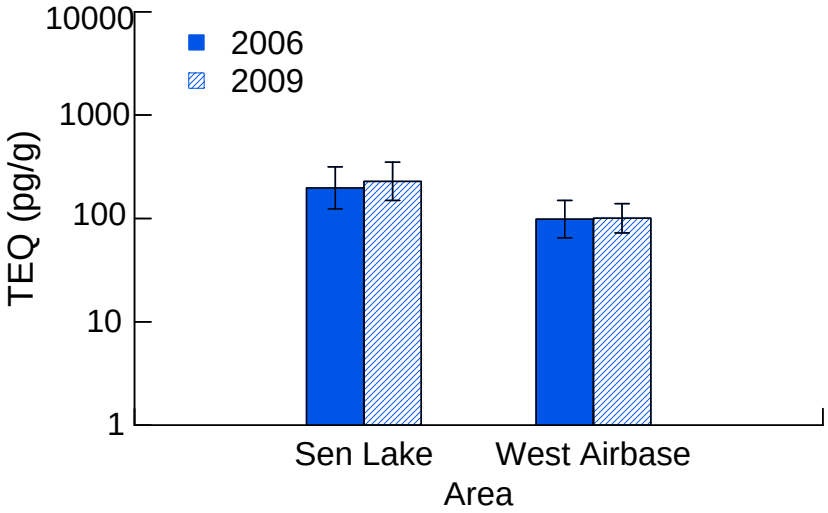


Figure 3.21 **Mean whole human blood TEQ (lipid basis; ± SE) between years for Sen Lake and West Airbase workers; Da Nang Airport, Viet Nam, 2006 and 2009.**



3.3.8.6 Blood Congener Profiles – Principal Components Analysis (PCA) and Discriminant Function Analysis (DFA)

PCA

Principal components analysis (PCA) of the blood congeners of dioxin and furans revealed a total of 3 principal components (PCs; Table 3.13). The first PC explains 57% of the variation, while the second and third PCs explain relatively little (23.36% cumulatively). Several variables have very strong correlations with the PC1, including 1,2,3,7,8,9-HxCDD, 1,2,3,4,7,8-HxCDD, 1,2,3,6,7,8-HxCDF, 1,2,3,4,7,8-HxCDF, and 1,2,3,6,7,8-HxCDD; all of these variables had a greater than 0.85 correlation with the first PC. The second principal component had weaker relationships with all variables than PC1 and was moderately correlated with OCDF (r_s=-0.603) and, 1,2,3,7,8,9-HxCDF (r_s=-0.688). The third principal component was moderately correlated with 2,3,7,8-TCDF (r_s=-0.577), and 2,3,7,8-TCDD (r_s=-0.690).

Although the first two PCs accounted for 69.64% of the variation in the data set, no separation was evident when the participant's principal components were plotted by area (Figure 3.22). The wide variety of congeners and their variable concentrations created overlap between groups when the principal components were plotted.

The PCA reveals that where a person lives has little to do with the levels of congeners that are found in their blood; use of PCA on all congeners measured in blood did not separate the different geographic groups of people. The overlap of the *a priori* defined groups (high-risk [i.e., Sen Lake and West Airbase] and low-risk [i.e., Khue Trung, Thuan Tay, and Anh Khe Wards]) and variability within groups suggests that there is widespread dioxin and furan contamination of the population sampled from around the Airport. The variability seen within the groups suggests that contamination of the people included in this study is a result of exposure to a variety of dioxin/furan sources and that this contributes to a high level of basal contamination in the population. The overlap of dioxin and furan summary variables generated in the PCA suggests that there are similarities in the contamination patterns between the groups, or between individuals within separate groups. These could include people with similar occupations or exposure of people to diffuse sources that are common to all areas.

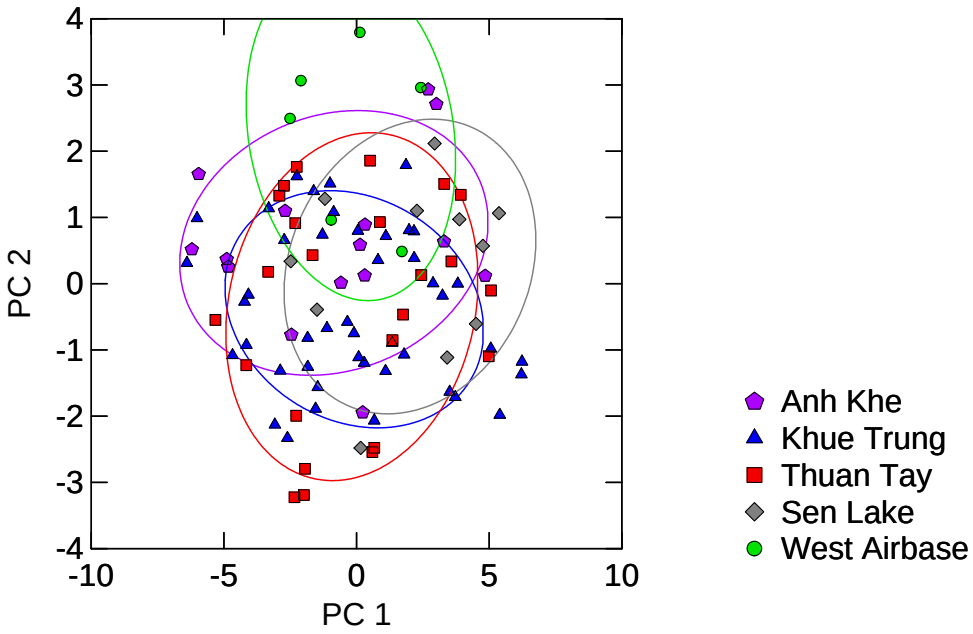
Table 3.13 Spearman Correlation coefficients; PCs and input variables for whole human blood PCDD and PCDF congeners; Da Nang Airport, Viet Nam, 2009. (n=101; r_s=|0.196|; bolded values are significant).

Input Variables	Principal Components		
	1	2	3
1,2,3,7,8,9-HxCDD	**0.923**	**0.212**	0.002
1,2,3,4,7,8-HxCDD	**0.906**	**0.332**	-0.107
1,2,3,6,7,8-HxCDF	**0.902**	0.040	**0.285**
1,2,3,4,7,8-HxCDF	**0.896**	0.024	**0.301**
1,2,3,6,7,8-HxCDD	**0.876**	**0.362**	-0.124
2,3,4,6,7,8-HxCDF	**0.849**	**-0.204**	0.023
2,3,4,7,8-PeCDF	**0.838**	**0.309**	-0.123
1,2,3,7,8-PeCDD	**0.823**	**0.416**	**-0.257**
OCDD	**0.796**	0.007	**0.220**
1,2,3,4,6,7,8-HpCDD	**0.788**	0.095	0.070
1,2,3,4,7,8,9-HpCDF	**0.776**	**-0.320**	**0.354**
1,2,3,4,6,7,8-HpCDF	**0.763**	**-0.271**	**0.469**
1,2,3,7,8-PeCDF	**0.629**	**-0.456**	**-0.430**
2,3,7,8-TCDF	**0.501**	**-0.455**	**-0.577**
OCDF	**0.458**	**-0.603**	0.079
1,2,3,7,8,9-HxCDF	**0.358**	**-0.688**	**-0.382**
2,3,7,8-TCDD	**0.334**	**0.334**	**-0.690**
% Variance Explained	57.01	12.63	10.73

Strong correlations r_s> |0.75|

Moderate correlations |0.5|>r_s<|0.75|

Figure 3.22 Plot of first two summary variables (principal components); 68% confidence ellipses by whole human blood groups; Da Nang Airport, Viet Nam, 2009.



DFA

Stepwise forward discriminant analysis using area as a grouping factor created 4 discriminant functions and separated four variables at an alpha-to-enter value of 0.05 (Table 3.14). The first function explains 75.5% of the dispersion and the second function accounts for 21% (95.7% cumulatively) among the groups. The ratio of eigenvalues of the first two discriminant functions is 3.75 which also supports that the first function captures most of the differences among the groups; the discriminant function was significant between groups ($p<0.0001$).

The relative size of the standardized value describes the contribution of the compound to the discriminant function (Table 3.14). Dioxin (2,3,7,8-TCDD) contributes strongly to the first function as does 1,2,3,6,7,8-HxCDF. 1,2,3,4,7,8-HxCDD also contributes strongly to the second function as does 1,2,3,4,7,8-HxCDD, but all four congeners selected by the stepwise forward model contribute to the discriminant functions.

Using the models generated during the DFA and the congeners listed in Table 3.14, classification of the individuals to groups were conducted. In the classification matrix generated during the analysis (Table 3.15) on average, 70% of cases were properly assigned to the correct group. The range of correct assignment, however, ranged from 33% in Thuan Tay to 89% in Khue Trung. The level of correct assignment reflects the similarity of a randomly selected individual to the average for a particular group. The best classifications were for Khue Trung (89%), Sen Lake (82%), and West Airbase (83%), while the worst

were at Thuan Tay (29%) and Anh Khe (60%). The low level of correct assignment of people at these two latter areas suggests the people there have a wide range of congeners in their blood which may be reflective of exposure to a wide range of risk factors.

In the jackknifed classification matrix (Table 3.16), using all data except the individual being classified, the group assignment performed slightly worse (63%), but still has a similar success rate. The range of correct assignment decreased to 21% at Thuan Tay, 73% at Sen Lake, 67% at West Airbase, and 47% at Anh Khe. The likelihood of correct assignment for Khue Trung was identical between the two classification matrices. The similarity of the Khue Trung data between the two classification methods suggests that the discriminant functions were particularly valuable at assigning people in this group based on a typical blood congener profile for this area. The decrease in all other groups suggests that people living in these areas have more varied exposure patterns.

Table 3.14 Summary of stepwise forward discriminant analysis for whole human blood; Da Nang Airport, Viet Nam, 2009.

Compound	Standardized Canonical Discriminant Functions			
	1	2	3	4
2,3,7,8-TCDD	1.024	0.599	0.035	0.197
1,2,3,4,7,8-HxCDD	0.493	-1.814	0.271	-0.955
2,3,7,8-TCDF	-0.448	0.214	-0.924	-0.495
1,2,3,6,7,8-HxCDF	-0.736	1.726	0.582	0.195
Eigenvalues	1.787	0.477	0.1	0.002
Proportion of Dispersion	0.755	0.202	0.042	0.001

Table 3.15 Classification matrix for area groupings for whole human blood; Da Nang Airport, Viet Nam, 2009. Actual groupings are presented as rows and the assigned groups are columns.

Area	Anh Khe	Khue Trung	Sen Lake	Thuan Tay	West Airbase	% Correct
Anh Khe	9	0	1	3	2	60
Khue Trung	1	40	1	3	0	89
Sen Lake	0	0	9	1	1	82
Thuan Tay	6	6	2	8	2	33
West Airbase	1	0	0	0	5	83
Total	17	46	13	15	10	70

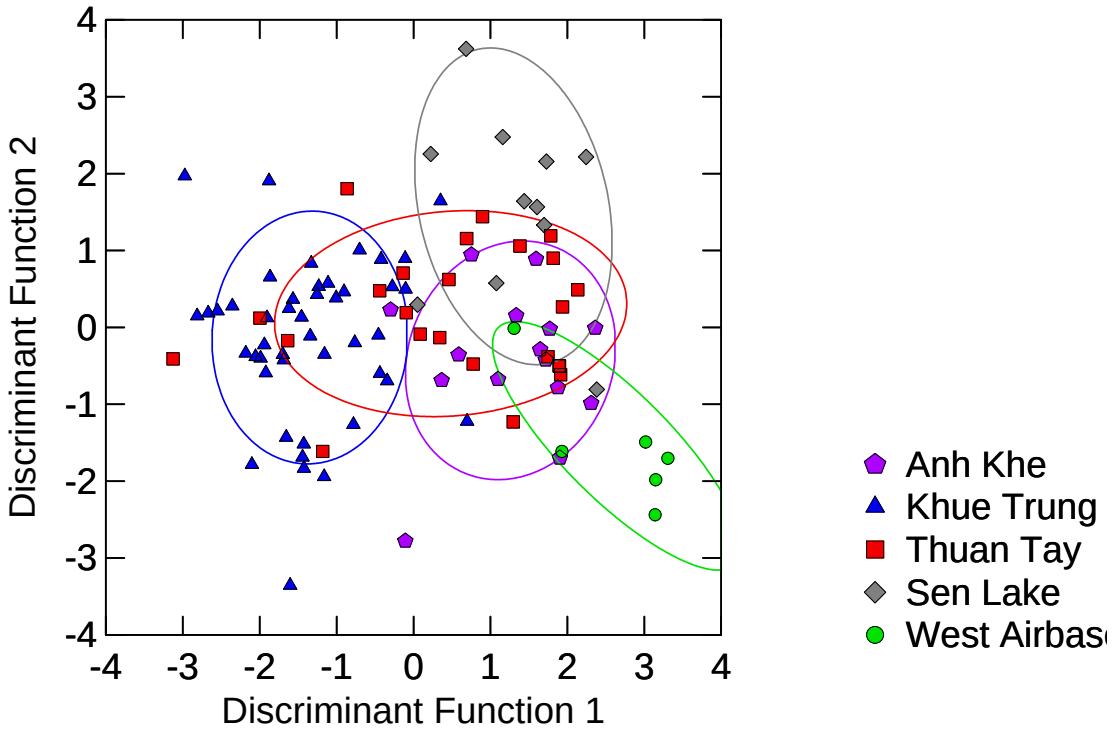
Table 3.16 Jackknifed classification matrix for whole human blood; Da Nang Airport, Viet Nam, 2009. Actual groupings are presented as rows and the assigned groups are columns.

Area	Anh Khe	Khue Trung	Sen Lake	Thuan Tay	West Airbase	% Correct
Anh Khe	7	2	1	3	2	47
Khue Trung	1	40	1	3	0	89
Sen Lake	0	1	8	1	1	73
Thuan Tay	8	6	3	5	2	21
West Airbase	2	0	0	0	4	67
Total	18	49	13	12	9	63

The canonical scores generated by the discriminant analysis of each individual person are plotted in Figure 3.23. There is a large amount of overlap between groups, particularly with Anh Khe and Thuan Tay which overlap with each other and, to varying degrees, with the three remaining areas. Khue Trung, however, is unique from both Sen Lake and West Airbase workers. Sen Lake and West Airbase workers show a small amount of overlap in their confidence ellipses along the second axis. The largest separation between areas is along the x-axis of the plot (first discriminant function) between Khue Trung and Sen Lake and West Airbase workers.

The overlap of Anh Khe and Thuan Tay with all other groups suggests that people in these areas have blood congener signatures that are similar to the distinct profiles of Khue Trung, West Airbase, and Sen Lake. This suggests that people in Anh Khe and Thuan Tay are a mixture of people exposed to different risk factors; some of these risk factors overlap with people that were selected for this study because they have worked on the base. They therefore show intermediate signatures of dioxin/furans between Khue Trung and Sen Lake/West Airbase workers. The distinction of Khue Trung from the West Airbase and Sen Lake workers is largely a function of the TCDD levels measured in their blood.

Figure 3.23 Canonical scores from Discriminant Functional Analysis for each person measured for blood dioxin/furans in 2009 with 68% confidence ellipses; Da Nang Airport, Viet Nam, 2009.



3.3.8.7 Demographics

Demographic and lifestyle data were analyzed as possible explanatory variables for the TCDD and TEQ values found among people not in the high-risk groups. Sen Lake and West Airbase Workers were excluded from these analyses, but they are presented for comparative purposes in Table 3.17.

Several variables showed a large degree of variability among the separate areas, including if the people eat fish fat, if they eat fish from the base, and if they work on the base.

Specific analysis of a pooled group of Khue Trung, Anh Khe, and Thuan Tay Wards together showed that the all factors examined separately were non-significant predictors of blood TCDD or TEQ ($p>0.015$), except working on the base ($p<0.0007$; Figure 3.24) or visiting the base ($p<0.001$) at $\alpha=0.01$; both of these variables significantly increased the blood TCDD and TEQ values in people that had either been to or worked at the base.

In examining the relationship between going to the base and working on the base on blood TCDD further, using a two-way ANOVA, working on the base was found to be a significant factor ($p=0.007$) and visiting the base was not ($p=0.873$); there was no interaction between working on the base and visiting the base ($p=0.454$). This result suggests that working on the base was the controlling

factor in the one-way ANOVA of people visiting the base. This means that people that worked on the base also answered 'yes' to visiting the base, biasing the results for the latter analysis.

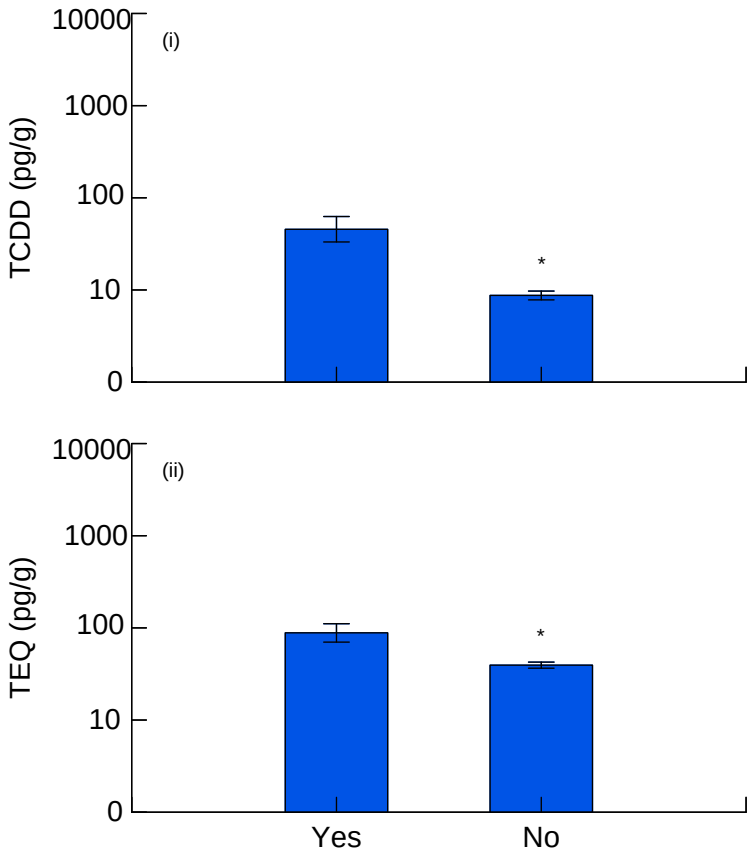
The Sen Lake and West Airbase workers were also pooled in a high-risk group and analyzed for effects of the grouping factors in Table 3.13. The tests within this group, however, were limited by the lack of variation in the answers. For instance, all Sen Lake and West Airbase workers admitted to eating fish from the base and almost all people reported working on the base. Among the Sen Lake and West Airbase workers, eating fish from Sen Lake is not a significant factor in determining blood TCDD ($p=0.28$) and TEQ ($p=0.45$; data not shown); all other demographic factors were also not significantly different ($p>0.034$).

When all people that reported working on the base from all areas are pooled, significant differences were found in these workers that reported eating fish from Sen Lake in TCDD ($p=0.008$), but not in TEQ ($p=0.011$) at $\alpha=0.01$. No significant differences were found in other tested variables ($p>0.022$) at $\alpha=0.01$. Burning garbage was significant at $\alpha=0.05$ in increasing TEQ ($p=0.028$) and TCDD ($p=0.022$) blood concentrations.

Table 3.17 Selected demographic information of people sampled for blood dioxin levels; Da Nang Airport, Viet Nam, 2009. Bolded values represent greater than half of respondents answered 'yes' to the Grouping Factor question.

Grouping Factor	Khue Trung	Anh Khe	Thuan Tay	Sen Lake	West Airbase
Eat fat	0.36	0.13	0.17	**0.90**	0.17
Eat all parts of fish	0.24	0.13	0.08	0.20	0.17
Use wood burning stove	**0.78**	**0.67**	**0.58**	**0.90**	**0.83**
Burning garbage	0.11	0.27	0.00	**0.60**	0.33
Eating fish from base	0.16	**0.53**	0.04	**1.00**	**1.00**
Fishing on base	0.38	0.27	0.21	**0.60**	**0.83**
Eat fish from Sen Lake	0.14	0.13	0.00	**0.60**	0.33
Eat fish from other lakes	0.18	0.27	0.00	0.20	0.33
Worked on base	0.00	0.47	0.13	**0.73**	**1.00**
Visited base	0.20	**0.73**	0.21	**0.91**	**1.00**

Figure 3.24 Mean blood TCDD (i) and TEQ (ii) ±SE grouped by the question "Have you ever worked on the Airport" for Anh Khe, Khue Trung and Thuan Tay wards (excludes Sen Lake and West Airbase workers); Da Nang Airport, Viet Nam, 2009. Asterisk notes significant difference.



3.3.9 Summary of Blood Data

Several key results can be drawn from the statistical analysis presented above. Analysis of blood dioxin/furan levels by area yields significant results in both years; Sen Lake had significantly elevated blood TCDD and TEQ values from both 2006 and 2009 relative to other areas, but other data from the 2009 analyses suggest that living in an area *per se* does not always accurately predict congener levels in blood. The PCA suggests that exposure to a wide variety of contaminants (and possibly a wide variety of sources) is indeed occurring in most people measured for dioxin/furans in the areas surrounding Da Nang. The results from other analyses, however, show us that a large proportion of dioxin contamination results from working on the Airport. For instance, the first axis from the discriminant analysis captures most of the dispersion of the data, is strongly related to TCDD, and shows strong separation between Khue Trung Ward and West Airbase and Sen Lake workers. Thus, although contamination of people around the Airport is clearly from a variety of sources, working on the Airport significantly increases blood TEQ and TCDD levels above the background noise generated from other sources.

The analysis of people randomly selected in the wards surrounding the Airport (Anh Khe, Khue Trung, and Thuan Tay Wards) show that working on the base is the strongest predictor of blood dioxin levels in these people. In addition, the DFA shows a progression from left to right along the x-axis that matches the percentage of people in an area that reported working on the base. For instance, no one in Khue Trung reported working on the base; some people in Anh Khe and Thuan Tay (described as intermediates between Sen Lake/West Airbase and Khue Trung people) reported working on the base (13 to 47%); most people from West Airbase and Sen Lake reported working on the base (73 to 100%); this pattern, although only suggestive, follows the x-axis of the DFA from left to right.

The relation of specific risk factors, such as working on the base to the randomly selected group (people pooled from Anh Khe, Khue Trung, and Thuan Tay Wards) shows that differences of blood TCDD and TEQ reported between areas are significantly influenced by the proportion of people who have worked on the base versus people that have not. No other risk factor examined was related to the levels of blood dioxin in this group. Based on these analyses, working on the base (versus not working on the base) appeared to be enough of trigger to increase an individual's blood TCDD and TEQ levels.

In analysing all people that reported working on the base for factors that could explain their blood dioxin levels, eating fish from Sen Lake was a significant factor. This analysis, however, is difficult to interpret because Sen Lake and West Airbase workers were included in the study because they were suspected of having high blood dioxin; their inclusion with other people that reported working on the base at unknown positions biases this analysis. Although this result is confounded, it is highly suggestive of the influence of eating patterns on the resulting blood dioxin levels of people.

The typical range of TCDD in the general population of industrialized countries has been reported as 3 to 7 pg/g (lipid-based) (ATSDR 1998). ATSDR also indicated that TCDD in human blood rarely exceeds 10 pg/g and that typically, lower levels of this contaminant are recorded in less industrialized countries. In all wards surrounding Da Nang Airport, TCDD concentrations were often higher than 10 pg/g. Figure 3.25 provides the minimum, median and maximum TCDD and TEQ values reported for each ward or group of workers for comparison with these international values.

TCDD concentrations in human blood from donors of Khue Trung Ward, which exhibited the statistically lowest TCDD and TEQ levels, were ≤15 pg/g. The low percent TCDD of TEQ values (none exceeded 40%) also indicate that it is unlikely that these participants are significantly impacted by Agent Orange exposure from soils, sediment, water or food supplies. This was also true for individuals sampled in 2006 from Thuan Phuoc Ward, Hai Chau District (reference area), where TCDD concentrations were <10 pg/g.

In other wards, some individuals exhibited TCDD concentrations less than 10 pg/g; these include residents from Anh Khe and Thuan Tay Wards, and 2006

donors from Chinh Gian Ward. These wards are located on the east, north and west sides of the Airport, near the boundary.

Sen Lake and West Airbase workers that were retested in 2009 indicated a slight increase in TCDD and/or TEQ levels compared to 2006 results. However, high variability in blood lipid measurements between years was also recorded, which confounded interpretation of results. Hatfield requested AXYS to conduct a detailed investigation of blood lipid analytical variability recorded in 2006 and 2009, which is presented in Appendix A4.

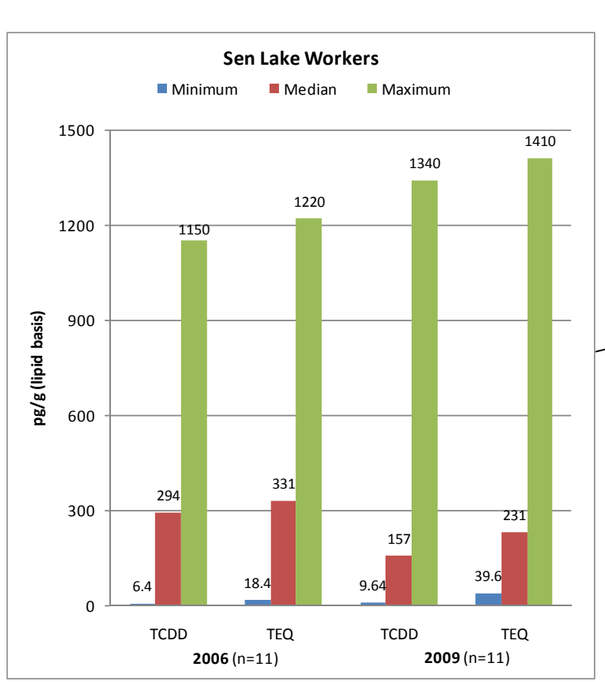
The Sen Lake workers have been relocated and all fishing and agricultural activities in the north Airport area have been halted (with the exception of the West Airbase Ponds, which are still in operation). The movement of dioxin from the highly contaminated lands adjacent to Sen Lake, and ultimately into humans (via ingestion of contaminated fish and direct contact with soils and sediments), was evident in the 2006 human blood samples and appeared to be directly linked to historical Agent Orange use at the Airport. Following implementation of interim mitigation measures in 2007, there has been a significant reduction in the potential dioxin exposure pathways for residents of Da Nang. However, it is premature to conclude if these interim measures have resulted in a significant change in actual blood dioxin concentrations.

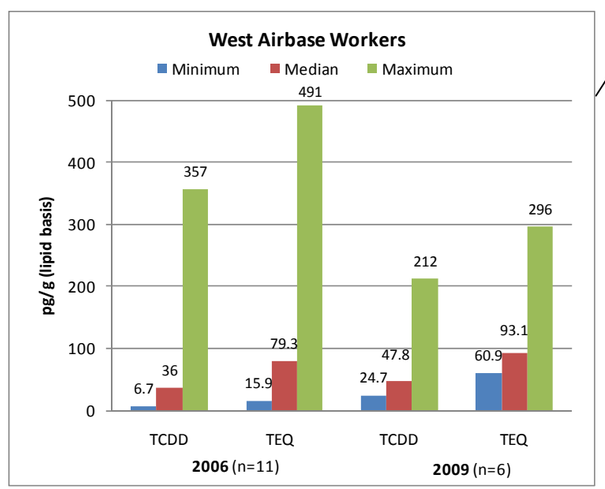
This study reports the percent TCDD present in the TEQ as the marker for Agent Orange exposure given that it is the only dioxin/furan congener that was a contaminant in Agent Orange. TCDD is considered the most toxic dioxin/furan congener, and has a multiplier of "1" when calculating WHO 2005 TEQs.

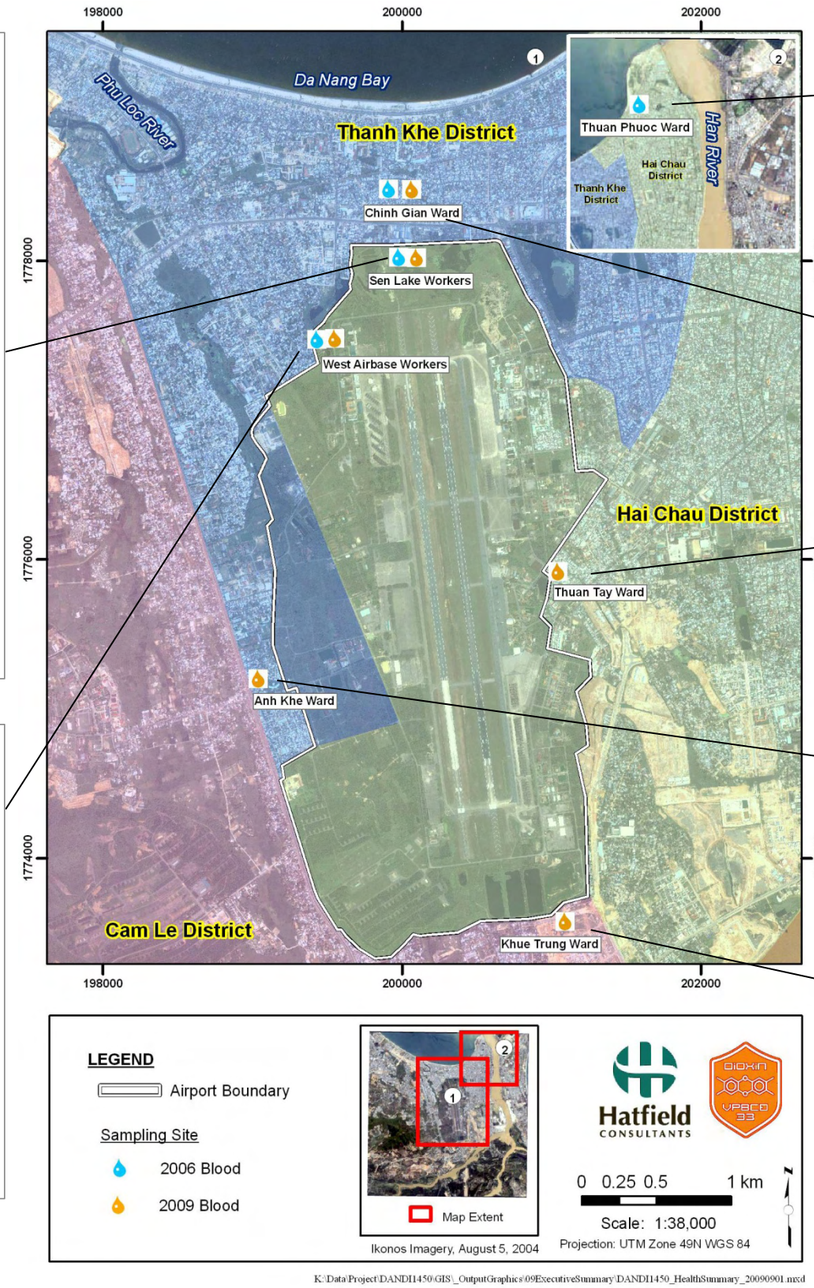
Where TCDD percent of TEQ is low, there are several other dioxin and furan congeners that are primary contributors to TEQ calculations for human blood samples in this study. These include 1,2,3,7,8-PECDD (TEF = 1), 2,3,4,7,8-PECDF (TEF = 0.3), 2,3,7,8-TCDF and all hexa-dioxins and furans (TEF = 0.1). Note that although OCDD and OCDF concentrations are quite high, the TEF is very low (0.0003), and the contribution of OCDD/F to TEQ is consequently low. Several of the hexa-dioxin and furan congeners were identified in PCA and DFA statistical analyses as providing strong correlations among data groups.

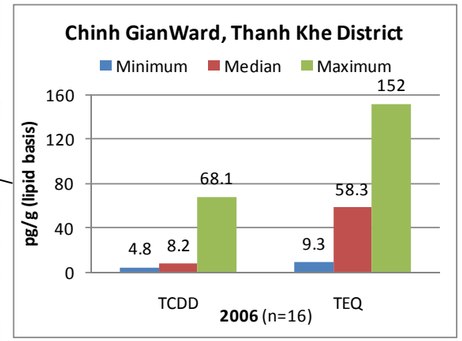
In samples where penta- and hexa-dioxins and furans contribute more to TEQ, sources of contamination may include biphenyls, PCBs, pesticides, or incineration. Polychlorinated dibenzo-p-dioxins and furans (PCDDs and PCDFs) are mainly the by-products of industrial processes (such as metallurgical processing, bleaching of paper pulp, and the manufacturing of some herbicides and pesticides) but they can also result from natural processes like volcanic eruptions and forest fires (Srogi 2008). Waste incineration, particularly if combustion is incomplete, is among the largest contributors to the release of PCDDs and PCDFs into the environment. Consumption of food is considered as the major source of non-occupational human exposure to PCDD/Fs with foodstuffs from animal origin accounting for more than 90% of the human body burden, with meat, dairy and fish products being the main contributors (Srogi 2008). Other potential dioxin sources in Da Nang need to be determined and quantified in order to verify the total dioxin load to the environment and human population.

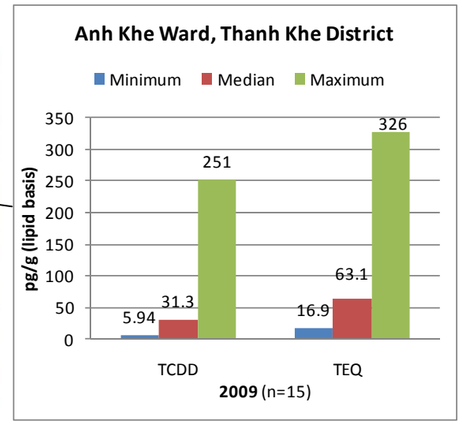
Figure 3.25 Summary of TCDD and TEQ values (minimum, median and maximum; pg/g lipid basis) for human blood samples by area in Da Nang, Viet Nam, 2006 and 2009. The ATSDR (2006) standard for TCDD is 10 pg/g (lipid basis). [Note: Males and females were combined for each area and year.]

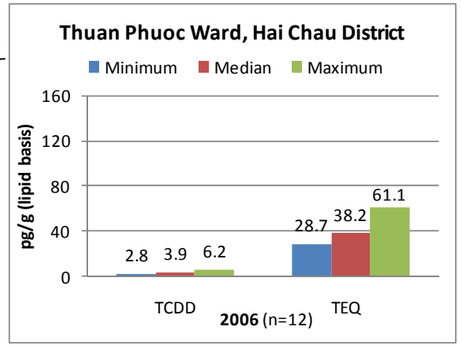


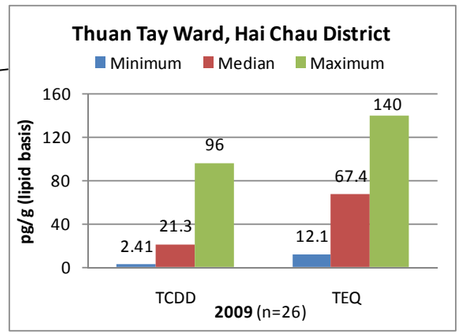


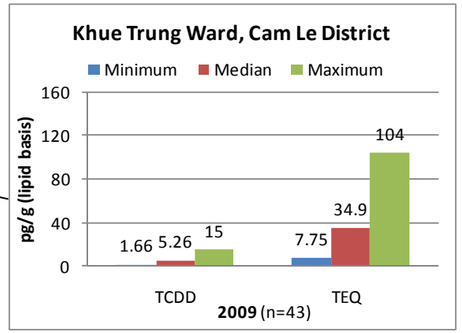












3.4 BREAST MILK

- **Table 3.18 and 3.19, Figure 3.26**

Dioxins and furans were analyzed in human breast milk collected from a total of 14 female donors in Da Nang from the Districts of Thanh Khe (n=5), Cam Le (n=2), and Hai Chau (n=7). Only one sample was collected in 2006 from a woman living in the Thanh Khe District north of the Da Nang Airport. All milk TCDD/TEQ data are provided on a lipid normalized basis.

Of the 14 breast milk donors, six were breastfeeding their first infant, five were feeding their 2nd infant, two were with their 3rd infant, and one was unknown (no questionnaire completed) (Table 3.19). The mother sampled in 2006 was breastfeeding her first infant.

3.4.1 Thanh Khe District

One milk sample (09VN343A) was collected from a relocated "Sen Lake Worker" who resided in Thanh Khe District in 2009; this sample exhibited very high TCDD (232 pg/g) and TEQ (263 pg/g) levels relative to all other samples collected in 2009. TCDD contributed 88% of TEQ, indicating Agent Orange as the likely contamination source; the donor is known to have consumed Sen Lake fish on numerous occasions in the past.

Dioxin concentration in one sample was also elevated (24.4 pg TCDD/g, sample 09VN344A, West Airbase Worker) and the remaining three samples for females from Anh Khe Ward exhibited much lower TCDD levels (2.74 to 4.39 pg/g). TEQs ranged from 7.41 pg/g to 53.2 pg/g with TCDD representing 17% to 48% of total TEQ. Other dioxin congeners also contributed to total TEQ in breast milk samples.

3.4.2 Cam Le District

Two samples of breast milk exhibited low TCDD concentrations (1.15 pg/g and 3.46 pg/g), which comprised 17% and 15%, respectively, of total TEQ levels. These results indicate that contamination from Agent Orange is unlikely for these individuals sampled from this area.

One mother contributed both breast milk and blood for analyses. The TCDD concentrations were similar in both samples (09VN331A – 1.15 pg TCDD/g in milk; 09VNB120 – 1.2 pg TCDD/g in blood). The TEQ was slightly higher (6.6 pg/g) for the breast milk sample relative to her blood sample (5.28 pg/g).

Table 3.18 Concentrations of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in human breast milk from districts near the Da Nang Airport (pg/g [ppt], lipid basis), Viet Nam, April 2009 and December 2006.

Sample ID	District	Ward	Age	PCDD (pg/g lipid basis)						PCDF (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD as % of TEQ (2005)
				2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF				
09VN340A	Thanh Khe	Anh Khe	35	4.39	4.39	4.44	13.7	13.7	79.6	1.56	1.56	6.27	15.3	7.58	NDR 0.677	6.65	14.7	13.7	32%
09VN341A	Thanh Khe	Anh Khe	27	3.58	3.58	1.52	4.32	5.2	18.3	1.69	1.89	4.15	6.45	2.7	NDR 0.142	7.04	8.07	7.41	48%
09VN342A	Thanh Khe	Anh Khe	37	2.74	2.74	7.52	20.6	18.7	102	1.52	2.18	6.4	16.6	5.56	< 0.527	4.53	17.6	16.3	17%
09VN343A		Sen Lake	24	232	232	16.5	45.2	17.5	127	1.02	1.49	15.6	54.9	21.1	1.06	6.3	266	263	88%
09VN344A		West Airbase	27	24.4	24.4	16.1	43.7	20.3	114	1.29	1.88	19.3	24.8	7.79	0.23	4.35	56.8	53.2	46%
09VN331A	Cam Le	Khue Trung	33	1.15	1.15	2.01	5.61	10.5	75.4	1.18	1.74	4.62	13.3	10.1	NDR 0.592	2.53	7.36	6.6	17%
09VN332A	Cam Le	Khue Trung	38	3.46	3.46	7.58	26.1	23.9	123	5.92	9.1	13.2	40.4	< 2.90	< 2.90	2.11	25.4	22.7	15%
09VN330A	Hai Chau	Thuan Tay	25	5.82	5.82	3.88	13.8	12.6	43.7	1.28	1.76	7.76	31.1	13.2	< 0.441	2.27	18	16.6	35%
09VN335A	Hai Chau	Thuan Tay	27	23.6	23.6	12.3	33.1	26.4	120	2.09	2.09	12.1	25.7	10.2	< 0.696	2.82	48	45.8	52%
09VN334A	Hai Chau	Thuan Tay	25	5.08	5.08	7.31	24.3	14.7	125	1.15	1.53	8.55	31.9	13.4	NDR 0.585	4.45	22.4	20.8	24%
09VN336A	Hai Chau	Thuan Tay	34	4.39	4.39	6.32	20.9	17	81.2	1.74	2.33	11.2	46.2	20.4	NDR 1.02	4.89	23.6	21.4	21%
09VN337A	Hai Chau	Thuan Tay	32	1.11	1.11	1.84	7.09	6.95	47.6	1.01	1.49	4.03	17.1	8.17	0.486	2.88	7.66	6.86	16%
09VN339A	Hai Chau	Thuan Tay	40	8.10	8.10	3.94	13.8	11.5	73	6.61	8.64	22.1	28.4	14.6	0.535	2.62	22.3	20.3	40%
09VN338A	Hai Chau	Thuan Tay	27	7.00	7.00	8.67	33.1	25.8	152	1.91	2.97	16	61.1	34.5	1.67	4.14	32.4	29.8	23%
06VN201M	*Thanh Khe*	*Chinh Gian*	*30*	*6.76*	*6.76*	*15*	*46.3*	*27*	*145*	*0.895*	*0.895*	*23.9*	*82.4*	*23.7*	*NDR 1.88*	*3.24*	*47.2*	*42.4*	*16%*

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for "Total TEQ" calculations, NDR was treated as ND.

Figure 3.26 TCDD and Total TEQ (pg/g [ppt], lipid basis) for human breast milk from females in the vicinity of Da Nang Airport, April 2009 and December 2006.

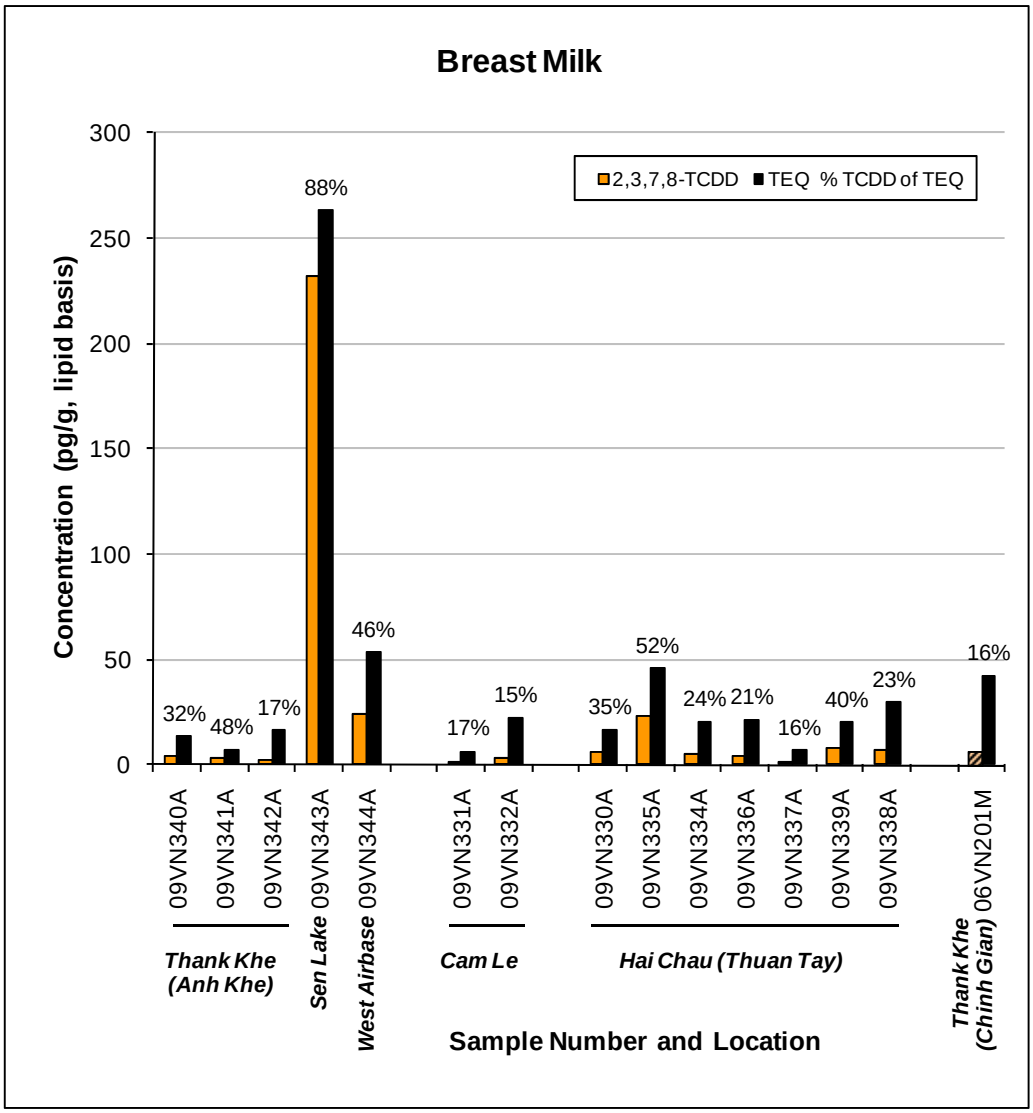


Table 3.19 Average daily intake[1] (pg TEQ/kg bw/d) of TCDD and Total-TEQ by infants consuming human breast milk[2] collected from females (first, second or third child), Da Nang, Vietnam, 2006 and 2009.

Sample ID	District	Ward	Age	Infant # Currently Breast-feeding	% Lipid	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	Average Daily Intake			
								TCDD (actual lipid)	T-TEQ (actual lipid)	TCDD (3.5% lipid)	T-TEQ (3.5% lipid)
09VN340A	Thanh Khe	Anh Khe	35	2nd	6.65	4.39	13.7	40.9	128	21.5	67.1
09VN341A	Thanh Khe	Anh Khe	27	2nd	7.04	3.58	7.41	35.3	73.0	17.5	36.3
09VN342A	Thanh Khe	Anh Khe	37	2nd	4.53	2.74	16.3	17.4	103	13.4	79.9
09VN343A	Sen Lake		24	1st	6.3	232	263	2046	2320	1137	1289
09VN344A	West Airbase		27	NA[3]	4.35	24.4	53.2	149	324	120	261
09VN331A	Cam Le	Khue Trung	33	2nd	2.53	1.15	6.6	4.1	23.4	5.6	32.3
09VN332A	Cam Le	Khue Trung	38	3rd	2.11	3.46	22.7	10.2	67.1	17.0	111
09VN330A	Hai Chau	Thuan Tay	25	1st	2.27	5.82	16.6	18.5	52.8	28.5	81.3
09VN334A	Hai Chau	Thuan Tay	25	1st	4.45	5.08	20.8	31.6	130	24.9	102
09VN335A	Hai Chau	Thuan Tay	27	1st	2.82	23.6	45.8	93.2	181	116	224
09VN336A	Hai Chau	Thuan Tay	34	1st	4.89	4.39	21.4	30.1	147	21.5	105
09VN337A	Hai Chau	Thuan Tay	32	1st	2.88	1.11	6.86	4.5	27.7	5.4	33.6
09VN338A	Hai Chau	Thuan Tay	27	2nd	4.14	7.00	29.8	40.6	173	34.3	146
09VN339A	Hai Chau	Thuan Tay	40	3rd	2.62	8.10	20.3	29.7	74.5	39.7	99.5
06VN201M	*Thanh Khe*	*Chinh Gian*	*30*	*1st*	*3.24*	*6.76*	*42.4*	30.7	192	33.1	208

[1] Average Daily Intake = (volume of milk per day in ml)x(% lipid in milk/100)x(concentration of chemical in pg/g)/(infant weight in kg).

[2] Average daily intake via human milk based on an infant body weight of 5 kg and consuming 700 ml of milk per day (WHO/EURO 1989).

[3] NA = not available.

3.4.3 Hai Chau District

Dioxins and furans were recorded in all breast milk samples collected from females in Thuan Tay Ward of Hai Chau District. The highest TCDD concentration (09VN335A) was 23.6 pg/g, which comprised 52% of total TEQ (45.8 pg/g). Other milk samples exhibited TCDD levels ranging from 1.11 ppt to 8.10 ppt; TEQs ranged from 6.86 pg/g to 21.4 pg/g, with the percentage of TCDD ranging from 16% to 40%. Other dioxin congeners found in breast milk contributed to total TEQ.

3.4.4 Summary of Breast Milk Data

The WHO acceptable standards (1 to 4 pg TEQ/kg bw/day) cover the range of established Tolerable Daily Intake PCDD/F exposures for several countries (as presented in Table 1.9). In Canada, the TDI has been reduced to 2.3 pg TEQ/kg bw/d (Health Canada 2005) from 10 pg TEQ/kg bw/d. The most highly exposed part of the population is the breastfed infant, where exposure to PCDDs and PCDFs via ingestion can be higher, on a body weight basis, than during other periods in a person's life (Lakind 2007).

To assess the impact of TEQ levels in breast milk recorded during the Da Nang studies, the Average Daily Intake (ADI) was calculated based on recommended parameters established by WHO (WHO/EURO 1989). These parameters assume an infant weight of 5 kg, milk consumption by the infant of 700 ml/d, and a percent milk fat of 3.5%. Table 3.19 presents these calculations and the ADI based on actual milk fat (lipid) percentages by donor.

Utilizing the WHO parameters, all individual ADI values from the Da Nang study exceeded the 4 pg TEQ/kg bw/d WHO standard. The ADI was lowest with sample 09VN331A, a mother from Khue Trung, Cam Le District, who was feeding her second child. The ADI was 23.4 pg TEQ/kg bw/d based on the actual lipid percent, and 32.3 pg TEQ/kg bw/d when the 3.5% WHO parameter was used. As reported in Section 1.3.4, breastfed babies often have a daily dioxin intake 1- to 2-times greater than adults, and can be as high as 35 pg I-TEQ/g milk fat in industrialized countries. The Khue Trung sample and 09VN337A (Thuan Tay, Hai Chau District) fall within this exposure level.

The ADI calculated with actual milk fat (lipid) for the young Sen Lake mother (09VN343A) is extremely high (2,320 pg TEQ/kg bw/d), followed by the West Airbase mother's sample. ADIs greater than 100 pg TEQ/kg bw/d were also observed for residents of Thuan Tay, Hai Chau District, and Anh Khe, Thanh Khe District. The 2006 milk sample from a Chinh Gian, Thanh Khe District, mother was calculated as 192 pg TEQ/kg bw/d.

Lakind (2007) reports that there appears to be a decline in global levels of PCDDs/Fs in human milk from the 1970s to 2005. However, the question of whether the presence of PCDDs/Fs in milk is from the lifetime accumulation of PCDDs/Fs in adipose tissue or current diet (or a combination of both) remains unanswered. There is evidence that the first child is exposed to higher concentrations of PCDDs/Fs than second and later children (Fürst *et al.* 1989).

3.5 QA/QC

3.5.1 Environmental Samples

- **Table 3.20**

Lab QA/QC

AXYS performed a number of duplicate and replicate dioxin and furan analyses as part of the QA/QC for this project (Table 3.20). In all cases, soil, sediment and fish tissue duplicate samples were in close agreement, and were within acceptable levels of variability.

- **Table 3.21**

Field QA/QC

QA/QC replicate samples were collected by Hatfield throughout the Airport. Soil replicates were collected at the West, East and North Base Perimeters and Sediment replicates were collected from the North Airport drainage ditch (302A) and Lake M. Fish tissue replicates were collected for Tilapia muscle sampled in Sen Lake. The difference between replicates was calculated as a relative percent difference (RPD). RPDs calculated for TCDD and TEQ were greater than 20% for soil collected at the East Base Perimeter (297A) and for sediment collected from the North Airport drainage ditch (302A). The variability in TCDD and TEQ for sample 297A could be attributed to the fact that the sample concentrations were very low and near the detection limit. The variability for sample 302 is attributed to soil heterogeneity, as was also seen in samples collected over several years at the same location. All other replicates had RPDs below 20% for both TCDD and TEQ indicating good homogenization of samples, and a high level of confidence in lab analysis.

3.5.2 Rinseate Water

- **Table 3.20**

Two samples were analyzed from rinseate water used to clean sampling equipment used in this study (Table 3.20). One sample, collected at the start of the January Airport sampling program (Rinsate 1) did not have detectable levels of dioxins and furans. The second sample, collected at the end of the Airport sampling program (Rinsate 3), had similar results indicating no cross-contamination between sites.

Table 3.20 AXYS Lab QA/QC analyses for dioxin and furan analyses, Da Nang, Viet Nam, January 2009 and April 2009.

Sample ID	Location	Media	PCDD (pg/g)						PCDF (pg/g)						TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
Soil and Sediment - dry weight																	
210A	Pacer Ivy Storage Area	Soil	123	239	168	206	355	2200	NDR 67.0	583	336	39.1	22.8	27.4	189	189	65.1
210A (Dup)	Pacer Ivy Storage Area	Soil	121	232	162	199	349	1710	NDR 65.4	582	318	37.8	24.8	24.7	183	183	66.1
325A	Pacer Ivy Storage Area	Soil	1.25	17.1	5.13	53.8	310	4260	0.7	0.7	1.38	12.4	23	19.4	5.93	6.61	18.9
325A(Dup)	Pacer Ivy Storage Area	Soil	1.43	17.5	7.6	60.7	297	4310	0.881	7.84	6.08	14.3	23.5	18.7	7.24	7.93	18.0
224A	Pacer Ivy Re-Drumming Area	Soil	2.55	3.29	0.833	37.1	153	938	1.27	5.34	9.22	18.2	25	14.2	5.03	5.2	49.0
224A (Dup)	Pacer Ivy Re-Drumming Area	Soil	NDR 2.37	0.727	7.97	34.5	150	960	1.31	5.79	10.4	20.8	26.1	14	3.88	3.92	NC
238A	South Airport Perimeter	Soil	145	153	26.4	149	897	4730	5.67	17.3	36	76	107	75	160	161	90.1
238A (Dup)	South Airport Perimeter	Soil	162	170	9.52	163	1190	5350	6.27	16.1	40	82.6	108	76.3	179	180	90.0
270A	West Airport Perimeter	Soil	NDR 0.869	< 0.680	21.2	297	2100	10700	1	7.03	69.2	378	1020	1160	36.5	38.8	NC
270A (Dup)	West Airport Perimeter	Soil	NDR 0.610	2.82	20.2	299	2120	10800	1.13	10	75.6	367	1010	1220	35.9	38.2	NC
281A	Lake M	Sediment	0.2	0.992	2.48	12.4	82.9	2780	0.723	4.06	3.82	4.83	6.28	4.68	1.8	2.28	8.8
281A (Ex. Dup)	Lake M	Sediment	0.188	0.991	1.82	12	70.1	2800	0.58	3.34	2.9	2.73	4.25	4.56	1.63	2.13	8.8
Fish - wet weight																	
254B	Lake D	Fish	2.99	3.28	0.274	< 0.214	< 0.278	2.01	1.05	1.05	0.4	< 0.277	< 0.315	< 0.497	3.57	3.49	85.7
254B (Dup)	Lake D	Fish	2.87	2.88	< 0.204	< 0.298	< 0.349	2.82	1.15	1.15	< 0.316	< 0.211	< 0.372	NDR 0.283	3.28	3.2	89.7
259A	Lake H	Fish	NDR 0.511	< 0.0492	< 0.0492	0.431	0.67	2.19	< 0.0492	< 0.0492	< 0.0492	0.059	< 0.0492	0.096	0.131	0.126	NC
259A (Dup)	Lake H	Fish	0.496	0.496	< 0.0618	0.437	0.572	1.99	< 0.0618	< 0.0618	0.272	< 0.0618	0.078	< 0.0618	0.689	0.653	76.0

NC= Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for “Total TEQ” calculations, NDR was treated as ND ("0").

Dup = Duplicate

Ex. Dup = External duplicate performed in a different batch

Table 3.21 Hatfield Consultants QA/QC for dioxin and furan analyses, Da Nang, Viet Nam, January 2009.

Sample ID	Location	Media	PCDD (pg/g)						PCDF (pg/g)						TEQ (WHO 1998) ND=1/2DL	TEQ (WHO 2005) ND=1/2DL	TCDD as % of TEQ (2005)
			2,3,7,8-TCDD	Total T4CDD	Total P5CDD	Total H6CDD	Total H7CDD	Total O8CDD	2,3,7,8-TCDF	Total T4CDF	Total P5CDF	Total H6CDF	Total H7CDF	Total O8CDF			
Soil/Sediment - dry weight																	
271A	West Airbase Perimeter	Soil	1.61	1.99	1.78	23	104	863	0.503	0.503	1.71	< 0.185	6.42	5.15	2.71	2.85	56
272A	West Airbase Perimeter	Soil	1.71	1.71	0.686	20.9	101	814	0.392	1.24	< 0.273	3.28	5.36	4.52	3.43	3.56	48
Relative Percent Difference (%)			6.02													22.15	
297A	East Base Perimeter	Soil	1.05	5.23	17.3	138	1050	4800	2.01	12.1	36.6	73.8	66	22.8	15.8	16	7
205A	East Base Perimeter	Soil	1.97	5.42	17.9	150	1070	5160	2.33	11	33.7	85.2	69.3	24.4	18.6	18.9	10
Relative Percent Difference (%)			60.93													16.62	
304A	North Base Perimeter	Soil	11200	12000	1750	3090	3320	5060	449	2350	3190	700	178	42	11700	11700	96
305A	North Base Perimeter	Soil	12200	13000	1810	3130	3230	4880	498	2500	3310	694	174	65.3	12700	12700	96
Relative Percent Difference (%)			8.55													8.20	
302A	North Base Perimeter	Sediment	4080	4390	426	792	1010	4380	198	795	903	211	70.2	41.4	4200	4200	97
303A	North Base Perimeter	Sediment	3250	3500	349	655	853	3870	162	662	735	174	58.8	35.6	3350	3350	97
Relative Percent Difference (%)			22.65													22.52	
Fish Tissues - wet weight																	
309A	Sen Lake A (West)	Fish	39.2	39.2	< 0.0499	< 0.0499	< 0.0499	0.454	16.6	16.6	< 0.0499	< 0.0499	< 0.0499	< 0.0499	40.9	40.9	96
310A	Sen Lake A (West)	Fish	40.5	40.5	< 0.0492	0.074	0.309	0.713	17.9	17.9	0.092	0.074	0.12	0.172	42.3	42.3	96
Relative Percent Difference (%)			3.26													3.37	
Rinseates - pg/L																	
1	09VN-RINSATE1	Water	< 0.493	< 0.493	< 0.493	< 0.493	< 0.493	9.39	NDR 0.766	< 0.493	< 0.493	0.498	< 0.493	1.09	0.859	0.807	30
3	09VN-RINSATE3	Water	NDR 0.790	< 0.499	< 0.499	< 0.499	1.45	10.5	< 0.499	< 0.499	< 0.499	< 0.499	< 0.499	< 0.499	0.856	0.804	NC

NC= Not calculated (e.g., samples with 2,3,7,8-TCDD concentrations that were NDR - not quantifiable).

ND = Not detected; for "Total TEQ" calculations, if ND, 1/2 detection level was used.

NDR = Peak detected but did not meet quantification criteria; for 'Total TEQ' calculations, NDR was treated as ND ("0").

4.0 CONCLUSIONS AND RECOMMENDATIONS

The 2009 environmental and human population studies at Da Nang Airport and in surrounding communities has provided a more complete picture of the overall dioxin contamination issue in the Da Nang area, including the suspected Pacer Ivy sites in the southwestern area of the Airport. When combined with data collected in 2006 from the most highly contaminated areas in the northern Airport area (Hatfield/Office 33 2007), we now have a better understanding of dioxin-contaminated areas, exposure pathways and affected populations. A total of 410 environmental samples have been analyzed for dioxin/furan concentrations from Da Nang Airport and Da Nang City since 2005, under studies conducted by Hatfield, Office 33 and 10-80 Division (Hatfield/10-80 2005; Hatfield/Office 33 2007). These data will help facilitate planned remediation efforts for Da Nang Airport, which are currently being discussed between the Governments of Viet Nam and the United States.

Dioxin (particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin; also referred to as 2,3,7,8-TCDD or TCDD), a known component of the Agent Orange mixture, is known to cause an increased risk of cancers, immunodeficiencies, reproductive and developmental changes, nervous system and other health problems. Dioxins in soil can pose a lingering threat to human health; Paustenbach *et al.* (1992) has indicated that the half-life of dioxins in subsurface soils can extend to 100 years. Once in the human body, the half-life is estimated at approximately 7 to 11 years.

A "standards/guideline" approach to human health protection has been taken to address the dioxin issue in many western jurisdictions. Numerical standards and guidelines addressing TCDD contamination have been established by many reputable organizations and scientists (e.g., WHO/EURO 1988, 1989, 1991, 1998a, 1998b, 2001, Agency for Toxic Substances and Disease Registry 1997, 1998; International Agency for Research on Cancer [a division of the World Health Organization] 1997). New standards have also recently been released for Viet Nam (National Standard TCVN 8183:2009). When these contamination guidelines are exceeded in soils or human food, mitigation action is recommended and/or enforced.

Despite the fact that dioxins are known to be a significant environmental hazard, it has only been in recent years that adequate measures have been taken to properly assess the extent and impact of contamination around known hot spots in Viet Nam, especially in Da Nang, Bien Hoa and Phu Cat. Protection of human health in the vicinity of these dioxin hot spots is of key concern, and Da Nang is a priority area for intervention.

Primary conclusions from studies conducted at Da Nang Airport and vicinities between 2006-2009 are as follows:

- Significant quantities of TCDD, a contaminant in Agent Orange, were detected in samples analyzed from the north of the Da Nang Airport in December 2006. 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 analyzed were >100,000 ppt TCDD, and 17 of 23 (74%) soil samples analyzed from the Airport were >1,000 ppt. As of 2009, dioxin continues to enter the aquatic ecosystem, the general environment and the food chain. To this day, dioxin levels recorded in the north of the Da Nang Airport continue to exceed all international standards and guidelines for these toxic chemicals.

- TCDD levels measured in 2009, in the central and southern Da Nang Airport areas, were significantly lower than contaminant levels detected in the north; the exception being a small area in the Pacer Ivy Storage Area (PISA). The analytical chemistry undertaken at AXYS, a WHO-tested and approved dioxin laboratory, indicated elevated TCDD levels in one soil sampling location near the PISA site (13,400 ppt TCDD, 20,600 ppt TEQ; 65% TCDD). In addition, one fish fat sample (25.1 ppt TEQ) from Lake D in southern Da Nang Airport exceeded the Health Canada consumption guideline of 20 pg/g TEQ.

- Dioxin congener profiles confirm that the main source of dioxin contamination in the northern Da Nang Airport area was Agent Orange and other dioxin-containing herbicides. TCDD contributed over 90% of the TEQ (TCDD toxic equivalents) in soil and sediment samples collected from the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake. A more detailed account of past site investigations, and contaminant distributions is available in Hatfield/Office 33 (2007) and Young (2009). The proportion of TCDD to TEQ concentrations at, and adjacent to, the PISA and Pacer Ivy Redrumming Area (PIRA) was generally low.

- The present study (and previous work by Hatfield/10-80/Office 33 [1998, 2000, 2003, 2006, 2007]) has verified that the highest concentrations of Agent Orange dioxin in soils/sediments in Viet Nam are found in the top 10 cm layer; some contamination is found at deeper strata (e.g., >30 cm), but only in limited areas on the former Mixing and Loading Area, former Storage Area, and the PISA at Da Nang Airport. In this study, the depth profile at the Pacer Ivy Storage Area indicated elevated TEQ levels in the 0-10 cm and 10-30 cm depth profiles.

- The maximum TEQ value recorded in Tilapia fat from Sen Lake in 2009 was 8,350 ppt (wet weight basis), which is more than 400 times the acceptable level established by Health Canada. In 2006, Tilapia fat levels were 3,120 ppt TEQ (wet weight basis), which is more than 100 times the acceptable fish consumption level. It is likely other aquatic biota in Sen Lake (such as frogs, snails, ducks, etc.) are also contaminated. Possible explanations for increased dioxin concentrations in Sen Lake Tilapia between 2006 and 2009 include higher bioconcentration in larger fish over time. Since cessation of fishing practices at Sen Lake in 2007, average fish sizes (and average age) appear to have increased over time, resulting in increased bioaccumulation in biological tissues.

- Other contaminants which contribute to total PCDD/PCDF load (including polychlorinated biphenyls, organochlorine pesticides and hydrocarbons) are also present in the environment, both inside and outside the perimeter of Da Nang Airport. Potential dioxin sources in Da Nang need to be determined and quantified in order to verify the total dioxin load to the environment and human population.

- Collectively, the concentrations of total dioxins and furans indicate extremely high contamination, and confirms the northern end of Da Nang Airport as a significant PCDD/PCDF hot spot. The southern end of Da Nang Airport exhibits limited dioxin contamination.

- The evidence indicates dioxin moves from the former Mixing and Loading and Storage Areas into Sen Lake, and ultimately into humans (via ingestion of contaminated fish and direct contact with soils and sediments), and is directly linked to historical Agent Orange use on the Airport. The Sen Lake ecosystem, located on the Da Nang Airport property, has recently (2007) been restricted from public access, which has resulted in a reduction of critical dioxin exposure to the local human population of Da Nang.

- People who may come into close and regular contact with contaminated soils derived from the site may ingest small amounts of the soil through incidental hand-to-mouth activity. Because of the notably high PCDD concentrations, even small amounts of incidental soil ingestion have the potential to cause significant exposure from ingestion.

- Dermal absorption of PCDD from soil or sediment may occur in situations where certain people contact the soil or sediment during activities such as working on site, or wading into sediments while fishing, harvesting lotus, etc. Soil or sediment contacting the skin for prolonged periods may result in small amounts of contaminant adhering and absorbing across the skin.

- Because the surficial soil is contaminated, the finer contaminated particulates may on occasion become suspended in the air due to wind erosion or disturbance by cars and trucks. Airborne particulates carrying PCDDs may then be inhaled, resulting in a portion of the contaminants being absorbed across the respiratory pathway. Although no airborne particulate data are presented in this report, inhalation of such particulates is likely a pathway under periodic conditions.

- Given the high environmental levels of dioxin recorded in the northern Airport area, the human population of Da Nang likely continues to be exposed to dioxin from contaminated food (especially fish), and likely also absorbs dioxin through the skin and lungs as a result of direct exposure to contaminated soils, sediments and dust from the Airport.

- The people most affected by direct exposure to dioxins from the Da Nang Airport hot spot are members of an extended family who previously fished and harvested lotus from Sen Lake, and gardened along its banks. Others may also have been affected by eating fish and other aquatic animals harvested from the Airport lakes, although exact numbers are presently unknown.

- Blood dioxin levels recorded in the 2006 study (n=55 blood donors sampled) for some Da Nang residents directly associated with the Airport were the highest reported for Viet Nam to date, and exceeded all international standards for these chemicals. Individuals who harvested fish and plants from Da Nang Airport had dioxin concentrations in their blood more than 100 times globally acceptable levels (Hatfield/Office 33 2007). The maximum TCDD concentration of 1,150 ppt lipid (1,220 ppt TEQ; 94% TCDD) was recorded in a 42-year old male who actively harvested fish and plants from the Da Nang Airport; two other individuals also had >500 ppt TEQ. These results support the contention that various people (either present on site or at peripheral locations), activities and conditions coexist to create operative exposure pathways and potential for health risks (Table 4.1).

- Sen Lake and West Airport Workers that were retested in 2009 demonstrated no statistical differences in blood TCDD or TEQ levels (lipid-based) from those recorded in 2006. Sen Lake Workers were relocated and all fishing and agricultural activities in the north Airport area were halted in 2007 (with the exception of the West Airport Ponds, which are still in operation).

- Analysis of blood and breast milk dioxin/furan levels from different communities surrounding the Airport in 2009 confirmed elevated concentrations in people living north and east of the Airport. Exposure to a wide variety of contaminants (and possibly a wide variety of sources) is indeed occurring in people measured for dioxin/furans in the areas surrounding Da Nang Airport. The results indicate that a large proportion of dioxin contamination results from direct exposure to, and working on, the Airport. Although contamination levels in people living around the Airport is clearly from a variety of sources, working on the Airport significantly increases blood TEQ and TCDD above the background levels generated from other sources.

- The analysis of blood dioxin levels in people randomly selected in wards surrounding the Airport (Anh Khe, Khue Trung, and Thuan Tay) show that working on the base is the strongest predictor of blood dioxin levels in these people.

- In analysing all people that reported working on the base for factors that could explain their blood dioxin levels, eating fish from Sen Lake was deemed a significant factor.

- High variability in blood lipid values between 2006 and 2009 confounded interpretation of trend results. Future blood sampling programs need to account for this variability, and consideration should be given to measuring serum as opposed to whole blood.

- The typical range of TCDD in the general population of industrialized countries has been reported as 3 to 7 pg/g (lipid-based) (ATSDR 1998). ATSDR also indicated that TCDD in human blood rarely exceeds 10 pg/g and that typically, lower levels of this contaminant are recorded in less industrialized countries. TCDD concentrations in human blood from donors of Khue Trung Ward in Cam Le District, which exhibited the statistically lowest TCDD and TEQ levels, were ≤15 pg/g. The low percent TCDD of TEQ values (none exceeded 40%) also indicate that it is unlikely that these participants are directly exposed to Agent Orange from soils, sediment, water or food supplies. This was also true for individuals sampled in 2006 from Thuan Phuoc Ward, Hai Chau District (reference area).

- Some, but not all, individuals sampled from other wards or areas surrounding the Airport exhibited TCDD concentrations in blood greater than 10 pg/g. These include residents from Anh Khe Ward in Thanh Khe District, Thuan Tay Ward in Hai Chau District, and donors from Chinh Gian Ward in Hai Chau District (sampled in 2006). These wards are located on the east, north and west sides of the Airport, within 1 km of the boundary.

- Dioxins and furans were recorded in all breast milk samples analyzed in 2009 (N=14). Maximum levels were recorded in a young primaparous female (232 ppt TCDD) who previously consumed fish from Sen Lake. Average Daily Intake of breast milk per infant was calculated based on WHO/Euro (1989); Total TEQ ingested by infants ranged from 23.4 to 2,320 pg TEQ/kg bw/d.

- All breast milk samples analyzed exhibited TEQs exceeding the WHO Tolerable Daily Intake guideline of 4 pg TEQ/kg bw/d. High dioxin and furan levels in breast milk are cause for concern, and emphasize the need for raising awareness of potential contaminated food items originating from Da Nang Airport.

- Given the high levels of dioxin on Da Nang Airport and in the human population recorded in this study, a number of mitigation measures were proposed by Hatfield/Office 33 in 2007. Ford Foundation provided funding to implement these interim mitigation measures.

- Results from the 2009 study suggest that the interim mitigation measures implemented in 2007 have reduced the potential dioxin exposure pathways for the human population residing in the north end of Da Nang Airport, and that there is minimal dioxin exposure risk for people residing in the southern Airport area.

Table 4.1 Potentially Affected Groups in Da Nang.

Locality	Contaminant Source	Exposure Pathways	People Potentially Impacted
Sen Lake Workers	High dioxin concentrations and metals, PCB-118	Ingestion and dermal contact - water, fish, other aquatic organisms, lotus, other vegetation, soil and sediments from Sen Lake.	Workers and families
West Airbase Workers	Dioxin concentrations	Direct contact with, and/or ingestion of water, sediments, fish, other aquatic organisms, lotus and vegetation from fishponds located on the Western perimeter of the Airport.	Workers and their families
Thanh Khe District Residents North and West of Airport and Hai Chau District Residents East of Airport	Dioxin concentrations	Ingestion of contaminated fish and vegetation; dermal contact; and inhalation and/or accidental ingestion of contaminated dust.	Local residents (1km radius) in densely populated urban communities north, west and east of the Airport

Recommendations:

- Implementation of final mitigation measures and clean-up of Da Nang Airport is required immediately to ensure protection of the local population from future exposure to dioxins from historical Agent Orange use at the site. Time is of the essence to implement final clean-up, as the Governments of Viet Nam and Da Nang City have plans to expand the current Airport runway as early as 2010.
- Final remediation and clean-up efforts should focus on mitigating dioxin and furan contamination at the northern end of the Airport. Current plans being considered include construction of a secure onsite landfill in the south of the Airport, near the former Pacer Ivy site. Remediation options need to carefully assess the risk of re-mobilization of contaminated soils and sediments from the Former Mixing and Loading Area, Former Storage Area and Sen Lake during excavation and transport.
- Other potential dioxin and furan contamination sources, particularly uncontrolled combustion and industrial emissions, need to be identified.
- Awareness raising of dioxin exposure pathways (eating contaminated fish, access to the northern Airport area, uncontrolled combustion, etc.) is required to help reduce dioxin loads in local Da Nang residents, especially nursing mothers.
- Other major dioxin hot spots in Viet Nam, particularly Bien Hoa and Phu Cat, also require remediation and clean-up, to protect the local populations from continued exposure to Agent Orange and other herbicides used over 40 years ago during the US-Viet Nam war.

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6.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

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