MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
OFFICE OF NATIONAL STEERING COMMITTEE (OFFICE 33)

Project "Environmental Remediation of Dioxin Contaminated Hotspots in Vietnam"

COMPREHENSIVE REPORT

AGENT ORANGE/DIOXIN CONTAMINATION AT THREE HOTSPOTS: BIEN HOA, DA NANG AND PHU CAT AIRBASES

Updated in November, 2013


Dioxin Remediation in Da Nang Airbase
Photo by Dioxin Project, 2013


Z1 Lake in Bien Hoa Airbase
Photo by Dioxin Project, 2013


Landfill Construction in Phu Cat Airbase
Photo by Dioxin Project, 2012

HANOI, 2013

OFFICE OF NATIONAL STEERING COMMITTEE 33
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Preface

Office of National Steering Committee 33, in cooperation with national and international experts, published the first edition of "Comprehensive Report Agent Orange/Dioxin Contamination at three hotspots: Bien Hoa, Da Nang, Phu Cat Airbases" in 2011. This Comprehensive Report summarizes results from valuable reports carried out by Ministry of National Defense, Office 33, Committee 10-80, Hatfield Consultant, USAID and other related sectors.

From 2011 to present, some additional researches and environmental remediation activities have been conducted in hotspots; for examples: research on 7 former airports by Vietnam Ministry of National Defense; additional study on dioxin contamination in Bien Hoa and Phu Cat Airbases by Dioxin Project (GEF/UNDP funded); study on dioxin contamination in the vicinities of Bien Hoa Airbase by DONRE, Dong Nai province, and other researches.

In order to keep sharing information, Office of National Steering Committee 33 and UNDP agreed to update and edit this Comprehensive Report. We hopefully expect that this new edition will serve as a useful source of information scientists and authorities who are interested in Agent Orange/Dioxin issue in Vietnam. Moreover, this Comprehensive Report also contributes to call the interest and attention of international community in sharing with Vietnam in overcoming consequences caused by Agent Orange/Dioxin. Editors would like to welcome all the contributions for the following update.

Office of the National Committee 33, Ministry of Natural Resources and Environment Vietnam and United Nation Development Program, Hanoi, Vietnam

PART A

AMERICAN WAR IN VIETNAM

1. AMERICAN WAR IN VIETNAM

During the US-Vietnam war, the American Force realized that the war would continue as the advancement of the Vietnamese Revolution Force strengthened. The US military experts recognized that it was effective to use the herbicide chemicals. Opening jungle canopy that provided hiding place to army force was one of the primary targets for toxic chemical operations. It was performed by the United States Military Force from 1961 to 1971 with the following objectives.

1.1. Strategy

- To prevent the penetration of the Liberation Army through the boundary and the territory of the South of Vietnam.

- To destroy the self-sufficient economic potential of the Liberation Army, especially in remote areas that the American Force was not able to control, such as the logistics area, the army base, the training center, the stock of weapons and the army ordnance placed underground, thick forest that prevented the observation from ground and air.

1.2. Tactics

- Provide necessary support to the American Force for its military activities;
- Strengthen security of road and waterway traffic along wild and thick forests;
- Improve security to defend important establishments, airbases, and military storages;
- Assist landing operations to the terrain of thick forests and steep mountains;
- Restrict the movement of the Liberation Army, and utilize maximum advantage of the terrain with thick forests for its military activities; and
- Promote the policy of stability in rural areas.

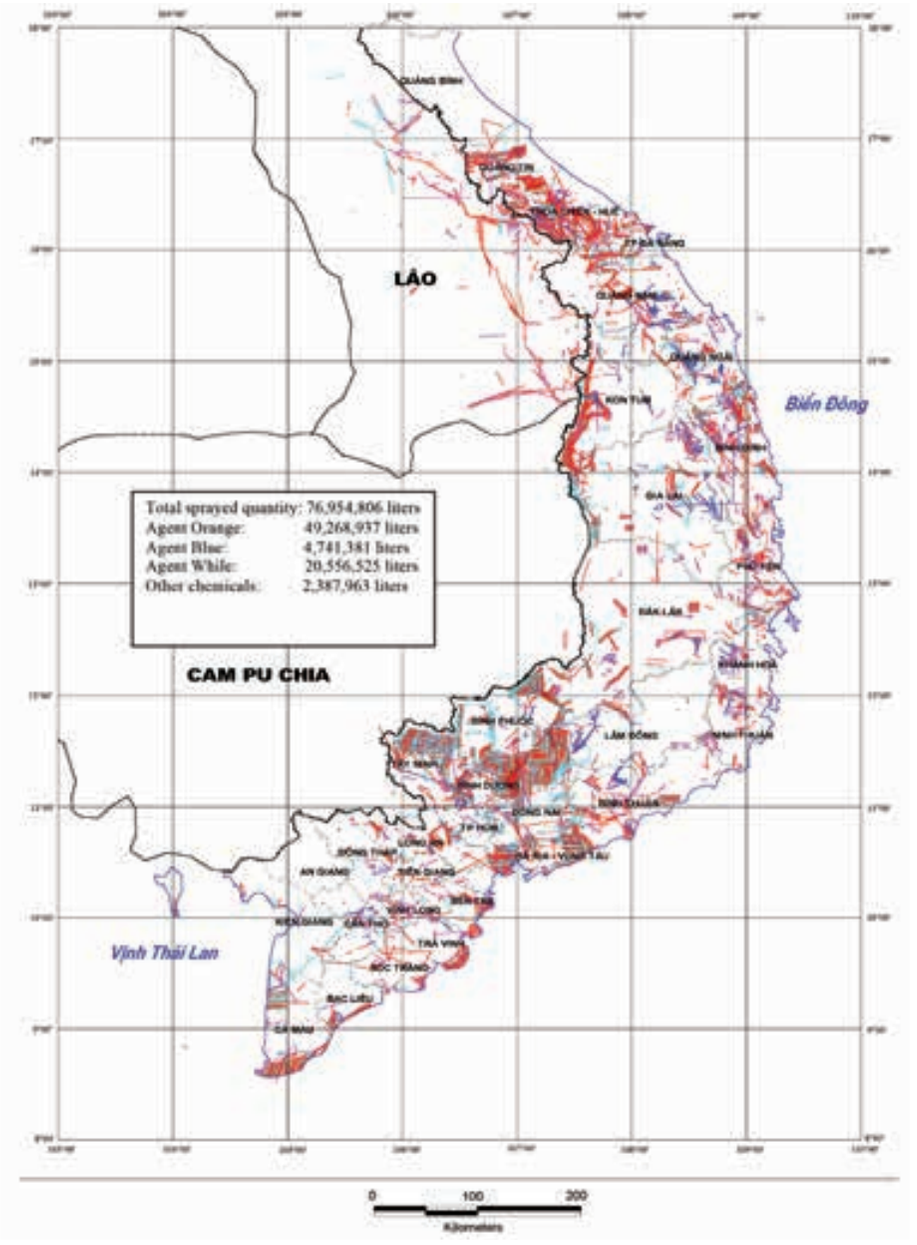

Figure 1.1 Map of toxic chemical spraying arena

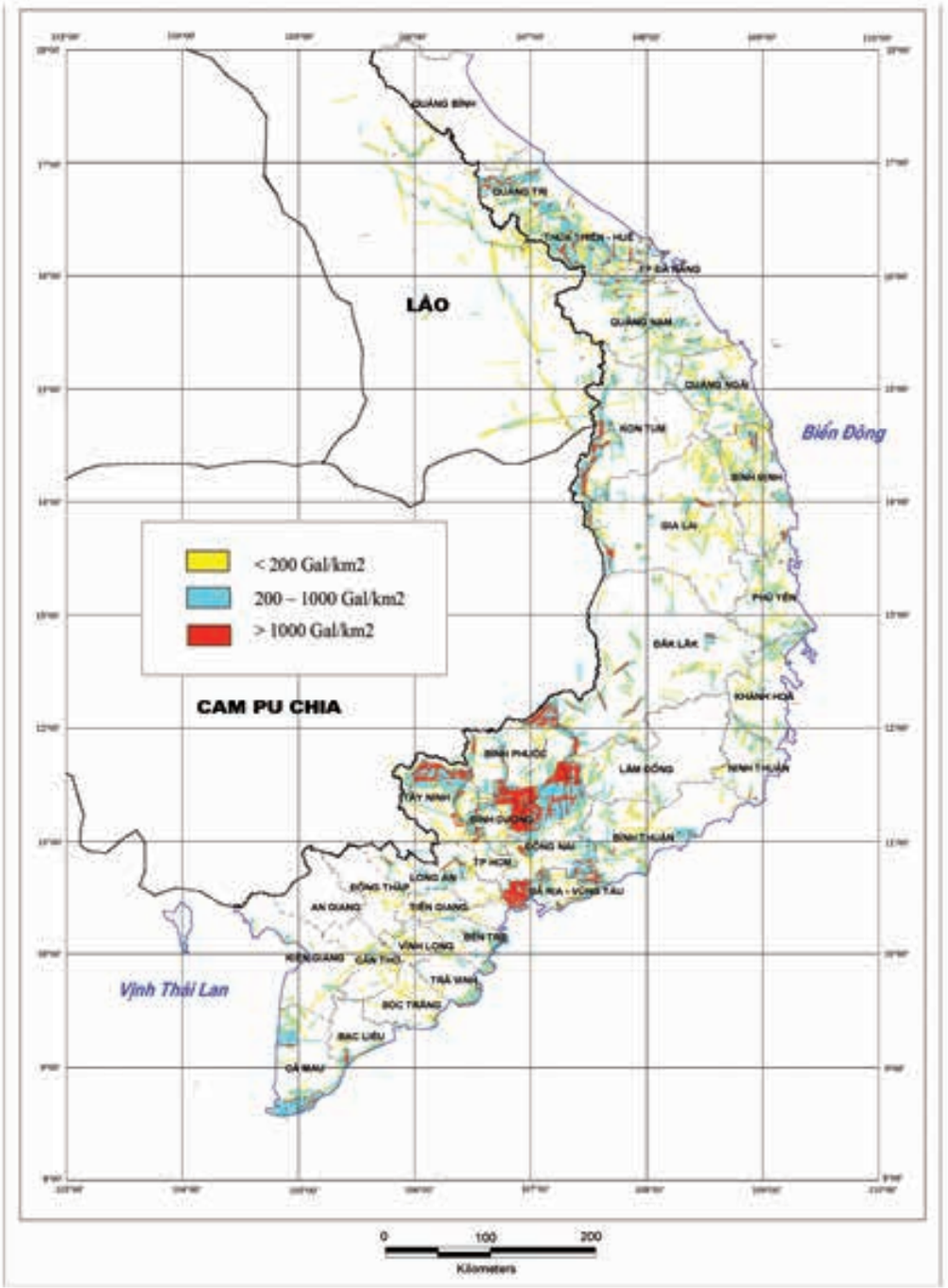

Figure 1.2 Map of toxic chemical spraying density

The US chemical operations were divided into three phases:

1. *The trial phase (1961-1964)* aimed at selecting effective chemicals, spray method and density suitable for conditions in Southern Vietnam.

2. *The full implementation phase of the "Ranch Hand" operation (August 1962 to September 1971)*: using toxic chemicals to serve military purposes outlined above (Figures 1.1 and 1.2).

3. *The withdrawal phase "Pacer Ivy" (September 1971 to April 1972)*: In this operation, the American Force transported 25,200 barrels of Agent Orange back to the United States in order to destroy the toxic chemicals from Vietnam.

2. THE USE OF DIOXIN CONTAINING HERBICIDES IN VIETNAM DURING US– VIETNAM WAR

2.1. The amount of herbicides used

There are several estimations of herbicide amount used for the military operations. Table 1.1 provides a few notable research results.

Table 1.1. The amount (in liters) of herbicides used in Southern Vietnam during the US -Vietnam war (cited from different sources).

Source	Agent Orange	Agent White	Agent Blue	Others (Pink, Purple and Green)	Total
Westing (1976)	44,373,000	19,835,000	8,182,000	-	72,390,000
Stellman (2003)	49,268,937	20,556,525	4,741,381	2,387,963	76,954,806
Young (2009)	43,332,640	21,798,400	6,100,640	2,944,240	74,175,920

It should be noted that the data by Westing (1976) did not include the total Agent Purple, Agent Pink and Agent Green, which contained very high level of dioxin. According to Young (2009), the total amount of herbicides brought into Vietnam was 79,488,240 liters. By 1972, 25,200 barrels of Agent Orange (equivalent to 5,241,600 liters) were brought back to U.S under Pacer Ivy Operation, the total amount of herbicides used was 74,175,920 liters. According to Stellman (2003), the total amount of herbicides was 76,954,806 liters, equivalent to 95,112,688 kg (~ 95 million kgs), in which dioxin-containing herbicides occupied 67%, mainly Agent Orange with the amount of 49.27 million liters, equivalent to 63,000 tons.

2.2. Estimation of dioxin residual in Southern Vietnam environment by the US-VietNam War

Table 1.2. The TCDD concentration in the herbicides used for US-Vietnam war

Herbicide	Reference	TCDD concentration, ppm	Production Year
Agent Orange	Young (1971)	11	1958-1969
	NAS (1974)	3	-
	Phederov (1993)	30-40	1960's
	Masatoshi (2001)	10	1960's
	EPA (2003)	10	1950's
	Stellman (2003)	13	-
	Netcen (2006)	10	1960's
Agent Purple	Lindsey	45	
Agent Pink		65.5	
Agent Green		65.5	

The estimation of dioxin residual in the Southern Vietnam environment were performed based on the amount of herbicides containing dioxin used and the concentration of dioxin in the herbicides when they were used during the US-Vietnam war (1961-1971).

According to the various sources, the concentration of TCDD in 2,4,5-T (i.e. active ingredient of the herbicides) produced during that period were very different (Table 2.2).

Based on the difference in amount of agents and the difference in percentage of TCDD in the agents, the amounts of evaluated dioxin were also different:

VA (1981):	109 kg
Westing (1989):	170 kg
Wolfe (ATSDR,1997):	167 kg
Eva Kramárová (1998):	230 kg
Stellman (2003):	366 kg
Fokin (1983):	500 - 600 kg
NX Net (2006):	653 kg

According to Westing (1989), the quantity of dioxin sprayed in Vietnam by the American Force was about 170 kg, this data used to be cited by both of international and national reports. In recent years, the data provided by Stellman are often cited.

2.3. The general overview of the effects of the herbicides used in the war to the environment and people of Vietnam

The amount of 95,112,688 kg of herbicides were sprayed over 2.63 million hectares, accounting for 15.2% of total area of Southern Vietnam (172.54 million hectares, according to SIPRI (1971)). The area sprayed by the herbicides containing 2,4,5-T was 1.68 million ha, accounting for 9.7% area of Southern Vietnam (Stellman et al., 2003).

Base on above data, the spraying density can be estimated as following: overall average chemicals density were 36 kg/ha, in which the Agent Orange with the volume of 49,268,937 liters, equivalent to 63,064,240 kg, spraying over area of 1.68 million ha was the density of 37.5 kg / ha. This spraying density was 17 times higher than the one used for agriculture (i.e. 2.2 kg/ha under the guidance of the U.S Force, TTND Vietnam-Russia, 1995, p.52). At this density, the herbicides become toxic and could destroy the crops.

During US-Vietnam War, more than two millions hectares of forests were affected at different levels: it was reported that more than 90 million m^3 of timber (Phung Boi Tuu et al, 2002), and 150,000 ha of mangrove forests were destroyed (Phan Nguyen Hong, 2002), and the ecosystem in Southern Vietnam was severely damaged.

According to NAS (2003) and Stellman (2003), 3,181 villages among 20,585 registered villages were directly sprayed. The number of people exposed to dioxin was 2.1 - 4.8 millions. In addition, other 1,430 villages were reportedly sprayed but the affected population was not knownable to estimate.

The huge amount of remnant dioxin from the war to the environment of Southern Vietnam has seriously affected the health of millions of people and veterans in whole country. Millions of victims of Agent Orange suffer a variety of diseases: cancer, immunodeficiency etc. Especially, at some airbases, such as Bien Hoa, Da Nang and Phu Cat, Agent Orange/Dioxin concentrations are still very high. These areas are considered as "hotspots" of dioxin contamination. In those areas, the concentration of dioxin (especially 2,3,7,8-TCDD) in soil, sediment are extremely high, several hundred times higher than national standard (i.e. 1,000 ppt TEQ for soil, 150 ppt TEQ for sediment and sludge), and several thousand times higher than the normal background levels.

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PART B

CONTAMINATION BY AGENT ORANGE/DIOXIN AT THREE HOTSPOTS: BIEN HOA, DA NANG AND PHU CAT AIRBASES

1. INTRODUCTION

The dioxin contamination problem in Southern Vietnam hase been studied since the early 1970's (Papke and cs et al, 2003), starting with the Baughman and Meselson›s researches in 1973 - 1974. They are the first researchers analyzed the dioxin in the fish and shrimp samples collected from the rivers in Southern Vietnam.

National Committee for Investigating the Consequence of the chemical US-Vietnam war, abbreviated as the 10-80 Committee, was established in October 1980. All samples collected from Vietnam were sent to abroad to analyze at the laboratories under the cooperation program of 10-80 Committee, or some scientists and/or laboratories in other countries.

In 1995, the dioxin analysis laboratory of the Vietnam-Russia Tropical Centre (VRTC) came to operation. Since then, this laboratory performed most of the analysis of dioxin residues in the environment national and international projects.

In 1995, with the financial support from the Japan - Vietnam Center of Medicine, the 10-80 Committee received a GC/MS instrument. Since then, several hundreds of samples were analyzed by 10-80 Committee by using this GC/MS instrument. The Viet Nam - France Center of Analytical Services in Ho Chi Minh City also analyzed dioxin concentrations in some environmental samples. As a result, by 1995, a total of 17 congeners of Dioxin and furans with TEF values were able to be analyzed by using the GC/MS instrument. This was one of the very important achievements on dioxin research in Vietnam.

Recognizing the serious effects of Agent Orange/Dioxin to the human health and environment, the Vietnamese Government has undertaken many activities since immediately after the war in order to mitigate the negative effect to human and environment as well as to recover the environment. Especially since 1995, the Vietnamese Ministry of Defense has implemented several research projects, projects of investigation, collection and processing of environment, etc. This included the survey and evaluation of the residue of Agent Orange/Dioxin project, focusing on the toxic effects to the human health in hotspots areas as well as the measures to minimize the contamination of Dioxin to human and environment. The projects entitled: «Overcoming consequences of herbicides contaminated areas in Bien Hoa Airbase», also known as Z1 (conducted from 1995 to 1997); «Survey, evaluation to overcome the consequences of dioxin containing toxic chemicals in Da Nang Airbase", a.k.a. Z2 (conducted from 1997-1999); and «Survey, evaluation to overcome the consequences of dioxin containing toxic chemicals in Phu Cat Airbase», a.k.a. Z3 (conducted from 1999-2003). Besides the above projects, a number of projects to survey and assess the pollution level have been carried out by the Office of the National Committee 33 in cooperation with other international organizations since 2006, which mainly focused on Da Nang, Bien Hoa and Phu Cat Airbases.

In recent years, most of the studies on dioxin contamination in Vietnam was performed by both of the national and international projects in cooperation with other countries, such as Canada, Japan, Germany, USA, which were financially supported by international organizations, such as UNDP, FORD Foundation, etc. In the PART B, the summary of the results of the survey projects on dioxin contaminated in Bien Hoa, Da Nang, and Phu Cat Airbases were reported. These projects have been performed by Vietnamese Ministry of Defense, Vietnam-Russia Tropical Centre, 10-80 Committee and Office of Steering Committee 33 since 1995.

Since 2006, the Office 33 and Vietnam-Russia Tropical Centre have conducted extensive studies in cooperation with Hatfield Consultant, Canadian laboratories, CDM-Smith, etc. on the status of dioxin contamination to the environment and the level of human exposure in three hotspots, Bien Hoa, Da Nang and Phu Cat Airbases, and their neighboring communities. This report will provide the overall picture on dioxin contamination in these hotspots and give recommendations for the areas that require treatment and remediation.

Sampling activity in Bien Hoa Airbase
Photo by Dioxin Project, 2010

BIEN HOA AIRBASE

Bien Hoa Airbase
Photo by Dioxin Project, 2010

2. SÂN BAY BIÊN HÒA

2.1. Historical records of the contaminated areas and geographical, hydro-meteorological and soil characteristics

The Bien Hoa Airbase is located in Dong Nai province at 10° 58'30" N, 106° 49' 10" E, 700 meters to the east from the Dong Nai River (Figure 2.1, provided by US Department of Defense).

The Bien Hoa Airbase was the major base point for the Operation "Ranch Hand" in Southern Vietnam. Previous studies showed that the dioxin contamination in Bien Hoa was very high (Z1 Project, Vietnamese Ministry of Defence, Hatfield Consultant and 10-80 Committee, etc.). The high population density in Bien Hoa City was considered to be one of the highest risk area where the human health could be affected by dioxin. Therefore, this hotspot should be of primary concern.

During the military operation, the airbase stored and utilized 98,000 barrels of Agent Orange, 45,000 barrels of Agent White, and 16,000 barrels of Agent Blue (US Department of Defense, 2007). More than 11,000 barrels of herbicides were shipped out of Bien Hoa Airbase during Pacer Ivy Operation in 1970. The previous studies focused on evaluating and eliminating dioxin contamination in area and lakes (Bien Hung, Airbase Lakes) located in the south of Bien Hoa Airbase. Vietnam – Russia Tropical Center analyzed some soil and sediment samples in Bien Hoa. Hatfield Consultant and 10-80 Committee (2007) has provided information on dioxin contamination in the vicinity of Bien Hoa Airbase.

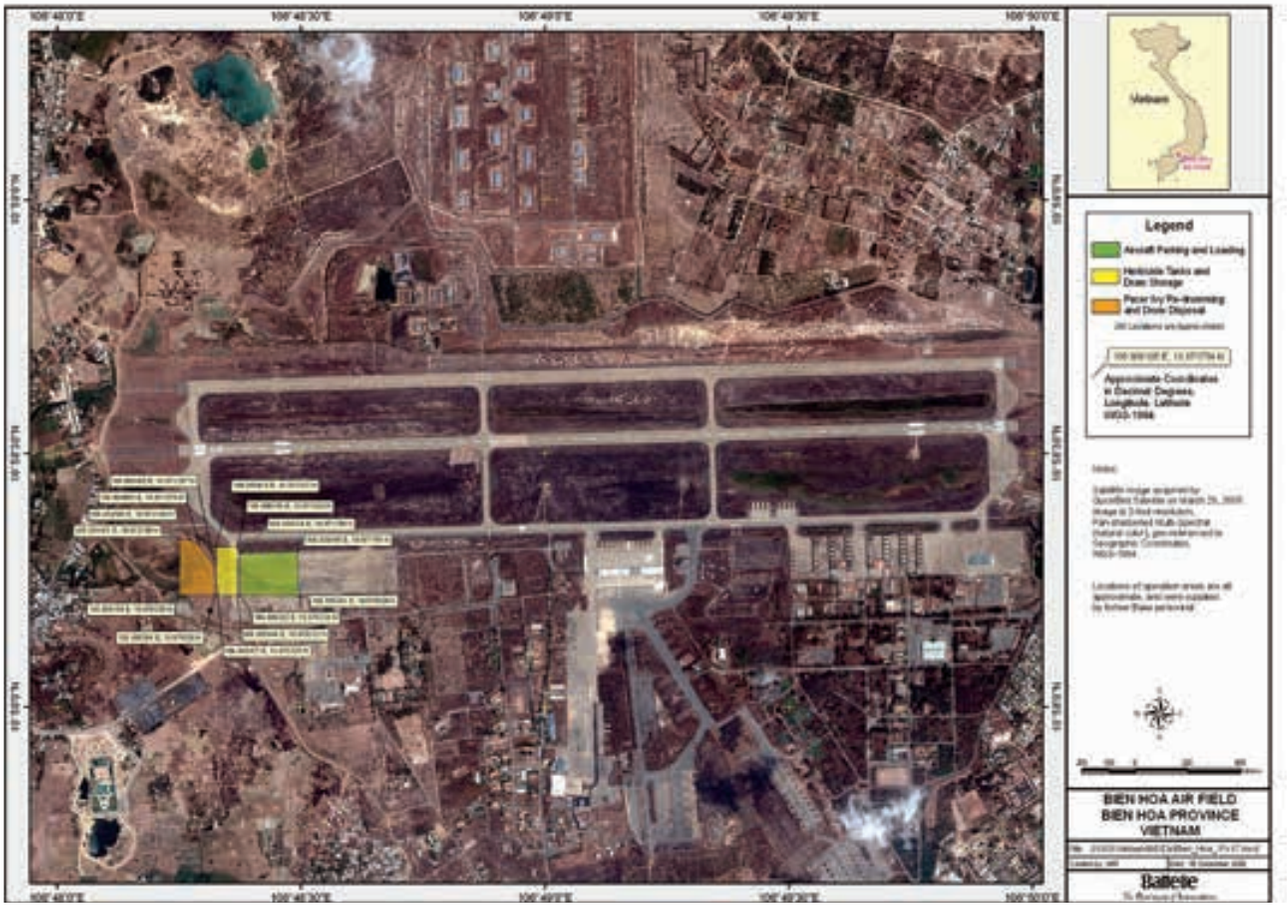

Fig. 2.1. Map of Bien Hoa Airbase provided by US Department of Defense.

Hydro-meteorological conditions

Bien Hoa has a tropical-climate area with two distinct seasons: the rainy season from February to August; and the dry season from September to January. During the rainy season, the average temperature is 27.4 °C; the average humidity is 89%; the number of rainy days is 118; and the number of sunny days is 65. During the dry season, the average temperature is 27.7 °C; the average humidity is 81%; the number of rainy days is 23; and the number of sunny days is 159. The sunshine hour is over 5.4 hours/day in rainy season and 8 hours/day in dry season.

Hydrographic properties

The annual average rainfall ranges from 1,600 mm to 1,800 mm. A 10 km long section of the Dong Nai River runs through Bien Hoa city and branches off into the Cai River and forms the Hiep Hoa Island. Before the Tri An hydroelectric plant was developed, water flow of the Dong Nai River reduced to 50m^3/s during the end of the dry season, and brackish water penetrated deeply into the city. After the Tri An hydroelectric plant was built, the brackish water was driven back to the lower section of the Bien Hoa city.

In airbases, there are always ponds and lakes to drain water from airbases when it rains. At the South of Z1 area, a ditch drains water from airbase to Lake 1, Lake 2, ponds and vegetable fields in surroundings. Area of Lake 1 and Lake 2 is 6,300 m^2 and 21,000 m^2 respectively. From Lake 2, rainwater consisting toxicants flows into Bien Hung 1 Lake and Bien Hung 2 Lake in Trung Dung Ward, then into Dong Nai River through sewer system which runs through some residential groups in Buu Long Ward. To southwest of Z1 area, there is Lake Gate 2, from this Lake, toxicants would spread into surrounding fields and fields in 29 team.

According to Ministry of Defence (2007), a system of ditches, ponds and lakes exists toward the taxiway. Rainwater from airbase flows into ponds, lakes then into Dong Nai River in Buu Long Ward.

2.2. Results of survey on soil parameters

The contaminated area (Z1) on the south of the airbase includes the former storage area, washing area, the area for storage of barrels of toxic chemicals, and the surrounding land.

Surface soil characteristics of the contaminated area

The natural and human influences have caused the contaminated area to change its appearance drastically over the years, specifically from the activities such as concrete capping, digging of contaminated materials, cutting of trees, and the erosion of streams by rain and wind. Vegetation cover at the contaminated site is generally poor, as grass does not cover completely. The east of the contaminated site has a sparse eucalyptus trees. According to Z9 project (2012), top soil layer is mainly yellow sand. At the tip of parking area, there is much big concrete debris from damaged pavement. Under the pavement, there is soil mixed with rock, brick, etc. in the depth of 1 meter.

The following results were also obtained:

- pH: pH_{H_2O} ranged from 4.0 to 7.9 and pH_{KCL} ranged from 4,0 to 7,8 .The soil in this area is acidic to neutral.

- Humus content: Humus content ranged from 1.0 to 2.6 %. According to the soil classification, the soil in Z1 is poor in humus. With depth, the percentage of humus does not increase/decrease naturally. The soil is not fertile and humus content of each stratum varies because the soil of these strata came from many different areas during the construction of the airbase.

- Total nitrogen content: Nitrogen content comes mostly from organic sources (degradation of organic material, or nitrogen fixing micro-organisms). The results indicated that the total nitrogen content was directly proportional to the humus content, and was approximately 10%. In general, the soil in Z1 is poor in nitrogen but at reasonable level in relation to the humus contents, and considering the status of the land.

- Al and Fe content: These two values in Z1 vary significantly between areas, so it is assumed that the soil came from many different sources. Al and Fe contents, especially Fe^{2+} contents, play important roles in decontamination if chemical methods are applied.

- Other heavy metals: Arsenic concentration at contaminated sites showed significantly higher that national standard value, which is unlikely been natural geological future but might have caused by human activities. Copper and lead in a few samples also showed elevated concentration levels (Ocffice 33 / UNDP 2011).

- Particle compositions of the soil: Analysis of 20 samples revealed specific characteristics of particle compositions of the soil, which varied according to location and depth. The soil in Z1 mainly consisted of loose soil up to 0.7 meter deep with clay content ranging from 0.87 to 11.89%, very poor in clay. The percentage of clay content is not consistent between areas, as the soilland has been introduced during the construction of the airbase.

- Trace elements: The soil in Z1 has a zinc content that varies from medium to very rich, and a low mobile-molybdenum content.

Because of the soil properties in Z1 (high acidity, low humus content, low nitrogen content, loose soil, and low clay content), toxic chemicals can infiltrate into the deeper layers of the soil, and rainwater can easily carry soil containing toxic chemicals/dioxins to ponds, lakes and rivers downstream of the contaminated site.

2.3. The Agent Orange/Dioxins contamination in Bien Hoa Airbase and the vicinities

The dioxin concentration at the Bien Hoa Airbase has been studied since 1993 as a part of the Z1 Project. The soil samples were analyzed at the Vietnam-Russia Tropical Centre (VRTC) in Ha Noi, Viet Nam. At that time the exact sampling locations were not determined and were only shown on the map. After Z1 Project, other studies have been implemented by national and international organisations. The most recent study on Bien Hoa Airbase is implemented by Ministry of National Defense in 2012 (Z9 project). The past surveys are summarized in the Table 2.1.

Table 2.1 Summary of the dioxin survey projects with the level of contamination (pg-TEQ/g) reported

Project	Location/Area	Sample matrix	Sample number (n)	Range (pg-TEQ/g)
Project Z1, 1995-96 & Program 33, 2000	Z1 area	Soil	44	n.d. – 410,000
		Sediment	3	1,380 – 5,470
	Paddy field near Cong 2 Lake	Soil	14	n.d. - 412
	Cong 2 Lake	Sediment	2	44 – 59
		Sediment	6	236 – 508
	Paddy field near Quang Vinh Ward	Soil	7	26 – 108
		Sediment	7	17 – 112
	Bien Hung Lake	Soil	8	5 – 256
		Sediment	9	59 – 210
Committee 10-80 & Hatfield, 2004-05	East of airbase	Soil	2	267 – 424
		Sediment	3	48.3 – 101
	South base lake and Bien Hung lake	Soil	4	39.4 – 294
		Sediment	6	36 – 833
	West of airbase	Soil	3	2.76 – 22.6
		Sediment	1	1.19
	Suoi Lon and Dong Nai River	Sediment	4	3.26 – 14.8

Table 2.1 Summary of the dioxin survey projects with the level of contamination (pg-TEQ/g) reported

Project	Location/Area	Sample matrix	Sample number (n)	Range (pg-TEQ/g)
Office 3/UNDP, 2008	Southwest area	Soil	16	4.12 – 65,500
	Pacer Ivy site	Soil	11	80.3 – 22,800
		Sediment	4	1,090 – 5,970
		Z1 area	8	109 – 262,000
	Perimeter of Z1 area	Soil	30	6.15 – 13,300
		Sediment	1	413
	Ponds and Lakes surrounding Z1 area	Sediment	5	20.9 – 2,240
Officer 33 & Hatfield, 2010	Z1 area	Soil	12	1.46 - 3,210
		Sediment	3	39.8 - 219
	Pacer Ivy	Soil	21	0.836 - 61,800
		Sediment	7	32.1 - 2,020
	Southwest of airbase	Soil	8	9.22 - 5,150
	Northeast of airbase	Soil	8	12.1 - 1,040
		Sediment	3	6 - 633
	Northern perimeter	Soil	4	8.47 - 459
		Sediment	5	5.66 - 372
	Southern perimeter (Bien Hoa city)	Sediment	2	26.9 – 95.6
	Lakes in and around airbase	Whole fish*	2	62.2 – 96.5
		Fish muscle*	9	0.0782 – 33.2
		Fish fat*	9	4.54 – 4,040
Dong Nai DONRE, 2011	Around Bien Hoa airbase	Soil	73	0.01 – 3,232.96
		Sediment	24	4.01 – 1,720.78
		Surface water**	25	0.0 – 44.1
		Groundwater**	18	0.0 – 29.6
		Aquatic species*	22	0.00 – 143.39
Office 33/UNDP, 2011	Pacer Ivy area	Soil (surface)	37	7.59 – 21,196
		Sediment (surface)	9	19.9 – 6,681
		Soil (core)	42	0.118 – 962,559
		Sediment (core)	7	1.22 – 2,180
Z9 Project, MOD, 2012	Pacer Ivy and other areas	Soil and sediment	121	3 – 884,730

Note:

**: Wet weight basis*
***: pg-TEQ/L*
n.d.: Reported as 'Not Detected'
The dioxin concentration is reported in middle-bound (n.d. = 1/2 of detection limit) concentration unless specified

2.3.1. Results of Project Z1 (1995-96) and Program 33 (2000)

In Project Z1, samples were collected on the topographic features and the dispersion pathways of toxic chemicals. Samples were collected up to 1.2 meters in depth. In 1995, surface samples were collected at the depth of 0 - 20 cm and the core samples were collected at different depths, with the interval of 0-20 cm; 20-40 cm; and 40-60 cm. In 1996, samples were collected in 30 cm increments (0-30 cm and 30-60 cm). At VRTC, Agent Orange (2,4-D and 2,4,5-T) was analyzed in 49 samples at 32 sites, and the results indicated that the concentrations of Agent Orange were high (maximum of 1.62 ppm of 2,4-D and 2.55 ppm of 2,4,5-T). The dioxin concentrations varied at different depths, and contamination has penetrated up to a depth of 80 cm.

The results indicated that: Dioxins concentrations in the surface layer in Z1 were very high, up to 410,000 pg-TEQ/g (Figure 2.2).

The results from the project belonging to Program 33, in which samples were collected inside the airbase (buffer area) and outside the airbase, are shown in Figure 2.4 and 2.5.

Areas outside the airbase on the southwest following the dispersion direction are inhabited by local people who engage in agriculture in the area. Dioxin levels in soils from some locations such as the field beside the Cong 2 Lake, the field of the Group 29, Quang Vinh Commune, the Cong 2 Lake and Bien Hung Lake were generally lower than 500 ppt which is below national limit of soil but above that of sediment.

Fig. 2.2. Dioxin concentrations (TEQ) in soils and sediments in Z1 Area, Bien Hoa Airbase, 1995-1996

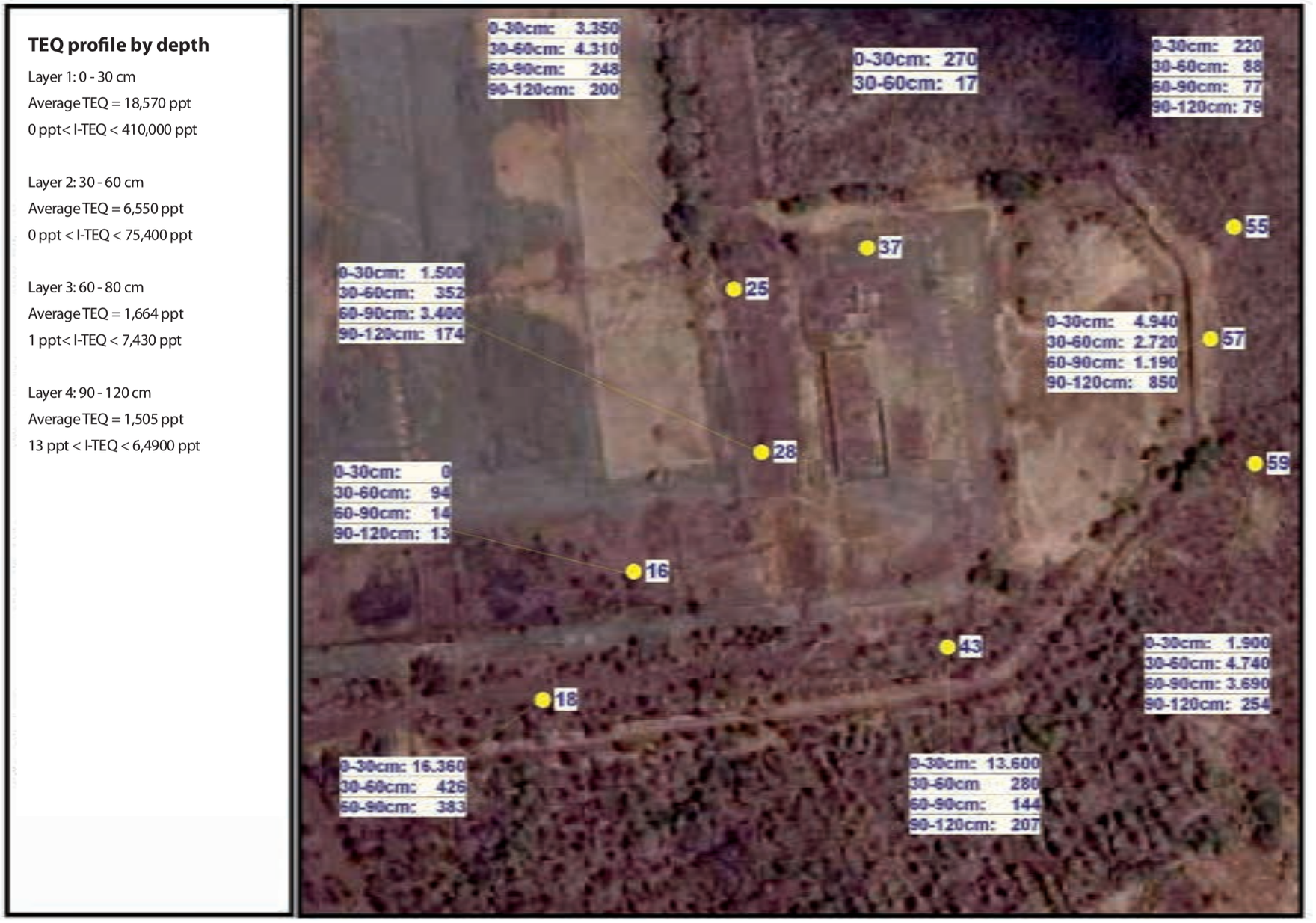

Fig. 2.3. Depth profile of dioxin concentrations (TEQ) in soils in Z1 area, Bien Hoa Airbase, 1995-1996

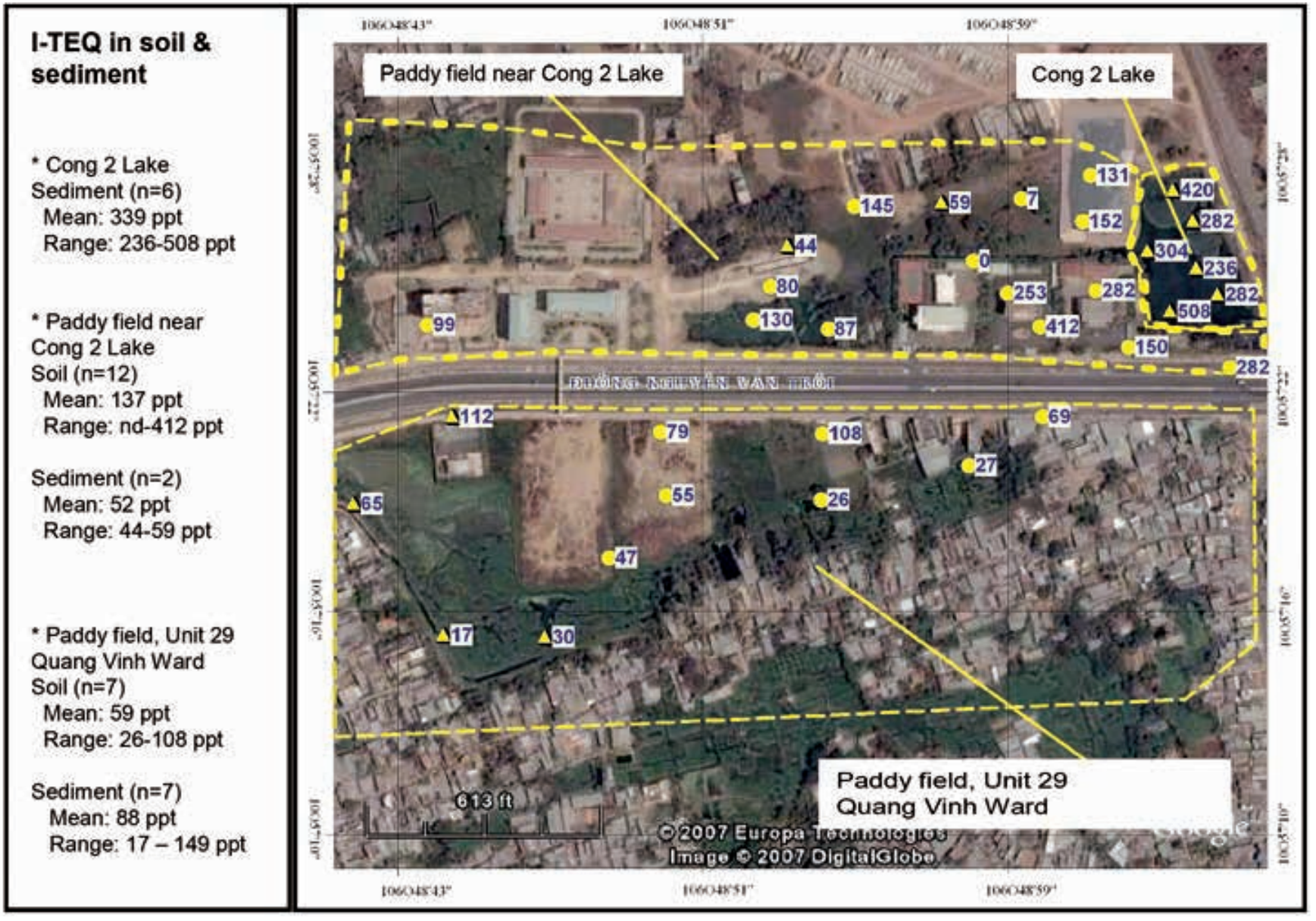

Fig 2.4. The dioxin concentrations in soil and sediment (TEQ) from Cong 2 Lake and paddy field in Bien Hoa , 2000-2001

Fig. 2.5. The dioxin concentrations (TEQ) in soils and sediments from Bien Hung Lake, 2000-2001

2.3.2. Results of survey by Committee 10-80/Hatfield (2004- 2005)

Hatfield Consultant and 10-80 Committee collected samples outside Bien Hoa Airbase in 2004 and 2005. Sixteen (16) soil samples and twenty (20) sediment samples were collected. 23 selected samples were sent for dioxin analysis. The summary of the total TEQ values are shown in Table 2.2. The highest TCDD in soil was recorded at Site 89, 392 pg/g, with a resulting TEQ of 425 pg/g (92% TCDD of TEQ. The highest dioxin value in sediment sample was recorded at Site 78, (797 pg/g TCDD and 833 pg/g TEQ). The TCDD occupied over 96% of total TEQ clearly indicating the Agent Orange as the source. Sites 89 and 78 are located in two geographically separate regions near the Bien Hoa airbase suggesting extensive contamination in different areas outside the Airbase. The origin of the contamination at these aforementioned sites is likely the former herbicide storage area.

Sites 85, 86, 87, 88, and 89 all exhibited dioxin in levels >40 pg/g TCDD (and greater than 80% TCDD of TEQ). A number of sites located near South (S) Base Lake and Bien Hung Lake also exhibited elevated dioxin levels. The TCDD level in sediment samples from this area ranged from 31.1 pg/g TCDD (86% TCDD of TEQ) to 797 pg/g TCDD (96% TCDD of TEQ; 833 pg/g TEQ).

Two distinct TCDD "groupings" (i.e., east end of the runway and South Base/Bien Hung Lakes) have very high percent TCDD of TEQ values. These data indicate high Agent Orange involvement in the soils and sediment contamination near the Bien Hoa Air base. With the spreading by rain run-off, dioxins contamination may spread over a large area, so the transport of dioxin-contaminated soil and sediments to nearby water bodies is a very important issue that deserve particular attention.

Table 2.2. 2,3,7,8-TCDD, TEQ (pg/g), and percent TCDD of the TEQ value for soil and sediment samples from Bien Hoa (2004-05)

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
05VN078	Sediment	Lake in airbase	797	833	96
05VN089	Soil	Natural vegetation	392	424	92
05VN080	Soil	Natural vegetation	284	294	97
05VN074	Soil	Grazing area/wetland	279	287	97
05VN087	Soil	Grazing area	257	267	96
05VN079	Sediment	Lake in airbase	224	234	96
05VN095	Soil	Garden	208	224	93
04VN014	Sediment	Bien Hung Lake	96.7	106	91
05VN102	Sediment	Bien Hung Lake	96	131	73
05VN088	Sediment	Base stream	82.8	101	82
05VN081	Sediment	Lake in airbase	76.9	80.3	96
05VN085	Sediment	Hoa Bang stream	41.5	48.3	86
05VN086	Sediment	Hoa Bang stream	40.6	48.7	83
05VN103	Sediment	Bien Hung Lake	31.1	36	86
05VN077	Soil	Old rice field	27.1	39.4	69
05VN073	Soil	Old rice field	18.8	22.6	83
04VN013	Soil	Farmers field	12.2	14.3	85
05VN094	Sediment	Fish pond	5.22	8.24	63
05VN097	Sediment	Suoi Lon	3.73	14.8	25
05VN101	Sediment	Dong Nai River	2.72	9.03	30
05VN101 (duplicate)	Sediment	Dong Nai River	2.73	8.81	31
05VN098	Sediment	Suoi Lon	0.969	3.26	30
05VN096	Soil	Cultivated land	0.596	2.76	22
04VN011	Sediment	Marsh SW of base	0.304	1.19	26

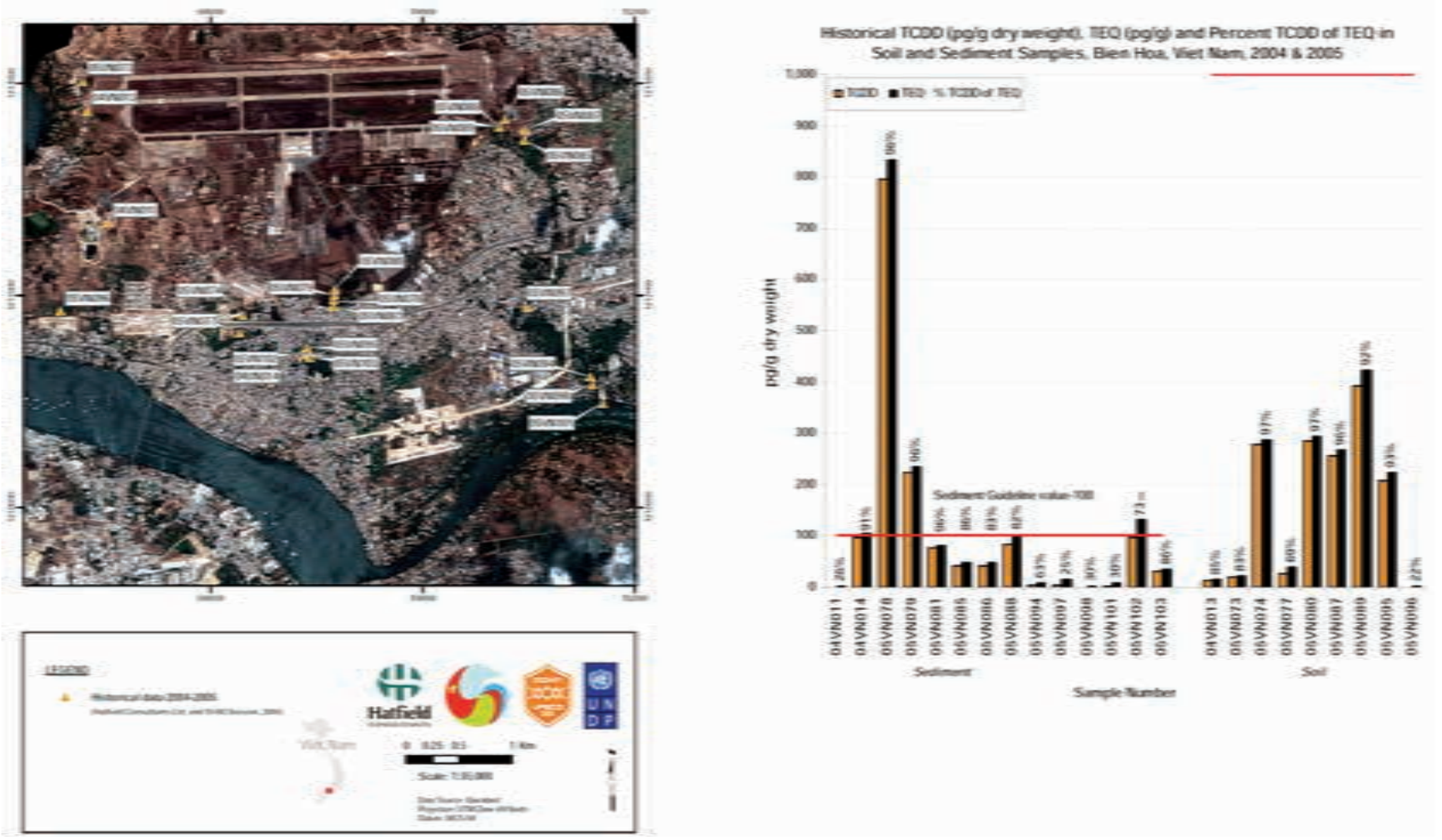

Fig. 2.6 . Sampling locations and the dioxin concentrations (pg/g dry wt) in soils and sediments from Bien Hoa, Vietnam in 2004-2005 survey.

2.3.3. Results of survey by Office 33/UDNP (2008)

A survey in 2008 was conducted by Office 33, Hatfield Consultants and the Vietnam-Russia Tropical Center (VRTC) under a UNDP funded project. A complete list of soil and sediment samples collected in Bien Hoa Airbase during this survey is given in the Appendix. Samples were analyzed in VRTC and by AXYS Analytical Services (abbreviated by AXYS), Vancouver, Canada. A total of 125 samples, including 114 soil samples and 11 sediment samples, were collected at Bien Hoa Airbase.

All samples were collected in duplicate, with one sample kept in Viet Nam, and one sample sent to the international laboratory. The soil samples were collected from a variety of depths, but most were between 0-10 cm, 10-30 cm and 30-60 cm (maximum 100 cm); sediments were collected using a stainless steel dredge and/or spatula.

The samples were collected from areas formally used for storage, transport and loading of Agent Orange and other herbicides during the US-Vietnam War, and were selected as representative samples of these respective areas. Sampling locations, including GPS coordinates, are provided in the Appendix. Samples were analyzed for dioxin and furan concentrations; TEQ concentrations were calculated as the sum of 17 toxic congeners which have been assigned Toxicity Equivalency Factors (TEF) (WHO, 2005).

Samples were collected from the following areas:

- Southwest Corner of Airbase;
- Pacer Ivy area, Southwest corner of Runway on the Airbase, as suggested by the US Department of Defense; and
- Site Z1 (Hotspot area) and the Perimeter (including wetland areas and ponds/ditches in the south)

Southwest Area of Airbase (Newly Discovered Area)

The Southwest Area of the Airbase was sampled as a result of new information provided to VRTC from US Department of Defense (2007) regarding potential dioxin contamination from historical use of Agent Orange in the area; this site had not been sampled before. Covering an area of 2,000 m^2, the site has an even and flat terrain, slightly sloping to the west. Run-off water (rainwater) carries soil through the residential areas to adjacent rice fields. Analytical results are presented in Table 2.3.

In this area, 39 soil samples were collected from 31 stations; samples were collected at several depths from surface to 1.5 m (sample 08VNBH088). Of these 39 samples, 16 were selected for analysis.

Five samples (08VNBH067, -068, -076, -084, and -085) of 16 analyzed samples exhibited TEQ concentrations greater than 1,000 pg/g TEQ; TCDD comprised >98% of the TEQ in these samples. Sample 08VNBH084 exhibited a very high TCDD concentration (65,400 pg/g). The remaining 11 samples had lower dioxin concentrations; however, TCDD comprised 75.3% to 98% of the TEQ. These results clearly demonstrate that dioxin in the area originated from historical use of Agent Orange at the site. However, contamination appears be limited to a relatively small area.

Table 2.3. The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soil samples from the Southwest Airbase corner of Bien Hoa Airbase

No.	Sample Code	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ** (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08 VNBH 067*	Soil	0-10	1,890	1,920	98.4
2	08VNBH 068	Soil	0-10	1,380	1,400	98.6
3	08VNBH 074	Soil	0-10	439	449	97.8
4	08VNBH 076	Soil	0-10	1,530	1,540	99.4
5	08VNBH 077	Soil	0-10	70.5	74.0	95.3
6	08 VNBH 084*	Soil	0-10	65,400	65,500	99.8
7	08VNBH 085	Soil	0-10	1,980	2,000	99.0
8	08VNBH 087	Soil	0-10	428	440	97.3
9	08VNBH 088	Soil	0-10	71.5	78.3	91.3
10	08VNBH 088-2	Soil	10-30	15.9	19.0	83.7
11	08 VNBH 088-3*	Soil	30-60	NDR 12.6	4.12	-
12	08VNBH 088-4	Soil	60-90	3.40	5.40	63.0
13	08VNBH 091	Soil	0-10	214	245	87.3
14	08VNBH 097	Soil	0-10	9.5	12.8	74.2
15	08VNBH 099	Soil	0-10	132	140	94.3
16	08VNBH 112	Soil	0-10	30.4	42.8	71.0

Note:
** Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Southwest Corner of Runway (Pacer Ivy site identified by the US Department of Defense)

The Pacer Ivy area was recommended by the US Department of Defense for further investigation, given its historical use as the herbicide storage and re-drumming location. This area is located in the south-west corner of the Bien Hoa Airbase, close to the runway. The study was the first sampling program conducted in this area of Bien Hoa Airbase. Sampling sites covered an area of 150,000 m2; the southwest of the concrete yard is a buffer zone sloping to surrounding drainage ditches, small creeks and ponds. Fish are grown and harvested in man-made ponds in this area. 19 soil and sediment samples were collected and 15 samples were analyzed;

Analyses indicated that two samples, 08VNBH104 and 08VNBH105, collected west of the contaminated area down-slope of the runway, have high concentrations of dioxin: 2,000 pg/g and 22,300 pg/g TCDD, respectively. Soil samples collected to the west and the south of the runway exhibited lower levels of dioxin. Following the slope of the area and runoff direction, sediment samples were collected in surrounding ponds, lakes and ditches downstream of the site. Dioxin levels in samples 08VNBH108 (1,090 ppt TEQ), 08VNBH109 (2,780 ppt TEQ), 08VNBH110 (1,500 ppt TEQ), and 08VNBH111 (5,970 ppt TEQ) were significantly higher than the Vietnamese and internationally accepted guidelines. Percentage of TCDD in the TEQ in several samples was >90%, indicating Agent Orange was the most likely source of dioxin contamination in this area.

The site has complex terrain with numerous fishponds and lakes. Contamination varied significantly in the different areas sampled in this study, and appears to concentrate in drainage areas downstream (e.g., samples 08VNBH108 to 08VNBH111).

Table 2.4. The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soil/sediment samples collected at the Southwest Corner of Runway (Pacer Ivy Site identified by the US Department of Defense), Bien Hoa Airbase

No.	Sample Code	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ**	2,3,7,8-TCDD /WHO-TEQ (T%)
1	08VNBH 102	Soil	0-10	29.2	80.3	36.4
2	08VNBH 104	Soil	0-10	2,000	2,040	98.0
3	08VNBH 105	Soil	0-10	22,300	22,800	97.8
4	08VNBH 106	Soil	0-10	140	147	95.2
5	08VNBH 107	Soil	0-10	489	556	87.9
6	08VNBH 108	Sediment	0-10	1,030	1,090	94.5
7	08 VNBH 109*	Sediment	0-10	2,650	2,780	95.3
8	08VNBH 110	Sediment	0-10	1,400	1,500	93.3
9	08 VNBH 111*	Sediment	0-10	5,810	5,970	97.3
10	08VNBH 113	Soil	0-10	68.7	92.9	74.0
11	08VNBH 114	Soil	0-10	467	516	90.5
12	08VNBH 115	Soil	0-10	1.00	780	0.13
13	08 VNBH 116*	Soil	0-10	844	894	94.4
14	08VNBH 119	Soil	0-10	70.1	217	32.3
15	08 VNBH 120*	Soil	0-10	221	289	76.5

Note:
**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

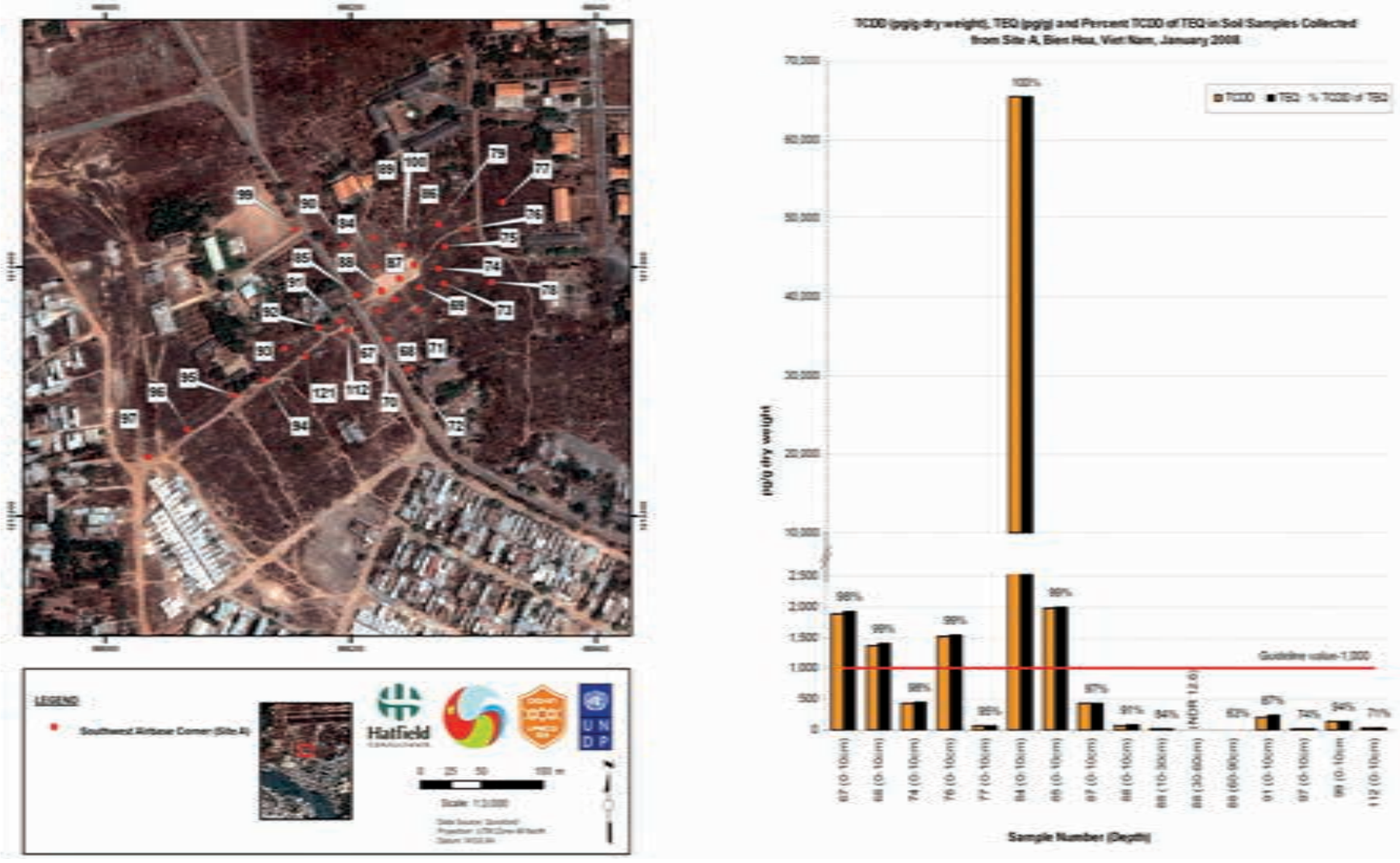

Fig. 2.7. Sampling locations and the dioxin concentrations in soils from the Southwest Airbase Corner, Bien Hoa Airbase, 2008.

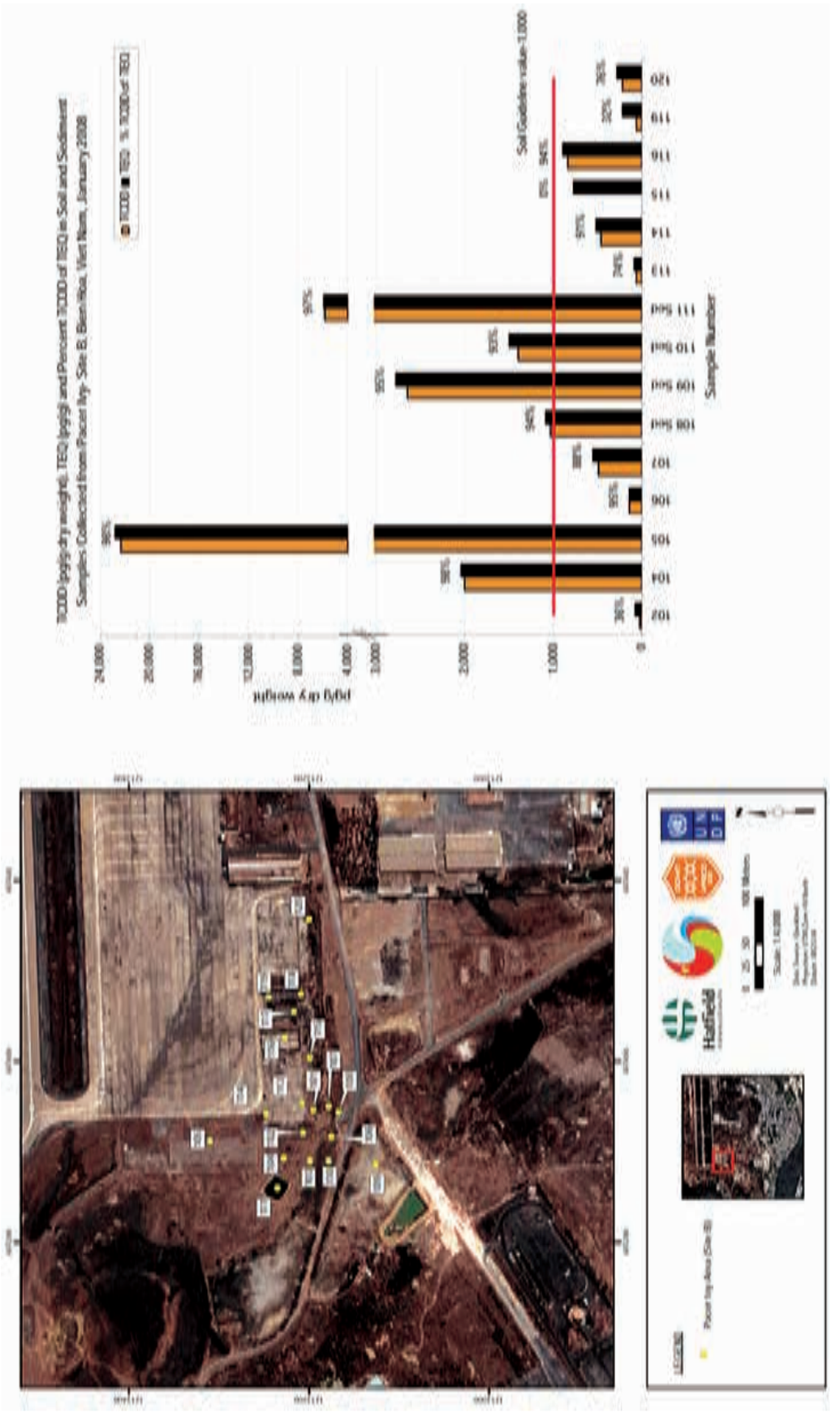

Fig. 2.8. Sampling locations and the dioxin concentrations in soils and sediment from the Southwest Corner of Runway (Pacer Ivy Site identified by the US Department of Defense), Bien Hoa, Airbase 2008.

Z1 Area

Located in the south-central area of Bien Hoa Airbase, Z1 is highly contaminated with dioxin, given that it was the main storage area for Agent Orange, Blue and White herbicides during the US – Vietnam War, large herbicide storage tanks were present at this location, and the area surrounding Site Z1 was subject to spillage. At least four times between December 1969 and March 1970, major spills occurred in this area; approximately 25,000 liters of Agent Orange and 2,500 liters Agent White were released to the environment (US DOD, 2007).

Eight samples were taken from three locations at the remediated site; core samples were collected in 30 cm increments to a depth of 180 cm. Core sample 08VNBH080 was collected below the site of the former Agent Orange containment tank; core sample 08VNBH082 was collected below the former Agent Blue containment tank, and core sample 08VNBH083 was collected below the former Agent White containment tank.

Results of core sample 08VNBH080 demonstrate that TCDD concentration generally increased with depth: in the 0-30 cm fraction, the TCDD concentration was 36,800 pg/g; at 30-60 cm, 144,000 pg/g; at 60-90 cm, 259,000 pg/g; 90 120 cm, 215,300 pg/g; 120-150 cm is 26,200 pg/g; and in the fraction 150 180 cm, 184,000 pg/g. These results demonstrate that dioxin migrated into deeper layers of soils in this area, and suggest extremely high concentrations of herbicide were used in the area. In addition, TCDD comprised over 98% of the total TEQ in all samples from this area.

The highest level of dioxins (262,000 ppt TEQ) was recorded at a depth of 60 90 cm. Sample 08VNBH080-6 (150 – 180 cm) still exhibited a dioxin level of 185,000 ppt TEQ. These results confirm that dioxin penetrated below a depth of 1.8 m at this site.

The sample collected below the Agent Blue containment tank (08VNBH082) exhibited a dioxin level of 49,100 ppt TEQ; furthermore, the sample collected below the Agent White containment tank (08VNBH083) had a dioxin level of 109 ppt WHO-TEQ.

Table 2.5. The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soil samples collected from Z1 Area, Bien Hoa Airbase, Viet Nam

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ** (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
1	08VNBH 080	Soil	0-30	36,800	37,500	98.1
2	08VNBH 080-2	Soil	30-60	144,000	146,000	98.7
3	08VNBH 080-3	Soil	60-90	259,000	262,000	99.0
4	08VNBH 080-4	Soil	90-120	215,000	217,000	99.0
5	08VNBH 080-5	Soil	120-150	26,200	26,400	99.3
6	08 VNBH 080-6*	Soil	150-180	184,000	185,000	99.5
7	08VNBH 082	Soil	0-10	48,600	49,100	99.0
8	08VNBH 083	Soil	0-10	99.7	109	91.5

Note :
**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Perimeter (Vicinity) of Z1 Area

The perimeter (downstream) of the Z1 area receives drainage from the hotspot site, and there are a number of ponds and lakes used for aquaculture. The area has changed significantly since the remediation efforts have been implemented. Specifically, rainwater from the Z1 Area no longer flows to Bien Hung Lake and other lakes inside the Airbase. Following initial remediation efforts, rainwater now flows to the Dong Nai River via newly dug ditches. With the aim of identifying possible other areas containing high levels of dioxin outside and downstream of the Z1 Area, a total of 52 soil samples from 43 sites on the perimeter of the Z1 Area were collected. Analytical results are presented in Table 2.6.

At the site which the sample numbered 08VNBH141 was collected, samples were collected from 5 depths (surface to 1.5 m). Six sediment samples were collected from ponds and lakes located at the end of slope of Z1 arena.

In general, samples collected from the landfill area of the Z1 Area exhibited a wide range of dioxin concentrations. Dioxin levels ranged from 22.6 ppt TEQ (08VNBH150) to 13,300 ppt TEQ (08VNBH170). Samples collected Southwest of the Z1 Area exhibited high levels of dioxin (sample 08VNBH123, 1,330 ppt TEQ); in sample 08VNBH141-3, dioxin levels at the depth of 30-60 cm were 8,310 ppt, demonstrating that deeper soil layers in this area need to be concerned.

The dioxin concentrations in the samples collected from Southern and Southwestern areas of Z1 containment area were higher than that of samples collected from the Eastern and Northern areas. The sediment samples taken from the drainage ditch which receives water from the Z1 Area (08VNBH125) exhibited a concentration of 2,010 pg/g TCDD (96.4% of the TEQ was TCDD).

Perimeter soils near the Z1 site generally exhibited dioxin levels less than 1,000 pg/g, except those collected from lowland areas, including the drainage ditches in the area. Site C, which includes ponds/lakes and lowland areas South of Z1, exhibited relatively high levels of dioxin.

Table 2.6. Dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soils in the perimeter of the Z1 area.

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ** (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08VNBH 122	Soil	0-10	194	223	87.2
2	08 VNBH 123*	Soil	0-10	1310	1,330	98.5
3	08 VNBH 124*	Soil	0-10	387	395	98.0
4	08VNBH 125	Soil	0-10	2010	2,090	96.2
5	08 VNBH 126*	Soil	0-10	70.8	74	95.7
6	08VNBH 127	Soil	0-10	65.8	70.4	93.5
7	08 VNBH 128*	Soil	0-10	850	879	96.7
8	08VNBH 130	Soil	0-10	566	589	96.1
9	08 VNBH 132*	Sediment	0-10	405	413	98.1
10	08VNBH 134	Soil	0-10	41.1	48.3	85.1
11	08 VNBH 135*	Soil	0-10	2,620	2,670	98.1
12	08VNBH 136	Soil	0-10	67.4	72.9	92.5
13	08VNBH 137	Soil	0-10	396	411	96.4
14	08VNBH 139	Soil	0-10	20.0	26.3	76.0
15	08VNBH 141	Soil	0-10	742	753	98.5
16	08VNBH 141-3	Soil	30-60	8,240	8,310	99.2
17	08VNBH 141-6	Soil	120-150	11.8	22.2	53.2
18	08VNBH 142	Soil	0-10	31.3	40.7	76.9
19	08 VNBH 143*	Soil	0-10	84.1	113	74.4
20	08VNBH 143-3	Soil	30-60	3.80	6.15	61.8
21	08VNBH 145	Soil	0-10	81.8	94.4	86.7

Table 2.6. Dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soils in the perimeter of the Z1 area.

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ** (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
22	08VNBH 147	Soil	0-10	236	259	91.1
23	08 VNBH 148*	Soil	0-10	29.5	31.5	93.7
24	08VNBH 149	Soil	0-10	94.3	106	89.0
25	08 VNBH 150*	Soil	0-10	19.6	22.6	86.7
26	08VNBH 153	Soil	0-10	738	757	97.5
27	08VNBH 161	Soil	0-10	311	323	96.3
28	08 VNBH 162*	Soil	0-10	393	442	88.9
29	08VNBH 163	Soil	0-10	17.4	25.3	68.8
30	08VNBH 166	Soil	0-10	80.9	98.0	82.6
31	08VNBH 170	Soil	0-10	12,400	13,300	93.2

Note :
**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Ponds and Lakes in Z1 area

A number of ponds, lakes, and other aquatic habitats are located approximately 300 m south of the Z1 Area. Prior to the implementation of remediation efforts, rainwater carried toxic chemicals from the Z1 Area, including dioxins, into these ponds and lakes, including Bien Hung Lake outside of Bien Hoa Airbase.

The highest dioxin level was recorded in sample numbered 08VNBH155 (2,240 ppt TEQ), which was collected from a fishpond, and in sample numbered 08VNBH157 (1,790 TEQ) from a nearby aquatic habitat. Other sediment samples (08VNBH156 and 08VNBH158) were collected from drainage ditches, which are connected to the fishponds; these samples contained relatively low levels of dioxin (20.9 ppt and 22.0 ppt TEQ, respectively).

Table 2.7. The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in sediment samples in ponds and lakes near downstream of Z1 Area.

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ** (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08 VNBH 155*	Sediment	0-10	2,200	2,240	98.2
2	08VNBH 156	Sediment	0-10	15.2	20.9	72.7
3	08 VNBH 157*	Sediment	0-10	1,740	1,790	97.2
4	08VNBH 158	Sediment	0-10	18.0	22.0	81.8
5	08VNBH 159	Sediment	0-10	727	756	96.2

Note :
** Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

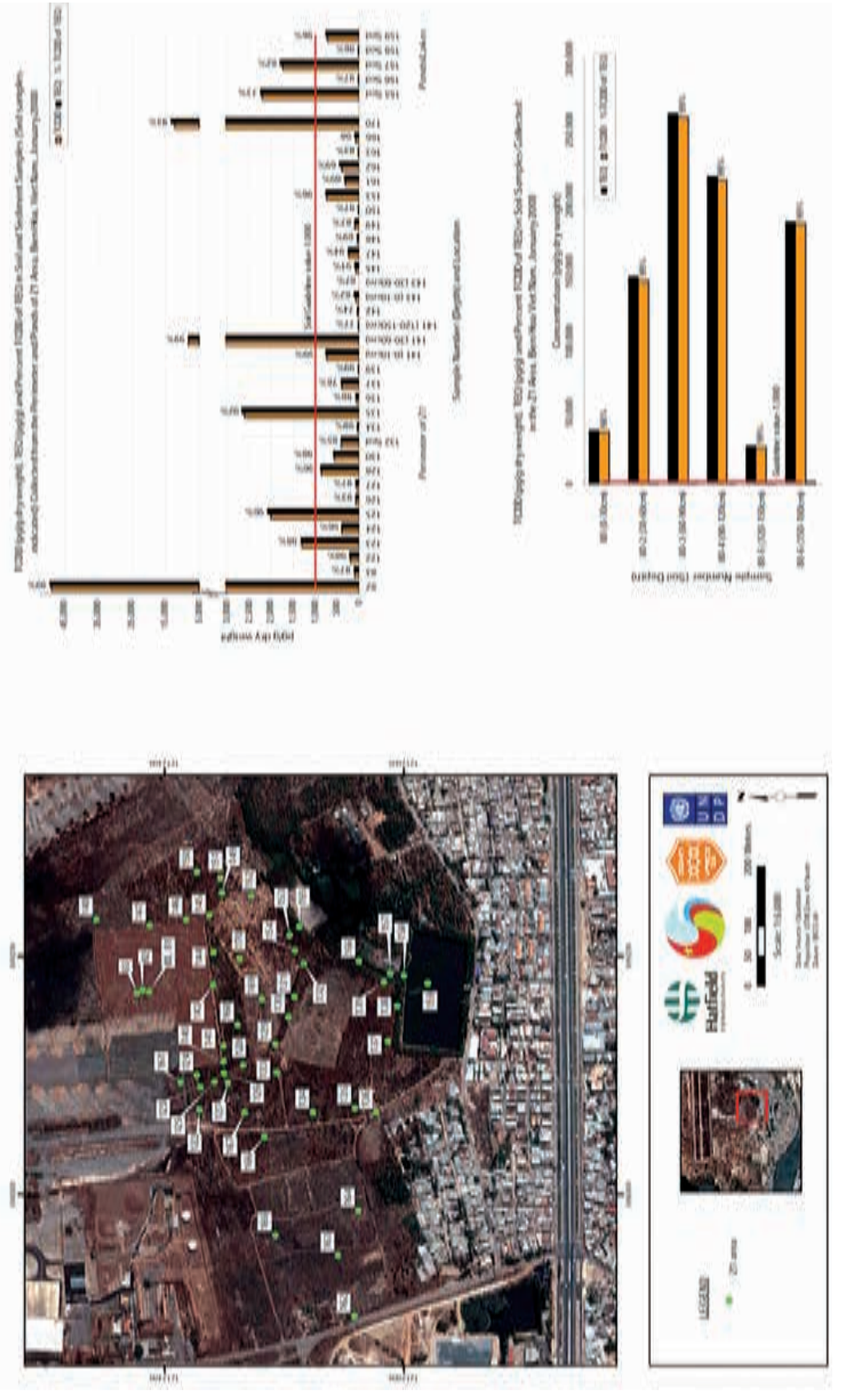

Fig. 2.9. Sampling locations and the dioxin concentrations in soils and sediments in the perimeter and ponds/lakes of Z1 Area, Bien Hoa Airbase, 2008.

2.3.4. Results of Office 33/Hatfield (2010)

In 2010, Office 33/Hatfield Consultant implemented study on environment and human health in Bien Hoa Airbase, this study aims to make the contamination situation in Bien Hoa clearer. Sampling areas including: Pacer Ivy area, Z1 area, Southwest of airbase, Northeastern perimeter, Northern perimeter, and Bien Hoa city.

Pacer Ivy Area

In Pacer Ivy area, 42 soil and sediment samples were collected. Among those , 30 samples (23 soule , 7 sediment samples) loas analysed in AXYS laboratory (2 QA/QC samples). Analytical results are presented in Table 2.8.

Table 2.8. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g) in soil and sediment samples collected in Pacer Ivy, Bien Hoa Airbase.

Sample ID	Sample Matrix	Depth	2,3,7,8-TCDD (pg/g	WHO-TEQ 2005* (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
10VNBH220	Soil	0-10	7,530	7,550	99.7
10VNBH221	Soil	0-10	3,940	3,990	98.7
10VNBH222	Soil	0-10	2,620	2,700	97.0
10VNBH224	Soil	0-10	1,090	1,120	97.3
10VNBH225	Soil	0-10	99.1	104	95.3
10VNBH226	Soil	0-10	5.81	7..13	81.5
10VNBH227	Soil	0-10	5.5	6.73	81.7
10VNBH228	Soil	0-10	49.4	56.4	87.6
10VNBH229	Soil	0-10	7.97	9.69	82.2
10VNBH230	Soil	0-15	83.9	86.7	96.8
10VNBH231	Soil	0-15	1,300	1,310	99.2
10VNBH232	Soil	0-10	62.4	65.8	94.8
10VNBH233	Soil	0-10	3,000	3,070	97.7
10VNBH234	Soil	0-15	1.87	2.79	67.0
10VNBH235	Soil	0-10	2.76	3.86	71.5
10VNBH236	Soil	0-10	336	346	97.1
10VNBH237-2	Soil	30-60	61,400	61,800	99.4
10VNBH237-4	Soil	60-90	30.9	34.2	90.4
10VNBH237-6	Soil	120-150	48.6	52.9	91.9
10VNBH238	Soil	0-10	0.264	0.836	31.6
10VNBH239	Soil	0-10	5.83	11.7	49.8
10VNBH240-1	Soil	0-30	2,310	2,340	98.7
10VNBH240-3	Soil	60-90	2.20	4.4	NC
10VNBH413	Sediment	0-10	665	675	98.5
10VNBH416	Sediment	0-5	30.9	32.1	96.3
10VNBH419	Sediment	0-5	586	605	96.9
10VNBH421	Sediment	0-10	605	628	96.3
10VNBH422	Sediment	0-10	1,710	1,770	96.6
10VNBH423	Sediment	0-10	605	622	97.3
10VNBH424	Sediment	0-20	50	2,020	2.5

***Note**: * 1/2 of detection limits (DL) were used for calculating TEQ*

After analyses, 8 among 23 soil samples have TCDD and TEQ levels which are higher than Vietnamese standard for dioxin (1000 ppt). The highest dioxin level was recognized in sample 10VNBH237-2 collected at the west of concrete area at the depth of 30-60 cm. TCDD and TEQ in this sample were 61,400 ppt and 61,800 ppt respectively. The result showed that 99.4% TEQ is TCDD, which proved that Agent Orange is the cause of dioxin contamination. Soil samples collected at other depths in the same area had lower TEQ level (34.2 ppt at 60-90 cm and 52.9 ppt at 120-150 cm). In study 2008, the highest dioxin level was found in a soil sample (08VNBH105) close to sample 10VNBH237-2.

The second highest dioxin concentration was recorded in 10VNBH220, which were collected at the west of concrete area. TCDD was 7,530 ppt and 99.7% of TEQ. Other six soil samples collected in Pacer Ivy were all higher than Vietnam dioxin standard for soil. These samples had high percentage of TCDD in TEQ, higher than 97%, therefore, Agent Orange is the cause of dioxin contamination. In this area, higher TCDD levels was detected at surface layers, and lower at the >60 cm depth.

Sediment samples collected in ponds and lakes in Pacer Ivy area exhibited high contamination levels. Six amongst seven sediment samples exhibited TEQ levels higher than Vietnam dioxin standard for sediment (150 ppt). The highest dioxin level was detected in sample 10VNBH424 collected in a lake which are just outside the airbase (2,020 ppt TEQ). TCDD (50 ppt) only accounted for 2.5% of the TEQ in this sample. Sample 10VNBH422 collected in the area near airbase boundary exhibited high TCDD level of 1,700 ppt TCDD, and TEQ of 1,770 ppt, TCDD accounted for 96% of TEQ. Other four sediment samples collected around concrete yard exhibited TCDD concentration ranging between 605 ppt to 675 ppt. All sediment samples (excepting 10VNBH424) exhibited above 96% of TCDD to TEQ proportions, indicating Agent Orange as the source of contamination.

In general, soil and sediment in Pacer Ivy area were contaminated with dioxin with high levels, proportion of TCDD to total TEQ was over 80%, indicating Agent Orange as the source of dioxin contamination.

Southwest of Airbase

Six soil samples collected in 2010 and 2 soil samples archived from 2008 study were analysed. One archived sample from 2008 study exhibited TEQ concentration higher than 1000 ppt (5,150 ppt); this sample has TCDD of 3,640 ppt; TCDD contributed 91% of the TEQ. Meanwhile, lower dioxin levels were recorded in six samples collected in study 2010, in range of 7.84 to 124 ppt; TCDD comprised more than 82% of TEQ in four samples. This result indicated that Agent Orange might be the cause of contamination. Analytical results are presented in Table 2.9. Analytical results indicated that dioxin contamination in this area located in small area.

Table 2.9. Dioxin concentration (2,3,7,8-TCDD và TEQ; pg/g) in soil collected in Southwest of Bien Hoa Airbase, 2010

Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ 2005** (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
08VNBH071	Soil	0-10	3,640	5,150	70.7
08VNBH072	Soil	0-10	51.2	56.2	91.1
10VNBH214	Soil	0-20	62.7	110	57
10VNBH215	Soil	0-10	7.84	9.22	85
10VNBH216	Soil	0-20	124	131	94.7
10VNBH217	Soil	0-10	33.8	41.1	82.2
10VNBH218	Soil	0-15	25.8	30	86.0
10VNBH219	Soil	0-15	21.5	47.4	45.4

***Note**: * 1/2 of detection limits (DL) were used for calculating TEQ*

Z1 Area

Most soil samples collected in 2010 in this area exhibited low TEQ, ranging from 1.46 ppt to 212 ppt. Two samples 10VNBH242 and 10VNBH243 exhibited high TCDD level (3,130 ppt and 2,540 ppt) and TEQ level (3,210 ppt and 2,650 ppt). In all samples, TCDD comprised 95% of TEQ, indicating Agent Orange as the source of dioxin contamination.

Two core samples collected to the south (10VNBH245) and the southeast (10VNBH246) of landfill area from surface to the depth of 150cm. TCDD levels in 10VNBH245 generally decreased with depth: at 0-30cm, TCDD was 7.66 ppt; at 60-90cm, dioxin wasn´t detected.

Table 2.10. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g) in soil and sediment in Z1 area, in Bien Hoa Airbase, 2010

Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ 2005* (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
08VNBH138	Soil	0-10	19.6	22.4	87.5
08VNBH167	Soil	0-10	985	1,000	98.5
10VNBH241	Soil	0-15	196	212	92.5
10VNBH242	Soil	0-15	3,130	3,210	97.5
10VNBH243	Soil	0-15	2,540	2,650	95.8
10VNBH244	Soil	0-15	74.9	88	85.1
10VNBH245	Soil	0-30	7.66	9.75	78.6
10VNBH245	Soil	60-90	< 0.921	1.46	NC
10VNBH246	Soil	60-90	NDR 1.69	1.53	NC
10VNBH246	Soil	120-150	< 0.986	1.56	NC
10VNBH247	Soil	0-10	93.7	113	82.9
10VNBH248	Soil	0-10	4.83	6.24	77.4
10VNBH250	Soil	0-10	28.3	34,8	81.3
10VNBH251	Soil	0-10	225	237	94.9
10VNBH426	Sediment	0-5	111	125	88.8
10VNBH427	Sediment	0-5	212	219	96.8
10VNBH428	Sediment	0-20	33.9	39.8	85.2

Note:
NDR = peak detected but did not meet quantification criteria, result reported represent the estimated maximum possible concentration.
** 1/2 of detection limits (DL) were used for calculating TEQ*

Sediment samples were either collected at drainage ditch of South Base Lake, at wetland situated to the Southeast of landfill, and at Z1 Lake. The sample (10VNBH427) collected at wetland exhibited TCDD concentration of 212 ppt, TEQ of 219 ppt (TCDD contributed to 96.8%). Analytical result of sample 10VNBH427 exceeds the standard for sediment (150 ppt). As regard of sample collected at drainage ditch of South Base Lake, exhibited either high dioxin concentration (111ppt TCDD; 125 ppt TEQ; 88.8% TCDD of TEQ). Meanwhile, dioxin concentration in sediment collected at Z1 area was relatively low (33.9 ppt TCDD, 39.8 ppt TEQ).

Northeastern perimeter of the Airbase

Eight soil samples and two sediment samples collected at the Northeastern of airbases were analysed. Surface soil sample (10VNBH208) collected at the low-lying grass land near Northeastern Perimeter Lake 1 exhibited TCDD of

996 ppt and TEQ of 1,040 ppt, this result was higher than Vietnam standard for dioxin in soil (1000 ppt). Another sample collected at perimeter (10VNBH204) either have the relatively high TCDD and TEQ values (333 ppt TCDD and 347 ppt TEQ). In both samples, TCDD contributed 95% of TEQ, indicating that dioxin contamination in this area are from Agent Orange. Analytical results of other samples exhibited lower dioxin concentration, TCDD in range of 3.4 to 47.9 ppt, TEQ in range of 12.1 to 56.1 ppt.

Sediment samples were collected at aquaculture lakes (Mr. San Lake and Perimeter Lake 1 and 2), near the Southeastern end of taxi way. Sample collected at Perimeter Lake 1 exhibited TCDD level of 600 ppt, TEQ of 633 ppt, higher than Vietnam standard for dioxin in sediment (150 ppt TEQ). Two other samples had low TCDD concentration.

Table 2.11. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g) in soil/sediment in Northeastern perimeter, Bien Hoa Airbase, 2010

Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ 2005* (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
10VNBH204	Soil	0-15	333	347	96.0
10VNBH205	Soil	0-20	39.2	48.5	80.8
10VNBH206	Soil	0-20	32.7	36.6	89.3
10VNBH208	Soil	0-10	996	1,040	95.8
10VNBH209	Soil	0-20	17	19.1	89.0
10VNBH210	Soil	0-20	3.4	12.1	28.1
10VNBH212	Soil	0-20	47.9	56.1	85.4
10VNBH213	Soil	0-20	17.8	18.7	95.2
10VNBH408	Sediment	0-20	11.6	12.3	94.3
10VNBH410	Sediment	0-5	600	633	94.8
10VNBH412	Sediment	0-120	5.11	6	85.2

***Note:** * 1/2 of detection limits (DL) were used for calculating TEQ*

Northern Perimeter and Bien Hoa City (Southern Perimeter)

Four soil samples and five sediment samples collected at northern perimeter of Bien Hoa Airbase. Soil samples exhibited low dioxin concentration which were not higher than Vietnam standard for dioxin in soil (1000 ppt). Only one soil sample had relatively high dioxin concentration (425 ppt TCDD, 459 ppt TEQ, and 92.6% TCDD of TEQ). Analytical results showed in Table 2.12.

Table 2.12. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g) in soil/sediment in Northern perimeter of Bien Hoa Airbase and Bien Hoa City, 2010

Sample ID	Sample Matrix	Depth (cm)	Depth (cm)	WHO-TEQ 2005*(pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
Northern Perimeter					
10VNBH200	Soil	0-15	10.8	11.6	93.1
10VNBH201	Soil	0-15	5.33	8.47	62.9
10VNBH202	Soil	0-20	425	459	92.6
10VNBH203	Soil	0-20	15.4	17.1	90.1
10VNBH400	Sediment	0-10	62.8	68.5	91.7
10VNBH402	Sediment	0-50	362	372	97.3
10VNBH403	Sediment	0-130	37.4	38.2	97.9

Table 2.12. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g) in soil/sediment in Northeastern perimeter, Bien Hoa Airbase, 2010

Sample ID	Sample Matrix	Depth (cm)	Depth (cm)	WHO-TEQ 2005*(pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
10VNBH404	Sediment	0-50	4.9	5.66	86.6
10VNBH406	Sediment	0-200	257	268	95.9
Southern Perimeter (Bien Hoa City)					
10VNBH429	Sediment	0-20	24.3	26.9	90.3
10VNBH430	Sediment	0-100	79.1	95.6	82.7

Note: ** 1/2 of detection limits (DL) were used for calculating TEQ*

Two sediment samples collected in Northern perimeter exhibited TEQ higher than Vietnam standard for dioxin in sediment (150 ppt). Among those, one sample collected in a small lake, located at northwestern perimeter, exhibited TCDD of 362 ppt and TEQ of 372 ppt, TCDD contributed 97.3% of TEQ. Another sample collected in Mr. Binh Lake also had high dioxin concentration (257 ppt TECC, 268 ppt TEQ, TCDD of 95.9% TEQ). Other sediment samples collected small pond at the west of Mr.Binh Lake and Mr. Quy Lake exhibited relatively low TCDD and TEQ values.

At the South of airbase, two sediment samples were collected at Gate 2 Lake and Bien Hung Lake. Sample at Gate 2 Lake exhibited low dioxin concentration (24,3 ppt TCDD and 26,9 ppt TEQ and 90,3% TCDD in TEQ). At Bien Hung Lake, analytical result showed higher dioxin concentration (79.1 ppt TCDD and 96,6 ppt TEQ, and 82,7% TCDD of TEQ).

Fish samples from lakes in and around the airbase

Dioxin/furan concentrations in fish tissues were determined from several lakes (N = 11) in Bien Hoa Airbase and Bien Hoa City.

Table 2.13. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g wet weight basis) in fish tissue in and around Bien Hoa Airbase and Bien Hoa City, 2010

Sample ID	Fish Species	Tissue Type	2,3,7,8-TCDD (pg/g)	WHO-TEQ 2005** (pg/g)	2,3,7,8-TCDD/ WHO-TEQ (T%)
NE Perimeter					
Tilapia	Tilapia	Muscle	1.4	1.49	94.0
Tilapia	Tilapia	Fat	73.3	76	96.4
Tilapia	Tilapia	Muscle	14.4	14.8	97.3
Tilapia	Tilapia	Fat	1,620	1,680	96.4
Northern Perimeter					
10VNBH504	Tilapia	Muscle	25.4	25.9	98.1
10VNBH505	Tilapia	Fat	2,410	2,460	98.0
Pacer Ivy Area					
10VNBH509	Tilapia	Muscle	31.2	31.5	99.0
10VNBH510	Tilapia	Fat	3,990	4,040	98.8
10VNBH521	Tilapia	Whole fish	618	622	99.4
Z1 Area					
10VNBH516	Tilapia	Muscle	18.6	18.9	98.4
10VNBH517	Tilapia	Fat	1,410	1,440	97.9
10VNBH522	Tilapia	Whole fish	94.7	96.5	98.1

Table 2.13. Dioxin concentration (2,3,7,8-TCDD and TEQ; pg/g wet weight basis) in fish tissue in and around Bien Hoa Airbase and Bien Hoa City, 2010

Sample ID	Fish Species	Tissue Type	2,3,7,8-TCDD (pg/g)	WHO-TEQ 2005** (pg/g)	2,3,7,8-TCDD/ WHO-TEQ (T%)
Outside Airbase					
10VNBH507	Tilapia	Muscle	32.7	33.2	98.5
10VNBH508	Tilapia	Fat	1,490	1,520	98.0
10VNBH512	Tilapia	Muscle	NDR 0.0862	0.0782	NC
10VNBH513	Tilapia	Fat	2.51	4.54	55.3
10VNBH514	Tilapia	Muscle	NDR 0.117	0.0856	NC
10VNBH515	Tilapia	Fat	3.29	5.9	55.8
10VNBH518	Tilapia	Muscle	1.25	1.35	92.6
10VNBH519	Tilapia	Fat	86.7	91.8	94.4

Note:
NDR = peak detected but did not meet quantification criteria, result reported represent the estimated maximum possible concentration.
** 1/2 of detection limits (DL) were used for calculating TEQ*

In 2010 study, levels of dioxin/furan in 11 fish samples collected in Bien Hoa airbase andBien Hoa city was analyzed (Figure 2.14). At least one of the fish tissuesamples analyzed from each of the lakes and ponds in 2010 from the Bien Hoa Airbase and its vicinity were above Health Canada consumption guidelines (20 ppt for edible fish tissue). In Z1 Area,Tilapia were collected from Z1 Lake, located south of the main hotspot, on the southern perimeter of the Airbase. Muscle tissue from a composite of 13 small Tilapia from the Z1 Lake had a TEQ concentration of 18.9 ppt (wet weight),which was below the Health Canada consumption guideline. Fat tissue taken from the same Tilapia composite had an extremely high TEQ concentration (1,440 ppt; 97.9% TCDD), indicating Agent Orange as the source of the contamination. Whole fish tissue (full body composite analysis) taken from a composite of 8 small Tilapia from Z1 Lake also had a very high TEQof 96.5 ppt (TCDD 98.1% of the TEQ).

In Pacer Ivy area, fish muscle, fat and whole fish tissues were sampled from 'Mr. Hoc Lake' and 'Pacer Ivy Lake' in the Pacer Ivy Area. All fish tissue samples analysed from this area exceeded Health Canada consumption guideline of 20 ppt. In 'Mr.Hoc Lake', a composite of Tilapia (n=3) were analyzed for dioxins in muscle and fat tissues. The muscle sample had a TEQ concentration of 31.5 ppt (99% TCDD), while the fat tissue sample exhibited an extremely high TEQ of 4,040 ppt (98.8% TCDD). A composite of 15 Tilapia sampled from the small pond north of 'Mr. Hoc Lake' also had a high TEQ (622 ppt), with TCDD making up 99.4% of the TEQ. Given that all samples exhibited a TCDD to TEQ proportion of 98% or greater indicates that Agent Orange is the source of contamination.

In Northeastern Perimeter, fish muscle and fat tissues were sampled from 'Mr. San Lake' and the 'NE Perimeter Lake 1' in the northeastern Airbase in 2010. A composite of 6 Tilapia were sampled from each lake. The muscle tissue sample analysed from 'Mr. San Lake' had a low TEQ concentration (1.49 ppt). The fat tissue had a higher TEQ (76 ppt), and a proportion of TCDD to the TEQ concentration of 96.4%, indicating Agent Orange as the source of contamination. In 'NE Perimeter Lake 1', the TEQ concentration in the fat tissue was extremely high (1,680 ppt). TCDD comprised 96.4% of the TEQ concentration in the fat tissue, again indicating that Agent Orange is the source of contamination.

In 2010, fish samples were collected from 'Mr. Quy Lake' near the northern perimeter of the Bien Hoa Airbase. Muscle and fat tissues sampled from a composite of 3 Tilapia from this lake exceeded Health Canada consumption guidelines of 20 ppt for dioxins. Muscle tissue of the Tilapia composite exhibited a TEQ concentration of 25.9 ppt, while the fat tissue was extremely high (2,460 ppt TEQ). The proportion of TCDD in the TEQ of muscle and fat tissues were 98.1% and 98%, respectively, clearly indicating Agent Orange as the source of contamination in this lake.Tilapia were sampled from 'Gate 2 Lake', Bien Hung Lake, Gate 2 Market, andBien Hoa Market, located outside the Airbase in Bien Hoa City. Muscle and fat tissue samples collected from a composite of 5 Tilapia from 'Gate 2 Lake' (outside the southern perimeter of the Airbase) exhibited TEQ concentrations well above Health Canada consumption guideline of 20 ppt.

Muscle tissue had a TEQ concentration of 33.2 ppt (98.5% TCDD), and the fat tissue had a TEQ of 1,520 ppt (98% TCDD). In Bien Hung Lake, the Tilapia composite (n=2) sample exhibited a low TEQ concentration in muscle tissue (1.35 ppt), but a high concentration in fat tissue (91.8 ppt). TCDD comprised 92.6% of the TEQ in muscle tissue and 94.4% in the fat tissue, indicating Agent Orange as the contaminant source. Fish sampled in Gate 2 Market and Bien Hoa Market exhibited low TEQ concentrations. Muscle tissues sampled from both markets had very low TEQ concentrations (NDR 0.0782 ppt from Gate 2 Market and NDR 0.0856 ppt from Bien Hoa Market). Fat tissues sampled had slightly higher TEQ concentrations: 4.54 ppt (55.3% TCDD) from Gate 2 Market and 5.9 ppt (55.8% TCDD) in Bien Hoa Market. These concentrations are lower than Health Canada guidelines.Given that the Bien Hoa Airbase has a general south sloping topography, dioxins are likely carried through runoff to lakes and ponds located in the south and southeast of the Airbase. As expected, fish sampled from 'Gate 2 Lake' exhibited high TEQ concentrations in both fat and muscle tissues. Fish from Bien Hung Lake also exhibited a high TEQ in fat tissue.

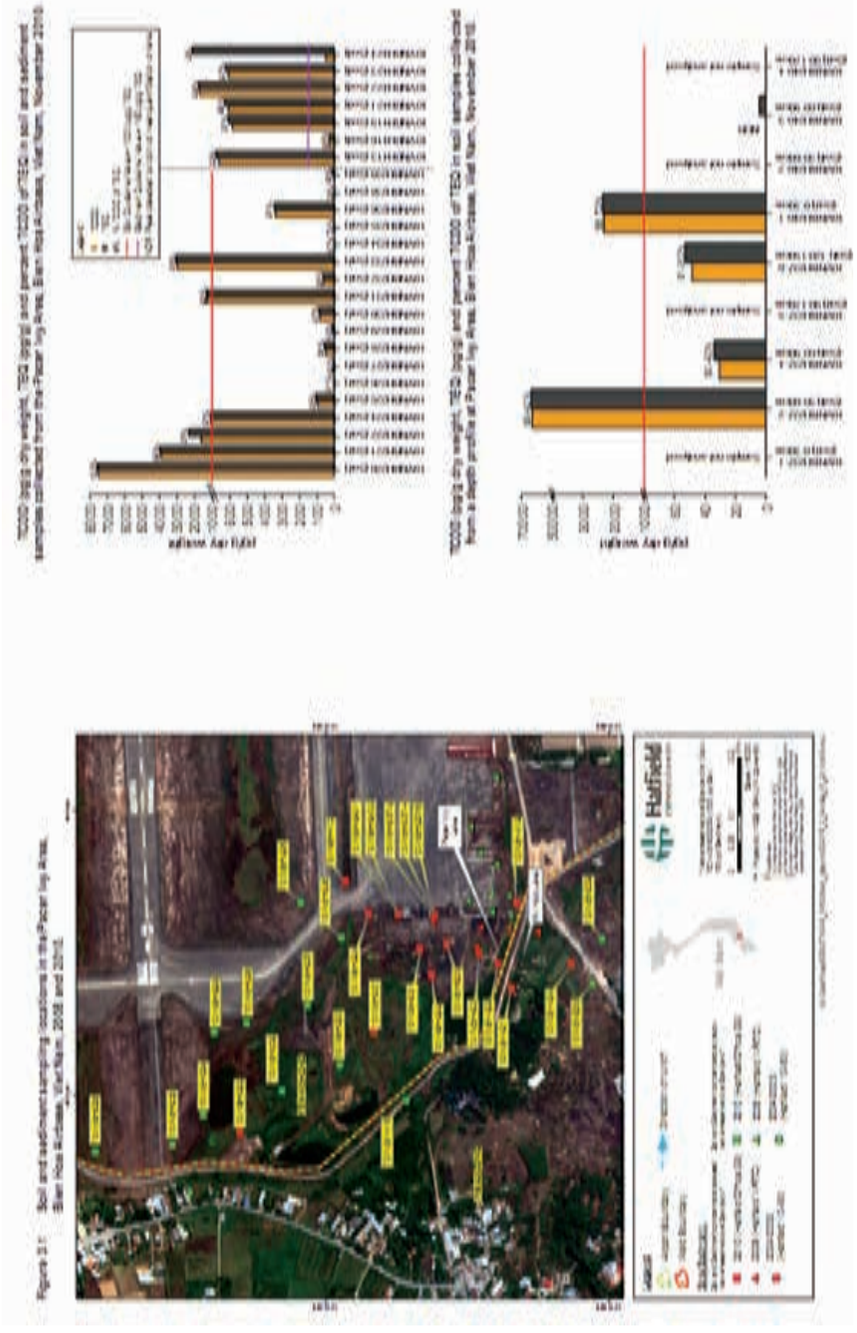

Fig.2.10. Sampling map and dioxin concentration in Pacer Ivy, Bien Hoa Airbse, in Hatfield study, Nov 2010

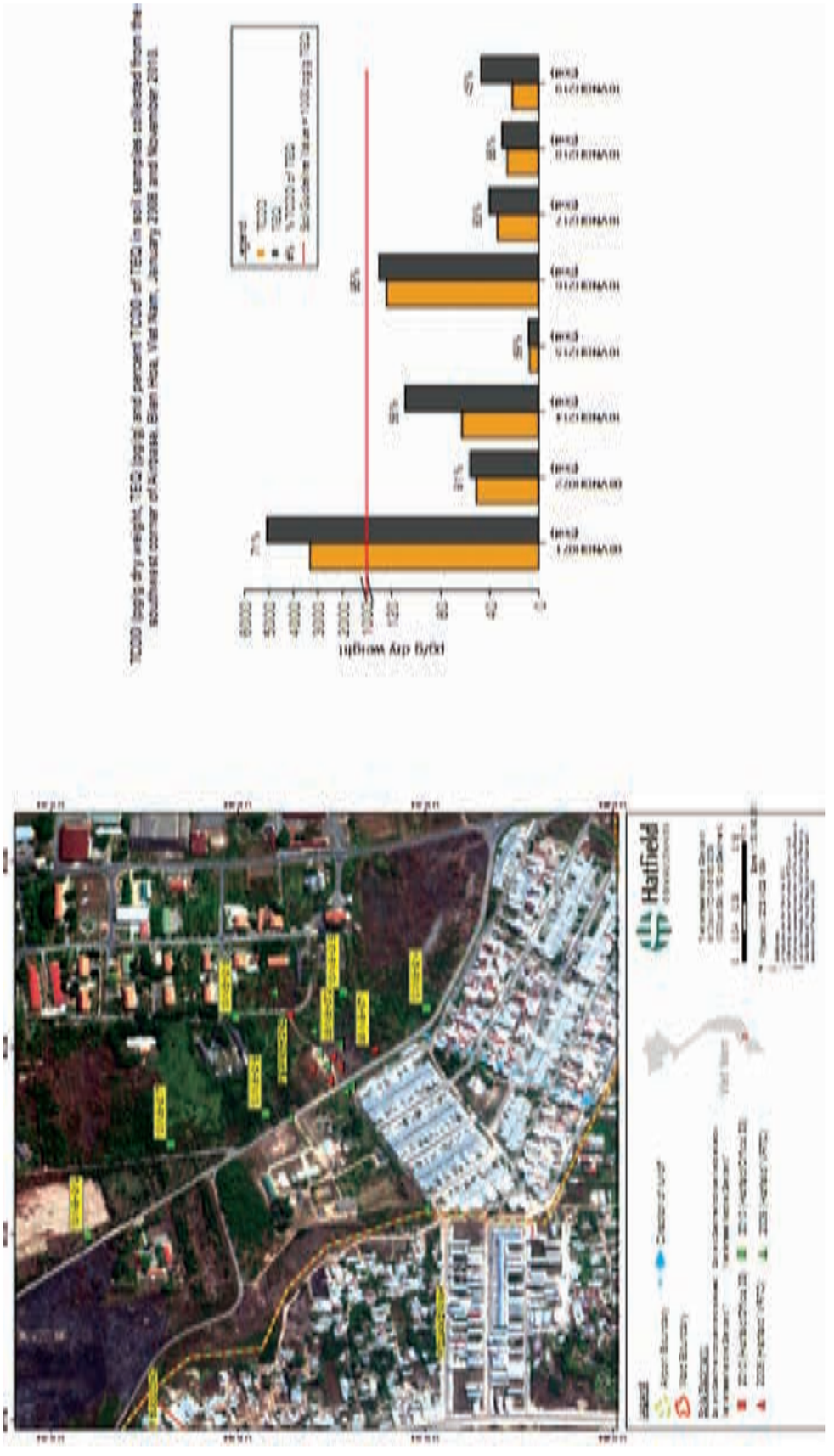

Fig.2.11. Sampling map and dioxin concentration in the southwest corner of Airbase, Bien Hoa, in Hatfield study, Nov 2010

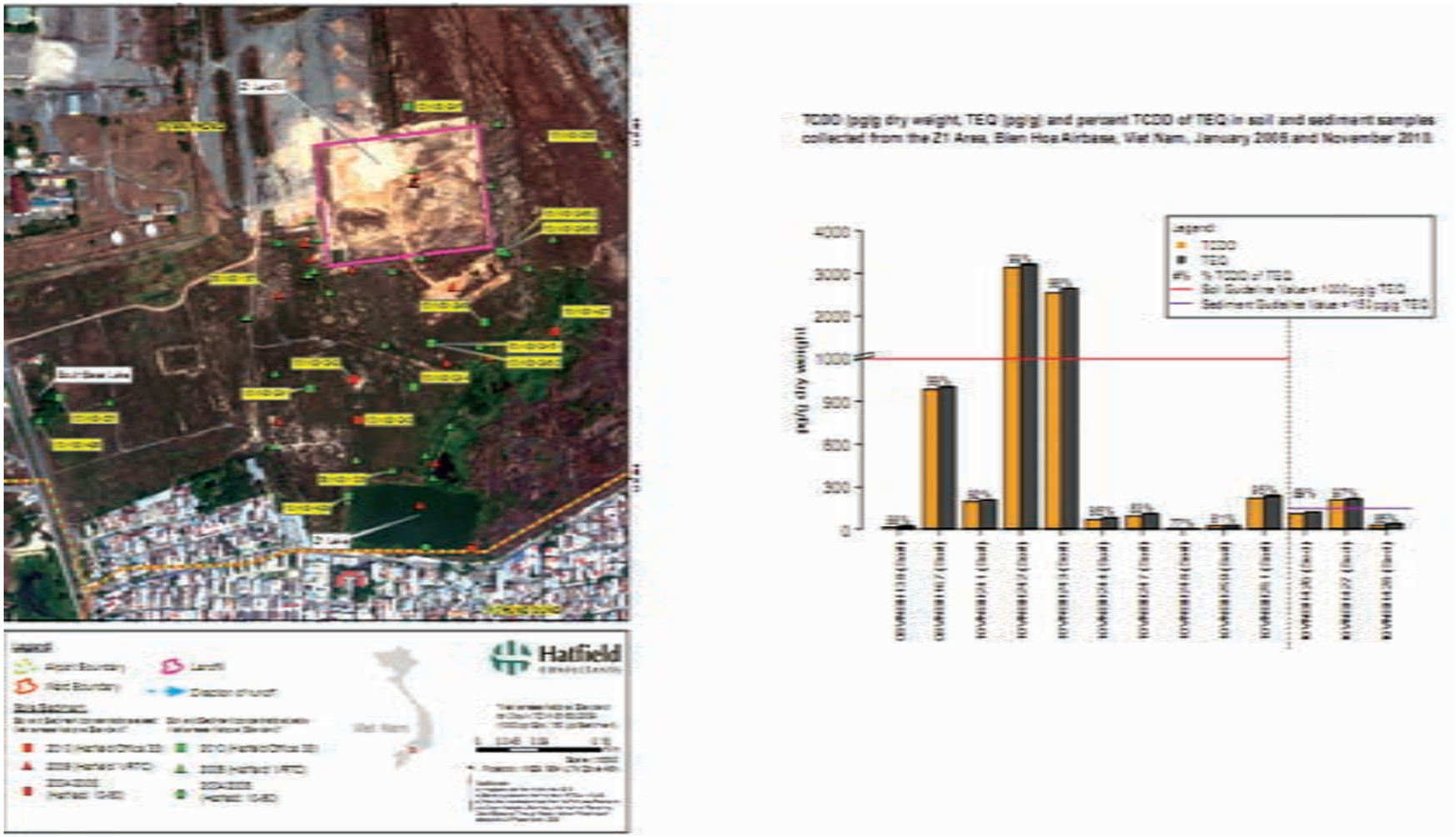

Fig.2.12. Sampling map and dioxin concentration in the Z1 Area , Bien Hoa, in Hatfield study , Nov 2010

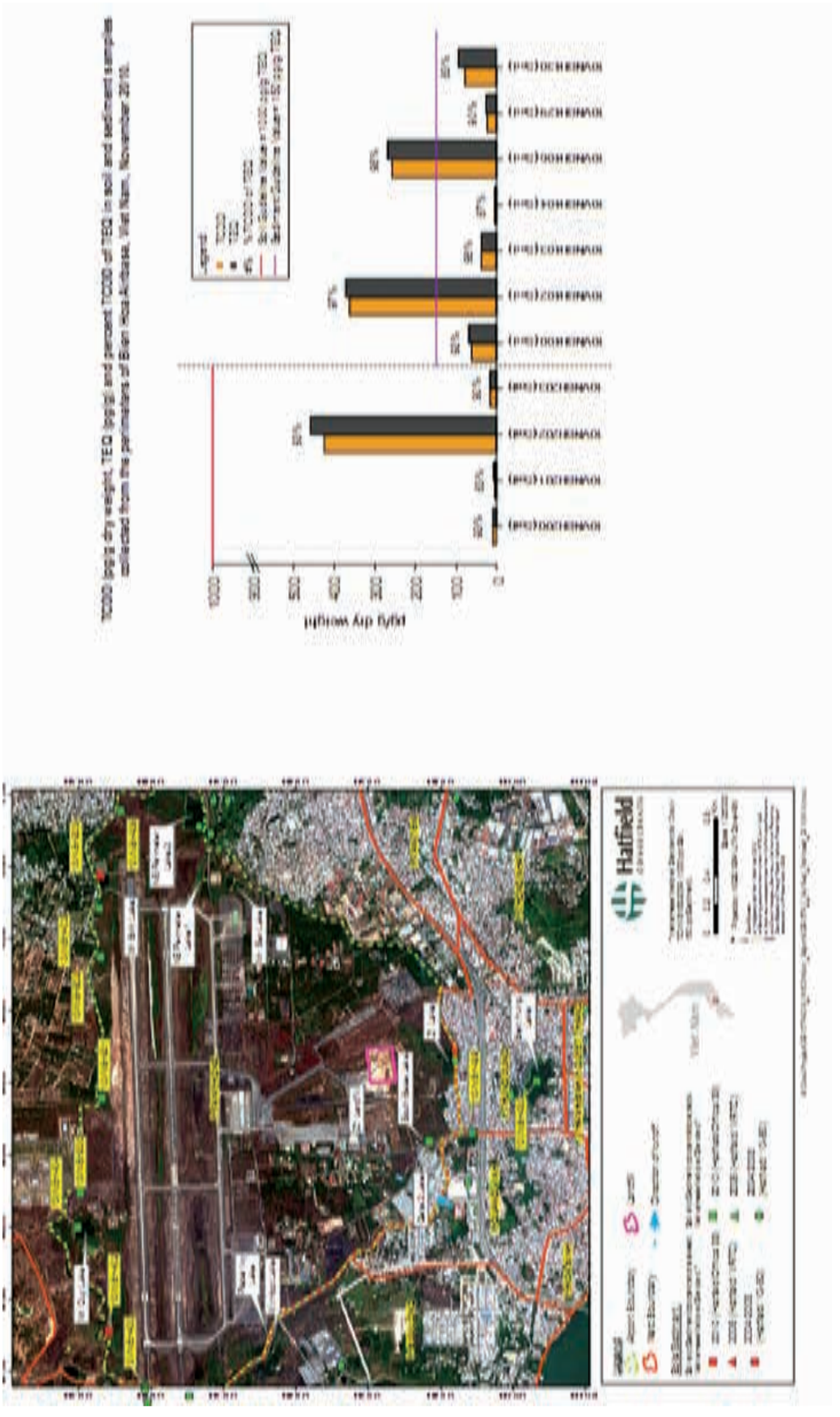

Fig.2.13. Sampling map and dioxin concentration in the perimeters of Bien Hoa Airbase, Bien Hoa, in Hatfield study, Nov 2010

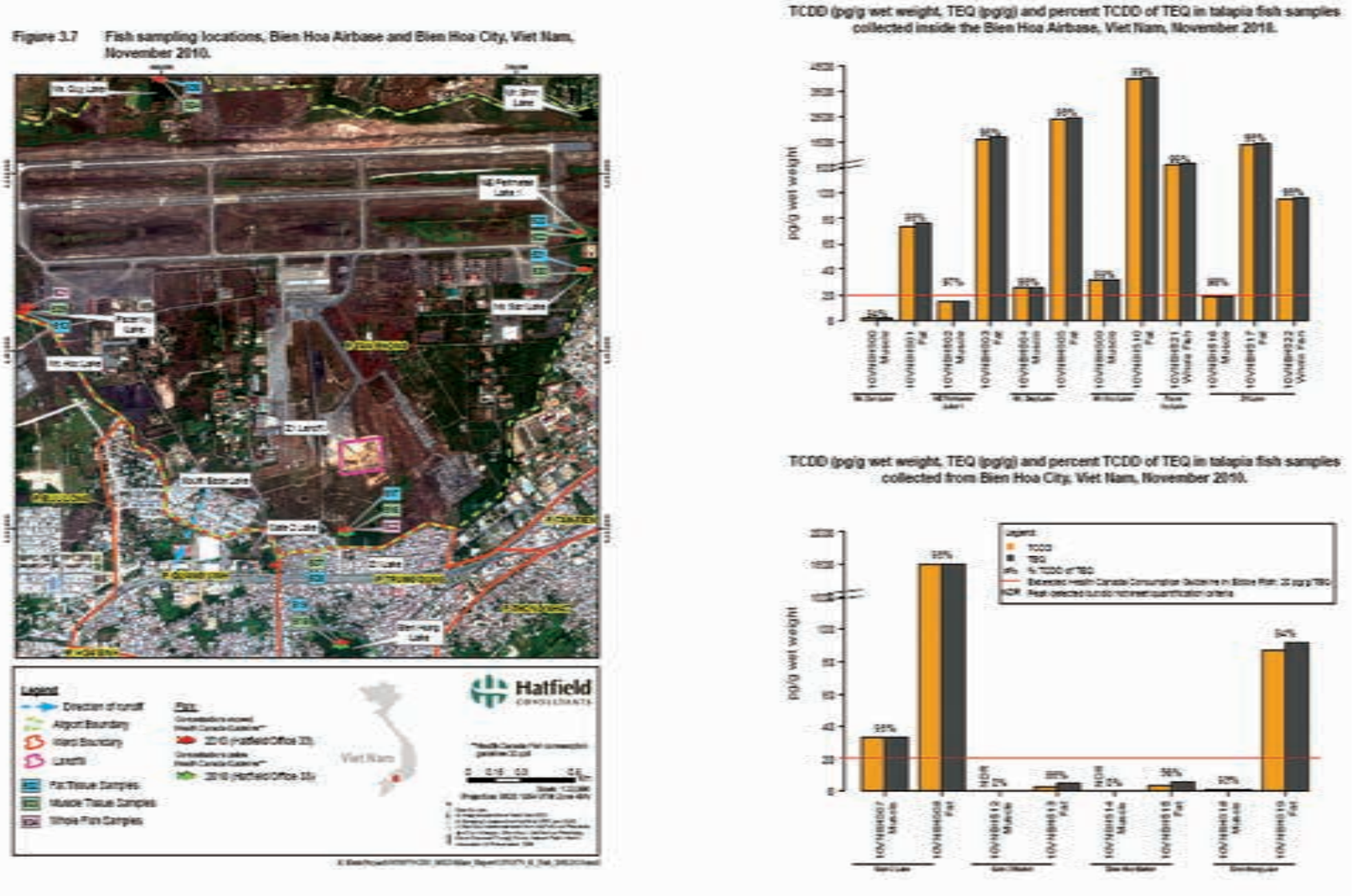

Fig.2.14. Fish sampling locations, Bien Hoa Airbase and Bien Hoa City, 2010

2.3.5. Results of environmental monitoring by Dong Nai People´s Council (2011)

In the study conducted by Dong Nai People´s Council in 2011, 162 samples were collected in vicinities of Bien Hoa Airbase (73 soil, 24 sediment, 25 surface water, 18 groundwater, 22 aquatic species samples). The monitoring was done twice in 2011 (in June and August). 10 sites around the airbase were sampled for the first monitoring. The number of the monitoring sites was increased to 23 for the second monitoring. The sampling sites are depicted in the Figure 2.15.

Fig.2.15. Location of Monitoring Sites around Bien Hoa Airbase

After analyses, samples collected at eastern area of No.9 ward (Tan Phong Ward), A42 gate, Gate 2 Lake, Bien Hung Lake, and vicinities to the southwest of airbase (Buu Long Ward, near Pacer Ivy Area) exhibited remarkable results.

At ***Eastern area of No.9 community (site 2a)***, total TEQ in one surface water sample, collected from the ditch beside the airbase wall in June, 2011, was 1.4 time higher than the standard of US.EPA (30 pg-TEQ/L), and 98% of total TEQ of this sample was 2,3,7,8 TCDD, However, all surface water samples collected in August, 2011 at the same site 2a exhibited TEQ levels lower than US EPA standard.

At ***A42 Gate (site 3)***, TEQ levels in soil were high and decreased with depth. The highest TEQ level was 3,119 ppt (98% 2,3,7,8 TCDD) in the sample collected at the depth of 0-30 cm, it was 3.1 time higher than TCVN 8183:2009. At the depth of 30-60 cm, dioxin level decreased drastically, total TEQ were 573 ppt (June, 2011) and 453 ppt (August, 2011) respectively, both of these values were lower than TCVN 8183:2009. Dioxin level gets lower even more when get deeper.

At ***Gate 2 Lake (site 5)***, sediment was contaminated with dioxin, total TEQ ranges from 145 to 328 ppt. Samples collected in June, 2011 exhibited high TEQ level (2.1 times higher than TCVN8183:2009).

At ***Bien Hung lake (site 13)***, the highest total TEQ in sediment was 1,721 ppt, 11.5 time higher than TCVN 8183:2009. The lake is used to receive the water flows from Bien Hoa Airbase, thus dioxin has accumulated into sediment in Bien Hung Lake and stayed there for a long time. In terms of soil and water samples, there were none of analytical results exceeding TCVN standard. Dioxin concentration in fish and snail samples collected from this lake were lower than WHO guideline.

The ***Vicinity at The Southwest of airbase (site 10)*** (Buu Long ward near Pacer Ivy), was contaminated with dioxin. Regarding soil and sediment, the highest dioxin levels was detected at the depth of 30-60 cm, and 1.83 to 2.79 times higher than TCVN 8183:2009. Following the water flow from this area to Huynh Van Nghe Street (site 10b), total TEQ at depth of 30-60 cm reaches the value of 3,233 ppt (3.2 times higher than TCVN 8183:2009).

In terms of ***aquatic species***, at Gate 2 Lake, fish samples collected in June, 2011 exhibited 82.4 ppt TEQ, 2.75 time higher than WHO-1998 (30 ppt). Besides, at Southwestern vicinity of airbase, fish sample collected from the site 10a where water flow out of airbase in June and August, exhibited 52.6 ppt and 56.6 ppt total TEQ respectively which were higher than WHO-1998 guideline. TCDD level was 99% and 100% of Total TEQ, respectively. At site 10b, high total TEQ was detected (86.1ppt). At the site where string flows in Dong Nai River, total TEQ in aquatic species samples was lower but still at high level (45.1ppt, 1.5 times higher than WHO-1998 guideline).

Table 2.14. Analytical results on study conducted by Dong Nai People's Council, 2011

Location	Sample Date	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)
1	June	Soil	0-30	31.3	57.82
1	August	Soil	0-30	14	27.18
1	June	Soil	30-60	32	58,01
1	August	Soil	30-60	38.7	66.85
1	June	Soil	60-90	62	83.80
1	August	Soil	60-90	110	154.33
1	June	Sediment		3.28	7.39
1	August	Sediment		<1.33	4.87
1	June	Surface water*		<4	0.0
1	August	Surface water*		<4	0.2
1	June	Groundwater*		<4	0.4
1	August	Groundwater*		<4	3.3
2a	June	Soil	0-30	7.33	18.99
2a	August	Soil	0-30	<1.33	17.73
2a	June	Soil	30-60	<1.33	0.63
2a	August	Soil	30-60	8.34	71.42
2a	June	Soil	60-90	<1.33	0.05
2a	August	Soil	60-90	2.25	3.12
2a	June	Sediment		15.89	23.71
2a	August	Sediment		6.94	14.28
2a	June	Surface water*		38	42.8
2a	August	Surface water*		<4	1.5
2a	June	Groundwater*		<4	0.6
2a	August	Groundwater*		<4	29.6
2a	August	Aquatic sample**		<1.33	0.25
2a	June	Aquatic sample**		6.62	6.71
2b	August	Soil	0-30	27.2	31.24
2b	August	Soil	30-60	33.4	36.69
2b	August	Soil	60-90	<1.33	0.11

Table 2.14. Analytical results on study conducted by Dong Nai People's Council, 2011

Location	Sample Date	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)
2b	August	Sediment		40.1	92.32
2b	August	Surface water*		<4	0.0
2b	August	Aquatic sample**		<1.33	0.18
2c	August	Sediment		9.15	34.88
2c	August	Surface water*		<4	0.3
2d	August	Soil	0-30	10.6	14.73
2d	August	Soil	30-60	10.6	13.33
2d	August	Soil	60-90	<1.33	5.02
2e	August	Sediment		24.7	80.25
2e	August	Surface water*		<4	1.4
2e	August	Aquatic sample**		<1.33	0.06
2e	August	Sediment		<1.33	17.79
2e	August	Surface water*		<4	0.2
2e	August	Aquatic sample**		<1.33	2.03
3	June	Soil	0-30	2,370	2,489.33
3	August	Soil	0-30	3,011	3,118.51
3	June	Soil	30-60	547	572.55
3	August	Soil	30-60	410	452.97
3	June	Soil	60-90	3.6	21.85
3	August	Soil	60-90	67.3	72.06
4	June	Surface water*		31	31.7
4	August	Surface water*		<4	0.0
4	June	Groundwater*		<4	0.0
4	August	Groundwater*		<4	1.7
5	June	Sediment		290	328.48
5	August	Sediment		134	146.07
5	June	Surface water*		31	32.1
5	August	Surface water*		<4	0.0
5	June	Groundwater*		<4	1.3
5	August	Groundwater*		8	8.9
5	June	Aquatic sample**		81.57	82.44
5	August	Aquatic sample**		26.3	27.15
5	June	Aquatic sample**		12.22	12.22
5	August	Aquatic sample**		3.53	3.80
6	June	Soil	0-30	13.95	38.83
6	August	Soil	0-30	5.3	12.76
6	June	Soil	30-60	3.99	7.73
6	August	Soil	30-60	36.4	116,80
6	June	Soil	60-90	116.80	6,86
6	August	Soil	60-90	3.31	6.86
6	June	Groundwater*		<1.33	3.32
6	August	Groundwater*		<4	0.0
7	June	Soil	0-30	<4	2.3
7	August	Soil	0-30	<1.33	0.52
7	June	Soil	30-60	<1.33	0.20
7	August	Soil	30-60	1.99	2.87

Table 2.14. Analytical results on study conducted by Dong Nai People's Council, 2011

Location	Sample Date	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)
7	June	Soil	60-90	<1.33	0.78
7	August	Soil	60-90	<1.33	0.29
7	June	Sediment		1.99	6.01
7	August	Sediment		<1.33	39.75
7	June	Surface water*		<4	0.4
7	August	Surface water*		<4	0.0
7	June	Groundwater*		<4	0.0
7	August	Groundwater*		<4	2.2
7	June	Aquatic sample**		0.38	0.38
7	August	Aquatic sample**		3.6	3.88
8	June	Soil	0-30	<1.33	0.27
8	August	Soil	0-30	<1.33	1.36
9	June	Soil	0-30	1.99	2.48
9	August	Soil	0-30	<1.33	5.61
9	June	Soil	30-60	<1.33	0.02
9	August	Soil	30-60	<1.33	0.03
9	June	Soil	60-90	<1.33	0.01
9	August	Soil	60-90	<1.33	0.01
9	June	Sediment		13.33	17.18
9	August	Sediment		4.36	12.07
9	June	Surface water*		<4	0.0
9	August	Surface water*		<4	0.0
9	June	Groundwater*		<4	0.0
9	August	Groundwater*		<4	0.8
9	June	Aquatic sample**		0.16	0.16
9	August	Aquatic sample**		16	16.12
10a	June	Soil	0-30	916	962.03
10a	August	Soil	0-30	2,752	2,795.35
10a	June	Soil	30-60	1,768	1,835.41
10a	August	Soil	30-60	2,737	2,785.40
10a	June	Soil	60-90	842	864.27
10a	August	Soil	60-90	891	915.19
10a	June	Sediment		392	450.51
10a	August	Sediment		139	141.19
10a	June	Surface water*		9	9.0
10a	August	Surface water*		8	44.1
10a	June	Groundwater*		<4	0.0
10a	August	Groundwater*		<4	4.9
10a	June	Aquatic sample**		52.08	52.58
10a	August	Aquatic sample**		56.6	56.60
10b	August	Soil	0-30	298	303.19
10b	August	Soil	30-60	3,232	3,232.86
10b	August	Soil	60-90	25	66.01
10b	August	Sediment		378	461.54
10b	August	Surface water*		5	5.0
10b	August	Aquatic sample*		84.8	86.08

Table 2.14. Analytical results on study conducted by Dong Nai People's Council, 2011

Location	Sample Date	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)
10c	August	Sediment		22.4	25,32
10c	August	Surface water*		4	4.4
10c	August	Aquatic sample**		44.9	45.11
11a	August	Soil	0-30	24.7	26.75
11a	August	Soil	30-60	13.7	50.38
11a	August	Soil	60-90	<1.33	1.92
11a	August	Sediment		8.73	9.53
11a	August	Surface water*		<4	2.1
11a	August	Groundwater*		<4	1.6
11a	August	Aquatic sample**		142	143.39
11b	August	Soil	0-30	<1.33	7.15
11b	August	Soil	30-60	<1.33	966.68
11b	August	Soil	60-90	<1.33	2.51
11b	August	Sediment		5,26	13.37
11b	August	Surface water*		<4	2.3
11b	August	Aquatic sample**		<1.33	0.00
12	August	Soil	0-30	14.2	15.50
12	August	Soil	30-60	<1.33	2.51
12	August	Soil	60-90	<1.33	6.74
13	August	Soil	0-30	37.9	40.02
13	August	Soil	30-60	11.2	11.76
13	August	Soil	60-90	84.7	86.30
13	August	Sediment		1,370	1,720.78
13	June	Surface water*		<4	0.0
13	August	Aquatic sample**		4.88	4.88
14a	August	Soil	0-30	12	12,61
14a	August	Soil	30-60	2	2.40
14a	August	Soil	60-90	<1.33	0.04
14a	August	Sediment		<1.33	4.01
14a	August	Surface water*		12	26.2
14a	August	Groundwater*		<4	7.0
14a	August	Aquatic sample**		<1.33	0.01
14b	August	Soil	0-30	210	221.07
14b	August	Soil	30-60	145	170.92
14b	August	Soil	60-90	<1.33	194.68
14b	August	Sediment		<1.33	151.30
15	August	Soil	0-30	3.33	3.51
15	August	Soil	30-60	<1.33	0.01
15	August	Sediment		44.9	54.49
15	August	Surface water*		<4	0.0
15	August	Aquatic sample**		<1.33	0.00

Note:

**: Water sample concentrations in pg-TEQ/L*

***: Aquatic sample concentrations in wet weight basis*

2.3.6. Results of survey Office 33/UNDP (2011)

In this study, 95 samples (46 surface samples and 49 core samples) were collected in Bien Hoa Airbase. Sampling map was presented in Figure 2.16.

After analyses, 34 samples exhibited dioxin concentration higher than Vietnam standard for dioxin in soil (1,000 ppt). The highest concentration encountered was 962,560 pg-TEQ/g at the first layer of the core number 11BH-K7. Most of the high concentrations were found at east and southeast corner of the Pacer Ivy site. Also it is notable that some high concentration in soil was observed at northwest of the Pacer Ivy site.

There was a small road in survey area which separated the site into two parts (South and West part, and North and East part where the highest contamination was found). Despite the assumption that dioxin concentrations in surface soil samples in Southwest would be low, the results (11BH-A3 and 11BH-B5) exhibited high concentrations (3,980 and 3,972 ppt), which indicated that the dioxin has been migrated larger than initially expected to the South andSouthwest of Pacer Ivy Area (outside Bien Hoa Airbase). At southeast to the Pacer Ivy Area, five samples were collected. Two samples 11BH-M12 and M13 showed low dioxin levels, while the other three samples had relatively higher dioxin levels up to 1,790 ppt (11BH-L13).

Table 2.15. Analytical results of surface soil samples, Office 33/UNDP 2011

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
1	11BH-A3	Soil	0-10	3,649	3,980	91.7
2	11BH-AB1	Soil	0-10	1,673	1,725	97.0
3	11BH-B1	Soil	0-10	417	430	97.1
4	11BH-B2	Soil	0-10	988	1,020	96.9
5	11BH-B3	Soil	0-10	286	297	96.3
6	11BH-B5	Soil	0-10	3,784	3,972	94.0
7	11BH-C2	Soil	0-10	292	301	96.8
8	11BH-C4	Soil	0-10	52.1	53.4	97.6
9	11BH-C6	Soil	0-10	253	285	88.9
10	11BH-D1	Soil	0-10	60.9	65.5	93.0
11	11BH-D2	Soil	0-10	30.7	31.6	96.9
12	11BH-D4	Soil	0-10	15.3	15.5	98.6
13	11BH-D5	Soil	0-10	1,469	1,507	97.5
	11BH-D55 (duplicate)	Soil	0-10	1,419	1,454	97.6
14	11BH-E1	Soil	0-10	9.97	11.1	89.7
15	11BH-E2	Soil	0-10	40.0	49.9	80.2
16	11BH-E3	Soil	0-10	903	934	96.7
17	11BH-E5	Soil	0-10	7.33	7.59	96.6
18	11BH-E6	Soil	0-10	399	406	98.2
19	11BH-E8	Soil	0-10	221	417	53.0
20	11BH-E10	Soil	0-10	382	411	92.9
21	11BH-F4	Soil	0-10	1,401	1,447	96.9
22	11BH-F5	Soil	0-10	20,807	21,196	98.2
23	11BH-F6	Soil	0-10	5,092	5,251	97.0
24	11BH-G1	Soil	0-10	165	177	93.0

Table 2.15. Analytical results of surface soil samples, Office 33/UNDP 2011

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
25	11BH-G3	Soil	0-10	391	402	97.1
26	11BH-G4	Soil	0-10	799	823	97.1
27	11BH-G6	Soil	0-10	1,166	1,222	95.4
28	11BH-G7	Soil	0-10	3,210	3,479	92.3
29	11BH-H1	Soil	0-10	52.8	68.8	76.7
30	11BH-H2	Soil	0-10	9.97	10.3	96.4
	11BH-H22 (duplicate)	Soil	0-10	7.33	7.73	94.8
31	11BH-H5	Soil	0-10	9,455	9,685	97.6
32	11BH-K8	Soil	0-10	1,041	1,123	92.7
33	11BH-K11	Soil	0-10	637	682	93.4
34	11BH-L12	Soil	0-10	446	484	92.1
35	11BH-L13	Soil	0-10	1,689	1,790	94.4
36	11BH-M12	Soil	0-10	19.9	22.4	89.1
37	11BH-M13	Soil	0-10	14.0	22.0	63.6

Surface sediment sample was collected in ditch from taxi way to ponds and lakes, along the internal road. These samples exhibited high dioxin level. Samples 11BH-DCH1, DCH2, DCH4, DCH6, DCH7, DCH8 and DCH9 showed dioxin level higher than 150 ppt TEQ.

Table 2.16. Analytical results of surface sediment samples, Office 33/UNDP , 2011

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)	2,3,7,8-TCDD / WHO-TEQ (T%)
1	11BH-DCH1	Sediment	0-10	2,785	2,872	97.0
2	11BH-DCH2	Sediment	0-10	1,609	1,670	96.3
	11BH-DCH22 (Duplicate)	Sediment	0-10	1,199	1,249	96.0
3	11BH-DCH4-1	Sediment	0-10	207	220	94.1
	11BH-DCH4-2 (Duplicate)	Sediment	0-10	238	252	94.4
4	11BH-DCH6	Sediment	0-10	457	486	94.0
5	11BH-DCH7	Sediment	0-10	2,171	2,215	98.0
6	11BH-DCH8	Sediment	0-10	6,518	6,681	97.6
7	11BH-DCH9	Sediment	0-10	1,260	1,305	96.6
8	11BH-DCH10	Sediment	0-10	540	554	97.5
9	11BH-DCH12	Sediment	0-10	19.2	19.9	96.5

Surface sediment sample was collected in ditch from taxi way to ponds and lakes, along the internal road. These samples exhibited high dioxin level. Samples 11BH-DCH1, DCH2, DCH4, DCH6, DCH7, DCH8 and DCH9 showed dioxin level higher than 150 ppt TEQ.

In this study, 12 soil and sediment core samples were collected to the maximum depth of 2.4 m. Among those, 10 samples (9 soil cores and 1 sediment core) were analysed to indentify dioxin concentration. Six samples exhibited high dioxin level, exceeding 1,000 ppt.

Fig. 2.16.Vertical profiles of dioxin at 3 location in Pacer Ivy area, Office 33/UNDP 2011

For the core sample 11BH-H6, soil was collected down to the depth of 180 cm. The analytical result showed dioxin level increased from the surface to the depth of 60-90 cm, then decreased when got deeper but still high dioxin concentration was detected (8,129 ppt TEQ) at the depth of 180 cm.

Core sample 11BH-K7 collected at the highest position land near concrete taxiway, extremely high dioxin concentration was detected at the top layer of core sample (approximately 962,000 ppt). This is the highest dioxin concentration ever detected in this area. The dioxin concentration decreased to 329,000 ppt TEQ at the depth of 30-60 cm, and then rapidly decreased to 210 ppt TEQ at the depth of 60 cm. The vertical profile of dioxin in this core sample differs from core sample H6. K7 core sample was collected at the higher elevation than K6 core sample, therefore, the elevation of core sample might have influnced the vertical moverment of dioxin.

One sediment core sample (11BH-C3) was collected at dry pond area, to the depth of 210 cm. Dioxin concentration decreased from 2,100 ppt at surface to 302 ppt to the depth of 90 cm. Dioxin concentration decreased rapidly at deeper layer, lower than 10 ppt TEQ. This result showed that dioxin concentration was high at the deeper layer of sediment in pond. However, it was not able to conclude that this is caused by the vertical movement of dioxin or accumulation of dioxin from the flows into this pond. One thing should be concerned is that the ponds, lakes near

Pacer Ivy area exhibited dioxin levels comparable or even higher than dioxin level in Z1. This result indicated that dioxin accumulated remarkablely in this area.

Table 2.17. Analytical results of core samples, Office 33/UNDP 2011

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
1	11BH-AB4-1	Soil	0-30	2,662	2,677	99.4
2	11BH-AB4-2	Soil	30-60	1,785	1,796	99.4
3	11BH-AB5-1	Soil	0-30	75.1	81.1	92.6
4	11BH-AB5-2	Soil	30-60	38.3	47.0	81.5
5	11BH-C3-1	Sediment	0-30	2,050	2,103	97.5
6	11BH-C3-2	Sediment	30-60	2,132	2,180	97.8
7	11BH-C3-3	Sediment	60-90	299	302	99.0
8	11BH-C3-4	Sediment	90-120	4.93	5.44	90.6
9	11BH-C3-5	Sediment	120-150	4.19	5.21	80.4
10	11BH-C3-6	Sediment	150-180	7.00	8.13	86.1
11	11BH-C3-7	Sediment	180-210	<1.33	1.22	-
12	11BH-F3-1	Soil	0-30	9.26	13.0	71.2
13	11BH-F3-2	Soil	30-60	15.7	16.2	96.9
14	11BH-F3-3	Soil	60-90	2.57	4.06	63.3
15	11BH-F3-4	Soil	90-120	4.28	4.56	93.9
16	11BH-G2-1	Soil	0-30	11.2	11.4	98.2
17	11BH-G2-2	Soil	30-60	4.94	5.00	98.8
18	11BH-G2-3	Soil	60-90	2.81	2.82	99.6
19	11BH-G2-4	Soil	90-120	1.69	2.01	84.1
20	11BH-G2-5	Soil	120-150	<1.33	0.118	-
21	11BH-G2-6	Soil	150-180	<1.33	2.04	-
22	11BH-H4-1	Soil	0-30	1,552	1,600	97.0
23	11BH-H4-2	Soil	30-60	26.9	42.6	63.1
	11BH-H4-22 (duplicate)	Soil	30-60	9.22	10.8	85.4
24	11BH-H4-3	Soil	60-90	4.40	49.4	8.9
25	11BH-H4-4	Soil	90-120	51.7	60.2	85.9
26	11BH-H4-5	Soil	120-150	63.7	78.5	81.1
27	11BH-H4-6	Soil	150-180	94.3	94.3	100.0
28	11BH-H4-7	Soil	180-210	26.4	41.4	63.8
29	11BH-H6-1	Soil	0-30	72,856	73,389	99.3
30	11BH-H6-2	Soil	30-60	108,900	109,791	99.2
31	11BH-H6-3	Soil	60-90	317,087	318,816	99.5
32	11BH-H6-4	Soil	90-120	183,940	185,142	99.4
	11BH-H6-44 (duplicate)	Soil	90-120	146,776	147,672	99.4
33	11BH-H6-5-1	Soil	120-150	19,560	19,692	99.3

Table 2.17. Analytical results of core samples, Office 33/UNDP 2011

No.	Sample ID	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g)	WHO-TEQ (pg/g)	2,3,7,8-TCDD /WHO-TEQ (T%)
	11BH-H6-5-2 (duplicate)	Soil	120-150	21,076	21,205	99.4
34	11BH-H6-6	Soil	150-180	8,087	8,129	99.5
35	11BH-H21-1	Soil	0-30	4,875	5,017	97.2
36	11BH-H21-2	Soil	30-60	9,695	9,883	98.1
37	11BH-K3-1	Soil	0-30	36.0	42.0	85.7
38	11BH-K3-2	Soil	30-60	6.72	6.73	99.9
39	11BH-K3-3	Soil	60-90	8.35	8.72	95.8
40	11BH-K3-4	Soil	90-120	1.46	1.46	100.0
41	11BH-K3-5	Soil	150-150	3.34	3.35	99.7
42	11BH-K7-1	Soil	0-30	949,368	962,559	98.6
43	11BH-K7-2	Soil	30-60	388,807	392,669	99.0
44	11BH-K7-3	Soil	60-90	209	210	99.5
	11BH-K7-33 (duplicate)	Soil	60-90	375	375	100.0
45	11BH-K7-4	Soil	90-120	465	466	99.8
46	11BH-K7-5	Soil	120-150	243	243	100.0
47	11BH-K7-6	Soil	150-180	6.68	6.68	100.0
48	11BH-K7-7	Soil	180-210	139	145	95.9
49	11BH-K7-8	slurry	210-240	7,567	7,611	99.4

2.3.7. Results of investigation Z9 by Ministry of Defense (2012)

The Z9 study was conducted by MOD that covered 7 former military airbases including Tan Son Nhat, Bien Hoa, Phan Rang, Nha Trang, Tuy Hoa, Phu Cat, and Da Nang. Besides, 3 more core samples were taken in Z9 project. In Z9 study, analytical results of the survey in Bien Hoa exhibited high dioxin contamination in this area in terms of both its depth and covering area. In total of 121 samples, 36 samples exhibited high dioxin concentration which were 1.2 to 885 times higher than standard. Sampling map is presented in Figure 2.18.

In the area at the west of airbase (i.e. Pacer Ivy), contamination scale is wide, the highest detected dioxin level in soil was 180,992 ppt (sample BH-Đ 144) at the depth of 0.4-0.5m. At the south of taxi way, contamination area was small, however, the highest dioxin contamination in this area was 884,730 ppt (sample BH-Đ 156) at the depth of 1-1.2 m. The highest dioxin concentration in sediment was 2,800 ppt.

The initially detected depth of soil contamination was 3.5 m. At the highest investigated depth (3-3.5 m), soil sample exhibited high dioxin concentration of 16,500 ppt, 16 times higher than standard.

Table 2.18.Analytical results of core samples, Z9 Project, MOD, 2012

STT	Sample ID	Easting	Northing	Depth (m)	WHO – TEQ (ppt)
1	BH-Đ 1.2	10.680.512	1.097.217	0.8-0.1m	55
2	BH-Đ 2.3	10.681.409	1.096.181	1.6-2 m	10
3	BH-Đ 3.3	10.681.405	1.096.201	1.2-1.4m	609

Table 2.18.Analytical results of core samples, Z9 Project, MOD, 2012

STT	Sample ID	Easting	Northing	Depth (m)	WHO – TEQ (ppt)
4	BH-Đ 4.2	10.680.582	1.097.023	1-1.2m	8
5	BH-Đ 4.1	10.680.582	1.097.023	0.8-1 m	36,560
6	BH-Đ 6.3	10.681.422	1.096.238	1.3-1.5m	29
7	BH-Đ 6.2	10.681.422	1.096.159	0.8-0.1m	15
8	BH-Đ 7.3	10.681.406	1.096.238	1.3-1.6m	131
9	BH-Đ 7.2	10.681.406	1.096.238	1-1.2m	30
10	BH-Đ 9.1	10.680.547	1.096.982	0.5-0.7m	377
11	BH-Đ 9.2	10.680.547	1.096.982	1.2-1.4m	256
12	BH-Đ 9.3	10.680.547	1.096.982	2-2.5m	72
13	BH-Đ 10.2	10.680.525	1.097.069	1.2-1.4m	63
14	BH-Đ 10.3	10.680.525	1.097.069	2-2.5m	312
15	BH-Đ 12.2	10.680.573	1.097.066	1-1.2m	56
16	BH-Đ 13.2	10.680.569	1.097.163	0.6-0.8m	8
17	BH-Đ 14.3	10.680.521	1.097.103	1.4-1.8m	6,997
18	BH-Đ 14.2	10.680.521	1.097.103	0.8-1.2m	6,666
19	BH-Đ 14.1	10.680.521	1.097.103	0.4-0.6m	20,043
20	BH-Đ 14.4	10.680.521	1.097.103	3-3.5m	16,088
21	BH-Đ 15.1	10.680.587	1.097.143	0.2-0.4m	98
22	BH-Đ 16.3	10.680.519	1.097.062	2-2.5m	77
23	BH-Đ 16.2	10.680.519	1.097.062	1.2-1.4m	36,381
24	BH-Đ 17.1	10.680.547	1.097.147	0.6-0.8m	6,541
25	BH-Đ 18.2	10.680.524	1.097.230	1-1.2	1,925
26	BH-Đ 18.1	10.680.524	1.097.230	0.4-0.6m	8
27	BH-Đ 20.2	10.680.572	1.097.067	0.6-0.8m	200
28	BH-Đ 24	10.680.512	1.097.217	0.2-0.3m	329
29	BH-Đ 25	10.680.455	1.097.217	0.3-0.5m	34
30	BH-Đ 26	10.680.573	1.097.066	0.8-1m	172
31	BH-Đ 27	10.680.152	1.097.202	0.3-0.5m	1,801
32	BH-Đ 31	10.680.189	1.097.180	0.3-0.5m	2,864
33	BH-Đ 35	10.680.132	1.097.213	0.3-0.5m	322
34	BH-Đ 43.2	106.48.180	10.58.304	60-80cm	3
35	BH-Đ 44.4	106.48.343	10.58.104	3.4-3.7m	9
36	BH-Đ 45.2	106.48.194	10.58.323	1.5-1.8m	11
37	BH-Đ 46.1	106.48.214	10.58.327	0.8-1.2m	1,847
38	BH-Đ 46.3	106.48.214	10.58.327	1.5-1.8m	6
39	BH-Đ 46.4	106.48.327	10.58.214	1.8-2m	6
40	BH-Đ 47.3	106.48.293	10.58.209	2.0-2.5m	27,411
41	BH-Đ 47.4	106.48.293	10.58.209	3m	1,925
42	BH-Đ 48.1	106.48.344	10.58.310	50-70cm	14
43	BH-Đ 49.1	106.48.309	10.58.252	0.5-0.7m	93,358
44	BH-Đ 49.4	106.48.309	10.58.252	3.5-3.8m	869

Table 2.18.Analytical results of core samples, Z9 Project, MOD, 2012

STT	Sample ID	Easting	Northing	Depth (m)	WHO – TEQ (ppt)
45	BH-Đ 50.3	106.48.357	10.58.211	3.2-3.5m	19
46	BH-Đ 51.3	106.48.357	10.58.202	2-2.3m	4
47	BH-Đ 52.3	106.48.292	10.58.308	2.8-3.1m	25
48	BH-Đ 52.1	106.48.292	10.58.308	50-60cm	15
49	BH-Đ 53.3	106.48.343	10.58.290	2.8-3.1m	5
50	BH-Đ 54.3	106.48.304	10.58.224	2.8-3.1m	133
51	BH-Đ 55.4	106.48.318	10.58.215	3.3-3.6m	286
52	BH-Đ 56.2	106.48.169	10.58.333	1.2-1.5m	56
53	BH-Đ 57.2	106.48.391	10.58.170	1.7-2.1m	4
54	BH-Đ 59.1	106.48.201	10.58.289	0.6-0.8cm	29
55	BH-Đ 60.1	106.48.267	10.58.278	0.4-0.6m	228
56	BH-Đ 61.1	106.48.267	10.58.276	0.4-0.6m	1,189
57	BH-Đ 63.1	106.48.192	10.58.315	1-1.4m	1,646
58	BH-Đ 64.1	106.48.239	10.58.242	0.4-0.6m	42
59	BH-Đ 64.3	106.48.239	10.58.242	2.2-2.5m	5
60	BH-Đ 64.2	106.48.239	10.58.242	1.5-1.7m	3
61	BH-Đ 65	106.48.283	10.58.168	-	741
62	BH-Đ 66	106.48.280	10.58.160	2 m	104
63	BH-Đ 69	106.48.169	10.58.261	-	777
64	BH-Đ 73	106.48.135	10.58.414	-	316
65	BH-Đ 75	106.48.213	10.58.438	-	19
66	BH-Đ 78	106.48.273	10.58.253	-	27
67	BH-Đ 96	106.48.308	10.58.284	0.05 – 0.1m	4,875
68	BH-Đ 97	106.48.166	10.58.324	2 m	5
69	BH-Đ 98	106.49.301	10.57.494		116
70	BH-Đ 99	106.49.330	10.57.460	0.3 – 0.5m	1,929
71	BH-Đ 100	106.49.305	10.57.481		58
72	BH-Đ108	106.48.281	10.58.269	0.5-0.8m	5
73	BH-Đ111	106.48.270	10.58.306	0.4-0.6m	6,034
74	BH-Đ112	106.49.375	10.57.463	Sediment Z1	560
75	BH-Đ113	106.49.371	10.57.489	Sediment Z1	767
76	BH-D-V				18,096
77	BH-Đ 114	106.49.374	10.57.521	0.5 – 0.6m	3,572
78	BH-Đ 115	106.49.374	10.57.521	0	1,895
79	BH-Đ 117	106.49.384	10.57.545	0.5-0.6 m	348
80	BH-Đ 119	106.49.441	10.57.584	0.2-0.3 m	34
81	BH-Đ 120	106.49.417	10.57.602	0.5-0.6m	136
82	BH-Đ 122	106.49.394	10.57.586	0	1,265
83	BH-Đ 123	106.49.367	10.57.553	0.3-0.4m	70
84	BH-Đ 125	106.49.350	10.57.515	0.2-0.3 m	154
85	BH-Đ 126	106.48.267	10.58.264	0.2-0.3 m	88

Table 2.18.Analytical results of core samples, Z9 Project, MOD, 2012

STT	Sample ID	Easting	Northing	Depth (m)	WHO – TEQ (ppt)
86	BH-Đ 129	106.48.166	10.58.257	0	2,227
87	BH-Đ 130	106.48.310	10.58.185	0.4-0.5 m	269
88	BH-Đ 131	106.48.310	10.58.185	0.1-0.2 m	5,043
89	BH-Đ 132	106.48.298	10.58.171	0.3-0.4 m	37
90	BH-Đ 133	106.48.244	10.58.236	0.2-0.3 m	12,874
91	BH-Đ 137	106.48.258	10.58.194	0.1-0.2 m	2,090
92	BH-Đ 142	106.48.305	10.58.286	1.0-1.1m	106,749
93	BH-Đ 143	106.48.305	10.58.286	0	734
94	BH-Đ 144	106.48.855	10.57.736	0.4-0.5m	180,992
95	BH-Đ 145	106.48.855	10.57.736	0.1-0.2 m	5,235
96	BH-Đ 147	106.48.850	10.57.728	0	17
97	BH-Đ 149	106.48.850	10.57.742	0.1-0.2m	5,321
98	BH-Đ 150	106.48.836	10.57.724	0	3,977
99	BH-Đ 152	106.48.841	10.57.719	0	6,700
100	BH-Đ 153	106.48.840	10.57.721	0.4-0.5 m	7,419
101	BH-Đ 155	106.48.848	10.57.718	0.5-0.6 m	118,532
102	BH-Đ 156	106.48.848	10.57.718	1.0-1.2 m	884,730
103	BH-Đ 158	106.48.856	10.57.712	1.0-1.2 m	86
104	BH-Đ 159	106.48.856	10.57.712	0.2-0.4 m	87
105	BH-Đ 160	106.48.839	10.57.714	0.8-1.0 m	16
106	BH-Đ 162	106.48.839	10.57.714	0.2-0.3 m	266
107	BH-Đ 163	106.48.859	10.57.723	1.0-1.2 m	11
108	BH-Đ 164	106.48.859	10.57.723	1.5-1.8 m	41
109	BH-Đ 165	106.48.859	10.57.723	0.2-0.3 m	50
110	BH-Đ 166	106.48.851	10.57.730	0.5-0.7 m	632
111	BH-Đ 167	106.48.851	10.57.730	1.4-1.5 m	4
112	BH-Đ 168	106.48.851	10.57.730	0.2-0.3 m	113
113	BH-Đ 173	106.48.831	10.57.722	0.9-1.1 m	9
114	BH-Đ 174	106.48.831	10.57.722	0.4-0.6 m	153
115	BH-Đ 176	106.48.358	10.58.222	0.9-1.1 m	123
116	BH-Đ 177	106.48.358	10.58.222	0.5-0.7 m	319
117	BH-Đ 185	106.48.284	10.58.232	2.4-2.5 m	5
118	BH-Đ 186	106.48.284	10.58.232	1.2-1.5 m	12
119	BH-Đ 187	106.48.284	10.58.232	0.5-0.8 m	40
120	BH-Đ 188	106.48.359	10.58.270	1.8-2.0 m	5
121	BH-Đ 190	106.48.342	10.58.264	1.5-1.8 m	24

Fig.2.17. Sampling positions in Pacer Ivy area, Bien Hoa Airbase in study by Office 33 /UNDP, 2011

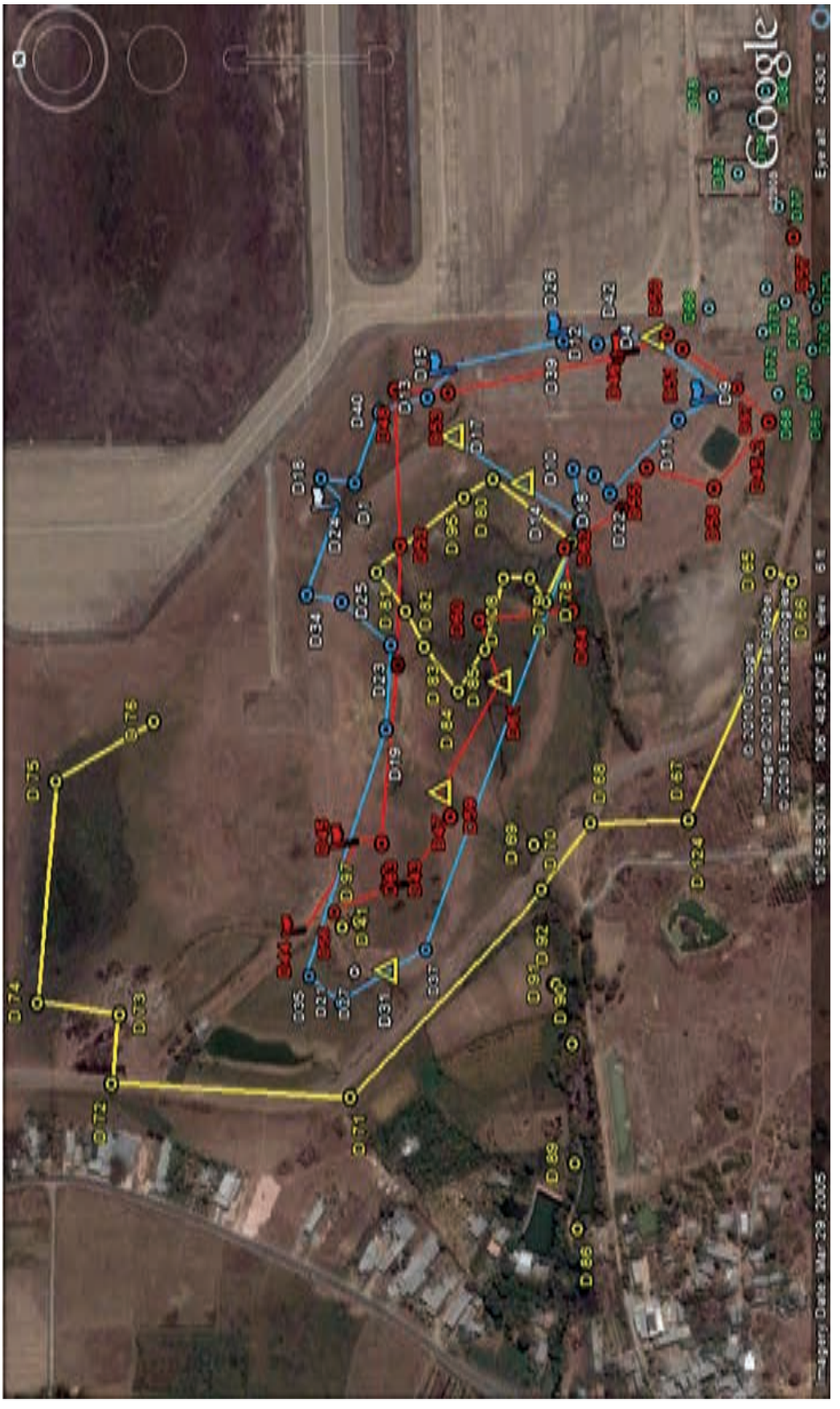

Fig.2.18. Sampling map in Z9 study in Bien Hoa Airbase, 2012

DA NANG AIRBASE

Dioxin remediation in Da Nang Airbase
Photo by Dioxin Project, 2013

3. DA NANG AIRBASE

3.1. Historical Record of the contaminated areas and geographical, hydrometeorological and pedologic characteristics of the airbase

During the US-Vietnam War, Da Nang city had a very important and strategic military position. The city had an airbase and a seaport strategically positioned in Central Viet Nam, and was a major base for the war operations. Herbicides were transported to Da Nang port and then to the airbase in order to spray over an area from the 17th parallel to Quy Nhon and Kon Tum, including several provinces such as Quang Tri, Thua Thien, Quang Nam, Quang Ngai, Binh Dinh, Kon Tum and a part of Laos.

In 1968, the 12th air-crew of the US Special Task Force troops used 17 UC-123 aircrafts for the military operations, among which 11 aircrafts were used for the spraying of the toxic chemicals. Da Nang Airbase and especially the former storage area were used during the operation "Ranch Hand" by the American Army from May 1964 to January 1971. During this period, 52,700 barrels of Agent Orange, 29,000 barrels of Agent White and 5,000 barrels of Agent Green were stored and used in Da Nang Airbase. From April 17, 1970 to March 31, 1972, Da Nang Airbase was a major site for recovery operation (Pacer Ivy) and transported 8,200 barrels of Agent Orange back to the United States in order to destroy the toxic chemical/dioxins (source: US Department of Defense).

During the period from 1964 to 1972, Da Nang Airbase and surrounding areas were heavily contaminated with toxic chemicals/dioxins. The chemicals were used in large quantities in this area, equal to one-third of the total quantity of herbicides used by the U.S. in the Indochina region. The chemical barrels were stored outside, subjected to severe climate, causing chemicals to leak out of rusty storage barrels. Due to improper usage and handling, approximately 2 - 5 liters of chemicals remained in the barrels after use and these barrels were disposed to the dump, used for building fences or for other purposes such as storing water or rice. These activities lead to the spread of contamination over a large area. After spraying, equipment was washed at the end of the runway. Thus, Da Nang Airbase became a hotspot of contamination by toxic chemicals/dioxins. This airbase has received considerable attention from both Vietnamese and international organizations in recent years, and a number of surveys have been conducted since 2005.

Da Nang Airbase is situated at 16° N, 108°15' E. It belongs to Thac Gian commune, Thanh Khe district, Da Nang City. The airbase area is located behind Bach Ma Mountain, giving the climatic properties of this area distinct from those of the rest of the North Central Coast Region. The airbase is located in tropical monsoon region. There are two distinct seasons, dry season from January to August, and rainy season from September to December. The dry season falls very little rain; the driest months are March, April, and May.

The daily temperature change is 7.2 °C, while the annual amplitude is 7.8 °C. The highest temperature occurs in June and July, when the temperature rises over 30 °C, and occasionally up to 40 °C. The lowest temperature (average of 21 °C) is in November and December. The number of sunny hours in Da Nang remains high and steady all year round, but are generally higher during the dry season. The annual total radiation is 140-150 kcal/cm^2 and the sunny hours are 2,200 per year.

Every year, Da Nang is affected directly by at least one typhoon or one tropical low pressure system of level 6 or higher. Annually, Da Nang has approximately 30 days of dry-hot-south-west wind during the months of June, July, and August. The temperature during the day ranges from 35 °C to 39 °C, while the humidity ranges from 40% to 55% (data supplied by the Da Nang hydro-meteorological station).

The average annual rainfall in Da Nang is about 2,400 mm and is mainly concentrated in the rainy season. In Da Nang, as well as in other central provinces of Vietnam, heavy rains last several days, receiving a total rainfall amount of 100-500 mm per event, and sometimes up to 1000 - 2000 mm. The highest amount of rainfall is typically during October (approximately 600 mm), while the lowest is in February, March, and April. Heavy rains affect wide areas, combined with flood-tides, causing inundation (on average, the inundation occurs 4 times per year).

The climatic properties of Da Nang affect the processes of transport, evaporation, and photochemical degradation of toxic chemicals/dioxins, and are favorable conditions for land erosion, especially erosion of land without vegetative cover.

Da Nang Airbase has a length of approximately 4.12 km, a width of 1.5 km (calculated based on the wall enclosing the airbase, and an area of approximately 6 km^2. The main axis of the airbase runs from north to south, with a 10-degree skew to the west.

Da Nang Airbase is a principal airbase located in central Vietnam and it plays an important role in security and defense in the country. The airbase is located inside the city; therefore, all activities undertaken at the airbase, which cause the generation of noise, exhaust gases and waste water, affect the surrounding communities.

The contaminated toxic chemicals/dioxins areas in the Da Nang Airbase are located at the bottom of an old alluvial plain, which is subject to influences of human activity (building the airbase, roads, infrastructure, etc.). The terrain is comprised of undulated hills and mounds. The gentle and low hills of the area growing eucalyptus, sloped sub-area, flat buffer area, concaved Sen Lakes and the ditches, flat concrete of the airbase runway, and internal roads are landscapes that have been designed or strongly influenced by humans. This type of terrain facilitates the transport of chemicals/dioxins from contaminated sites in to the environment.

Terrain of Da Nang Airbase:

The contaminated area in the Da Nang Airbase is located primarily at the northern end of the runway. The terrain in this area is relatively flat; the highest altitude is 6 meters and the lowest is 2 meters above sea-level. Due to the nature of this terrain, the contaminated area and the lakes are periodically flooded by heavy rains and flood-tides.

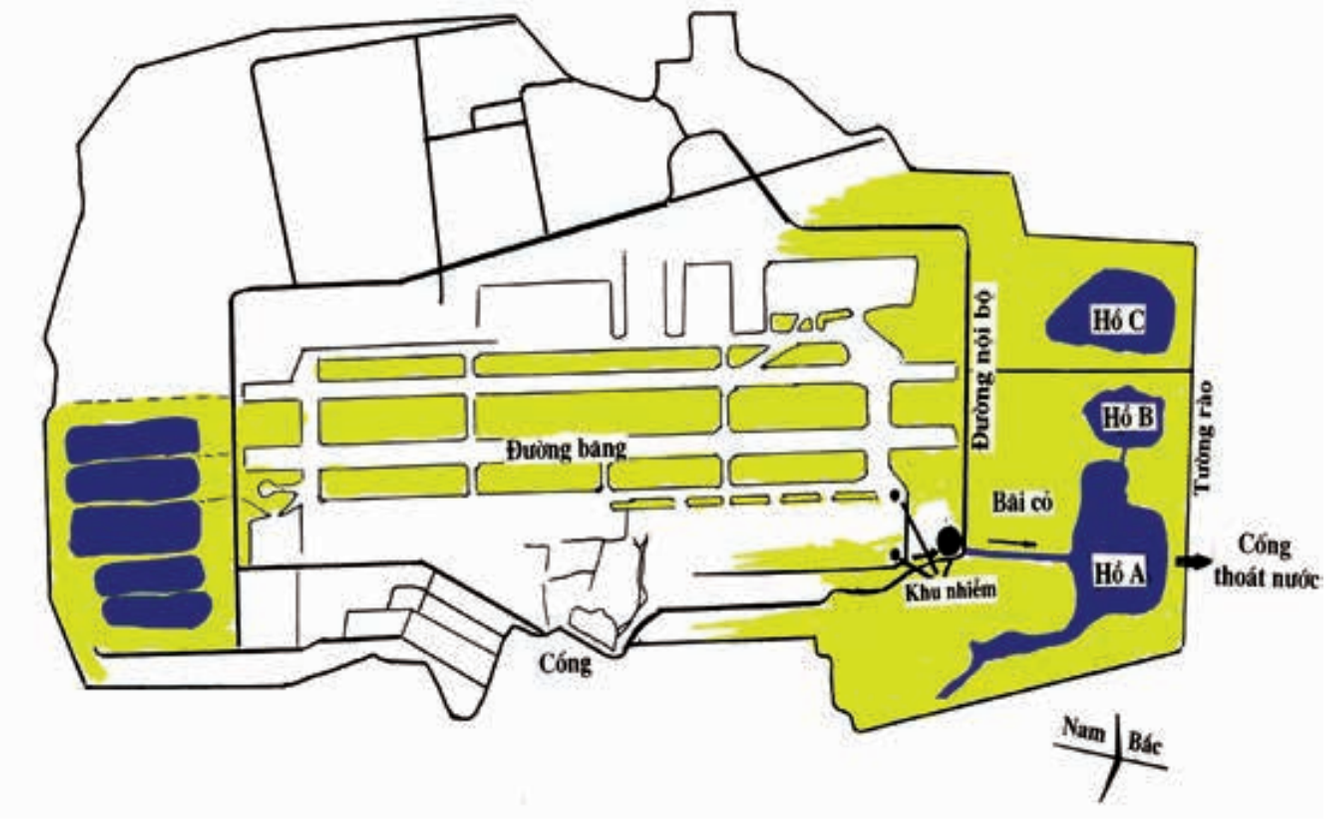

Fig. 3.1. Map of Da Nang Airbase.

Fig. 3.2. Aerial Photo of northern part of Da Nang Airport

Characteristics of the lakes in the airbase

Because the terrain within the airbase is relatively flat, and the area is a closed system, i.e. unaffected by rivers and springs, a pond-lake system has been formed by heavy rains and floods,. The south site has 5 man-made lakes and the north site has 3 lakes, which play a major role in drainage for the airbase. The lakes at the north of airbase directly receive rainwater from the contaminated area, and are referred to as Sen Lake A, B, and C (Figure 3.2).

Characterization of lakes

Sen Lake A (the largest one): Sen Lake A (the largest one): Lake A has a natural appearance and a complex shape. In the dry season, the lake has an area of > 7 ha. During the rainy season, the area expands about 1.5 times. The lake is situated 300 m apart from the contaminated area and receives rainwater runoff directly from the lake slopes; this water flows through the contaminated area and through a ditch system, finally to the lakes. The surface of the lake bottom is relatively flat. The depth of the lake changes with seasons; the average depth ranges from 1.4 to 1.8 m. In the rainy season, the deepest point in December is 2.4 m . The thickness of the sediment in the Lake A ranged from 0.3 to 1.1 m. The sediment is rich in organics from dead animals and plants (lotus, water hyacinth, grass, etc.). At the sluice gate where the rain water runs from the contaminated to the lake has little sediment and is mainly hard-solid sand bed. Surrounding the lake is a thick vegetation cover. Lotus and water hyacinth grow densely or thinly in the lake depending on the depth, humus content, and the total nitrogen content. Lake A has an outlet drainage into the Da Nang City sewer system.

Lake B: Lake B has the smallest area of the three lakes, measuring about 3 ha. It does not receive rainwater directly from the contaminated area and Sen Lake A (except during floods). The deepest site of the lake during the dry season is 1.4 meters. The lake bottom is relatively flat with low humus content. The lake bottom is mainly composed of sand, and very few plants grow on the lake surface. Lake B was previously used by residents to raise fish and ducks. A drainage sewer connects between Lake B and Lake A supports water running from Lake B to Lake A in rainy season.

Lake C: Covering an area of approximately 7 ha, Lake C is situated at about 1000 meters from the contaminated area. The depths of lake are different at different sites due to the exploitation of sand from the lake bottom. The surface of the lake is multiform, but poor in vegetation cover. The lake was previously used by residents to raise fish and water birds. Between Lakes C and B is a road that prevents rainwater from carrying toxic chemicals from the contaminated area to Lake C.

Previous and current status of the dioxin contaminated area in the airbase

The contaminated area was formed by the use of herbicides from 1964 to 1972 includes the former storage area, former mixing and loading area, former washing area, and the drainage canals in these areas. The contaminated area is located at the north-east of the airbase, at the end of runway in a depression area. The US Army had considered the avoidance of the adverse effect of toxic chemicals/dioxin to everyday working areas of the airbase and the convenience for transportation. The contaminated area of the Da Nang Airbase was first identified in 1993, and the evaluation of contamination started from the survey under Project Z2. At that time, the contaminated area did not have a fence, and no restrictions were placed on grazing cattle and exploiting aquatic-products in Sen Lake A. At present, a barbed wire fence is separating the contaminated area from the road; a ditch collects runoff, a sediment pond has been constructed; and part of the former mixing and loading area has been capped with concrete. Before 2000, an army unit working in the airbase was stationed on the former storage area. After 2000, this unit was relocated near the gate of the airbase. Still, the contaminated area has a distinct chemical odor, which is noticeable especially after rain.

Based on the information from field surveys and analytical results of toxic chemicals/dioxins in Project Z2, the contaminated area was divided into 3 sub-areas: sub-area A (the area storing empty barrels and toxic chemicals); sub-area B (the washing vehicles area), sub-area D (the storing and loading the herbicides into spraying vehicles area). The buffer areas located in between sub-areas A, B and D are referred to as sub-area C.

Sub-area A – Storage Area: this is the lowest land in the contaminated area, located south beside the internal road and slightly sloping from a part of the airbase and from sub-area B towards the drainage ditch. Covering an area of 1.5 ha, the surface has no grass and is indurated and patchy color with black and brown due to the impacts of chemicals. This sub-area has existed for over 40 years and has not been subjected to human influences. In the rainy season, a large volume of rainwater inundates up to 40 percent of area of the airbase, causing floods up to over 1 meter in height for many hours.

Sub-area B – Mixing and Loading Area: in this sub-area, foundations for placing tanks of toxic chemicals are observed at the washing place at the end of the airbase, beside the runway and sloping towards the drainage ditch. The surface of sub-area B includes a concrete yard and surroundings with plants.

Sub-area D: This sub-area, located at a corner of the airbase, was used to store and load toxic chemicals. Covering an area of about 1 ha, this sub-area slopes towards the drainage ditch to Sen Lake A.

Fig. 3.3. Overall view of sub-area A

3.2. Results of surveys on soil parameters in Da Nang Airbase

Inside the contaminated area

The observation of the soil profile indicated that the soil is sandy, containing few roots and soil organisms, and composed of a yellow-grey surface layer and grey-yellow deeper layers sandwiched with dark black layer. The soil was relatively homogeneous and separated to layers by color. A clay layer was not observed up to the depth of 1.5 meters.

Results of analyzing 38 samples (1996) indicated that pH of soil in the contaminated area ranged from 2.6 to 5.0; the pH value increases with the depth. A higher pH value was observed in samples collected from the former washing place of sub-area B. The soil in the contaminated area is classified as acidic soil, particularly in sub-area A. The acidity here could have resulted from the degradation of Agent Orange.

The humus content of the contaminated areas was low, ranging from 0.3% to 3%, but was higher in sub-area B, where it was up to 5%. This result is consistent with the natural conditions of the site (plants and animals grow poorly, low possibility of wind to bring organic material from other places).

The cation-exchange capacity (CEC) was very low – below 8 milli-equivalents per 100 g of dry soil. The adsorption capacity was also low, ranging from 2 to 9 milli-equivalents per 100 g of dry soil. Exchanging acidity was low, approximately 1 milli-equivalent per 100 g. The Fe^{2+} content ranged from 0.1 to 0.5 mg/g in dry soil.

Regarding soil particle compositions, the contaminated area has a high percentage of sand (85-90%) and a low percentage of clay (6-14%). Soil is composed mainly of sand, little gravel and the soil color is black yellow.

These properties of soil have accelerated the vertical penetration of toxic chemicals/dioxins into deeper soil layers, as well as the aquifer below. The soil of the contaminated area has a poor capacity to retain organic materials.

Soil around the contaminated area and sediments from the lake located in the contaminated area

Analytical results of 19 soil samples collected around the contaminated area indicated that the pH of the soil ranged from 3.76 to 6.16, which is higher than the pH of the soil within the contaminated area, which ranged from 2.6 to 5.0. The soil is poor in humus, from 0.5% to over 3.6%. The total nitrogen content is low (below 0.14%). The total iron content ranged from 0.11 to 0.6%. It was concluded that the quality of the soil is poor. The area contains high sand percentage of 80-90% and clay percentage of 4.4-17.2%.

The pH values of sediment samples from Sen Lake A were above 5.0, which is higher than Lake B. The humus content was high, ranging from 8 to 75.5%, depending on the position of water stream flow and the depth of lake. The sediment layer of the lake ranged from 0.3 to 1 m in thickness. The humus content also depends on the vegetation cover in the lake. Total nitrogen content was high, from 0.212 % to 0.575 %, depending on the humus content. The Ca^{2+} and Mg^{2+} concentrations were higher than in the soil samples in the area. High total humus and nitrogen contents can affect the accumulation and half-life of dioxins and the development of micro-organisms in the lake.

Analytical results of metal ions in the soil and sediment samples from Sen Lake A, Lake B and Lake C were much lower than the allowable standards and therefore there is no harmful effect on living organisms in the ecosystem of the contaminated area.

The soil on the north of the Da Nang Airbase is poor in humus, and humus content decreases gradually with depth. The soil has acidic properties, with a sand content of 80-90%, a low CEC, and a low total nitrogen content. Therefore, toxic chemicals/dioxins can penetrate into deeper layers of soil in this area.

3.3. Status of Dioxin contamination in Da Nang Airbase

Results from all studies on dioxin/furan in Da Nang Airbase were summarized in Table 3.1. Most of studies listed in the table presented in the following sections. The analytical results of dioxins in Da Nang Airbase and the surrounding areas are firstly obtained from Project Z2 of the Vietnamese Ministry of Defense, projects of Program 33, Hatfield Consultants and other authors.

Table 3.1 Summary of the results on dioxin contamination in Da Nang Airbase.

Project	Location	Sample matrix	Sample number	Range
Project Z2, 1997-98	Da Nang Airbase	Surface soil	47	51 – 200,400 ppt
		Sediment	3	64 – 54,200 ppt
		Deep core soil	23	182 – 64,190 ppt
Program 33, 2002-2004	Sen Lake	Sediment	11	282 – 12,390 ppt
	Lake B	Sediment	2	30 – 45 ppt
	Lake C	Sediment	1	42 ppt
	Park 293 and Thac Giam Lakes	Soil	6	2-17 ppt
		Sediment	9	2-111 ppt
	Xuan Ha Lake and neighbors	Soil	7	1 – 13 ppt
		Sediment	11	1 – 79 ppt
	Han river	Sediment	3	1 – 1 ppt
	Cam Le river	Sediment	3	1 – 9 ppt
	Phu Loc river	Sediment	4	2 – 4 ppt
	Drainage ditch to Sen Lake	Plant*	2	519.8 – 2,803.5 ppt
	Sen Lake	Plant*	12	0 – 498.1 ppt
		Aquatic animal	14	0.002 – 158.6 ppt
	Lake B	Aquatic animal	5	0.43 – 2.9 ppt
	Lake C	Aquatic animal	4	28.7 – 155.4 ppt
	Contaminated areas	Terrestrial animals	5	0.06 – 5.7 ppt
	Outside Airbase	Aquatic animal	5	n.d – 0.49 ppt
		Terrestrial animals	1	n.d
VAST, MONRE, MOD and USEPA, 2005	Former Storage Area	Soil***	43	0 – 11,934 ppt
	Mixing & Loading	Soil***	58	16 – 11,577 ppt
	Sen Lake	Soil***	3	5,499 – 10,999 ppt
Committee 10-80 & Hatfield, 2004-05	Outside Airbase	Soil	21	0.42 – 269 ppt
Office 33 & Hatfield, 2007	Former mixing & loading area	Soil	9	899 – 365,000 ppt
	Former storage area	Soil	9	24.5 – 106,000 ppt
	Between storage & loading area	Soil	3	170 – 6,520 ppt
	Airbase perimeter	Soil	19	0.643 – 5,690 ppt
	Drainage system	Sediment	2	8,580 – 27,700 ppt
	Da Nang City	Soil	6	3.14 – 36.1 ppt
	Sen Lake (A)	Sediment	19	18.9 – 6,820 ppt
		Fish**	2	34.5 – 3,120 ppt
		Vegetation**	2	0.332 – 7.25 ppt
	Lake B	Sediment	2	39.4 – 70.5 ppt
		Fish**	2	0.967 – 72.6 ppt
	Lake C	Sediment	3	7.99 – 20.1 ppt
		Fish**	2	0.22 – 8.22 ppt
	West airbase fishponds	Sediment	1	7.14 ppt
		Fish**	4	1.38 – 56.1 ppt
	Xuan Lake	Sediment	3	6.66 – 17.8 ppt
		Fish**	1	6.37 ppt
	March 29 Lake	Sediment	1	26.9 ppt
	Luan Lake	Fish**	1	0.223

Table 3.1 Summary of the results on dioxin contamination in Da Nang Airbase.

Project	Location	Sample matrix	Sample number	Range
Office 33 & Hatfield, 2009	Pacer Ivy Re-drumming Area	Soil	11	1.21 – 99.7 ppt
	Pacer Ivy Storage Area	Soil	19	1.72 – 20,600 ppt
	South airbase perimeter	Soil	14	1.14 – 103 ppt
	South airbase (outside airbase)	Soil	1	3.87 ppt
	West airbase perimeter	Soil	17	1.67 – 115 ppt
	West airbase (outside airbase)	Soil	2	15.3 – 37 ppt
	East base (outside airbase)	Soil	1	8.95 ppt
		Sediment	1	35.1 ppt
	East base perimeter	Soil	5	7.6 – 38.5 ppt
	North base perimeter	Soil	1	11,700 ppt
		Sediment	2	674 – 4,200 ppt
	Lake D	Sediment	1	0.537 ppt
		Fish**	6	0.0758 – 25.1 ppt
	Lake E	Sediment	1	23.8 ppt
		Fish**	1	0.0762 ppt
	Lake F	Sediment	1	6.89 ppt
		Fish**	1	0.0786 ppt
	Lake G	Sediment	1	3.54 ppt
		Fish**	1	0.094 ppt
	Lake H	Sediment	1	13.2 ppt
		Fish**	2	0.126 – 12.8 ppt
	Outside airbase	Sediment	1	44.5 ppt
	Lake I	Sediment	1	11.9 ppt
	Lake J	Sediment	1	9 ppt
		Fish**	4	0.0789 – 5.63 ppt
	Lake L	Sediment	1	146 ppt
		Fish**	1	0.849 ppt
	Lake M	Sediment	1	2.28 ppt
		Fish**	2	0.234 – 5.64 ppt
	Sen Lake	Sediment	2	2,740 – 4,540 ppt
		Fish**	7	40.9 – 8,350 ppt
	West Airbase Lake	Sediment	1	64
		Fish**	2	0.464 – 4.24 ppt
CDM and Hatfield, 2010	Sen Lake (open water)	Sediment	9	5.3 – 5,370 ppt
	Sen Lake (east wetland)	Sediment	10	6.96 – 570 ppt
	Drainage ditch/treatment pond	Sediment	2	1,890 – 6,960 ppt
	Area between drainage ditch and Sen Lake eastern wetland sampling area	Soil	2	728 – 1,620 ppt
	Drainage ditch (perimeter)	Soil	7	152 – 13,100 ppt
	Former Storage Area	Soil	12	50 – 41,900 ppt
	Former Mixing and Loading Area	Soil	20	1.73 – 14,100 ppt
	Proposed landfill site	Soil	4	1.33 – 1,260 ppt
	Sen Lake	Surface water**	2	0.92 – 0.942 ppt
	Drainage canal at SA	Surface water**	1	94.1 ppt
	Near NW airport	Well water**	1	0.875 ppt
	Near landfill	Well water**	1	0.859 ppt
Z9 Project by MOD 2012	South of airbase	Soil	18	2.4-1,360 ppt

Note:*n.d.: Below detection limit ;* Dry weight basis ;** Wet weight basis ;*** Results by CALUX*

3.3.1. Results from Project Z2 by Ministry of Natural Defense (1997-1998)

Prior to the Project Z2, dioxins were analyzed for 4 samples and Agent Orange (2,4-D and 2,4,5-T) for 10 samples from the suspicious area in the Da Nang Airbase. The results indicated that average concentrations of 2,3,7,8-TCDD, 2,4,5-T and 2,4-D in surface soil samples (0 - 20 cm) were 46,212 ppt, 55.4 ppm and 38.9 ppm, respectively (Final report of Project Z2/Vietnamese Ministry of Defense). These results suggested that the accumulation of dioxin in the contaminated area of Da Nang Airbase is still very high.

During 1997-1998, under the framework of Project Z2, VRTC collected surface soil samples and samples at different depths. A total of 101 samples from 66 sites were collected, out of which 73 samples (47 surface soil, 23 core depth and 3 sediment) were analyzed for dioxins and 65 samples for Agent Orange. The analytical results of surface and core samples are shown in Figures 3.3 and 3.4, respectively.

Most of the samples were collected from sub-area A, where the average concentration of 21 samples was 45,570 ppt TEQ. In sub-area B (former washing area), the average concentration of 5 samples was 62,440 ppt TEQ. Table 3.2 shows the vertical profiles of dioxins in soils from Z2 Zone, Da Nang Airbase.

Table 3.2. Vertical profiles of dioxins (TEQ; ppt) and Agent Orange in soils from Z2 Zone, Da Nang Airbase.

No.	Depth (cm)	Number of samples	Average level of dioxins (ppt)	Average level of Agent Orange (ppm)
1	0-30	14	45,330	582
2	30-60	14	11,620	581
3	60-90	7	10,290	400
4	90-120	7	5,010	81
5	120-150	5	952	27

Source: Report from the Project Z2- Vietnamese Ministry of Defense

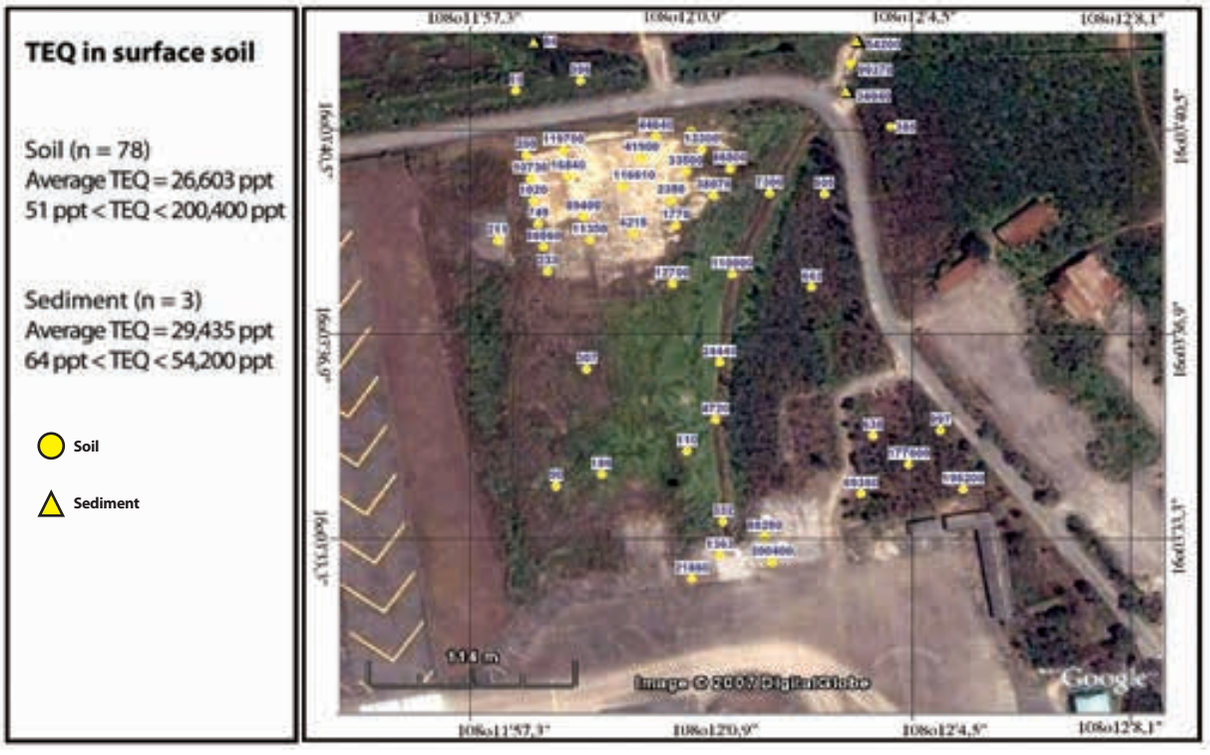

Fig. 3.4. Dioxin concentration (TEQ, dry wt.) in soils from contaminated area, 1997-1998

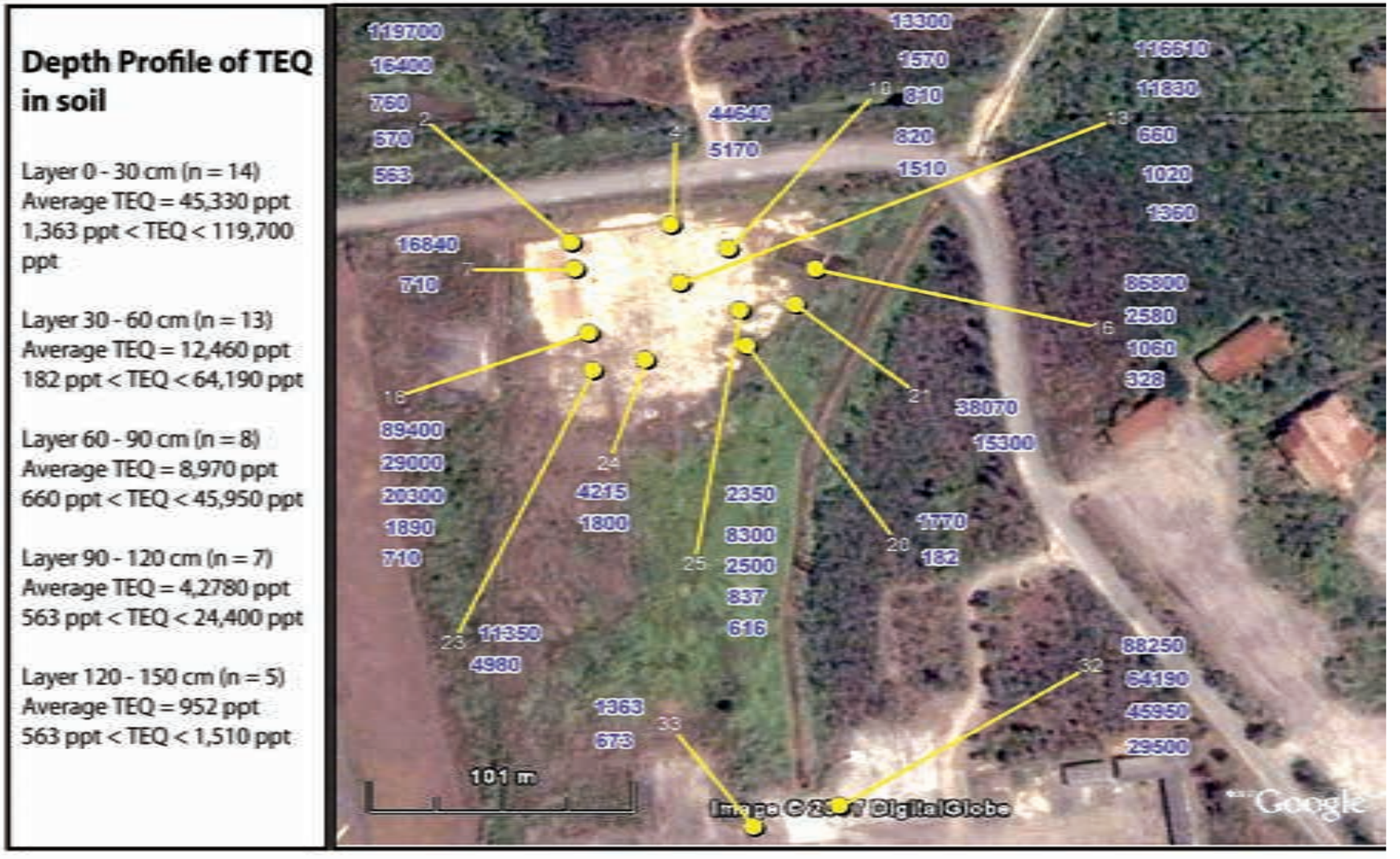

Fig. 3.5. Depth profile of dioxin concentrations (TEQ) in contaminated area, 1997-1998 (Project Z2).

3.3.2. Results from Program 33(2002-2004)

In 1998, the total areas of contaminated sub-areas with high dioxins concentration were estimated is about 32,000 m2. The number of samples collected under Project Z2 was rather limited. Most samples were collected from the heavily contaminated area and only a few were collected from surrounding areas. In 2002 and 2004, under the Research on persistent impacts of toxic chemical/dioxins in the contaminated area in Da Nang Airbase on environment and ecosystem project of Program 33, soil samples around Sen Lake A, Lake B and Lake C (14 samples) and 48 organism samples (including aquatic animals and plants, rats and water birds) were collected and analyzed for dioxins.

The analytical results of dioxin contamination in the vicinity of Da Nang Airbase are shown in Figures 3.6, 3.7 and 3.8. These results indicate that the accumulation of dioxins in soil and sediment samples in the area from the airbase to the Thanh Binh Bay was low; the average concentration was below 75 ppt for I-TEQ and T% was lower than 30%. In summary, the dioxin levels in soil and sediment samples outside the airbase were below the allowable limits. These areas therefore do not require remediation.

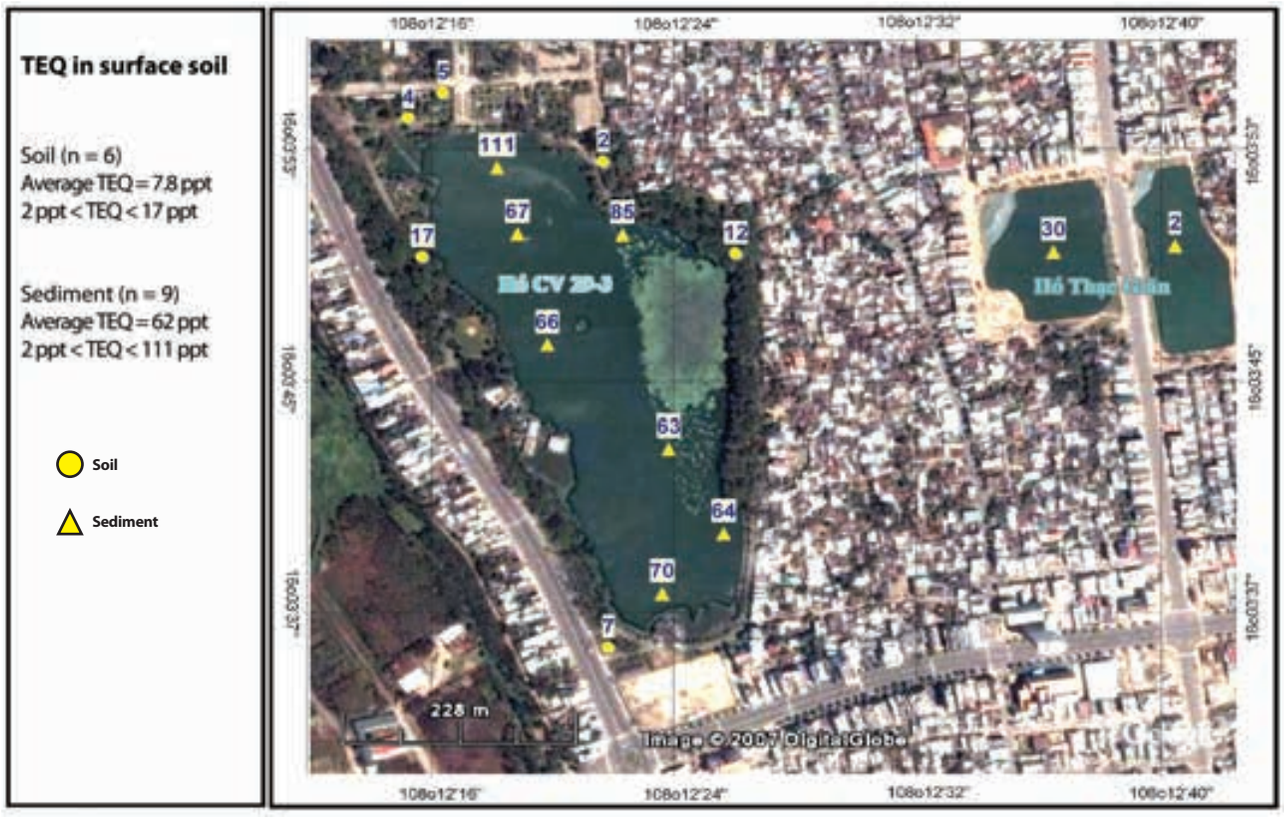

Fig. 3.6. Dioxin concentrations (TEQ) in soils and sediments from Thac Gian Lake, Da Nang, 2002-2004.

Fig. 3.7. Dioxin concentrations (TEQ) in soils and sediments from Xuan Ha Lake, Da Nang, 2002-2004.

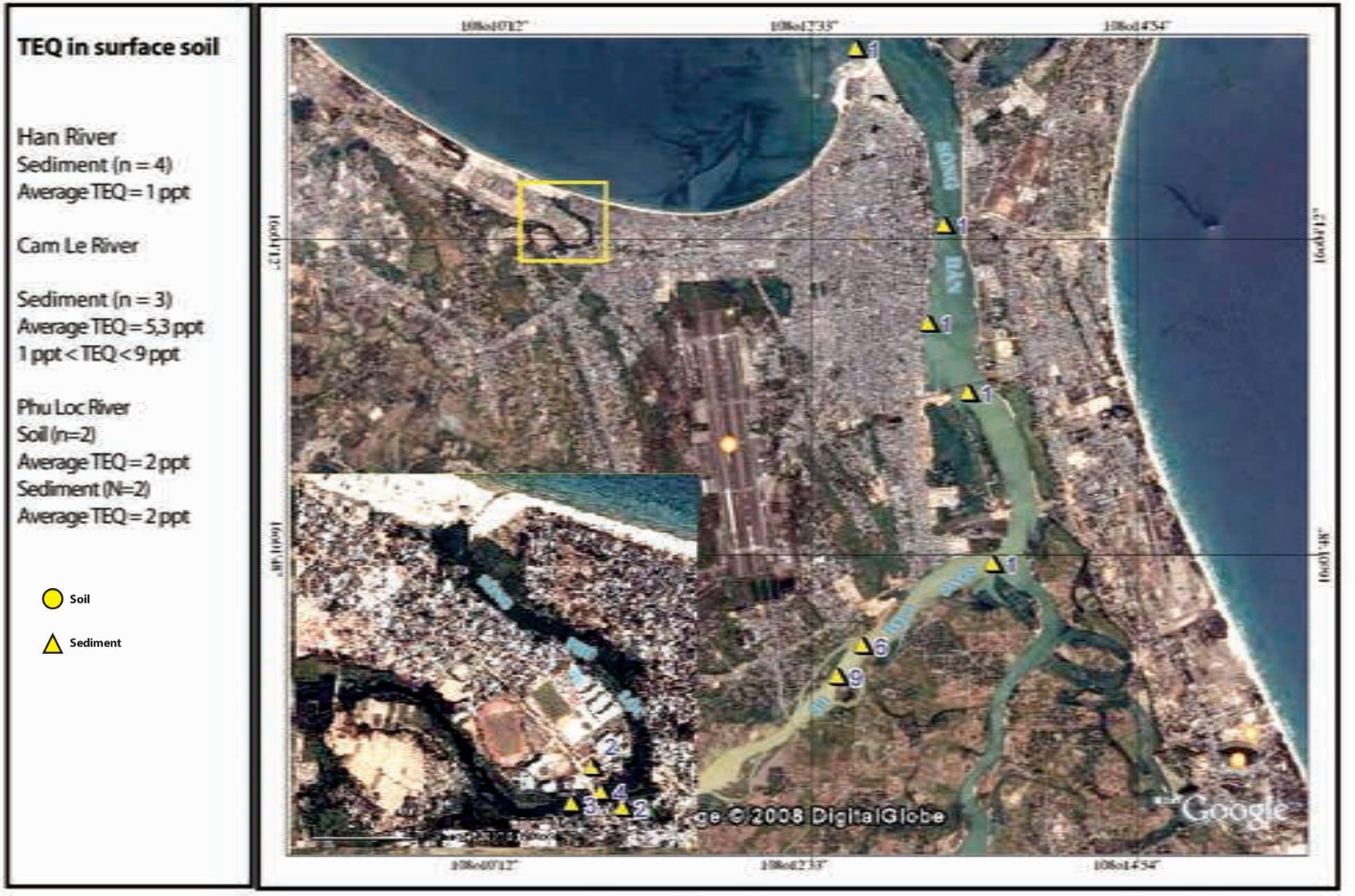

Fig. 3.8. Dioxin residues (TEQ) in soils and sediments from Han, Cam Le and Phu Loc River, Da Nang ,2002-2004.

The dioxins levels in plant samples from different sources are shown in Table 3.3.

Table 3.3.The dioxins concentrations in plant samples.

No.	Type of sample	I-TEQ (ppt dry weight)	2,3,7,8-TCDD (ppt)	Percentage of 2,3,7,8-TCDD/I-TEQ
Drainage ditch from contaminated area to Sen Lake A				
1	Root of grass	519.8	513.2	98.7
2	Moss	2,803.5	2,713.6	96.8
Sen Lake A				
1	Root and tuber of lotus	498.1	484.5	97.3
2	Body and stem of lotus	69.4	67	96.5
3	Leave of lotus	8.3	6.7	80.8
4	Seed of lotus	0	< 1.0	0
5	Ceratophyllum demersum	92.1	85.9	93.2
6	Root of spinach	115.7	110.6	95.6
7	Body of spinach	12.4	11.6	93.3
8	Root of coconut greens	73.3	66.1	90.2
9	Body and leave of coconut greens	18.4	16.8	91.6
10	Root of water hyacinth	111.6	97.8	87.6
11	Tuber of water-taro	1.7	1.3	75.1
12	Tuber of nenuphar	169.1	160.1	94.7
Ave.	**Root, tuber (n=6)**	**161.6**	**153.4**	**94.9**
	Body, leaves (n=5)	**40.1**	**37.6**	**93.8**
	Seed (n=1)	**0**	**n.d.**	**-**
Average in plant (n = 12)		**97.5**	**92.4**	**94.8**

Source: Final report of the state-level project - Program 33

It is known that dioxins are not absorbed by plants, especially vascular plants, because of both of dioxins and plants properties. In this report, the samples were analyzed in order to estimate the dioxins adsorbed on the surface of plants or penetrated into the plants though the scars of plants and find the plants which have high ability to accumulate dioxin in the dioxin contaminated areas (Table 3.3). The results clearly indicate that plants in the highly contaminated area have accumulated dioxins. In particular, the highest dioxin level (2,803.5 ppt I-TEQ dry weight and a T% of 96.8%) was observed in mosses, while the dioxin level in the root of nenuphar was 169.1 ppt. These results suggest that parts of plants flooded with dioxin-contaminated water are able to accumulate dioxins at significant levels.

The analytical results of dioxins in aquatic animal samples collected inside and outside the contaminated area are shown in Table 3.4.

Table 3.4 The dioxin concentrations (ppt, TEQ and TCDD) in aquatic animals (fish, eels, snails, clam, and frogs).

No.	Type of sample	Concentration (ppt I-TEQ)	Concentration	2,3,7,8-TCDD (ppt)	% 2,3,7,8-TCDD/ I-TEQ
(ppt I-TEQ) (lipid)	Knife fish	155.4	24,344	149.0	95.9
(ppt)	Knife fish	116.7	44,300	115.5	99.0
I-TEQ	Knife fish	101.8	25,984	99.5	97.8
4	Snake-head	28.7	11,737	28.6	99.7
5	Eel	29	16,480	27.9	96.1
6	Crucian carp	4.6	654.6	4.5	98.3
7	Crucian carp	14.7	5,363	14.6	99.5
8	Tilapia	11.6	2,436	10.3	88.8
9	Tilapia	1.4	267.6	1.3	95.6
10	Oyster	0.002	7.2	-	-
11	Large edible snail	3	2,562	2.8	94.0
12	Large edible snail	1.3	6,732	1.2	93.8
13	Carp	158.6	9,633	157.5	99.3
14	Field frog	2.98	385.9	2.4	80.7
Ave.	Fish of all species (n=9)	65.9	13,858	64.5	97.9
	Eel (n=1)	29	16,480	27.9	96.1
	Large edible snail (n=2)	2.15	4,647	2.0	93.9
	Oyster (n=1)	0.002	7.2	n.d.	nd
	Field frog (n=1)	2.98	385.9	2.4	80.7
Average conc. in fish, eel, snail, oyster, frog(n=14)		**44.98**	**10,777**	**43.93**	**88.46**
Lake B					
1	Tilapia	2.7	182.2	2.6	95.2
2	Catfish	0.43	59.1	0.4	93.0
3	Carp	2.9	240.2	2.7	91.7
4	Carp	2.6	312.0	2.5	96.2
5	Major cap	1.2	303.3	1.1	93.2
Average conc. in fish (n=5)		**2.0**	**219.4**	**1.9**	**95.0**
Lake C					
1	Knife fish	155.4	24,344	149	95.9
2	Snake-head	116.7	44,300	115.5	99.0
3	Crucian carp	101.8	25,984	99.5	97.8
4	Tilapia	28.7	11,737	28.6	99.7
Average conc. in fish (n=4)		**2,0**	**558**	**1,9**	**98,2**
Animal samples collected/bought from other places (outside the airbase)					
1	Snake-head	0.14	17.0	< 0.4	-
2	Eal	0.06	35.4	-	-
3	Crucian carp	-	-	< 2.1	-
4	Tilapia	0.49	9.7	0.4	82.1
5	Large edible snail	0.05	8.9	-	-
Average conc. in fish, eel, snail (n=5)		**0.15**	**14.2**	**0.08**	**53.3**

In the ponds and lakes having less aquatic plants, dioxin levels in benthos species were rather high. But in the Sen Lake A, where is rich in plants, including algae, mosses, lotus, nenuphars, and water hyacinths, the fishes feeding on the roots of aquatic plants exhibit high degree of dioxin accumulation.

Results of terrestrial animal samples collected from the contaminated area in Da Nang are shown in Table 3.5.

Table 3.5. The concentrations of dioxin (ppt, TEQ and TCDD) in terrestrial animal samples collected from the Da Nang Airbase area

No.	Type of sample	Concentration (ppt I-TEQ)	Concentration (ppt I-TEQ) (lipid)	Concentration of 2,3,7,8-TCDD (ppt)	Percentage of 2,3,7,8-TCDD/ I-TEQ
Samples collected in the contaminated area					
1	Duck leg	0.64	3.3	0.5	78.1
2	Internal organs of duck	1.02	5.7	0.9	88.2
3	Chicken leg	0.44	17.7	0.4	90.9
4	Internal organs of chicken	0.06	1.7	# 0.9	0
5	Rat	5.7	7,425.1	5.7	99.9
Samples from others (outside the airbase)					
1	Rat	-	-	<0.6	-
Ave.	**Chicken, duck (n=2)**	**0.54**	**10.5**	**0.45**	**83.3**
	Internal organs of chicken, duck (n=2)	**0.54**	**3.7**	**0.45**	**83.3**
Average concentration in duck, chicken, and rat (n=5)		**1.57**	**1,490.7**	**1.52**	**71.42**

High concentrations of dioxins were detected in rats inhabiting the contaminated area. This may be due to the fact that rats have burrows within the contaminated area, and were therefore exposed to dioxins at the site.

3.3.3.Results of surveys by Committee 10-80/ Hatfield (2004-2005)

In the 2005 study (Committee 10-80 và Hatfield Consultant, 2006), 21 samples (2 soil and 19 sediment) were collected and analyzed outside of the Da Nang Airbase (see site map in Fig 3.9.). The high levels of dioxin were recorded in sediment collected in Thanh Khe District, near site 18 (269 ppt TEQ); over 80% of the TCDD in the TEQ was TCDD, suggesting Agent Orange as the primary source of dioxin contamination at this site (Table 3.6).

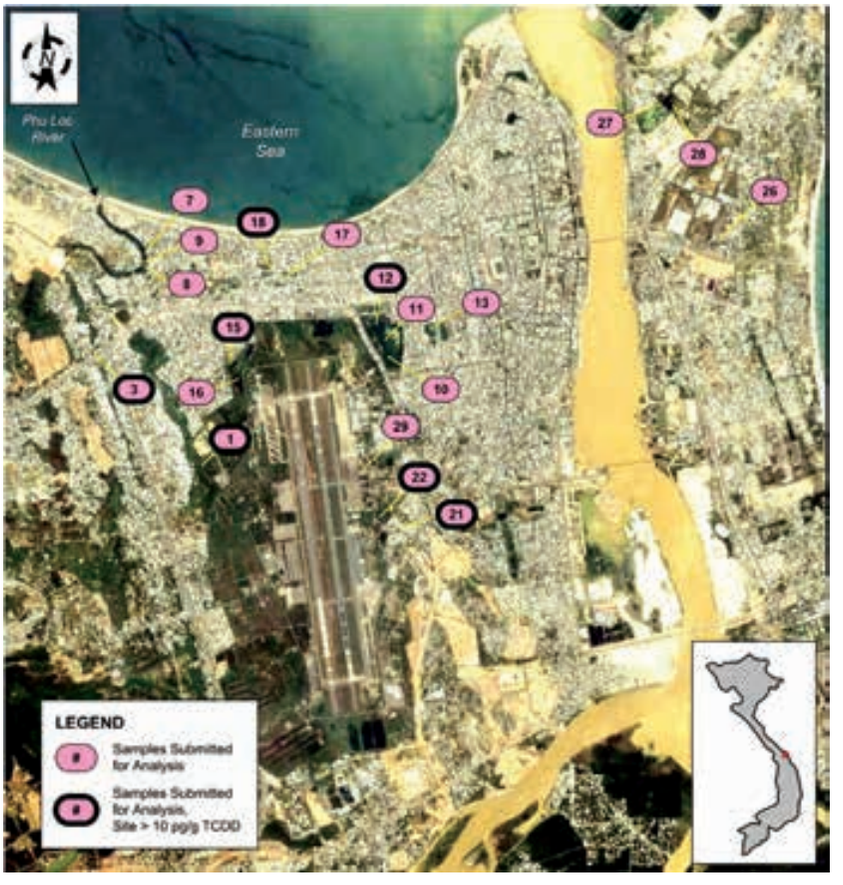

Fig. 3.9 Survey site map Da Nang Airbase and surrounding in 2005, by Hatfield and 10-80 Division

Table 3.6. 2,3,7,8-TCDD, TEQ and the percentage for soil and sediment samples outside Da Nang Airport, 2005-06

No.	Sample ID	Sample Matrix	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
1	05VN018	Soil	Cultivated land	227	269	84
2	05VN022	Sediment	Ditch	130	191	68
3	05VN001	Sediment	Ditch	27	34.3	79
4	05VN012	Sediment	Lake 29.3 (new park)	22.6	154	15
5	05VN015	Sediment	Lake WTLD 2 (Xuan Ha Lake)	11.7	29.9	39
6	05VN003	Sediment	Ditch	11	34	32
7	05VN021	Sediment	Ditch	10.8	16.4	66
8	05VN017	Soil	Cultivated land	9.06	24.7	37
9	05VN009	Sediment	Ditch	6.84	13.7	50
10	05VN007	Sediment	Pho Loc River	6.46	11.9	54
11	05VN029	Sediment	Ditch	5.14	10.5	49
12	05VN016	Sediment	Lake WTLD (Xuan Ha Lake)	3.23	32.9	10
13	05VN013	Sediment	Thao Gian Lake	2.28	33.6	7
14	05VN026	Sediment	An Don ditch	1.64	20.2	8
15	05VN011	Sediment	Lake 29.3 (new park)	1.61	8.69	19
16	05VN011 (duplicate)	Sediment	Lake 29.3 (new park)	1.46	8.47	17
17	05VN010	Sediment	Lake 29.3 (new park)	0.415	2.34	18
18	05VN028	Sediment	An Don pond	0.262	1.42	18
19	05VN008	Sediment	Pho Loc River	0.175	0.449	39
20	05VN027	Sediment	An Don ditch	0.07	0.44	16
21	05VN027 (duplicate)	Sediment	An Don ditch	0.07	0.42	17

3.3.4. Results of surveys by Office 33/ Hatfield (2007)

In the 2006 study (Office 33/Hatfield Consultant, 2007), a comprehensive survey and analyses were conducted. For soil and sediment, PCB, pesticides, PAH, TOC, pH, particle size, Chrolophenols, CCME fractions and heavy metals were analyzed for selected samples in addition to the dioxins and furans. The study also collected fish and vegetation samples from contaminated areas. The sampling locations are plotted on Figure.3.10.

Fig. 3.10. All sites sampled in Da Nang City and Airbase in December 2006

Dioxins and Furans

Soil from areas on the Airbase that were used to store and transfer herbicides are highly contaminated and are incompatible for any human/environmental use. The high levels of dioxin were recorded at the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake. The maximum soil TEQ concentration recorded was 365,000 ppt, from samples collected from the former Mixing and Loading Area (Table 3.7).

Bottom sediment in water bodies, particularly Sen Lake exhibited high level of TCDD as a result of direct drainage and sediment transport from former Mixing and Loading area and former Storage Area (Table 3.8).

The fish samples collected and analyzed in 2006 are presented on Table 3.9; the highest dioxins concentration (3,000 pg/g wet weight) was found in fat tissues of tilapia collected from the Sen Lake.

Table 3.7. Concentrations of PCDD and PCDF in soil and sediment samples, 2006

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
Former Mixing and Loading Area (MLA)						
06VN058	Soil	0-10	Site 2 – Centre	361,000	365,000	99
06VN059	Soil	10-30	Site 2 – Centre	330,000	333,000	99
06VN063	Soil	0-10	Site 1 – West	1,190	1,200	99
06VN064	Soil	10-30	Site 1 – West	8.730	8,770	100
06VN065	Soil	0-10	Site 3 – NE	27,700	27,900	99
06VN068	Soil	10-30	Site 3 – NE	36,800	37,000	99
06VN066	Soil	0-10	Perimeter – S of former barracks	858	899	95
06VN067	Soil	0-10	Perimeter – N of former barracks	4,820	4,980	97
06VN069	Soil	0-10	Perimeter – W of former barracks	165,000	167,000	99
Former Storage Area (SA)						
06VN075	Soil	0-10	Site 1 – NW	5,100	5,200	98
06VN076	Soil	10-30	Site 1 – NW	773	787	98
06VN077	Soil	30-50	Site 1 – NW	9.12	24.5	37
06VN078	Soil	0-10	Site 2 – NE	106,000	106,000	100
06VN083	Soil	0-10	Site 3 – Centre	61,500	62,200	99
06VN084	Soil	10-30	Site 3 – Centre	336	347	97
06VN085	Soil	30-50	Site 3 – Centre	136	143	95
06VN070	Soil	0-10	Site 4 – SW	3,350	3,520	95
06VN074	Soil	0-10	Site 5 - SE	63,200	64,600	98
Between SA and MLA						
06VN043	Soil	0-10	S of SA/W of ditch	136	170	80
06VN047	Soil	0-10	SE of SA/E of ditch	6,080	6,520	93

Table 3.7. Concentrations of PCDD and PCDF in soil and sediment samples, 2006

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
06VN048	Soil	0-10	N of MLA/W of ditch	3,840	4,150	93
Drainage System						
06VN072	Sediment	Grab	Water treatment basin	25,700	27,700	93
06VN081	Sediment	Grab	Ditch d/s/ of SA	8,390	8,580	98
Airbase Perimeter Areas						
06VN036	Soil	0-10	Military Garden	16.9	31	55
06VN035	Soil	0-10	Old Munitions Dump	103	149	69
06VN046	Soil	0-10	5m E of ditch, near main road	5,400	5,690	95
06VN042	Soil	0-10	N of airline staff residence	1,700	1,830	93
06VN045	Soil	0-10	NE of SA / E of ditch	598	674	89
06VN037	Soil	0-10	S of airline staff residence	165	270	61
06VN038	Soil	0-10	S of airline staff residence (duplicate)	150	253	59
06VN019	Soil	0-10	NE corner airbase (2)	7.91	17.1	46
06VN018	Soil	0-10	NE corner airbase (1)	43.6	72.9	60
06VN001	Soil	0-10	Btwn SA and Sen Lake (1)	9.66	16.4	59
06VN003	Soil	0-10	Btwn SA and Sen Lake (2)	6.44	12.2	53
06VN004	Soil	0-10	Btwn SA and Lake B (1)	219	232	94
06VN006	Soil	0-10	Btwn SA and Lake B (2)	14	26	54
06VN010	Soil	0-10	Btwn Lakes B & C	25.4	49.2	52
06VN014	Soil	0-10	Sen Lake garden	12.5	18	69
06VN015	Soil	0-10	Sen Lake residence	1.72	4.34	40
06VN013	Soil	0-10	NW corner airbase	53.1	68.2	78
06VN073	Soil	0-10	Footpath W airbase	0.212	0.643	33
06VN027	Soil	0-10	Garden SW airbase	2.29	15	15
Da Nang City						
06VN091	Soil	0-10	N of airbase / Dien Bien Phu Street	1.26	5.91	21
06VN092	Soil	0-10	NE of airbase / Dien Bien Phu Street	0.649	7.36	9
06VN099	Soil	0-10	Thanh Khe garden (1)	26	36.1	72
06VN100	Soil	0-10	Thanh Khe garden (2)	1.28	3.94	32
06VN101	Soil	0-10	Thanh Khe garden (3)	0.616	5.34	12
06VN102	Soil	0-10	Hai Chau garden	0.644	3.14	21

Table 3.8 Concentrations of PCDD and PCDF in airbase lake sediments, 2006

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/ I-TEQ (%)
Sen Lake (A)						
06VN030	Sediment	Grab	Outlet to Da Nang City	253	292	87
06VN030**	Sediment	Grab	Outlet to Da Nang City	232	244	95
06VN031	Sediment	Grab	Centre	191	198	96
06VN031**	Sediment	Grab	Centre	184	192	96
06VN032	Sediment	Grab	Centre	2,750	2,980	92
06VN032**	Sediment	Grab	Centre	1,140	1,230	93
06VN033	Sediment	Grab	SE	61.4	68.6	90
06VN033**	Sediment	Grab	SE	63.6	69.2	92
06VN052	Sediment	Grab	NE	5,440	5,950	91
06VN053	Sediment	Grab	NW	6,240	6,820	91
06VN055	Sediment	Grab	Centre – West	3,190	3,520	91
06VN040	Sediment	Grab	Inlet from ditch	1,160	1,290	90
06VN062-1	Sediment	0-2	West	3,730	4,050	92
06VN062-2	Sediment	2-4	West	674	750	90
06VN062-3	Sediment	4-6	West	22.3	39.4	57
06VN062-4	Sediment	6-8	West	6.15	18.9	33
06VN062-5	Sediment	8-10	West	6.45	19.8	33
06VN062-6	Sediment	10-14	West	4.4	20.2	22
06VN062-11	Sediment	30-32	West	5.91	23.1	26
Lake B						
06VN024	Sediment	Grab	North	30.4	39.4	77
06VN029	Sediment	Grab	South	57.1	70.5	81
Lake C						
06VN021	Sediment	Grab	North	11.7	20.1	58
06VN022	Sediment	Grab	North (duplicate)	8.89	16	56
06VN023	Sediment	Grab	South	4.54	7.99	57
West Airbase Fishponds						
06VN080	Sediment	Grab	Centre	3.35	7.14	47
Xuan Lake						
06VN087	Sediment	0-10	Garden near Xuan Lake	2.58	6.66	39
06VN088	Sediment	0-10	Xuan Lake (N)	8.21	17.8	46
06VN090	Sediment	0-10	Xuan Lake (S)	2.63	16.7	16
March 29 Lake						
06VN093	Sediment	0-10	March 29 Lake	4.57	26.9	17

Table 3.9 Concentrations of PCDD and PCDF in fish tissue and vegetation samples (pg-TEQ/g wet weight), 2006

Sample ID	Common Name	Sample Type	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/ I-TEQ (%)
06VN216	Nile Tilapia	Fish Fat	Sen Lake	3,000	3,120	96
06VN217	Nile Tilapia	Fish Muscle	Sen Lake	33.2	34.5	96
06VN232	Nile Tilapia	Fish Fat	Lake B	68.4	72.6	94
06VN233	Nile Tilapia	Fish Muscle	Lake B	0.898	0.967	93
06VN224	Carp	Fish Fat	Lake C	6.61	8.22	80
06VN230	Carp	Fish Muscle	Lake C	0.163	0.22	74
06VN206	Nile Tilapia	Fish Fat	Pond W airbase	45.8	56.1	82
06VN203	Nile Tilapia	Fish Muscle	Pond W airbase	1.14	1.38	83
06VN209	Cat Fish	Fish Fat	Pond W airbase	33.6	53	63
06VN210	Cat Fish	Fish Muscle	Pond W airbase	0.943	1.39	68
06VN110	Snakehead Murrell	Fish Liver	Xuan Lake	3.21	6.37	50
06VN109	Snakehead Murrell	Fish Muscle	Luan Lake	0.171	0.223	77
06VN094	Sweet Potato	Root	Sen Lake garden	NDR 0.280	0.332	42
09VN0980	Lotus	Stem	Sen Lake	6.91	7.25	95

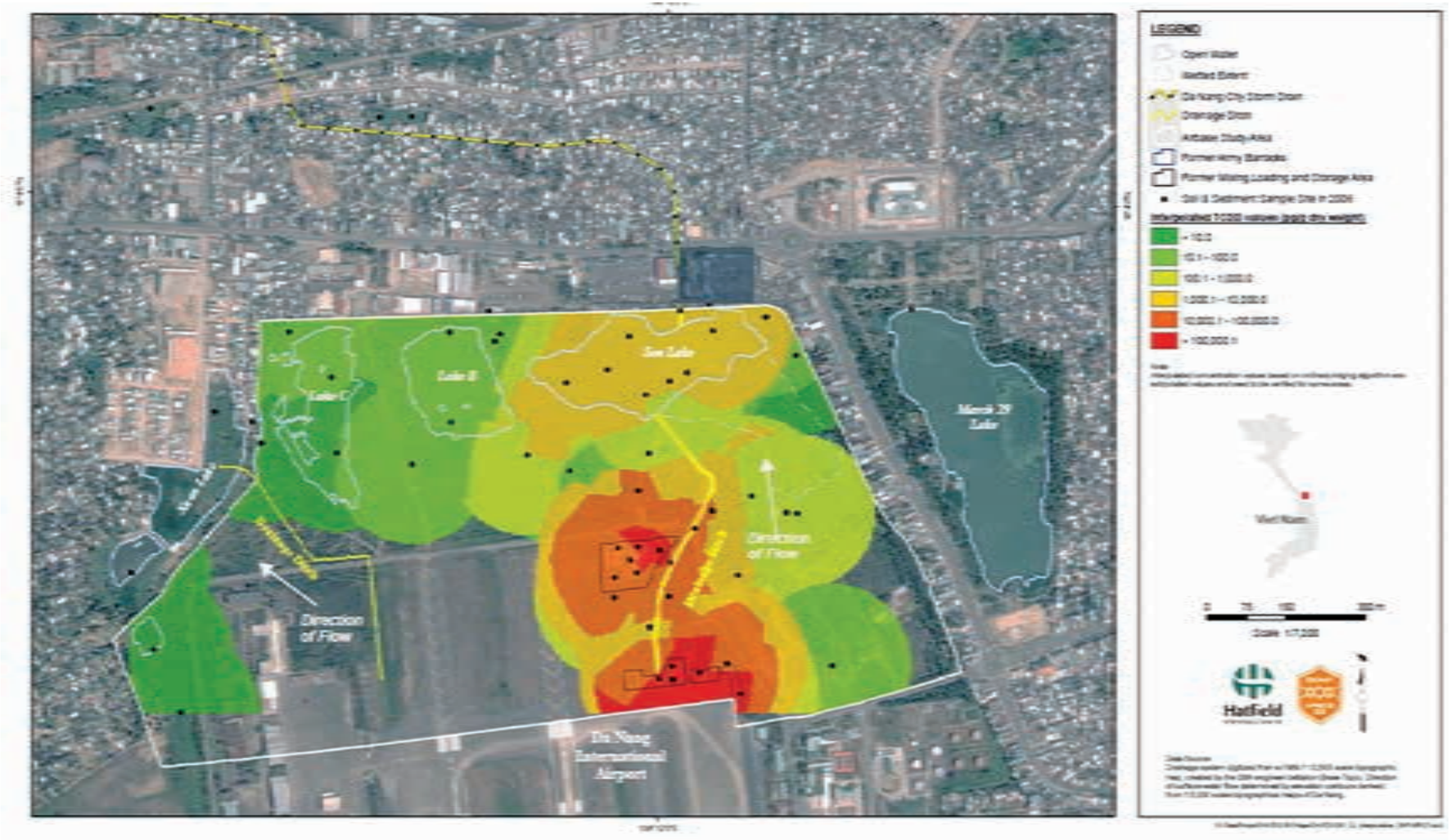

Fig. 3.11. Summary of interpolated TCDD values for the Da nang Airbase study area in December, 2006

3.3.5. Results of surveys by Office 33/ Hatfield (2009)

The study performed in 2009 subsequently investigated the dioxins concentration in the soil, sediment, and fish tissue samples which collected in the areas in the airbase and inside Da Nang city where border on the military airbase to evaluate the possibility of affecting the local population due to exposure to dioxins. This study mainly focused on determination of the dioxin contamination in the suspected areas near Pacer Ivy storage area (PISA) and Pacer Ivy re-drumming area (PIRA).

Soil and sediment samples

The concentrations of dioxins and furans in soils and sediments samples collected from different areas in and around Da Nang Airbase are provided in Table 3.10 and Figure 3.12, 13, 14 and 15. The soil and sediment were sampled inside and the location at the south, east and west of the Da Nang Airbase generally exhibited lower levels of dioxin contamination than those collected from the north of the Airbase. Dioxin levels varied greatly among locations surveyed, ranging from around 1 to 20,000 pg/g dry wt. The high levels of dioxins were encountered in Pacer Ivy Storage Area and several locations in the north of the airbase. Unlike previous surveys in other hotspots areas, only a few soils and sediment samples contained dioxin levels exceeding guideline values (1000 pg/g TEQs for soil and 100 pg/g TEQ for sediment).

Percentage of TCDD to total TEQ concentration was moderate (range: 18.9% to 80.1%) indicating that Agent Orange was not the only source of dioxins. Only a few samples collected in the Pacer Ivy Storage Area and the northern airbase exhibit percentage TCDD/TEQs higher than 80 %. A number of different dioxin and furan congeners contributed to the total TEQ of samples, including penta-, hexa-, hepta- and octa-chlorinated congeners .The Agent Orange also contributed to the high concentration of TCDD in soil and sediment samples collected in the north area of the Da Nang Airbase. The analyzing the soil and sediment samples collected from near the Former Mixing and Loading and Former Storage Areas exhibited very high TCDD levels in soil. The sediment samples collected from Sen Lake also contained very high levels of TCDD (2,510 ppt and 4,180 ppt).

Table 3.10. Concentrations of PCDD and PCDF in soil and sediment samples, 2009

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/ I-TEQ (%)
215A	Soil	0-10	PIRA	NDR 1.21	1.21	NC
216A	Soil	0-10	PIRA	5.14	16.1	31.9
218A	Soil	0-10	PIRA	NDR 1.82	2.85	NC
219A	Soil	0-10	PIRA	12	30.5	39.3
221A	Soil	0-10	PIRA	2.48	11.9	20.8
222A	Soil	0-10	PIRA	5.63	12	46.9
223A	Soil	0-10	PIRA	73.7	85.2	86.5
224A	Soil	0-10	PIRA	2.55	5.2	49.0
226A	Soil	0-10	PIRA	79.9	99.7	80.1
227A	Soil	0-10	PIRA	3.39	10.8	31.4
228A	Soil	0-10	PIRA	11.1	62.8	17.7
202A	Soil	0-10	PISA	1,180	1,420	83.1
203A	Soil	0-10	PISA	54.5	73.3	74.4
204A	Soil	0-10	PISA	6.81	22.2	30.7
206A	Soil	0-10	PISA	2.99	4.4	68.0
207A	Soil	0-10	PISA	30.2	34.7	87.0
213A	Soil	0-10	PISA	5.4	12.5	43.2

Table 3.10. Concentrations of PCDD and PCDF in soil and sediment samples, 2009

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/ I-TEQ (%)
214A	Soil	0-10	PISA	NDR 0.774	1.72	NC
321A	Soil	0-10	PISA	46.1	124	37.2
322A	Soil	0-10	PISA	NDR 1.62	1.79	NC
323A	Soil	0-10	PISA	NDR 1.22	4.6	NC
324A	Soil	0-10	PISA	1.97	6.93	28.4
325A	Soil	0-10	PISA	1.25	6.61	18.9
326A	Soil	0-10	PISA	44	75.3	58.4
327A	Soil	0-10	PISA	18.7	40.3	46.4
208A	Soil	0-10	PISA	13,400	20,600	65.0
209A	Soil	10-30	PISA	3,500	5,120	68.4
210A	Soil	30-60	PISA	123	189	65.1
211A	Soil	60-90	PISA	13.1	21.6	60.6
212A	Soil	90-115	PISA	4.15	6.96	59.6
229A	Soil	0-10	South airbase perimeter	1.05	2.06	51.0
230A	Soil	0-10	South airbase perimeter	4.14	17.1	24.2
231A	Soil	0-10	South airbase perimeter	1.29	3.44	37.5
232A	Soil	0-10	South airbase perimeter	NDR 1.37	2.96	NC
233A	Soil	0-10	South airbase perimeter	0.875	8.2	10.7
234A	Soil	0-10	South airbase perimeter	9.61	14.8	64.9
237A	Soil	0-10	South airbase perimeter	85.5	98.2	87.1
238A	Soil	0-10	South airbase perimeter	145	161	90.1
239A	Soil	0-10	South airbase perimeter	NDR 0.620	1.14	NC
240A	Soil	0-10	South airbase perimeter	1.69	6.13	27.6
241A	Soil	0-10	South airbase perimeter	1.65	11.2	14.7
242A	Soil	0-10	South airbase perimeter	18.3	103	17.8
243A	Soil	0-10	South airbase perimeter	NDR 1.05	10.9	NC
244A	Soil	0-10	South airbase perimeter	NDR 0.617	6.94	NC
315A	Soil	0-10	South airbase (outside airbase)	0.388	3.87	10.0
249A	Sediment	0-10	Lake D	NDR 0.639	0.537	NC
250A	Sediment	0-10	Lake E	15.6	23.8	65.5
251A	Sediment	0-10	Lake F	2.11	6.89	30.6
252A	Sediment	0-10	Lake G	0.911	3.54	25.7
245A	Sediment	0-10	Lake H	1.04	7.86	13.2
316A	Sediment	0-10	Outside airbase	13.7	30.8	44.5
248A	Soil	0-10	West airbase perimeter	17.5	30.9	56.6

Table 3.10. Concentrations of PCDD and PCDF in soil and sediment samples, 2009

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/ I-TEQ (%)
261A	Soil	0-10	West airbase perimeter	0.497	8.61	5.8
263A	Soil	0-10	West airbase perimeter	<0.256	1.67	7.7
264A	Soil	0-10	West airbase perimeter	NDR 0.580	3.89	NC
265A	Soil	0-10	West airbase perimeter	NDR 0.682	2.21	NC
266A	Soil	0-10	West airbase perimeter	46.1	115	40.1
267A	Soil	0-10	West airbase perimeter	0.623	4.29	14.5
268A	Soil	0-10	West airbase perimeter	2.55	9.98	25.6
269A	Soil	0-10	West airbase perimeter	1.65	2.24	73.7
270A	Soil	0-10	West airbase perimeter	NDR 0.869	38.8	NC
271A	Soil	0-10	West airbase perimeter	1.61	2.85	56.5
273A	Soil	0-10	West airbase perimeter	30.2	46.5	64.9
274A	Soil	0-10	West airbase perimeter	5.51	14.3	38.5
275A	Soil	0-10	West airbase perimeter	3.93	18.6	21.1
276A	Soil	0-10	West airbase perimeter	3.09	6.47	47.8
278A	Soil	0-10	West airbase perimeter	NDR 1.01	4.72	NC
279A	Soil	0-10	West airbase perimeter	1.48	23	6.4
317A	Soil	0-10	West airbase (outside airbase)	40.6	15.3	26.5
318A	Soil	0-10	West airbase (outside airbase)	1.91	37	5.2
246A	Sediment	0-10	Lake I	1.32	11.9	11.1
247A	Sediment	0-10	Lake J	0.597	9	6.6
308A	Soil	0-10	East base (outside airbase)	3	8.95	33.5
297A	Soil	0-10	East base perimeter	1.05	16	6.6
298A	Soil	0-10	East base perimeter	14.4	24.3	59.3
299A	Soil	0-10	East base perimeter	21.4	38.5	55.6
300A	Soil	0-10	East base perimeter	3.96	11.8	33.6
301A	Soil	0-10	East base perimeter	1.04	7.6	13.7
307A	Sediment	0-10	East base (outside airbase)	24.8	35.1	70.7
280A	Sediment	0-10	Lake L	93.2	146	64.2
281A	Sediment	0-10	Lake M	0.2	2.28	8.8
304A	Soil	0-10	North base perimeter	11,200	11,700	95.7
286A	Sediment	0-10	Sen Lake east	2,510	2,740	91.6
287A	Sediment	0-10	Sen Lake west	4,180	4,540	92.1
302A	Sediment	0-10	North base perimeter	4,080	4,200	97.1
306A	Sediment	0-10	North base perimeter	534	674	79.2
285A	Sediment	0-10	West Airbase Lake	24.2	64	37.8

Notes:
NC = Not calculated
ND = Not detected; for total TEQ calculation, if ND, ½ detection level was used
NDR = Non-detection ratio; peak detected but did not meet quantification criteria; for total calculation, NDR was treated as ND

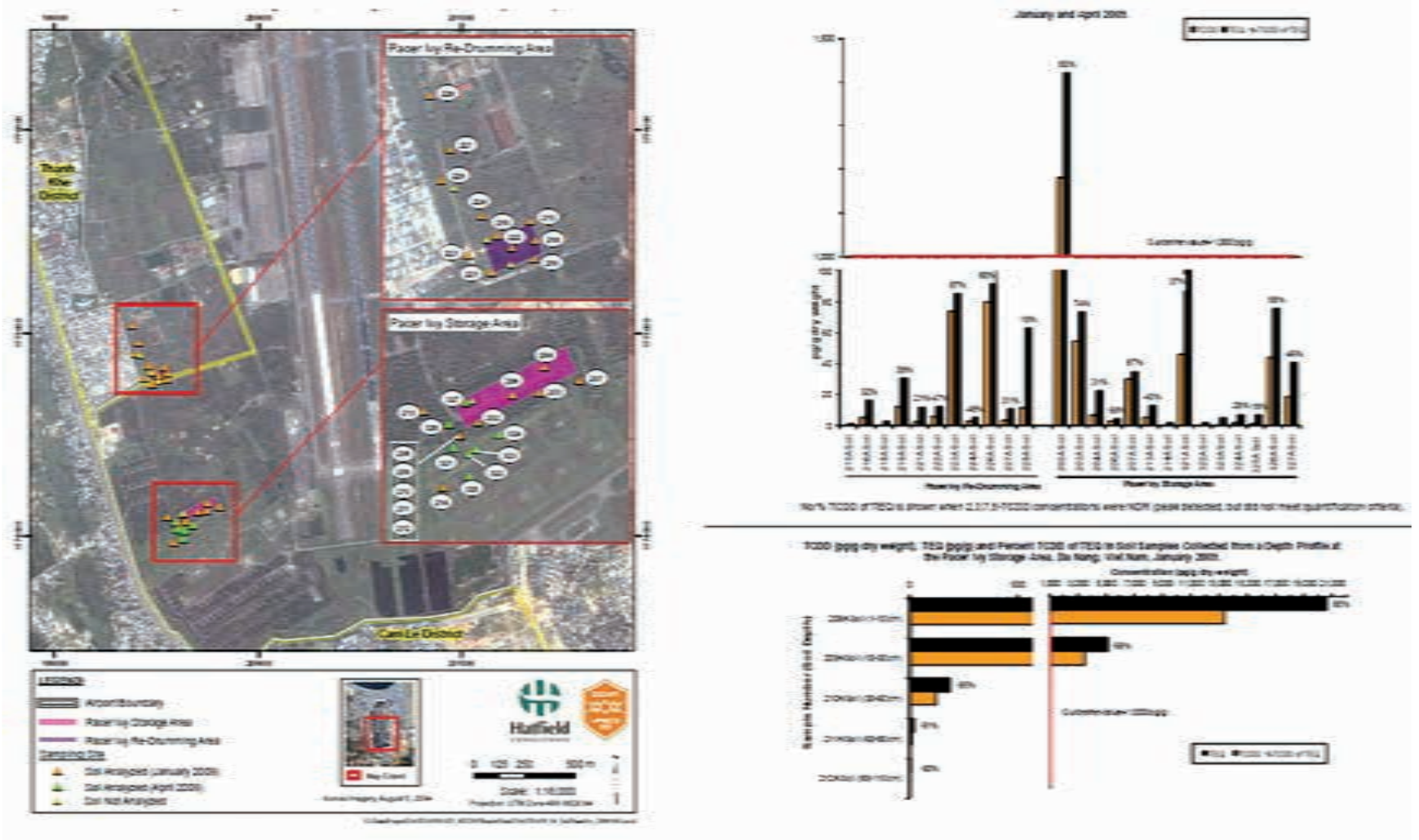

Fig. 3.12. Soil and sediment sampling locations in the Pacer Ivy Storage Area and Pacer Ivy Re-drumming Area, January and April 2009

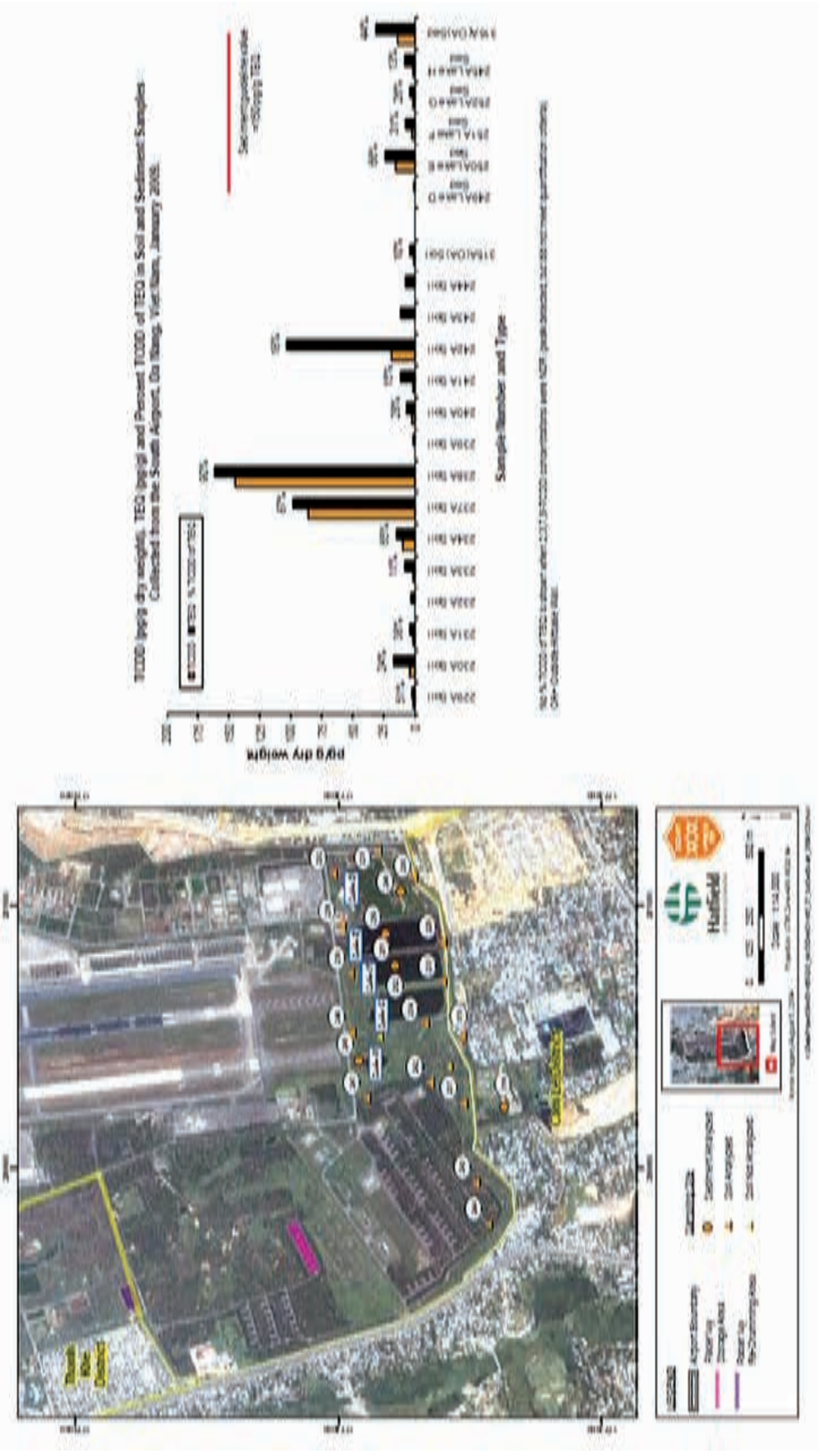

Fig. 3.13. Soil and sediment sampling locations in the south of Da Nang Airport, January 2009

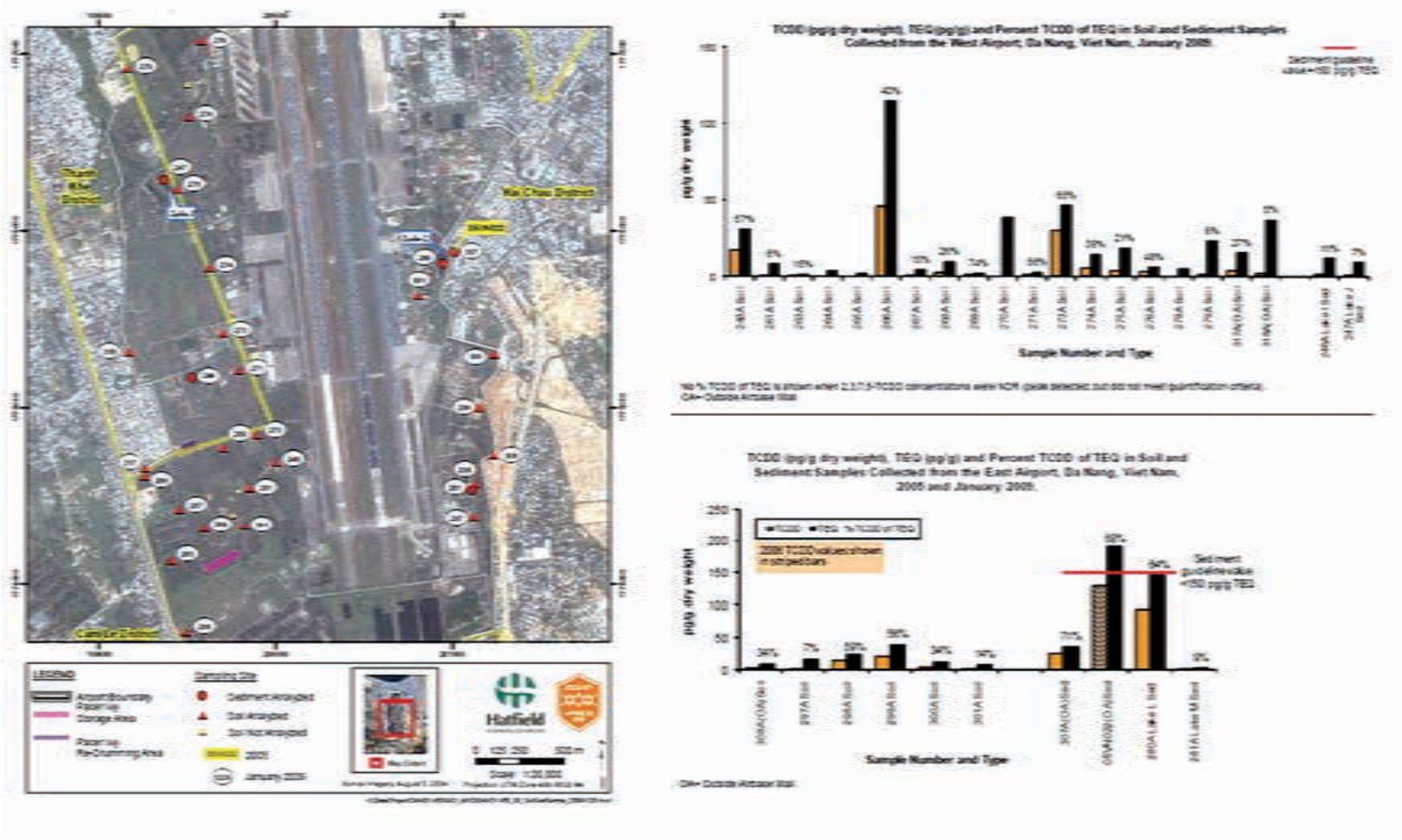

Fig. 3.14. Soil and sediment sampling locations in the central Airport area, 2005 and January 2009

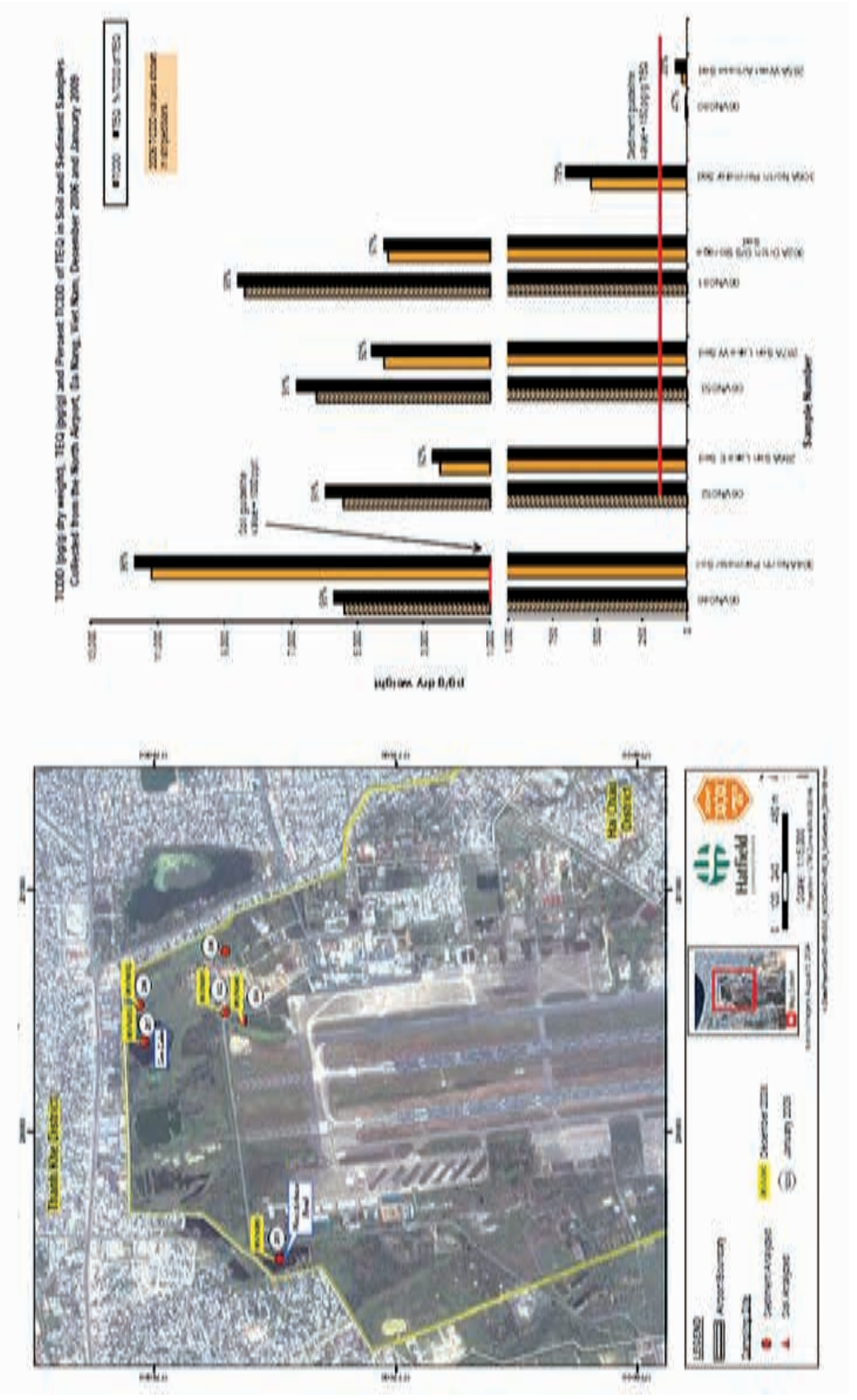

Fig. 3.15. Soil and sediment sampling locations in the north of Da Nang Airport, December 2006 and January 2009

Biological samples

Sen Lake A has the highest level of dioxins in sediments of all water bodies sampled, both inside and outside of Da Nang Airbase. Consequently, fish captured in Sen Lake in the North Airbase area also contained the highest level of TCDD recorded in biological tissues (fat 7,920 pg/g; liver 1,490 pg/g; eggs 1,230 pg/g; and muscle 84 pg/g; Table 3.11; Figure 2.12). In 2009, the fish samples collected from the Ponds in the north of the Airbase had comparatively low TEQ concentrations (4.24 ppt for liver and 0.464 ppt for muscle).

In the Southern Airbase lakes, fish tissue exhibited slightly higher TEQ concentrations than fish tissue analyzed in the central Airbase. The TEQ concentrations in muscle samples were low (<1 ppt) in all samples; however, in fat and liver sample, the TEQ concentrations were higher, ranging from 3.57 ppt in Tilapia liver to 25.4 ppt in Tilapia fat (both samples 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.

Table 3.11.Concentrations of PCDD and PCDF in fish tissue samples (pg-TEQ/g wet weight), 2009

Sample ID	Common Name	Sample Type	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
333A	Crab	Hepato-pancreas	Lake D	NDR 1.31	1.42	NC
253A	Tilapia	Muscle	Lake D	0.551	0.62	88.9
254A	Tilapia	Fat	Lake D	24	25.1	95.6
254B	Tilapia	Liver	Lake D	2.99	3.49	85.7
328AB	Tilapia	Muscle	Lake D	NDR 0.149	0.0758	NC
329A	Tilapia	Fat	Lake D	17.7	19.5	9.08
255A	Tilapia	Muscle	Lake E	NDR 0.148	0.0762	0.0
257A	Tilapia	Muscle	Lake F	NDR 0.069	0.0786	0.0
288A	Tilapia	Muscle	Lake G	NDR 0.111	0.094	0.0
259A	Snake head (1 fish)	Muscle	Lake H	NDR 0.511	0.126	0.0
260A	Snake head (1 fish)	Liver	Lake H	6.96	12.8	54.4
292A	Grass carp (2 fish)	Muscle	Lake J	NDR 0..88	0.0907	0.0
293A	Grass carp (2 fish)	Fat	Lake J	1.32	4.03	32.8
294A	Tilapia	Muscle	Lake J	NDR 0.111	0.0789	0.0
296A	Tilapia	Eggs	Lake J	3.59	5.63	63.8
312A	Tilapia	Muscle	Lake M	0.161	0.234	68.8
313A	Tilapia	Fat	Lake M	3.79	5.64	67.2
314A	Tilapia	Muscle	Lake L	0.755	0.849	88.9
282A	Tilapia (large comp.)	Muscle	Sen Lake	84	88.2	95.2
283A	Tilapia (large comp.)	Fat	Sen Lake	7,920	8,350	94.9
283B	Tilapia (large comp.)	Liver	Sen Lake	1,490	1,540	96.8
284A	Tilapia (large comp.)	Eggs	Sen Lake	1,230	1,290	95.3
309A	Tilapia (small comp.)	Muscle	Sen Lake	39.2	40.9	95.8
311A	Tilapia (small comp.)	Fat	Sen Lake	2,560	2,680	95.5
311B	Tilapia (small comp.)	Liver	Sen Lake	682	703	97.0
290A	Tilapia	Muscle	West Airport Lake	0.359	0.464	77.4
291B	Tilapia	Liver	West Airport Lake	3.48	4.24	82.1

Notes:
NC = Not calculated
ND = Not detected; for total TEQ calculation, if ND, ½ detection level was used
NDR = Non-detection ratio; peak detected but did not meet quantification criteria; for total calculation, NDR was treated as ND

3.3.6. Results of investigation by CDM and Hatfield Consultant in 2010

A survey in Da Nang Airbase was conducted by CDM and Hatfield Consultants in 2010 in the part of Environmental Assessment by USAID. The overall objective of this program was to collect data required to fill gaps in the existing data, to provide information required to complete the engineering designs and specifications for site remediation, and to provide information that would guide decision making related to site remediation. The specific objectives of the sampling effort were to:

- Determine the vertical and lateral extent of dioxin/furan contamination in soil in the Mixing and Loading Area, Storage Area, and Drainage Ditch;
- Determine the vertical and lateral extent of dioxin/furan contamination in sediment of Sen Lake and the eastern wetland;
- Determine chemical concentration baseline conditions for groundwater, surface water, and the proposed landfill site (one of the remedial alternatives included for evaluation in the Environmental Assessment [EA]);
- Determine whether chemicals of potential concern (COPCs) other than dioxins/furans are present in soils and/or sediments that may affect the remedial design, operations and maintenance (O&M) of the remedy, and/or health and safety aspects of the remedy implementation; and
- Determine whether soil properties of the contaminated soil would affect the remedial design.

The survey contributed the better understanding of contamination distribution both vertically and laterally. Groundwater and surface water samples provided baseline data for water hardness, total metal concentration, and VOC, PCB, and PAH concentrations. As for the contaminants of particular concern other than dioxin is arsenic, which ranged from 6 to 328 ppm in the soil and sediment analyzed. The soil property data collected confirmed that the soil and sediment will be compatible with the remediation technology.

Results of this survey are summarized in Table 3.12 and Figure 3.18, 19, 20 below.

Table 3.12.Concentrations of PCDD/PCDF in soil and sediment, January 2010

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
Sen Lake (open water)						
SAP503-1	Sediment	0-15	West Sen Lake	261	309	84.5
SAP503-2	Sediment	15-30	West Sen Lake	33.5	55.6	60.3
SAP503-3	Sediment	30-50	West Sen Lake	1.73	14.7	11.8
SAP504-1	Sediment	0-15	Mid Sen Lake	5,160	5,370	96.1
SAP504-2	Sediment	15-30	Mid Sen Lake	63.3	79.5	79.6
SAP504-3	Sediment	30-50	Mid Sen Lake	51.6	66.8	77.2
SAP505-1	Sediment	0-15	East Sen Lake	41.2	51.2	80.5
SAP505-2	Sediment	15-30	East Sen Lake	1.08	5.3	20.4
SAP526	Sediment	0-15	South Sen Lake	4,030	4,350	92.6
Sen Lake (east wetland)						
SAP501-1	Sediment	0-15	Wetland 'A'	58	72.5	80.0
SAP501-2	Sediment	15-30	Wetland 'A'	44.1	54.5	80.9
SAP510	Sediment	0-15	Wetland 'A'	19.9	23.7	84.0
SAP502	Sediment	0-15	Wetland 'B'	181	192	94.3
SAP513	Sediment	0-15	Wetland 'B'	25	55.2	45.3

Table 3.12.Concentrations of PCDD/PCDF in soil and sediment, January 2010

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
SAP517	Sediment	0-15	Wetland 'C'	3.96	6.96	56.9
SAP519	Sediment	0-15	Wetland 'C'	10.5	22.3	47.1
SAP597	Sediment	0-15	Wetland 'C'	394	570	69.1
SAP520	Sediment	0-15	Wetland 'D'	22.8	31.4	72.6
SAP523	Sediment	0-15	Wetland 'D'	106	121	87.6
Drainage ditch/treatment pond						
SAP527	Sediment	0-15	Weir at Sen Lake	1,780	1,890	15.0
SAP528	Sediment	0-15	Drainage canal at SA	6,770	6,960	97.3
Area between drainage ditch and Sen Lake eastern wetland sampling area						
SAP620	Soil	0-30	SE Sen Lake – N1	569	728	78.2
SAP624	Soil	0-30	SE Sen Lake – S2	1,220	1,620	75.3
Drainage ditch (perimeter)						
SAP626	Soil	0-30	Drainage canal – W2	5,220	5,650	92.4
SAP628	Soil	0-30	Drainage canal – W4	12,200	13,100	93.1
SAP630	Soil	0-30	Drainage canal – W6	47.4	152	31.2
SAP634	Soil	0-30	Drainage canal – E5	236	250	94.4
SAP635	Soil	0-30	Drainage canal – E4	2,190	2,360	92.8
SAP636	Soil	0-30	Drainage canal – E3	627	743	84.4
SAP637	Soil	0-30	Drainage canal – E2	1,640	1,970	83.2
Former Storage Area						
SAP601-3	Soil	60-90	NW Storage area	1,430	1,460	97.9
SAP601-5	Soil	120-150	NW Storage area	47.5	50	95.0
SAP602-3	Soil	60-90	SW Storage area	14,100	14,100	100.0
SAP602-5	Soil	120-150	SW Storage area	726	727	99.9
SAP603-3	Soil	60-90	East Storage area	967	980	98.7
SAP603-5	Soil	120-150	East Storage area	172	180	95.6
SAP640	Soil	0-30	Storage area – N1	722	768	94.0
SAP642	Soil	0-30	Storage area – N3	41,600	41,900	99.3
SAP644	Soil	0-30	Storage area – C1	8,070	8,100	99.6
SAP646	Soil	0-30	Storage area – S1	5,600	5,610	99.8
SAP648	Soil	0-30	Storage area – S3	5,940	6,100	97.4
SAP649	Soil	0-30	Storage area – S4	6,270	6,840	91.7
Former Mixing and Loading Area						
SAP605-2	Soil	30-60	Mid-west MLA	10,700	10,700	100.0
SAP605-4	Soil	90-120	Mid-west MLA	293	296	99.0
SAP606-2	Soil	30-60	Mid-east MLA	NDR 2.76	2.9	NC
SAP606-4	Soil	90-120	Mid-east MLA	NDR 2.45	1.73	NC

Table 3.12.Concentrations of PCDD/PCDF in soil and sediment, January 2010

Sample ID	Sample Matrix	Depth (cm)	Location	2,3,7,8-TCDD (pg/g)	I-TEQ (pg/g)	2,3,7,8-TCDD/I-TEQ (%)
SAP607-1	Soil	0-30	East MLA (perimeter)	11.7	14.6	80.1
SAP606-4	Soil	90-120	East MLA (perimeter)	NDR 8.12	2.57	NC
SAP606-6	Soil	150-180	East MLA (perimeter)	19.9	21.3	93.4
SAP652	Soil	0-30	MLA perimeter – NW2	396	418	94.7
SAP654	Soil	0-30	MLA perimeter – NW4	1,430	1,510	94.7
SAP655	Soil	0-30	MLA perimeter – NW5	321	329	97.6
SAP657	Soil	0-30	MLA perimeter – CW2	13,300	14,100	94.3
SAP658	Soil	0-30	MLA perimeter – CW3	43.1	49.7	86.7
SAP660	Soil	0-30	MLA perimeter – SW1	4,380	4,400	99.5
SAP661	Soil	0-30	MLA perimeter – SW2	6,860	6,930	99.0
SAP662	Soil	0-30	MLA perimeter – SW3	2,590	2,640	98.1
SAP663	Soil	0-30	MLA perimeter – NE1	596	606	98.3
SAP665	Soil	0-30	MLA perimeter – NE3	911	920	99.0
SAP667	Soil	0-30	MLA perimeter – NE5	350	385	90.9
SAP671	Soil	0-30	MLA perimeter – SE1	911	920	99.0
SAP674	Soil	0-30	MLA perimeter – SE4	4.35	6.36	68.4
Proposed landfill site						
SAP610-1	Soil	0-30	Landfill centre	0.504	1.33	37.9
SAP681	Soil	0-30	Landfill west	0.748	2.89	25.9
SAP682	Soil	0-30	Landfill north	1,010	1,260	80.2
SAP684	Soil	0-30	Landfill east	0.386	4.6	8.4
Surface water samples						
SAP701	Water*	Grab	Sen Lake – Mid-lake	NDR 7.34	0.92	NC
SAP702	Water*	Grab	Sen Lake – Outlet	NDR 3.24	0.942	NC
SAP703	Water*	Grab	Drainage canal at SA	90.4	94.1	96.1
Well water samples						
SAP706	Water*	Grab	Well 1 (near NW airport)	NDR 0.754	0.875	NC
SAP708	Water*	Grab	Well 3 (near landfill)	NDR 0.768	0.859	NC

Notes:
NC = Not calculated
ND = Not detected; for total TEQ calculation, if ND, ½ detection level was used
NDR = Non-detection ratio; peak detected but did not meet quantification criteria; for total calculation, NDR was treated as ND
** = water samples in pg/g wetweight*

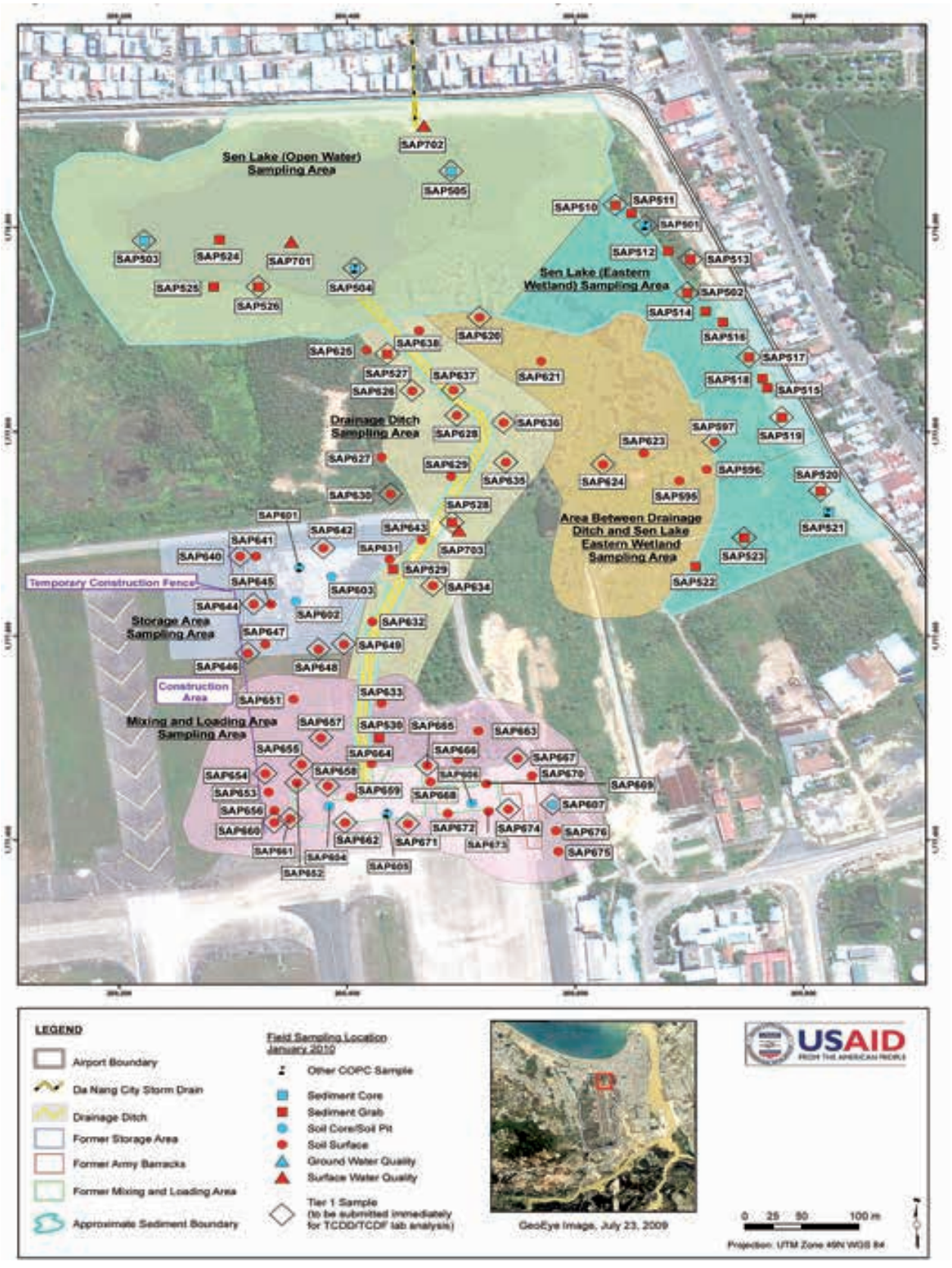

Fig. 3.16. Sampling locations of 2010 surveys in Da Nang Airbase.

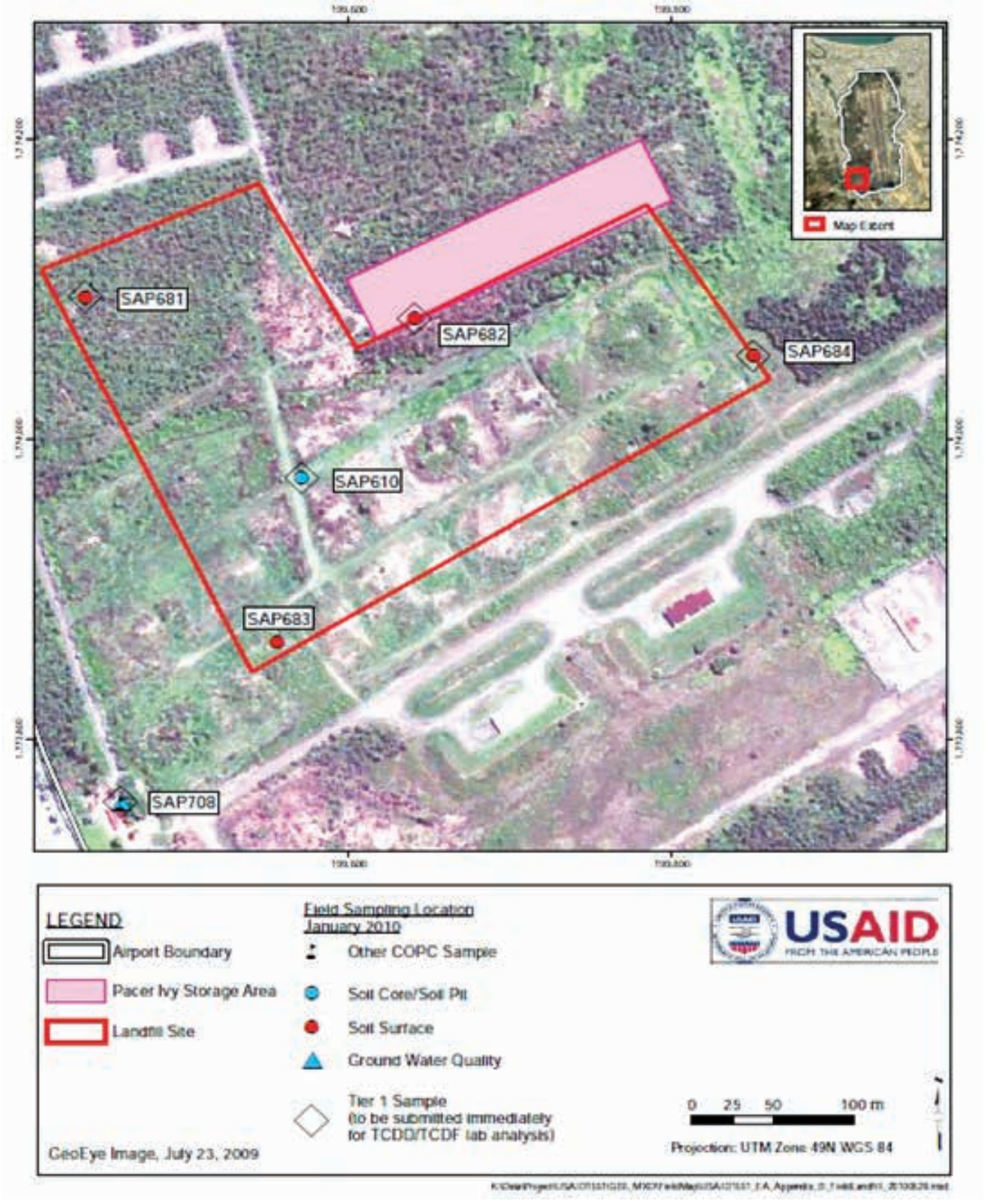

Fig. 3.17. Sampling locations of 2010 surveys in Da Nang Airbase.

Fig. 3.18. Sampling locations of 2010 surveys in Da Nang Airbase.

3.3.7. Results from Z9 study by Ministry of National Defense (2012)

The Z9 study was conducted by MOD that covered 7 former military airbases including Tan Son Nhat, Bien Hoa, Phan Rang, Nha Trang, Tuy Hoa, Phu Cat, and Da Nang. In Z9 study, samples were collected at the south of Da Nang Airbase and former bomb store. Analytical result showed one sample exhibiting high TEQ (1,360 ppt). Besides, other samples exhibited TEQ level under the standard. This result also agrees with other studies by international organization.

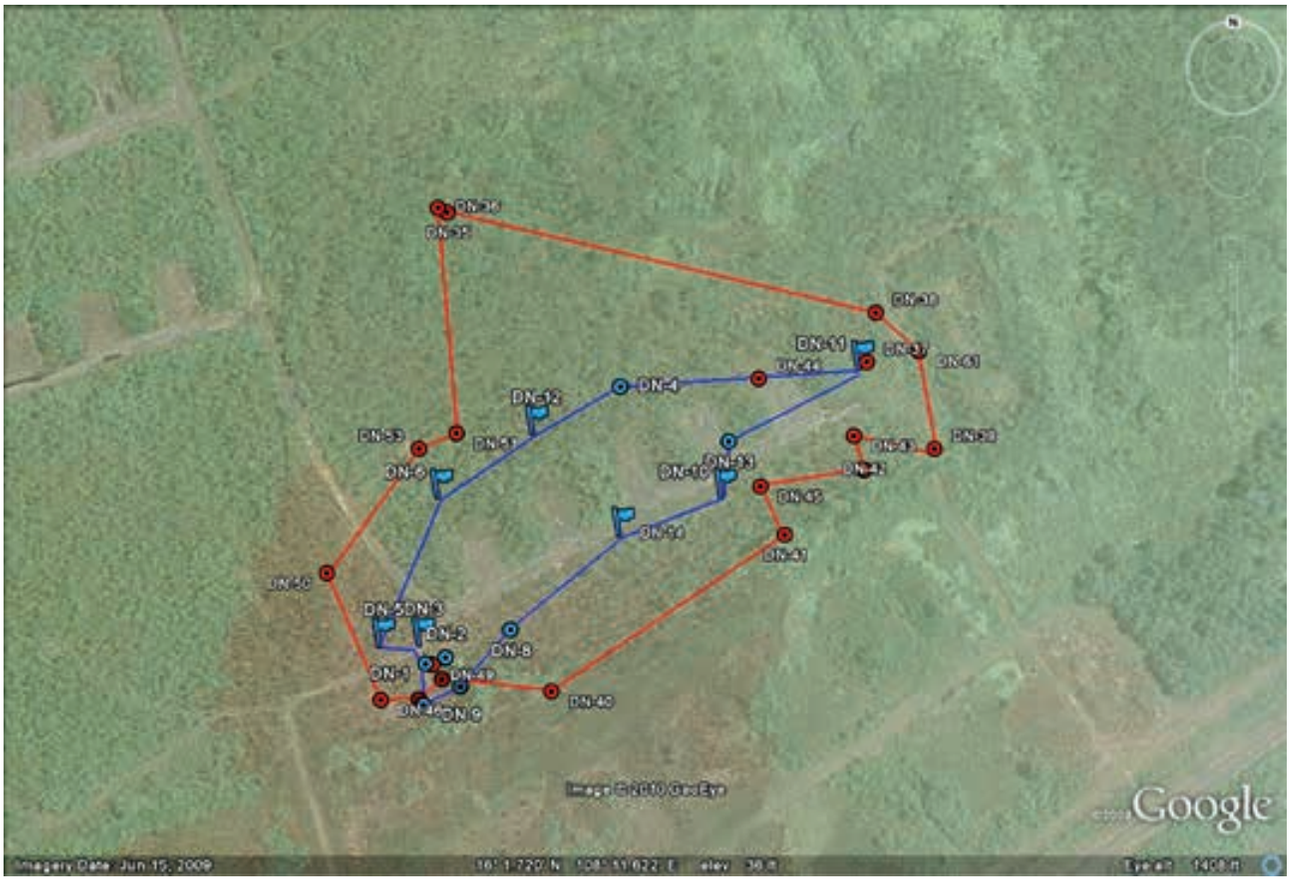

Fig 3.19. Sampling map in Z9 study by MOD (2012)

Table 3.13. Analytical results from Z9 study in Da Nang Airbase, MOD, 2012

No	Sample ID	E Co-ordinate	N Co-ordinate	Depth (m)	TEQ (WHO - TEQ (ppt)
1	ĐN-Đ 3.1	10,819,290	1,602,797	0 - 0.2	7.7
2	ĐN-Đ 5.1	10,819,276	1,602,797	0 - 0.2	80
3	ĐN-Đ 6.1	10,819,305	1,602,842	0 - 0.2	17
4	ĐN-Đ 10.1	10,819,401	1,602,838	0 - 0.2	1,360
5	ĐN-Đ 11.1	10,819,445	1,602,893	0 - 0.2	607
6	ĐN-Đ 12.1	10,819,337	1,602,854	0 - 0.2	103
7	ĐN-Đ 14.1	10,819,361	1,602,833	0 - 0.2	25.7
8	ĐN-Đ 14.3	10,819,290	1,602,778	1 - 1.2	3.4
9	ĐN-Đ 16.1	10,819,170	1,603,466	0 - 0.2	13.8
10	ĐN-Đ 17.1	10,819,176	1,603,424	0.3 -0.5	4.4
11	ĐN-Đ 18.1	10,819,189	1,603,433	0 - 0.2	5.4
12	ĐN-Đ 18.4	10,819,189	1,603,433	0.8 - 1	4.3
13	ĐN-Đ 19.1	10,819,222	1,603,440	0 - 20	3
14	ĐN-Đ 20.1	10,819,153	1,603,444	20 - 40	14
15	ĐN-Đ 21.1	10,819,227	1,603,456	0 - 0.2	15.5
16	ĐN-Đ 22.1	10,819,199	1,603,461	0 - 0.2	4.7
17	ĐN-Đ 24.1	10,819,163	1,603,445	0.8-1.0	8
18	ĐN-Đ 34.1	10,819,154	1,603,416	0 - 0.2	2.4
19	ĐN-Đ 37	108.11.669	16.01.735	0 - 0.2	
20	ĐN-Đ 39.2	108.11.683	16.01.717	2,5	
21	ĐN-Đ 39.1	108.11.683	16.01.717	2	
22	ĐN-Đ 41	108.11.651	16.01.700	0 - 0.2	
23	ĐN-Đ 45.1	108.11.646	16.01.710	0 - 0.2	
24	ĐN-Đ 49.1	108.11.576	16.01.675	0.4	
25	ĐN-Đ 49.2	108.11.576	16.01.675	0.8	
26	ĐN-Đ 50	108.11.554	16.01.694	0.5	
27	ĐN-Đ 53.1	108.11.574	16.01.717	0.5	
28	ĐN-Đ 54.2	108.11.490	16.02.072	1.0	
29	ĐN-Đ 57.2	108.11.538	16.02.068	1.5	
30	ĐN-Đ 59.1	108.11.520	16.02.072	0.6	

Z3 area, Phu Cat Airbase
Photo by Dioxin Project, 2010

Z3 area, Phu Cat Airbase
Photo by Dioxin Project, 2010

PHU CAT AIRBASE

Landfill construction in Phu Cat Airbase
Photo by Dioxin Project, 2011

4. PHU CAT AIRBASE

4.1. Historical record of the contaminated area and geographical, hydrometeorological and soi characteristics of Phu Cat Airbase

US Department of Defense (Conference in Hanoi, August 2007) informed that the Phu Cat Airbase was used during the operation "Ranch Hand" from June 1968 to May 1970. Main activities undertaken at the airbase included: receiving of fuels, storing and loading of herbicides to aircrafts, and washing of the aircrafts after spraying. The quantity of herbicides used at the Phu Cat Airbase was reported to be 17,000 barrels of Agent Orange, 9,000 barrels of Agent White and 2,900 barrels of Agent Blue. Herbicides were transported by ship to Quy Nhon port, and then by truck to the Phu Cat Airbase. There was considerable spillage of herbicides during storage and use. In addition, used barrels with remaining chemicals were brought to residential areas by soldiers, and were used for various domestic purposes. The dioxin-contaminated area in the Phu Cat Airbase includes the former storage area, the former loading area, and the former washing area, etc. Over time, the chemical contamination has spread to the perimeter areas of the airbase.

4.1.1. Geographical features, hydro-meteorological conditions of the Phu Cat Airbase

Geographical position: Phu Cat Airbase is located in Quy Nhon City, at longitude 109°03'57" east and latitude 13°57'48" north. The airbase is bordered by the Cap Tan Commune to the north, Nhon Thanh Commune to the south, highway 1A to the east and An Nhon to the west (28 km NW of Quy Nhon city).

Meteorological conditions: Phu Cat Airbase has a tropical-climate condition, characterized by two distinct seasons: the dry season from February to August, and the rainy season from September to January. The climate is further characterized by a relatively high average temperature of 27.4 °C, and maximum and minimum average temperatures of 36.7 °C and 20 °C, respectively. Occasionally, the temperature reaches up to 40.7 °C (May 1994) and as low as 15.8 °C (March 1986). The relative humidity is 79%, while the minimum average humidity is 51%. Average number of rainy day is 134 days/year, but rainfall is irregular, sometimes reaching up to 80% during the rainy season and the monthly rainfall reaches 152 mm. The average number of sunny days is 214 days/year. The wind blows mainly towards the south and northeast directions. The average number of sunny hours is 208.3 hours/month, while the average number of stormy days is 61.7 days/year.

Hydrographic conditions: With an altitude of 30 meters above sea-level, Phu Cat Airbase is situated 20 km from the Con River. The airbase is located on a hill, and therefore has a good drainage system. The airbase and its surroundings belong to the transition area between the mountains and the plains. There are no records of seismic activity in the area. The soil is composed of weathered rock with much grit and gravel, and a clay layer that is 3.0 to 4.1 meters in depth.

Groundwater can be found at a depth of 6 meters in this area. Aquifers have been formed by the weathered remnant layer. The recharge of well water often reaches 7 m^3/h.

Terrain of lakes and dispersion direction of chemicals/dioxins: the contaminated area is located in the high ground (30 meters above sea-level), at the northeast of the runway, making up two-thirds of the runway length from its south end. During the rainy season, rainwater runs off through the former storage area, the former loading area, the former washing area and their vicinities, and through the buffer area, and carry contaminated materials through a drainage canal into Lake A (Figure 4.1). The water from Lake A then flows into Lake B and Lake C. When heavy rains occur, rainwater from Lake C runs over the dam into the residential area and to nearby farmlands. Lake B and Lake C are used for irrigation.

Lake A covering an area of 9 ha, Lake A is located at 600 meters from the contaminated area, between the runway of the former ammunition storage area and the asphalted road within the airbase. This is a man-made lake, with a small island in the center of the lake. The lake has water all year round; its depth at the end of the dry season (August) is 2 meters at the deepest position. During the rainy season, the depth of the lake reaches up to 4 meters. A drainage system connects Lake A to Lake B, with a gate for regulating the water level of Lake A. Fish are cultivated in Lake A.

Lake B has an area of approximately 7 ha, however the area changes over the seasons of the year. During the dry season,

the lake is virtually dry, and is reduced to a small ditch around which plants develop; the area is used as grassland for grazing cattle. An internal asphalt road and a drainage canal have been constructed between Lake B and Lake C.

Lake C covers an area of approximately 15 ha, and consists of a dam, a spillway, and a drainage canal for irrigation at the end of lake. The animals and plants grow inside the lake.

Drainage system in Phu Cat Airbase:

The airbase is located on an area of high ground, therefore the former storage area, the former mixing and loading area, and the former washing area are not flooded during heavy rains. Rainwater from the north of the airbase and the contaminated area flows downhill, through the buffer area to Lake A, then to Lake B and Lake C. A portion of the water runs through the spillway to perimeter areas. Therefore, toxic chemicals could be dispersed from the buffer area to the system of lakes, and might accumulate in the lakes. Water currently used in the airbase originates from bore-wells near the north end of Lake B.

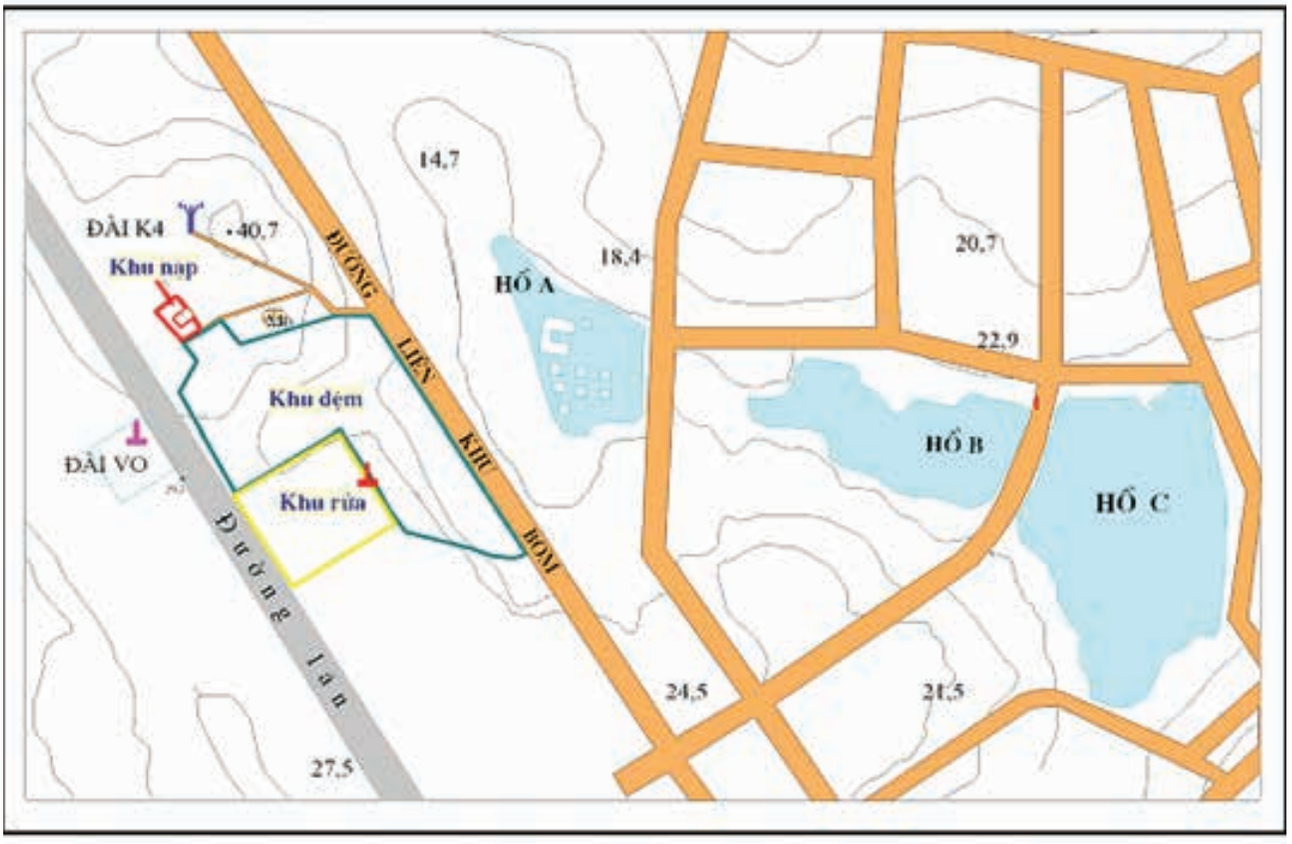

Fig. 4.1. Map of main contaminated area at Phu Cat Airbase.

4.1.2. Previous and current status of the land use

A number of changes have been observed in the airbase:

- Before 1975, people did not inhabit the area around the contaminated area. The American Army was stationed at the southeast end of the runway. The Army of the Republic of Vietnam (ARVN) was stationed at the north end of Lake B, in an area presently occupied by the Vietnamese Army.

- After 1975, the population living around the airbase increased significantly. The land was exploited for cultivation, forming a green belt. The airbase area was separated from the outside by wall and fence.

- At present, a part of the Phu Cat Airbase is used for civil aviation. This area is located approximately 1 km from the contaminated area and is not affected by toxic chemicals/dioxins. When the civil airport was expanded, the soil used for clean fill covered one-third of the former washing area.

Until 2007, plants and animals were raised in the buffer area from the contaminated area to the lakes. In 2007, the army unit plated eucalyptus trees in this area, therefore changing the terrain and vegetable-animal cover of the surface area.

In 2012, the contaminated soil identified by the time was removed and put into a containment landfill located at the northern end of the airbase. Approx. 7,500 m^3 of contaminated soil was contained. The landfill is equipped with water management facility and long-term monitoring program.

4.1.3. Results of some soil parameters

The surface observation: The surface of the contaminated area is located at the top of a steep slope, with over 15% of the surface soil mixed with gravel and sand. The soil has been eroded by rainwater, and therefore, is extremely hard. Vegetative cover is scattered, and mostly consists of shrubs and weeds, so the resistance against erosion is low. During heavy rains, the sloping terrain causes rainwater runoff, carrying small grains of soil and organics from the surface into the lakes.

Soil parameters:

- The land is characterized by lateritic soil, which has a weak capacity to retain water and mineral substances. The percentage of gravel and sand in the soil is high, and the soil has light mechanical composition and low clay content.

- The pH value: The pH value of the soil is low, ranging from 4.42 to 6.0, and is acidic.

- The humus content: The soil has a low organic material content of approximately 0.5% and is low in humus. The ion-exchange ability is low, which is common for soil with little or no fine materials. Iron content in the soil is also low; iron is mainly stored in the composition of rocks. Therefore, soil in the contaminated area is constantly in the process of weathering.

The soil properties of the terrain may facilitate the transport of toxic chemicals/dioxins in the Phu Cat Airbase. The humus content in sediment samples from the lakes ranged from 0.32% to 3.4%; therefore the soil is poor in terms of living organisms.

Fig. 4.2 .Aerial Picture of Phu Cat Airbase

Fig. 4.3. Buffer zones in Phu Cat Airbase

4.2. Dioxin contamination in Phu Cat Airbase and the Vicinity of Phu Cat Airbase

Table 4.1 includes results from all studies on dioxin/furan in Phu Cat Airbase.

Table 4.1.Summary of the dioxin survey projects with the level of contamination (pg-TEQ/g) reported

Project	Location	Sample matrix	Sample number	Range (total TEQs)
Project Z3, 1999-2002	Former Loading Area	Soil	28	nd – 49,500 ppt
	Buffer Zone	Soil	9	nd – 2,450 ppt
		Sediment	3	nd - 420 ppt
	Former Washing Area	Soil	2	18 – 21 ppt
	Lake A	Sediment	10	nd – 88 ppt
		Fish, Snail, Oyster*	6	1.77 – 5.491 ppt
	Lake B	Sediment	5	4 – 196 ppt
	Lake C	Sediment	3	2 – 9 ppt
Committee 10-80 & Hatfield, 2004-05	Outside airbase	Soil	10	0.485 – 169 ppt
		Sediment	8	0.766 – 201 ppt
Office 33& Hatfield, 2008	Former Storage Area	Soil	11	352 – 238,000 ppt
	Former Loading Area	Soil	7	2.6 – 876 ppt
	Buffer (Perimeter Zone)	Soil	5	1.50 – 2,950 ppt
	Former Washing Area	Soil	10	1.85 - 6.23 ppt
	Sedimentation tanks	Sediment	5	4.07 - 127 ppt
	Lake A	Sediment	2	16.0 - 33.7 ppt
	Lake B	Sediment	2	9.81 - 11.3 ppt
	Lake C	Sediment	1	4.5 ppt
	Southeast Corner of Phu Cat Airbase	Soil	11	5.63 - 236 ppt
Office 33& UNDP, 2011	New site	Surface soil	29	0.08 – 89,879 ppt
		Core soil	5	14.7 – 152.2 ppt
	Z3 Area	Soil	21	5.45 - 70,646 ppt
		Core soil	8	2.72 – 37,259 ppt
	Sedimentation tank and surroundings	Sediment	8	1.99-181 ppt
	Pace Ivy	Soil	5	0.17 – 331 ppt
	Landfill	Soil	1	14.8 ppt
Z9 study, MOD,2012	Pacer Ivy	Soil	3	1.29 – 2.61 ppt
	New site (north)	Soil	6	4 – 3,442 ppt

nd = Not detected
**: wet weight basis*

4.2.1. Results of Project Z3 by Ministry of Natural Defense (1999-2002)

The Vietnamese Ministry of Defense implemented the Project Z3 in the contaminated area of Phu Cat Airbase from 1999 to 2002. The Vietnam-Russia Tropical Centre (VRTC) collected 114 soil samples, 39 sediment samples, 3 water samples and 3 biota samples (fish, shellfish, and oyster). A total of 79 samples, including 52 soil samples, 21 sediment samples, 3 water samples and 3 biota samples were analyzed.

Depending on the extent of dioxin contamination, the survey site can be divided into the following areas:

- Highly contaminated area: the area used for storing and loading of toxic chemicals into aircrafts and other vehicles.

- Former washing area: the area used for washing the aircrafts after spraying.

- Buffer area: the area surrounding the former storage area, former loading area, and former washing area to the drainage canal, and the former ammunition storage area to the lakes.

- Lake A, Lake B, and Lake C.

Details of the analytical results are shown in Figures 4.4, 4.5, 4.6 and 4.7. The results indicate that the former storage area and the former loading area were contaminated with the highest concentrations of dioxin (Average: 11,400 ppt I-TEQ, n = 12). The buffer area and the former washing area were found to have much lower concentrations of dioxins, with an average of 269 I-TEQ ppt (n = 9) in the buffer area, and 18 ppt in the former washing area.

In Project Z3, some samples were collected at different depths, up to 150 cm. The results are shown in Table 4.2. The analytical results of dioxins in the Z3 zone showed that the percentage of 2,3,7,8-TCDD was over 90%, indicating Agent Orange as the main source of dioxins.

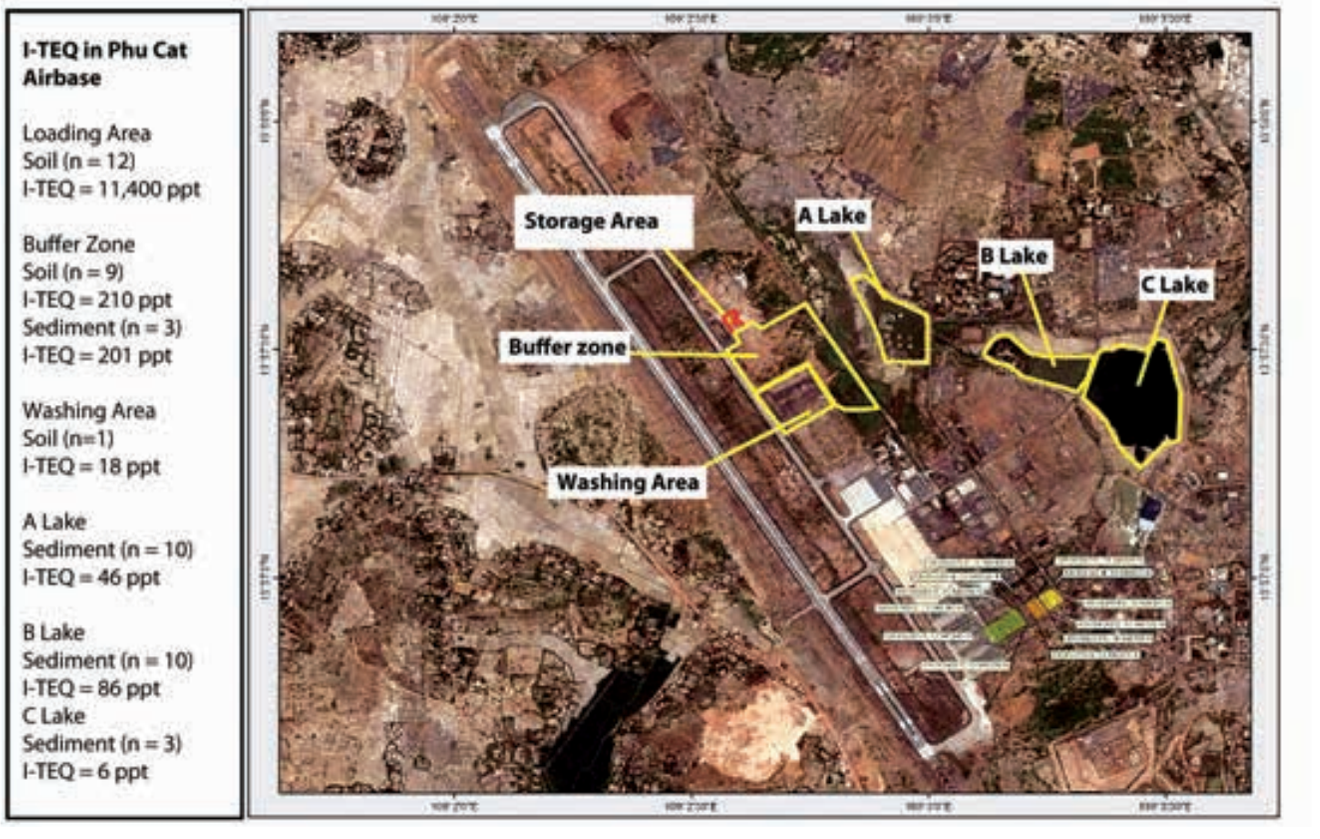

Fig 4.4.Dioxin concentrations (ppt, TEQ) in soils and sediments from Phu Cat Airbase 1999-2002

Fig. 4.5.Dioxin concentrations (ppt, TEQ) in soils and sediments in Phu Cat Airbase, 1999-2002. (Project Z3)

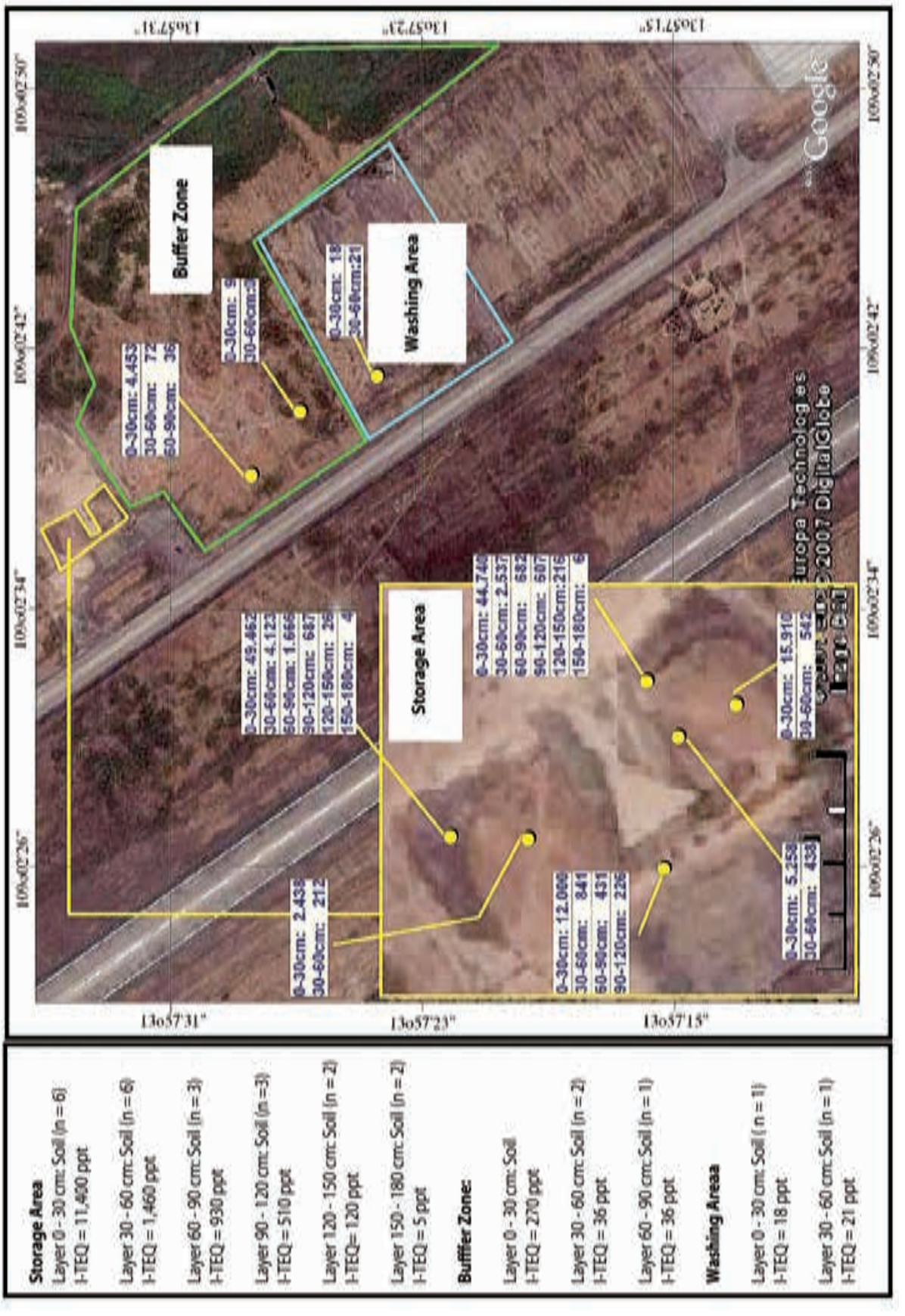

Fig. 4.6. Depth profile of dioxin concentration (ppt, TEQ) in soils from Phu Cat Airbase, 1999-2002. (Project Z3)

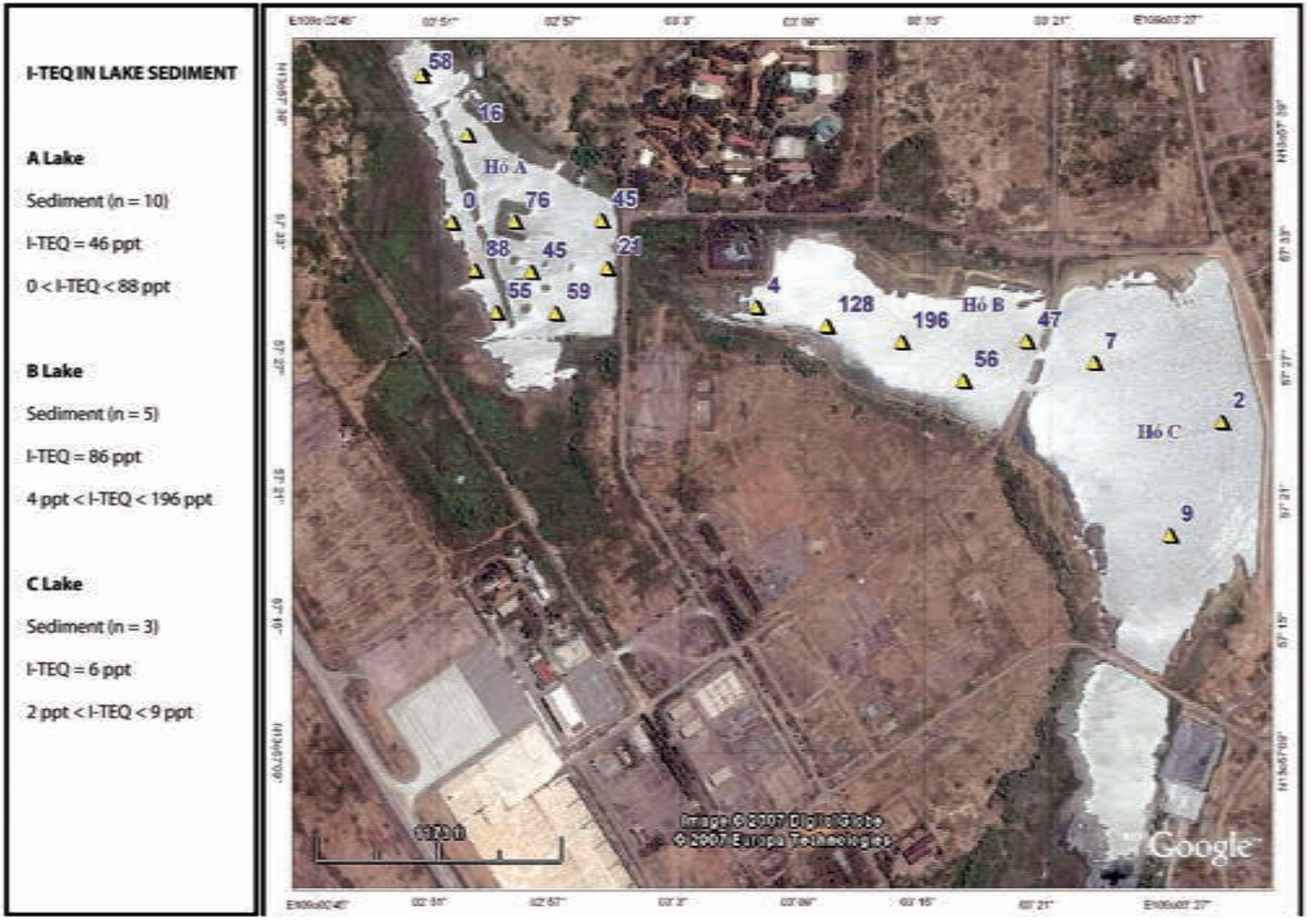

Fig 4.7. The dioxin concentrations (ppt, TEQ) in sediments from lakes in Phu Cat Airbase, 1999-2002 (Project Z3).

Table 4.2. Vertical distribution of dioxins (ppt, TEQ) and Agent Orange (ppm) in soils from the former storage area and the former loading area, Phu Cat Airbase.

No.	Depth (cm)	Dioxin level (ppt TEQ)	Agent Orange 2,4,5-T and 2,4-D level (ppt)
1	0-30	11,367	22.6
2	30-60	1,456	4.8
3	60-90	926	4.8
4	90-120	506	3.5
5	120-150	120	0.3
6	150-180	5	nd

The results indicate that dioxins and Agent Orange were able to penetrate into deeper layers of soils, down to the depth of 120-150 cm. Dioxin concentrations decreased with depth, the dioxin concentration decreased down to 926 ppt at the depth 60-90 cm and a trace level (5 ppt) was found at the depth of 150-180 cm. In the buffer area and the former washing area, concentrations of dioxins were low at a depth of 30-60 cm.

In Project Z3, sediment samples collected from Lake A, Lake B and Lake C were analyzed. The analytical results are shown in Figure 4.7. The concentration of dioxins in Lake A, Lake B and Lake C was low (below 100 ppt) except a few locations in Lake B. Dioxins were not detected in water samples collected from Lake A.

Results of dioxin concentrations in some biota samples collected from Lake A are shown in Table 4.3.

Table 4.3 The dioxin concentrations in some fish samples collected from Lake A

No	Fish	2,3,7,8 – TCDD (I-TEQ) pg/g	Percentage of 2,3,7,8 – TCDD/I-TEQ	I-TEQ (pg/g lipid)
1	Black carp	4.065	59.0	688.1
2	Carp	1.77	50.8	431.4
3	Knifefish	2.921	75.3	2,179.3
4	Major cap	2.54	90.6	1,051.2
5	Tilapia	5.491	65.6	464.7
6	Snail, oyster	6.8		

Source: Report of Project Z3 – Vietnamese Ministry of Defense

Based on the analytical results of dioxins in soil and sediment samples in the Z3 zone, Phu Cat Airbase, it can be concluded that:

- The former storage area and the former loading area were contaminated with high levels of dioxins. Rainwater run-off from these two areas carried toxic chemicals to the buffer area through the culvert to, to some extent, Lake A, Lake B, Lake C, and their vicinities.

- Rainwater from the former washing area also flowed to the end of the buffer area and finally to Lake A.

- Under Project Z3, some biota samples were collected. It was observed that that the concentrations of dioxins in biota samples from Lake A were relatively high, and are above safe consumption limits.

4.2.2. Results of surveys by Committee 10-80/ Hatfield (2004 – 2005)

Previous surveys conducted by Committee 10-80/Hatfield Consultant (2006) in 2004-2005 focused on areas outside Phu Cat Airbase. 20 soil and sediment samples were collected and 18 was sent to analysis. Three soil sites sampled (Sites 8, 48, and 50) exhibited high concentration of TCDD, with TEQs of 201 pg/g, 169 pg/g and 45.2 pg/g, respectively. Relatively high percent TCDD of TEQ occurred at these sites (97%, 97%, and 96%, respectively. Other dioxin congeners and the furans were low and were not significant contributors to overall toxicity.

The highest TCDD level in sediment was recorded at site 8 (194 pg/g). This location was downstream of a sediment treatment basin established by Vietnamese authorities. This site was also downstream of the suspected Ranch Hand operational area on the base. Consequently, sediments from site 8 may represent dioxins resulting from downstream flow of erosion components from the Ranch Hand zone near the runway. Wastewater from this zone ultimately flows into Lake A, which is used for irrigation and aquaculture purposes. It was reported that villagers using the lake could be exposed to dioxin through exposure during work in the paddy-fields, consumption of fish, and perhaps other food items. In this project, the food samples did not collected yet.

Soil Site 48 exhibited a TCDD value of 164 pg/g. Given this area is well removed from the suspected Ranch Hand site, it was suspected that the high TCDD value was related to historical perimeter ground spraying of Agent Orange. Soil Sites 50 and 52 also had slightly elevated TCDD concentrations (43.2 and 22.4 pg/g, respectively). Dioxin levels in soils collected at Phu Cat Airbase exceeded many international guideline values. Therefore, the treated method and overcome the consequences in Phu Cat Airbase.

Table 4.4 2,3,7,8-TCDD, TEQ (pg/g), and percent TCDD of the TEQ value for soil and sediment samples from Phu Cat (2004-2005)

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
04VN008	Sediment	Stream sediment	194	201	97
05VN048	Soil	Natural vegetation	164	169	97
05VN050	Soil	Natural vegetation	43.2	45.2	96
05VN052	Soil	Rice field	22.4	23.9	94
05VN061	Soil	Rice field	4.47	5.14	87
05VN045	Sediment	North Lake B	3.25	5.23	62
05VN057	Sediment	South Lake	2.52	7.19	35
05VN055	Sediment	Pond	2	9.91	20
05VN051	Soil	Cultivated land	0.899	1.34	67
05VN053	Sediment	Ditch	0.783	2.45	32
05VN054	Soil	Rice field	0.753	2.61	29
05VN060	Soil	Small river flood plain	0.748	2.03	37
05VN047	Sediment	Ditch	0.603	1.13	53
05VN058	Soil	Natural vegetation	0.554	1.1	50
05VN059	Soil	Grazing area	0.413	1.14	36
05VN062	Sediment	Water spring	0.338	1.21	28
05VN056	Sediment	Small river	0.301	0.766	39
05VN049	Soil	Natural vegetation	0.191	0.485	39

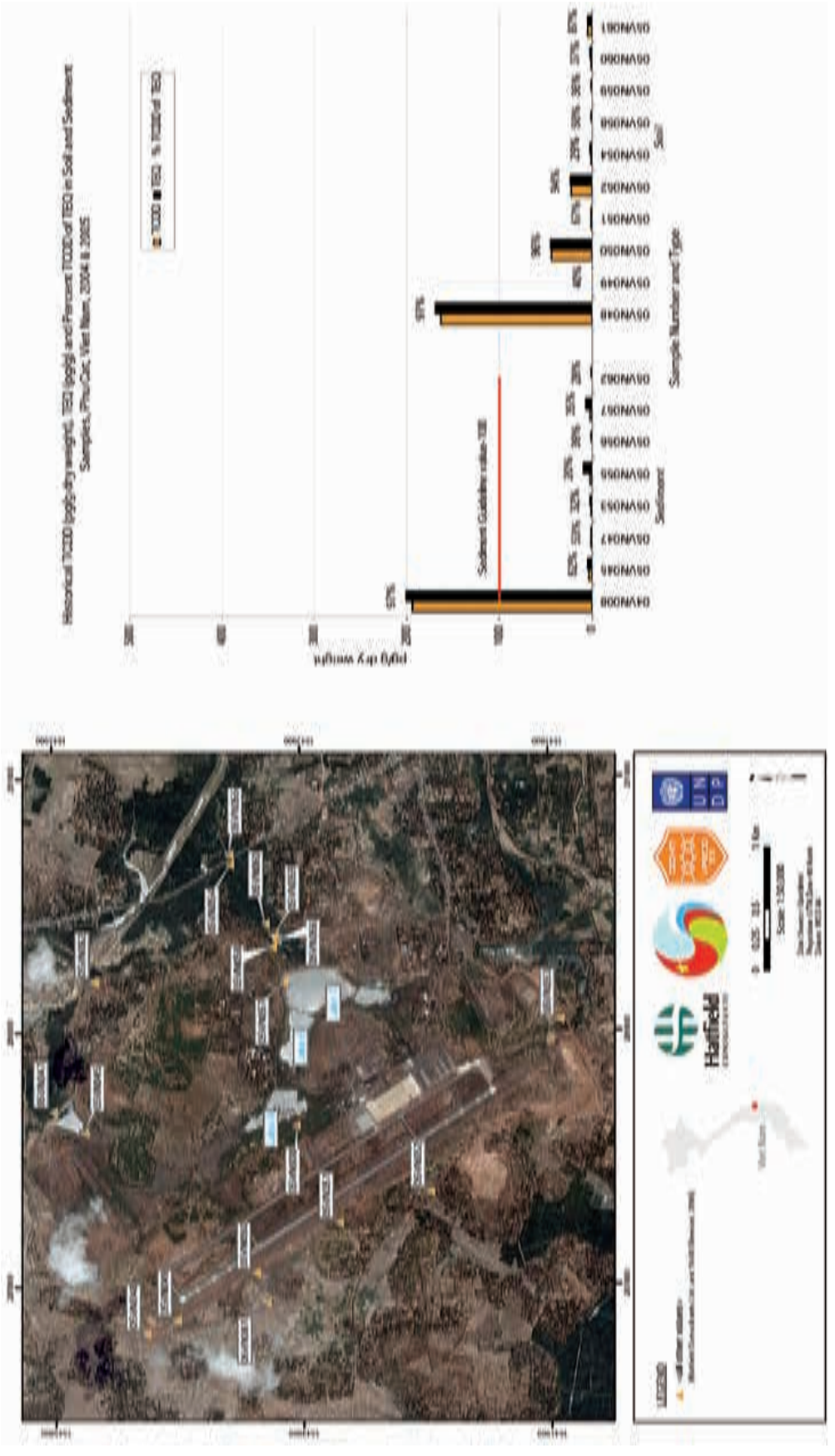

Fig. 4.8. Sampling locations and dioxin concentrations (ppt, TCDD and TEQ) in soils and sediments from Phu Cat Airbase during survey in 2004 and 2005.

4.2.3. Results of survey by Office 33/ Hatfield (2008)

In a survey on dioxin contamination in soils and sediment from Phu Cat Airbase in 2008, 45 samples were analyzed by VRTC and 17 samples were analyzed by AXYS Canada. 7 duplicated samples were analyzed. These included:

- Former Storage Area;
- Former Loading Area;
- Buffer (Perimeter) Area;
- Former Washing Area;
- Water Treatment/Sedimentation Tanks;
- Lakes (Lake A, Lake B, and Lake C);
- Southeast Corner of the Airbase (site information provided by the US Department of Defense).

Former Storage Area

The former Storage Area comprises an area of 8,000 m^2; a concrete apron covers 3,000 m^2 of the total area. In this project, 11 samples collected from the former Storage Area were analyzed (Table 4.5). The dioxins concentrations ranged from 345 pg/g to 236,000 pg/g TCDD. The highest dioxins concentration (sample 08VNPC002-2; 238,000 pg/g TEQ) was collected from beneath the concrete apron at the Former Storage Area, at a depth of 10-30 cm (Figure 4.9).

Most samples collected from the Storage Area exhibited dioxin levels exceeding 1,000 pg/g. TCDD represented over 97% of the TEQ in all samples analyzed, indicating Agent Orange as major source of dioxins.

During the rainy season, it is likely that dioxin-contaminated soils and sediments migrated downstream through the drainage ditch that surrounds the former Storage Area. One soil sample (08VNPC012) collected from a site within the drainage ditch exhibited a TEQ of 30,400 ppt. Downstream of the former Storage Area (samples 08VNPC014-1 and 14-2), dioxin levels decreased significantly, but still in high. Dioxin concentrations in samples collected downstream of the storage area (depths of 0-10 cm and 10-30 cm) were 1,810 ppt TEQ and 16,800 ppt TEQ, respectively. The study concluded that levels of dioxins in the former Storage Area remain extremely high.

Table 4.5 The Dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in the soil samples collected in the Former Storage Area, Phu Cat Airbase, Viet Nam.

No	Sample Code	Sample ID	Depth (cm)	2,3,7,8-TCDD (pg/g = ppt)	WHO-TEQ (pg/g = ppt)**	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08VNPC 001	Soil	0-10	36,400	37,000	98.4
2	08 VNPC 002*	Soil	0-10	73,100	74,500	98.1
3	08VNPC 002-2	Soil	10-30	236,000	238,000	99.2
4	08VNPC 003	Soil	0-10	4,100	4,280	95.8
5	08VNPC 004	Soil	0-10	3,430	3,590	95.5
6	08VNPC 010	Soil	0-10	7,300	7,520	97.1
7	08VNPC 011	Soil	0-10	345	352	98.1
8	08VNPC 012	Soil	0-10	30,000	30,400	98.7
9	08VNPC 012-2	Soil	10-30	549	564	97.3
10	08 VNPC 014-1*	Soil	0-10	1,760	1,810	97.2
11	08VNPC 014-2	Soil	10-30	16,500	16,800	98.2

**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Former Loading Area

The former Agent Orange Loading Area at Phu Cat Airbase covers an area of 13,000 m^2, and is covered by a concrete pad. At the former Loading Area, 7 samples were collected for dioxin analysis (Table 4.6; Figure 4.9). 2,3,7,8-TCDD concentrations in the samples collected from the former Loading Area were significantly lower than that of from the former Storage Area, and ranged from 2.24 pg/g to 850 pg/g. 2 samples collected from the outlet drainage ditch in the Loading Area exhibited the highest concentrations: 840 pg/g TCDD for sample 08VNPC018 (0-10 cm) and 850 pg/g TCDD for sample 08VNPC018-2 (10-30 cm depth). Dioxin levels in other samples were much lower, suggesting that contamination is restricted only to the drainage system at this site.

The dioxin levels in samples collected from this area were all lower than the Vietnamese standard of 1,000 ppt (pg/g) in soil.

Table 4.6 Dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in the soil samples collected in the Former Loading Area, Phu Cat Airbase, Vietnam.

No.	Sample Code	Sample ID	Depth (cm)	2,3,7,8-TCDD (pg/g = ppt)	WHO-TEQ (pg/g = ppt)**	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08VNPC 006	Soil	0-10	16.3	18.6	87.6
2	08VNPC 007	Soil	0-10	47.1	53.6	87.9
3	08VNPC 008	Soil	0-10	3.80	5.36	70.9
4	08 VNPC 017*	Soil	0-10	4.32	4.66	92.7
5	08VNPC 018	Soil	0-10	840	866	97.0
6	08VNPC 018-2	Soil	10-30	850	876	97.0
7	08 VNPC 020*	Soil	0-10	2.24	2.6	86.2

**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

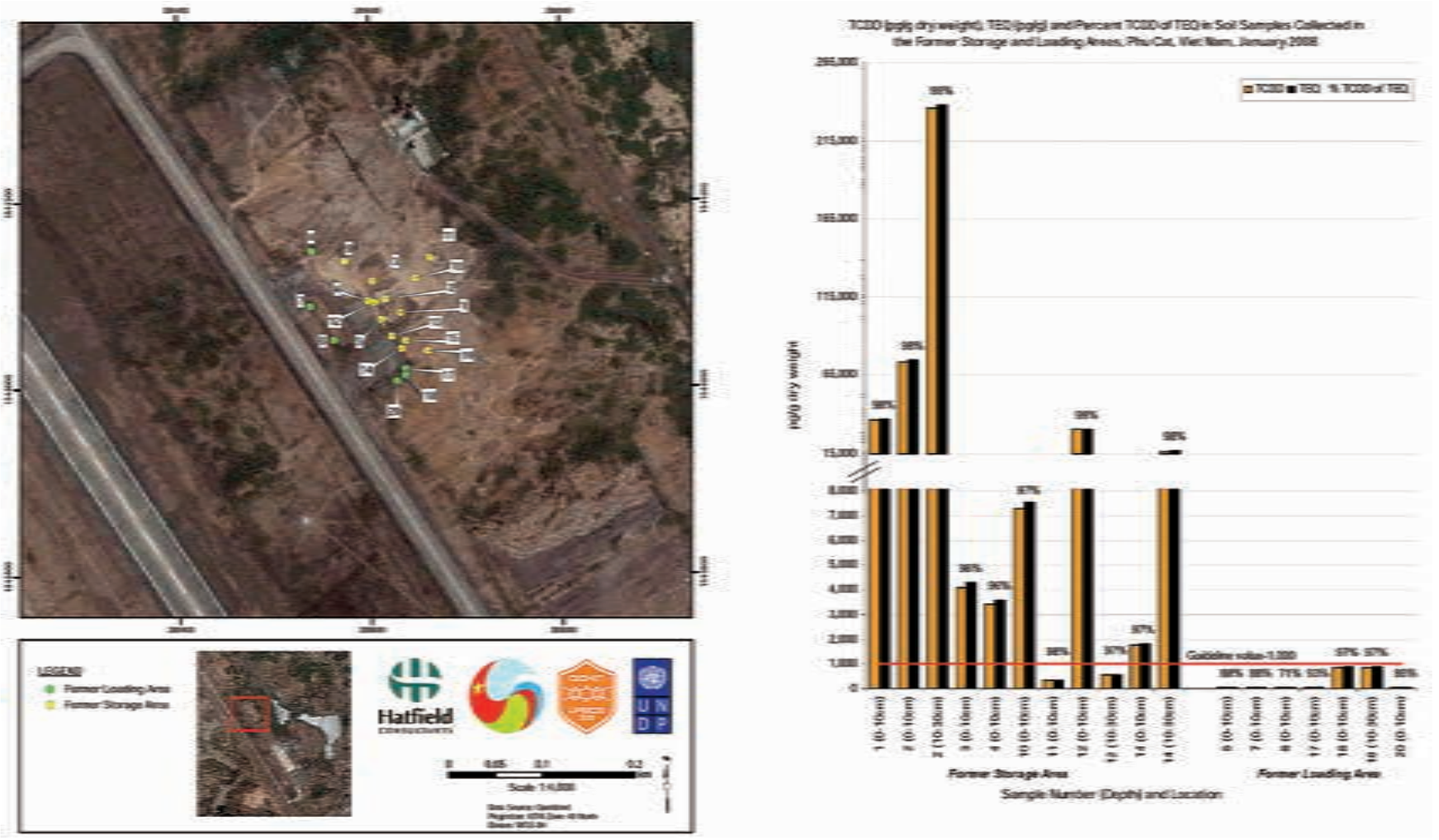

Fig. 4.9 Sampling locations and dioxin concentrations (ppt, TCDD and TEQ) in soils from Former Storage and Loading areas, Phu Cat Airbase, Viet Nam, 2008.

The Buffer Zone

Covering an area of 110,000 m^2, the Buffer Zone is a sloping hill area comprised of numerous natural gutters; the soil is characterized by low quantities of clay and humus.

VRTC analyzed 5 samples during the 2008 program however, one duplicate sample was analyzed by AXYS for QA/QC purposes (Table 4.7). The results indicate that sample 08VNPC016 (collected at the down-slope of the Storage Area, at the edge of the Buffer Zone) exhibited the highest dioxin concentration (2,890 pg/g TCDD), indicating that dioxin-contaminated soil migrate down-slope from this site (Figure 4.10). At the same location where the 08VNPC016 sample was collected from, other sample from Project Z3 exhibited a concentration of TEQ is 4,453 ppt. The results from Project Z3 and the 2008 study suggest that dioxin contamination remains at high concentration in the Buffer Zone, particularly in areas adjacent to the former Storage Area. Percentage of TCDD in total TEQ was >80% for all samples, except the sample 08VNPC052 collected in the Buffer Zone.

Table 4.7.The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in the Buffer Zone, Phu Cat Airbase, VietNam.

TT	Sample Code	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (ppt)	WHO-TEQ (ppt)	2,3,7,8-TCDD /WHO-TEQ (T%)
1	08VNPC 016	Soil	0-10	2,890	2,950	98.0
2	08VNPC 021	Soil	0-10	894	909	98.4
3	08VNPC 046	Soil	0-10	103	109	94.3
4	08VNPC 052	Soil	0-10	0.50	1.50	33.3
5	08VNPC 053	Soil	0-10	28.6	33.3	85.9

*** 1/2 of detection limits (DL) were used for calculating TEQ*

Former Washing Area

Covering an area of 36,000 m^2, the former Washing Area is covered by an asphalt pad and was used for washing vehicles, aircraft, and other herbicide spraying devices (including C-123 Agent Orange spray planes) during the US-Vietnam War. The water from the former Washing Area flowed via a pipe down a steep gradient to sedimentation tanks downstream.

Ten samples from the former herbicide Washing Area were analyzed by VRTC, 3 samples were analyzed by AXYS and 2 duplicate samples were analyzed by both laboratories (Table 4.8). The dioxin analytical results indicate that 2,3,7,8-TCDD concentrations are low, ranging from 0.70 pg/g to 4.10 pg/g TCDD (Figure 4.10). Given the low dioxin concentrations, it appears that remediation is not required at this site.

Table 4.8 The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in the soil samples collected in the Former Washing Area, Phu Cat Airbase, Viet Nam.

No	Sample Code	Sample Matrix	Depth (cm)	2,3,7,8-TCDD (pg/g = ppt)	WHO-TEQ (pg/g = ppt)**	2,3,7,8-TCDD /WHO-TEQ (T%)
1	08VNPC 023	Soil	0-10	1.00	2.74	36.5
2	08 VNPC 024*	Soil	0-10	1.67	1.85	90.3
3	08VNPC 024-2	Soil	10-30	0.90	2.02	44.6
4	08VNPC 025	Soil	0-10	0.70	2.56	27.3
5	08VNPC 026	Soil	0-10	1.20	2.38	50.4
6	08VNPC 027	Soil	0-10	2.10	6.23	33.7
7	08VNPC 040	Soil	0-10	2.90	4.85	59.8
8	08VNPC 041	Soil	0-10	4.10	5.53	74.1
9	08VNPC 050	Soil	0-10	2.40	4.33	55.4
10	08VNPC 051	Soil	0-10	2.30	5.86	39.2

**Samples analyzed by AXYS.*

*** 1/2 of detection limits (DL) were used for calculating TEQ*

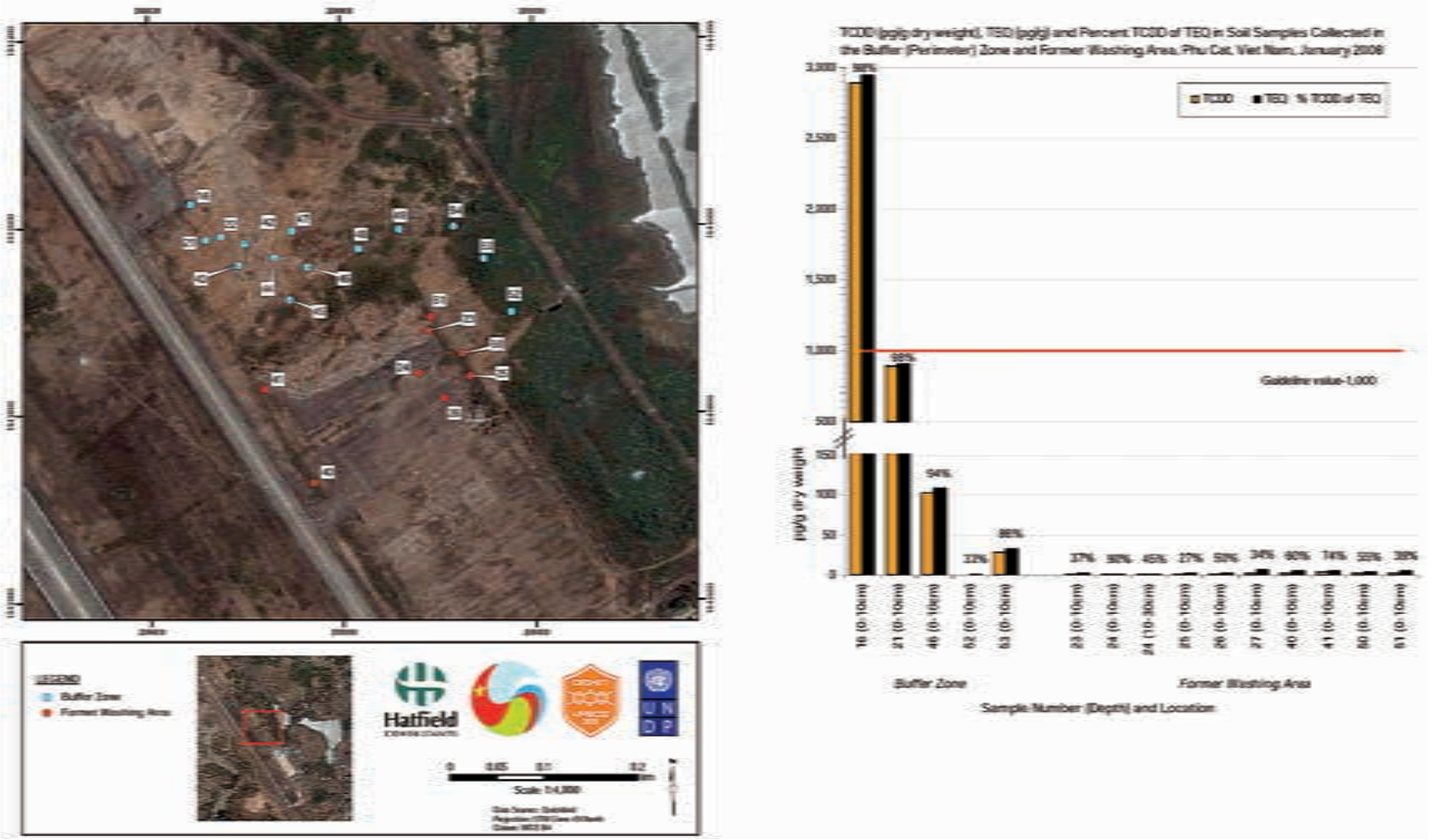

Fig. 4.10. Sampling locations and dioxin concentrations (ppt, TCDD and TEQ) in soils from the Former Washing Area and Buffer (Perimeter Zone), Phu Cat Airbase, January 2008.

Sedimentation tanks

Five sediment samples from the Sedimentation Tanks were analyzed (Table 4.9). The results indicate that dioxin concentrations were generally low, ranging from 3.60 to 127 pg/g TEQ; the sample (08VNPC055) was collected from the Sedimentation Tank closest to the former Storage Area. However, over 90% of the TEQ was TCDD for samples analyzed from the water treatment basins.

Table 4.9.The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in sediments from the sedimentation tanks, Phu Cat Airbase, Viet Nam.

No.	Sample Code	Sample ID	Depth (cm)	2,3,7,8-TCDD (pg/g = ppt)	WHO-TEQ (pg/g = ppt)**	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08VNPC 055	Sediment	0-10	124	127	97.6
2	08VNPC 056	Sediment	0-10	77.4	81.3	95.2
3	08VNPC 057	Sediment	0-10	2.10	3.60	58.3
4	08VNPC 058	Sediment	0-10	109	122	89.3
5	08 VNPC 059*	Sediment	0-10	3.84	4.07	94.3

**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Lakes A, B and C

Lakes A, B and C are the ultimate recipient of drainage water from the Phu Cat Airbase, once it passes through the Sedimentation Tanks and water treatment basin.

Table 4.10 presents the analytical results for samples collected in this study. Five samples were analyzed. Dioxin concentrations were relatively low, ranging from 3.0 to 22.9 ppt TCDD . The fish samples were not collected from this lake in the 2008 study.

Table 4.10.The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in sediments of Lakes A, B and C, Phu Cat Airbase, Viet Nam.

No.	Sample Code	Sample ID	Depth (cm)	2,3,7,8-TCDD (ppt)	WHO-TEQ (ppt)**	2,3,7,8-TCDD /WHO-TEQ (T%)
I	**Lake A**					
1	08VNPC 061	Sediment	0-10	10.9	16.0	68.1
2	08VNPC 062	Sediment	0-10	22.9	33.7	68.0
II	**Lake B**					
1	08 VNPC 063*	Sediment	0-10	7.06	9.81	72.0
2	08VNPC 064	Sediment	0-10	7.1	11.3	62.8
III	**Lake C**					
1	08VNPC 065	Sediment	0-10	3.0	4.5	66.7

**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

Southeast Airbase Corner

This area is located in the southeast portion of the Phu Cat airbase, close to the entrance of the airbase; the site was recommended for analysis by the US Department of Defense (US DOD 2007). This site consists of 3 separate paved areas (A, B, and C), one of which is situated above a concrete bunker. The size of yards A, B and C are approximately 110,000 m2, 90,000 m^2, and 158,000 m^2, respectively. Below those yards are former equipment storage areas, where abandoned electrical equipment was identified.

A total of 12 samples were collected at 12 sites (in each paved area, samples were collected in each of the 4 corners). VRTC analyzed 9 samples (3 samples from each paved area), and AXYS analyzed 3 samples (1 sample from each paved area).

The results indicate that 2,3,7,8-TCDD concentrations in all samples are low, ranging from 0.66 pg/g to 12.2 pg/g TCDD (5.63 to 236 pg/g TEQ) (Table 4.11; Figure 4.12). In all samples, the percentage of TCDD in the TEQ was also low (from 2.0% to 67.8%), indicating that other sources of dioxin contributed to the total TEQ. Therefore, it is highly unlikely that this site was used as a storage or loading area for herbicides, as suggested by the US Department of Defense. Based on geographical surveys of the area, it is more likely that, this area have been used as offices, accommodation, or for other purposes.

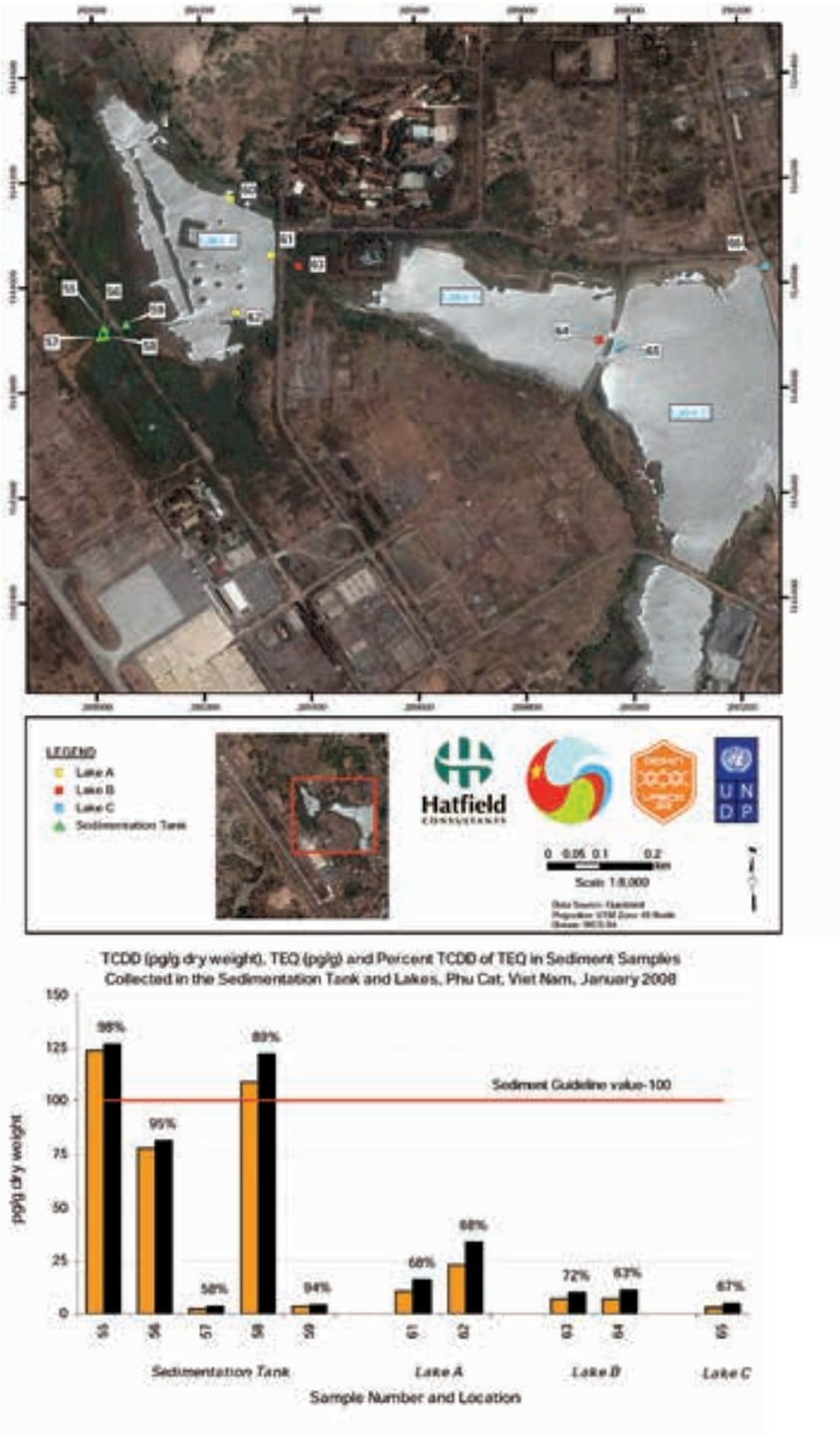

Fig. 4.11. Sampling locations and dioxin concentrations (ppt, TCDD and TEQ) in sediments from Lakes A, B and C and sedimentation tanks, Phu Cat Airbase, Viet Nam, January 2008.

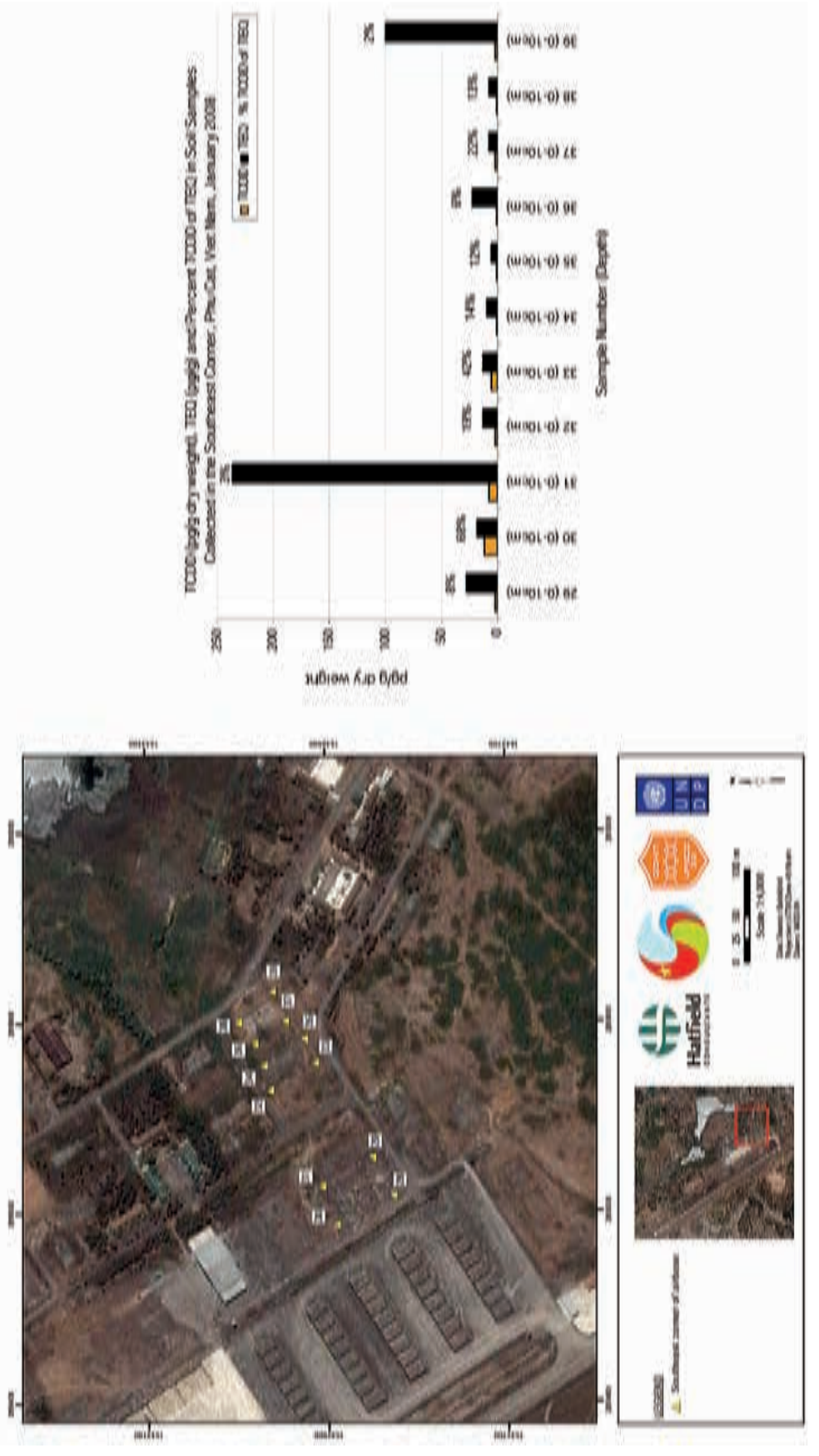

Fig. 4.12 .Sampling locations and dioxin concentrations (ppt, TCDD and TEQ) in soils from the Southeast Corner, Phu Cat Airbase, Viet Nam, January 2008.

Table 4.11.The dioxin (2,3,7,8-TCDD and TEQ; pg/g) concentrations in soils collected from the Southeast Corner of Phu Cat Airbase, Viet Nam.

No.	Sample Code	Sample ID	Depth (cm)	2,3,7,8-TCDD (pg/g = ppt)	WHO-TEQ (pg/g = ppt)**	2,3,7,8-TCDD / WHO-TEQ (T%)
1	08VNPC 029	Soil	0-10	2.20	27.6	8.0
2	08VNPC 030	Soil	0-10	12.2	18.0	67.8
3	08VNPC 031	Soil	0-10	7.50	236	3.2
4	08VNPC 032	Soil	0-10	2.40	12.4	19.4
5	08VNPC 033	Soil	0-10	5.10	12.3	41.5
6	08VNPC 034	Soil	0-10	1.30	9.40	13.8
7	08 VNPC 035*	Soil	0-10	0.66	5.63	11.8
8	08VNPC 036	Soil	0-10	1.40	22.7	6.2
9	08VNPC 037	Soil	0-10	1.70	7.83	21.8
10	08 VNPC 038*	Soil	0-10	0.93	7.07	13.1
11	08VNPC 039	Soil	0-10	2.00	99.6	2.0

**Samples analyzed by AXYS.*
*** 1/2 of detection limits (DL) were used for calculating TEQ*

4.2.4. Results from investigation by Office 33/UNDP (2011)

In this study, 91 samples were collected in Phu Cat Airbase, including 54 surface soil, 12 core soil and 9 sediment samples and 12 QC samples. 83 among 87 collected samples were analysed.

New site – North airbase

TEQ in soil and sediment samples collected in this area ranged from non-detected value to 89,879 ppt TEQ. 5 samples exhibited TEQ exceeding 1000 ppt. High dioxin concentration was detected in small bare area. Meanwhile, samples collected surrounding this area exhibited TEQ level lower than 1,000 ppt. There was 1 sample 11-PC-NS29 located far from the contamination area exhibited high dioxin concentration (607.9 ppt TEQ). In fact, 11-PC-NS29 was collected at the low land receiving rain flow from a large are including New Site. However, dioxin concentration in this area was still lower than standard, but high enough to raise the concern on bio accumulation and human exposure in the future. Therefore, this area needs to be observed and assessed further in future to understand its impact on human beings.

The sample collected in the proposed landfill site (11-PC-NS33) has concentration of 14.8 ppt TEQ and 2,3,7,8-TCDD contribution of 18% in total TEQ, which can be considered as free AO/Dioxin contamination. It should also be noted that the proposed landfill (positioned by 11-PC-NS33) is relatively higher in elevation compared to surrounding areas and currently covered by small eucalyptus trees.

In general, 2,3,7,8-TCDD in most samples collected in New site contributed 95% of TEQ, excluding some samples collected in tentative landfill.

Dioxin concentration by depth in core soil sample collected in New site (11-PC-CORE-2): 114 (0-30 cm), 49 (30-60 cm), 15 (60-90 cm), 27 (90-120 cm) ppt TEQ. However, dioxin concentration is much lower than threshold requiring remediation. In general, dioxin concentration decreased through the depth.

Table 4.12.Concentration of PCDD/Fs (ppt TEQ) in soil from new site, 2011

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
11-PC-NS1	Soil	New site	465	470	98.9
11-PC-NS2	Soil	New site	89,244	89,879	99.3
11-PC-NS3	Soil	New site	3,222	3,355	96.0
11-PC-NS4	Soil	New site	3,802	3,854	98.7
11-PC-NS5	Soil	New site	482	507	95.0
11-PC-NS52	Soil	New site	646	676	95.6
11-PC-NS6	Soil	New site	3,078	3,126	98.5
11-PC-NS7	Soil	New site	183	194	94.4
11-PC-NS8	Soil	New site	1,644	1,682	97.7
11-PC-NS9	Soil	New site	7.00	7.08	98.9
11-PC-NS10	Soil	New site	79	79	99.9
11-PC-NS11	Soil	New site	24	28	85.3
11-PC-NS12	Soil	New site	632	650	97.2
11-PC-NS13	Soil	New site	<1.33	0.06	NC
11-PC-NS14	Soil	New site	1.33	1.33	99.6
11-PC-NS15	Soil	New site	1.33	1.43	93.2
11-PC-NS16	Soil	New site	<1.33	0.08	NC
11-PC-NS17	Soil	New site	1.33	1.36	98.4
11-PC-NS18	Soil	New site	2.67	2.68	99.6
11-PC-NS19	Soil	New site	16.0	16.1	99.7
11-PC-NS25	Soil	New site	342	348	98.3
11-PC-NS26	Soil	New site	191	194	98.1
11-PC-NS27	Soil	New site	52	52	99.1
11-PC-NS28	Soil	New site	12.0	12.2	97.9
11-PC-NS29	Soil	New site	592	608	97.4
11-PC-NS30	Soil	New site	276	283	97.6
11-PC-NS31	Soil	New site	2.00	2.11	94.9
11-PC-NS32	Soil	New site	1.33	1.34	99.6
11-PC-NS33	Soil	Landfill site	2.67	14.8	18.0
11-PC-Core2-1	Soil	New site 0-20	114	116	98.0
11-PC-Core2-2	Soil	New site 20-40	49.1	59.4	82.5
11-PC-Core2-3	Soil	New site 40-60	14.7	14.7	99.9
11-PC-Core2-4	Soil	New site 60-80	26.6	26.6	99.9
11-PC-Core2-5	Soil	New site 80-100	152	152.2	99.9

NC = Not calculated

Z3 area

In this study, samples were collected at the downstream and deeper soil layer to identify the extent of the contamination. TEQ was in range from 5 to 70,646 pg/g. High concentration was detected in 4 sampling areas, including D4, F2, F3 and G2.

One core sample collected at former storage area to the depth of 80cm (11-PC-CORE_1). High dioxin concentration was observed in the surface (0-30 cm; 37,259 ppt TEQ).

Table 4.13.Concentration of PCDD/Fs (ppt TEQ) in soil from Z3 Area, 2011

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
11-PC-B1	Soil	Z3 area	47	49.1	95.9
11-PC-C1	Soil	Z3 area	44	47.1	93.4
11-PC-C2	Soil	Z3 area	<1.33	5.45	NC
11-PC-D1	Soil	Z3 area	52	56.5	92
11-PC-D2	Soil	Z3 area	312	317	98.3
11-PC-D3	Soil	Z3 area	837	850	98.43
11-PC-D4	Soil	Z3 area	11,211	11,546	97.1
11-PC-E1	Soil	Z3 area	356	363	98.2
11-PC-E2	Soil	Z3 area	84	90.4	93
11-PC-E3	Soil	Z3 area	8.00	8.92	89.7
11-PC-F1	Soil	Z3 area	80	85	94.1
11-PC-F2	Soil	Z3 area	1,824	1,980	92.1
11-PC-F3	Soil	Z3 area	70,434	70,646	99.7
11-PC-F5	Soil	Z3 area	468	481	97.3
11-PC-F6	Soil	Z3 area	16	19.1	83.7
11-PC-G1	Soil	Z3 area	307	309	99.5
11-PC-G2	Soil	Z3 area	952	965	99.7
11-PC-G3	Soil	Z3 area	248	256	97
11-PC-G4	Soil	Z3 area	434	445	97.5
11-PC-G5	Soil	Z3 area	8.00	9.06	88.3
11-PC-G6	Soil	Z3 area	828	852	97.2
11-PC-Core1-1	Soil	Z3 area 0-20	36,923	37,259	99.1
11-PC-Core1-2	Soil	Z3 area 20-40	62	62	90.0
11-PC-Core1-3	Soil	Z3 area 40-60	34	34	70.9
11-PC-Core1-4	Soil	Z3 area 60-80	423	423	98.4
11-PC-Core3-0	Soil	Z3 area 0-15	11.76	13.6	86.5
11-PC-Core3-02	Soil	Z3 area 0-15	32.0	35.5	90.1
11-PC-Core3-1	Soil	Z3 area 15-35	4.00	11.0	36.4
11-PC-Core3-2	Soil	Z3 area 35-55	<1.33	2.72	NC

NC = Not calculated

Sedimentation tank and vicinities

Eight samples were collected in sedimentation tank and surrounding low lands. Analytical results showed that one of eight samples exhibited TEQ higher than standard for dioxin in sediment (150 ppt TEQ). Three samples from the other side of the road low dioxin concentration, maybe because of the low dioxin contamination in this area, or the high volume of sediment and water dilute dioxin concentration in lake.

Table 4.14.Concentration of PCDD/Fs (ppt TEQ) in sediment near Z3 area, 2011

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
11-PC-SE-00	Sediment	Sedimentation tank	176	181	97.2
11-PC-SE-01	Sediment	Sedimentation tank	22.6	23.0	98.2
11-PC-SE-02	Sediment	Sedimentation tank	28.5	29.0	98.2
11-PC-SE-03	Sediment	Sedimentation tank	61.8	66.7	92.6
11-PC-SE-04	Sediment	Sedimentation tank	48.7	53.3	91.3
11-PC-SE-05	Sediment	Sedimentation tank	1.98	1.99	99.5
11-PC-SE-06	Sediment	Lake A	9.9	10.0	99.3
11-PC-SE-07	Sediment	Lake A	23.8	28.9	82.2
11-PC-SE-08	Sediment	Lake A	5.94	13.3	44.7

Pacer Ivy Area

Five samples collected in low land area. Dioxin concentration was ranging from 0.2 to 331 ppt TEQ. However, TCDD only contributed few percentages in TEQ. Therefore, this area may not be contaminated by Agent Orange. Odor in this area may be from diesel oil used by army.

Table 4.15. Concentration of PCDD/Fs (ppt TEQ) in soil at Pacer Ivy site, 2011

Sample ID	Sample Type	Location	TCDD (pg/g)	TEQ (pg/g)	% TCDD of TEQ
11-PC-RW1	Soil	Pacer Ivy	<1.33	0.93	NC
11-PC-RW2	Soil	Pacer Ivy	<1.33	0.17	NC
11-PC-RW3	Soil	Pacer Ivy	<1.33	87	NC
11-PC-RW4	Soil	Pacer Ivy	<1.33	181	NC
11-PC-RW5	Soil	Pacer Ivy	4.00	331	1.2

NC = Not calculated

Figure 4.13. Sampling point at Phu Cat Airbase in study by Office 33/UNDP, 2011

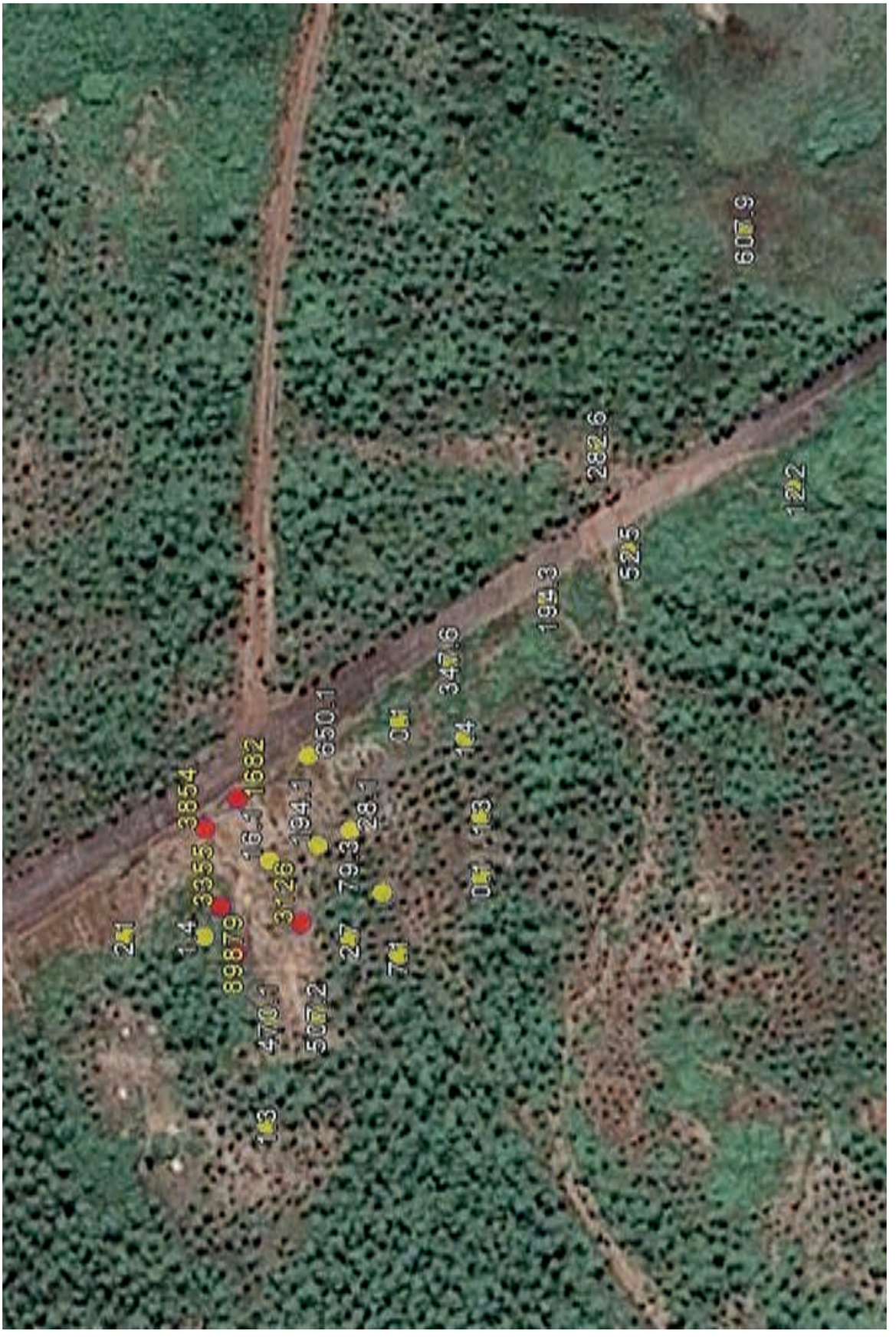

Figure 4.14. Distribution of TEQ concentration on the new site and downstream areas (red dots for above 1,000 ppt)

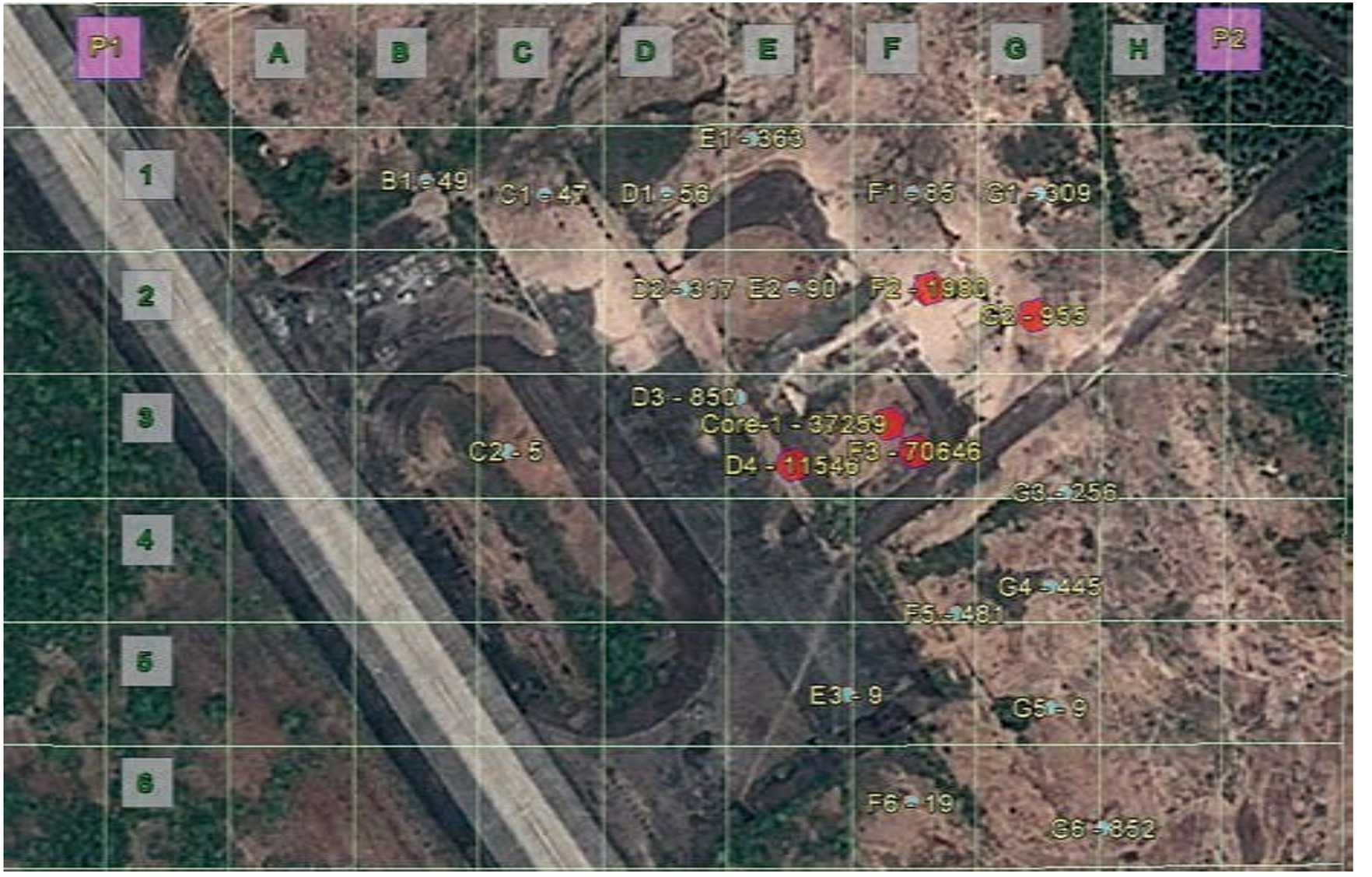

Figure 4.15. Distribution of dioxin concentration (ppt TEQ) in Z3 area (Marked by Name – Concentration; the study in 2011)

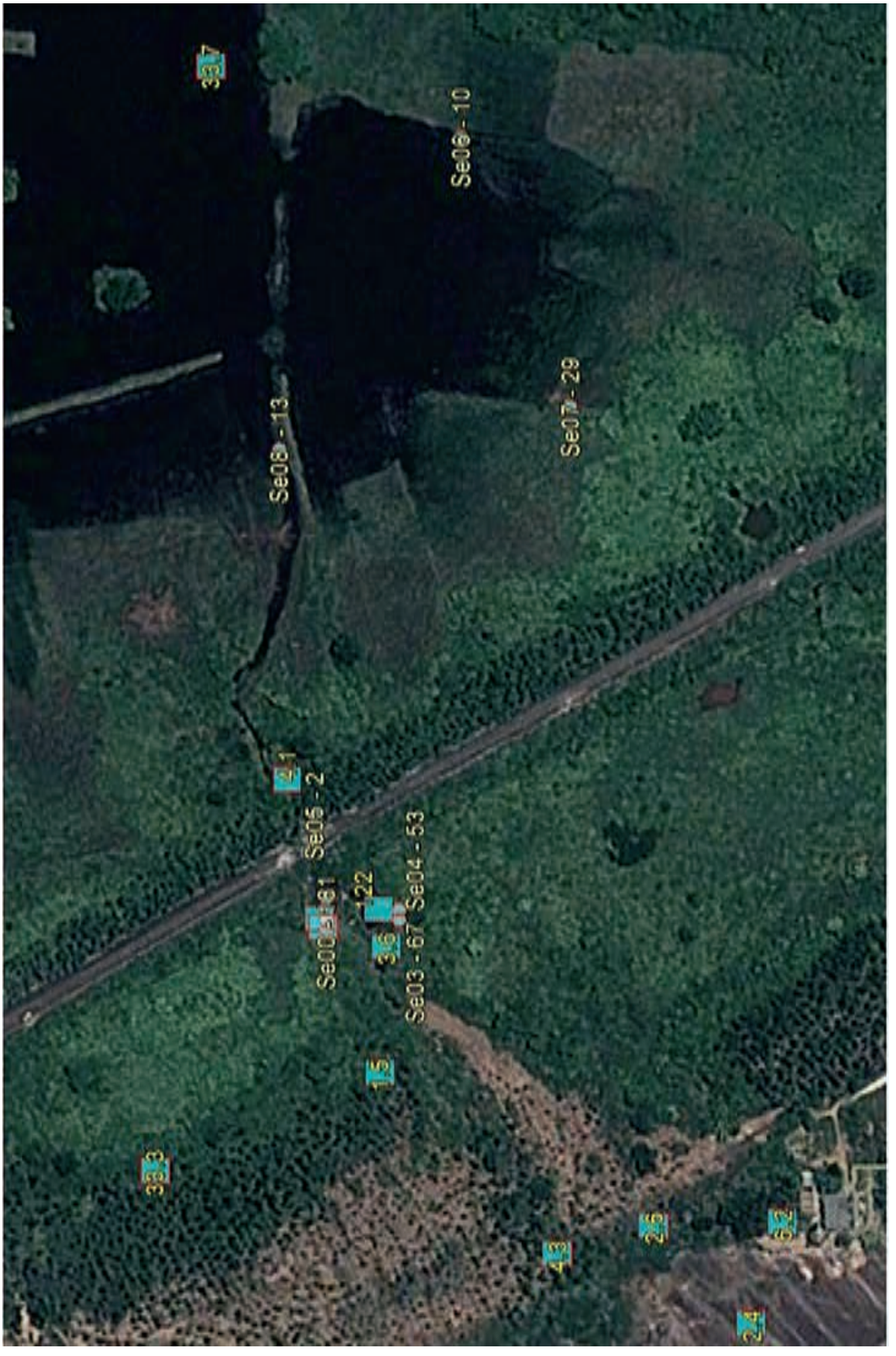

Figure 4.16. Comparison of dioxin levels in sediment and lowland samples (survey 2011 is circle points and survey in 2008 is square points – marked by concentration only)

Figure 4.17. Comparison of dioxin levels in soils in and nearby the suspected Pacer Ivy site (survey 2011 is triangle points and survey in 2008 is square points)

4.2.5. Results from Z9 study by MOD (2012)

The Z9 study was conducted by MOD that covered 7 former military airbases including Tan Son Nhat, Bien Hoa, Phan Rang, Nha Trang, Tuy Hoa, Phu Cat, and Da Nang. In Phu Cat, samples were collected from 2 locations, one newly disclosed site north of Z3 and the other former Pacer Ivy site. After analyses, TEQ in most of samples collected in this area was not higher than standard. Only 2 samples exhibited high TEQ concentration, 1-3.44 time higher than standard value of 1,000 pg-TEQ/g. This area is currently used to cultivate trees with high with high slop, soil layer structure did not differ to other area, laterite is the main component.

Table 4.16.Results from Z9 study, MOD, 2011

STT	Sample ID	E Co-ordinate	N Co-ordinate	Depth (m)	TEQ (WHO - TEQ (ppt)
1	PC-Đ 2.3	109.05.280	13.94.812	0.4 -0.6	1.7
2	PC-Đ 5.1	109.05.270	13.94.837	0 – 0.2	1.29
3	PC-Đ 16.1	109.04.181	13.96.561	0 – 0.2	2.61
3	PC- Đ19.1	109.02.484	13.57.941	0.2	3,442
4	PC-Đ 19.2	109.02.484	13.57.941	0.8	15
5	PC-Đ 21.3	109.02.494	13.57.940	1.0	4
6	PC-Đ21.2	109.02.494	13.57.940	0.3	128
7	PC-Đ21.1	109.02.413	13.57.940	0 – 0.2	1,052
8	PC-Đ 22.2	109.02.499	13.57.944	0.3	9.17
9	PC-Đ 24.2	109.02.153	13.57.937	0.5	
10	PC-Đ 26.3	109.02.505	13.57.948	1.0	
11	PC-Đ 29	109.02.505	13.57.943	0 – 0.2	
12	PC-Đ 30	109.02.507	13.57.940	0 – 0.2	

Fig 4.18. Z9 survey site north of the airbase newly discovered at Phu Cat by MOD, 2012

Fig 4.19. Z9 survey site at former Pacer Ivy in Phu Cat by MOD, 2012

5. GENERAL EVALUATION

5.1. Bien Hoa Airbase

Z1 Area and surrounding area

Results from investigation Z1 and program 33 by MOD showed that dioxin concentration in soil and sediment in Z1 area were very high with the highest TEQ of 410,000 ppt in soil and 5,470 ppt (dry weight) in sediment. In the following investigation in 2004-2005, dioxin concentration was again detected high in some sediment samples collected in Lake 2, the highest concentration in sediment sample was 833 ppt TEQ. In the investigation in January, 2008, dioxin contamination in Z1 area was also found very high with the high TEQ of 262,000 ppt.

In 2009, MOD completed remediation in Z1 by landfill method which isolated 4 hectares of heavily contaminated dioxin from 1.2 to 1.4 m in depth. There were 3 lots of 3.384 m^3 applied micro technology which named "active landfill", developed by Institute of Biology, Vietnam Academy of Sciences and Technologies (VAST).

Most of analyzed samples in Z1 area in study 2010 by Hatfield Consultant and Office 33 exhibited low TEQ concentration, the highest TEQ was 3,120 ppt. This proves that remediation effort by Vietnam is effective. However, this perimeter of Z1 area required more study, especially by depth.

Soil and sediment samples in ponds and lakes in Z1 area exhibited dioxin concentration exceeding standard: Lake 1 (2,240 pg-TEQ/g), Lake 2 (833 pg-TEQ/g), Gate 2 Lake (508 pg-TEQ/g). These lakes is used for aquaculture and residents consumes vegetable and fish from this lakes.

South of Airbase

This area was researched by Hatfield/Office 33 in 2008 and 2010.; and by MOD in 2012 in Z9 Project. Results showed that dioxin contamination in this area is at medium level, but there were some point at high to very high contamination. Meanwhile, the depth of contamination was 60 cm, and in 1 ha area.

Pacer Ivy Area

Up to 2013, there have been 4 researches in this area (2008, 2010, 2011, 2012), total amount of soil samples collected in these 4 researches were 94 samples. Dioxin contamination was medium and high, and very high at some points. The sediment in neighboring lakes and ponds were analyzed and numbers of lakes exceeded the acceptable dioxin levels. The survey by Office 33/UNDP (2011) discovered the extent of the contamination and it might have spread beyond the airbase boundary.

This contaminated area is hydraulically isolated from surrounding clean area by retaining wall and drainage ditch, which will reduce further spread of contamination to downstream. The work will be completed in 2013.

North and East perimeter of Airbase

Elevated dioxin was detected at a few locations at north and east perimeter of the airbase. They are far isolated from known contamination such as Z1 and Pacer Ivy, thus unlikely have been spread from these sites. Fish ponds and agricultural activities are ongoing at these areas, which may cause direct exposure to the field workers.

5.2. Da Nang Airbase

All Agent orange/dioxin contaminated sites were identified at Da Nang Airbase prior to the full-scale remediation: storage area, washing area loading area and a few other areas. The highest TEQ in soil recorded was 365,000 ppt in 2006 in the sample collected at former mixing and loading area, this TEQ value far exceeded the standard for dioxin

in soil (1,000 ppt). Collectively, the concentrations of total dioxins and furans indicate extremely high contamination, and confirm the northern end of Da Nang Airbase as a significant dioxin hot spot. The southern end of Da Nang Airbase exhibits limited dioxin contamination.

Former Mixing and Loading Area (MLA), Storage Area (SA) and Drainage Ditch

Dioxin contamination in these areas is the highest in the Airbase. The contamination reaches 150 cm deep and even more at some locations. Drainage ditch carries contamination from MLA and SA to Sen Lake.

Lakes and Ponds

Following rainwater run-off direction, dioxins has greatly accumulated in Sen Lakes (sediment, aquatic animals and plants). Sen Lake A is highly contaminated and requires treatment. Concentrations of dioxins in sediment, aquatic animal, and plant in Lakes B and C were lower and below 100 ppt. The aquatic animals and plants in Sen Lake A were contaminated with high dioxin concentrations, exceeding guideline values. Therefore, all fishing and harvesting of aquatic organisms from this site has been banned.

In the area outside of the airbase, dioxin concentrations in Xuan Ha Lake, 29-3 Lake, Han River, Cam Le River, Phu Loc River, were relatively low and lower than internationally accepted guideline values.

Eastern Wetland adjacent to Sen Lake also exhibited elevated dioxin around a few hundred ppt level but the sampling was very limited in this large area. A significant portion of the Eastern Wetland was not accessible due to the difficult terrain.

Pacer Ivy Area

Pacer Ivy storage area was surveyed in a few surveys. Some comtanination has been identified at a few samples with the highest concentration of 20,600 pg-TEQ/g. Depper soil (>30 cm) had lower TEQ concentration. Pacer Ivy Re-drumming area did not exhibit elevated level of dioxin.

The Da Nang hotspot is under full-scale remediation by USAID. All known contamination will be remediated by In-pile Thermal Desorption (IPTD) technology by 2016. The estimated volume of treating soil and sediment are approx. 73,000 m^3. US Government has commited full responsibility to complete the remediation at Da Nang.

5.3. Phu Cat Airbase

The US army used Phu Cat Airbase for the Ranch Hand Campaign from 1968 to 1972. The survey results showed that the former storage area at Phu Cat Airbase was contaminated with high levels of dioxin and the dioxin concentrations equivalent to concentrations in hot spots of the Da Nang Airbase. The following conclusions can be made regarding the status of dioxin contamination in Phu Cat Airbase:

- Dioxin concentrations in the Storage Area was extremely high (to 236,000 pg/g TCDD), and were comparable to those found at Bien Hoa and Da Nang.
- In the Loading and Washing Areas, the dioxin concentrations were considerably lower than that of in the Storage Area. Similarly, samples collected from the Buffer Area, including the sedimentation tank, and Lakes A, B, and C, all revealed relatively low levels of dioxin except a few locations with the dioxin level exceeding national standard.
- Samples collected from the recommended areas for investigation by the US Department of Defense (southeast Airbase Corner), indicated as former Pacer Ivy operation site, contained low levels of dioxin and a low percentage of TCDD to total TEQ (less than 50%). These results indicate that Agent Orange was likely not used extensively in this area during the war.

All known contaminated soil from Z3 area, new north site and sedimentation basin was put in containment landfill located at the northern end of the Airbase in 2012. The landfill is well isolated from airbase residential facilities and neighboring communities. The dioxin exposure risk at Phu Cat Airbase is greatly decreased.

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PART C

HUMAN EXPOSURE TO DIOXIN AT THE CONTAMINATED HOTSPOTS

1.SUMMARY OF DATA ON DIOXIN CONTAMINATION IN HUMAN BLOOD FROM CONTAMINATED HOTSPOTS

The results of past surveys on the dioxin residue concentrations in human blood from the hotspot areas in Southern Vietnam are summarized in Table 5.1.

Table 5.1. Dioxin concentrations (ppt, lipit wt) in human blood from hotspot areas.

Location	n	% Lipid	TCDD	TEQ	%TCDD/ TEQ (%T)
Bien Hoa Airbase Area					
Trung Dung Commune, Bien Hoa	20	-	70.2 (2.4-171.1)	83.3 (8.6-294)	71.1
Bien Hoa City	43	-	93.8 (2.4-413)	-	-
Da Nang Airbase Area					
Sen Lake	11	0.26	302 (6.4-1150)	359 (20.1-1230)	68
Western Da Nang Airport	11	0.28	37 (6.7-77.7)	87 (17.1-173)	45
Thank Khe District	16	0.22	18 (4.8-68.1)	71 (10-163)	21
Vicinity of Da Nang Airbase (Children have congenital malformation)	14 Pooled	-	13.2 (6.7-21.7)	-	-
	30	-	10 (5.6-14.7)	-	-
	1	-	353	-	-
Control Area					
Ha Noi	Pooled 100	-	2.2	11.1	20

Sources: Schecter, Dai et al., 2001, 2002; Office 33/Hatfield, 2007; Hung et al., 2008

The comparison of dioxin blood data from hotspot areas and sprayed areas is given in Table 5.2 and Figure 5.1.

Table 5.2. Comparison of dioxin levels (ppt, lipid wt) in human blood between hotspots, sprayed areas, and control areas.

Location	n	TCDD	TEQ	%TCDD/TEQ	Time
North Vietnam (control area)	82	2.7	20	13.5	1993
Entire South Vietnam (sprayed area)	2,492	9	36	27	1991-1992
Sprayed areas from South Vietnam	233	18.8	32	57.7	1993
Bien Hoa City (Hotspots)	43	93.8	-	-	1999-2001
Trung Dung Commune Bien Hoa (Hotspots)	20	70.2	83.3	71.1	1999
Sen Lake Area*/ Da Nang Airbase (Hotspots)	11	302	359	68	2006

*1 sample has TCDD concentration of 1150 ppt with %TCDD/TEQ of 93.5 %.

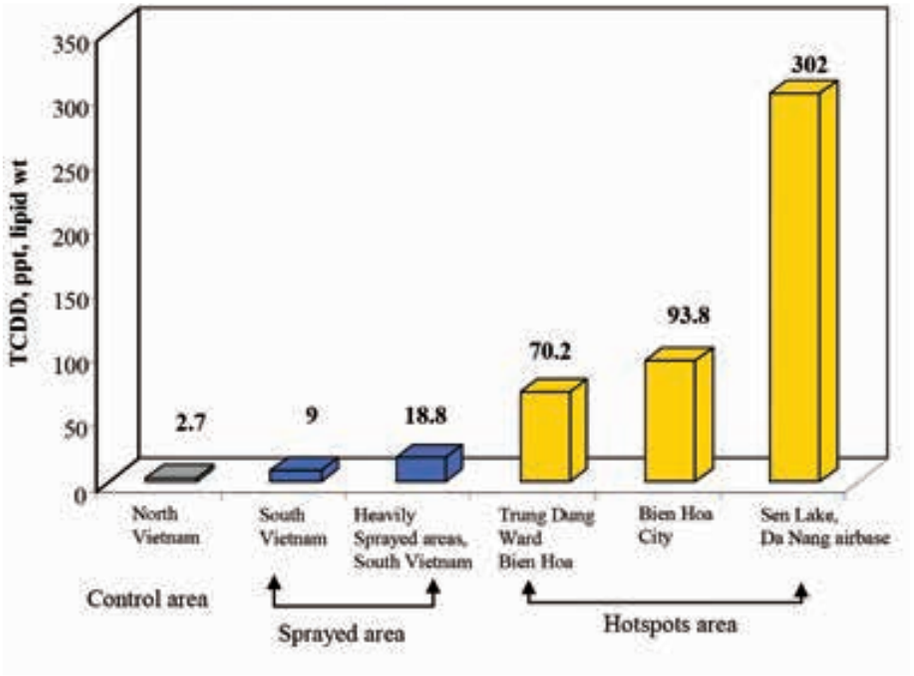

Fig. 5.1. Comparison of dioxin levels in human blood from different areas in Vietnam.

The results from Table 5.1 indicate that at the hotspot areas, the high dioxin levels were encountered in people from Sen Lake, Da Nang Airbase. Exposure to high levels of Agent Orange dioxin from contaminated hotspots has been directly linked to elevated levels in humans working on or consuming fish from Da Nang Airbase.

Data from Tabl 5.2 and Figure 5.1 showed the following contamination pattern: hotspot area has TCDD level higher than in sprayed area, and TCDD level in sprayed area is higher than in control area. Elevated dioxin contamination in hotspot areas and its potential impacts on human health require long-term investigations and appropriate remediation measures.

It should be noted that the above comparison only provide a rough picture of contamination because samples from investigated areas were collected at different times. Considering the half-life of TCDD in the human body is 7.6 years, TCDD concentrations in human blood in the sprayed areas could have reduced to the levels observed in control areas. While in hotspot areas, the recently collected samples have still contained relatively high concentrations of dioxins.

2. THE RESULTS OF SURVEY ON HUMAN EXPOSURE AT DA NANG AIRBASE AND THE VICINITIES

2.1.Assessment of Dioxin Contamination in Environment and Human Population in the Vicinity of Da Nang Airbase, April 2007

In this survey, dioxins and furans were analyzed from a total of 55 donors in Da Nang, including highly exposed groups working on and/or consuming fish collected from Sen Lakes and West Airbase fishponds. Comparative data for the general Da Nang population were obtained from a random sample of potentially exposed area residents in Thanh Khe District and Hai Chau District. One breast milk sample was analyzed in this survey.

The result of the survey is summarized in the Table 5.3.

Table 5.3. Summary of dioxin concentrations (pg/g lipid wt) in human samples collected from Da Nang Airbase in 2006.

Location, sample matrix		TCDD	TEQs (WHO 2005)	%TCDD/TEQs
Sen Lake workers				
Male, n = 7	Mean	289	335	70
	Range	9.42 – 1,150	18.4 – 1,220	48 - 94
Female, n = 4	Mean	324	385	68
	Range	6.36 – 567	52.2 – 662	12 - 89
West Airbase Workers				
Male, n = 5	Mean	35.0	90.5	55
	Range	<1.6 - 77.7	34.7 – 142	53 - 59
Female, n = 6	Mean	32.5	75.1	42
	Range	6.71 - 71.4	15.9 – 165	36 - 45
Chinh Gian Ward, Thanh Khe District				
Male, n = 9	Mean	17.1	62.2	25
	Range	5.14 - 43.7	9.31 – 122	13 - 54
Female, n = 7	Mean	17.1	70.7	19
	Range	4.8 - 68.1	40.7 – 152	11 - 45
Thuan Phuoc Ward, Hai Chau District				
Male, n = 6	Mean	4.30	40	11
	Range	3.76 - 5.92	28.7 - 60.9	8.0 - 18
Female, n = 6	Mean	4.27	42.1	10
	Range	2.77 - 6.15	32.3 - 61.1	8.0 - 13
Chinh Gian Ward, Thanh Khe District, non-random				
Male, n = 2	Mean	29.1	89.2	31
	Range	15.3 - 42.8	63.4 – 115	24 - 37
Female, n = 2	Mean	14.6	71.4	20
	Range	8.4 - 20.8	46.6 - 96.2	18 - 22
Thuan Phuoc Ward, Hai Chau District, non-random				
Female, n = 1		44.2	77.7	57
Chinh Gian Ward, Thanh Khe District, breast milk				
Female, n = 1		6.76	42.4	16

2.2. Comprehensive Assessment of Dioxin Contamination in Da Nang Airport, November 2009

In the project entitled Comprehensive Assessment of Dioxin Contamination in Da Nang Airbase, Viet Nam: *Environmental Levels, Human Exposure and Options for Mitigating Impacts* (Office 33/Hatfield Consultant 2009), human exposure to dioxins was investigated in human blood and breast milk samples collected from Da Nang Airbase and

the vicinities. The survey was conducted by the Office of the National Steering Committee 33 and Hatfield Consultant, and was funded by Ford Foundation Special Initiative on Agent Orange/Dioxin.

The project was conducted in April 2009 to determine potential human exposure to dioxins and furans in communities surrounding the Da Nang Airbase. The blood and breast milk samples were collected from randomly selected participants and from individuals who had been tested in 2006 in order to determine any temporal trends in dioxin levels. A comprehensive questionnaire survey was also implemented for all blood/milk donors.

2.2.1. Result of Dioxin Contamination in Human Blood Samples

Dioxins and furans were analyzed from a total of 101 residents in Da Nang (people living to the east, south and west of the airbase). The blood data were obtained from random samples of residents in An Khe Ward, Thanh Khe District (n = 15) west of the airbase; Khue Trung Ward, Cam Le District (n = 45) south of the airbase; and Thuan Tay Ward, Hai Chau District (n = 24) east of the airbase. 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.

Table 5.4. Summary of dioxin concentrations (pg/g lipid wt) in human samples collected from Da Nang Airbase in 2009

Location, sample matrix		TCDD	TEQs	%TCDD/TEQs (%T)
An Khe Ward, Thanh Khue District, blood				
Male, n = 10	Mean	64.1	109.8	45
	Range	5.94 - 251	31 - 334	15 - 77
Female, n = 5	Mean	29.4	63.9	52
	Range	8.51 – 43	18.1 – 108	31 - 71
Khue Trung Ward, Cam Le District, blood				
Male, n = 24	Mean	6.35	38.5	19
	Range	3.83 – 15	8.17 – 72.6	9 – 39
Female, n = 21	Mean	4.88	36.7	16
	Range	<1.66 – 14.2	7.75 – 104	8 – 26
Thuan Tay Ward, Hai Chau District, blood				
Male, n = 15	Mean	35.3	71.1	43
	Range	3.14 – 93.7	12.1 – 140	9 – 80
Female, n = 9	Mean	30.0	67.3	38
	Range	2.41 – 96	21.5 – 126	11 – 76

Table 5.4. Summary of dioxin concentrations (pg/g lipid wt) in human samples collected from Da Nang Airbase in 2009

Location, sample matrix		TCDD	TEQs	%TCDD/TEQs (%T)
Sen Lake Workers, blood				
Male, n = 7	Mean	289	337	64
	Range	13.3 – 1,340	39.6 – 1,410	34 – 95
Female, n = 4	Mean	411	487	69
	Range	9.64 – 785	67.7 – 893	14 – 89
West Lake Workers, blood				
Male, n = 3	Mean	106	161	62
	Range	48.1 – 212	91.6 – 296	51 – 72
Female, n = 3	Mean	32.8	74	44
	Range	24.7 – 47.4	60.9 – 97.6	41 – 49

The blood samples collection sites were representing the following groups of people (F = female, M = male):

1. **An Khe Ward, Thanh Khe District, 2009 (F=5, M=10):** representing people living outside the Airbase, 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 Airbase. Individual blood donors, selected randomly within the ward, lived near the boundary wall of Airbase, and were adults. 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 Airbase, 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 Airbase. Because of the Airbase drainage patterns, there was concern that people living in Khue Trung could be susceptible to any contaminants carried from the Pacer Ivy sites during the 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 Airbase. 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 Airbase, 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 Airbase. Individual blood donors were selected randomly within the ward.

4. **Thuan Phuoc Ward, Hai Chau District, 2006 (F=6, M=6): r**epresented the control individuals for the 2006 study. This area is located approximately 5 km northeast of the Airbase. Individual blood donors were selected randomly within the ward (Office 33 /Hatfield Consultant 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 Office 33 2006 site investigation. This population represents people known to have been exposed to and re-sampled in 2009 to monitor trends in blood dioxin levels, 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 Office 33 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 Airbase. These individuals were considered to be in an exposed group, given that the fishponds are located within the perimeter of the Da Nang Airbase.

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

Differences in sex were tested for the blood dioxin data. No differences were detected in both 2006 and 2009 data.
Blood TCDD and TEQ values were tested for differences between areas. Values in Khue Trung Ward were significantly lower than all other areas in 2009 ($p<0.0001$). For TCDD, Thuan Phuc Ward was statistically lower than all other areas surveyed in 2006 ($p<0.007$). TCDD concentration in Sen Lake workers was significantly higher than Chinh Gian Ward in 2006 ($p=0.001$) and Thuan Tay Ward in 2009 ($p=0.016$). No statistical differences were found in other areas.
Ten Sen Lake and five West Airbase workers were samples both in 2006 and in 2009. No statistical difference was found from 2006 to 2009 in TCDD or TEQ.

The results of two surveys in 2006 and 2009 indicated that Sen Lake workers has significantly elevated blood TCDD and TEQ values relative to other areas, but living in an area per se does not always accurately predict dioxin level in blood. Principal component analysis (PCA) of the blood congeners of dioxin and furans revealed three principal components (Table 1.5). The first PC has correlations with most of the Pe-, Hx- and Hp- CDD and CDF congeners and explains 57% of the variation. Although the first two PCs accounted for 69.64% of the variation in data set, no separation was evident when the participants' principal components were plotted by area (Figure 1.2), which revealed that where a person lives has little to do with the level of congeners that are found in the blood. The variability within groups suggested that exposure to a wide variety of contaminants (and possibly a wide variety of source) is indeed occurring in most people measured for dioxin/furans in the areas surrounding Da Nang.

Table 5.4.Principal components and input variables for whole human blood PCDD and PCDF congeners, Da Nang Airport, 2006 and 2009

Principal components	1	2	3
Congeners with strong or moderate correlations	123789-HxCDD, 123478-HxCDD, 123678-HxCDF, 123478-HxCDF, 123678-HxCDD, 234678-HxCDF, 23478-PeCDF, 12378-PeCDD, OCDD, 1234678-HpCDD, 1234789-HpCDF, 1234678-HpCDF, 12378-PeCDF, 2378-TCDF	123789-HxCDF, OCDF	2378-TCDD, 2378-TCDF
% Variance explained	57.01	12.63	10.73

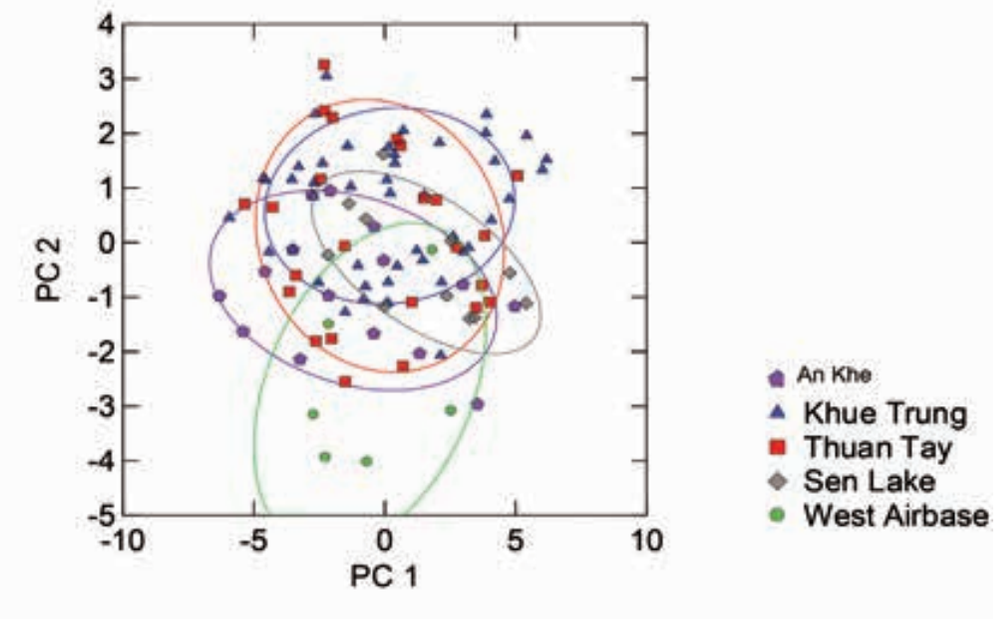

Fig. 5.2.Plot of first two summary variables (principal components); 68% confidence ellipses by blood groups; Da Nang Airbase, Vietnam, 2009.

Yet, Discriminant Factor Analysis (DFA) shows that a large proportion of dioxin contamination results from working in the Airport. For instance, the first axis from the discriminant analysis captures most of the dispersion of the data (Table 5.6) and shows strong separation between Khue Trung Ward and West Airbase and Sen Lake workers (Table 5.7). Thus, although contamination of people around the Airport is clearly from a variety of sources, working in the Airport significantly increase blood TEQ and TCDD level above the background noise generated from other sources.

Table 5.6.Summary of stepwise forward discriminant analysis for whole human blood; Da Nang Airport, 2006 and 2009

Compounds	Standardized Canonical Discriminant Functions			
	1	2	3	4
2378-TCDD	1.024	0.599	0.035	0.197
123478-HxCDD	0.493	-1.814	0.271	-0.955
2378-TCDF	-0.448	0.214	-0.924	-0.495
123678-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 5.7.Classification matrix for area grouping for whole human blood; Da Nang Airport, 2006 and 2009. Actual grouping 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

The relation of specific risk factors, such as working in the base shows that difference of blood TCDD and TEQ reported between areas are significantly influenced by the proportion of people who have worked in the base versus people who have not.

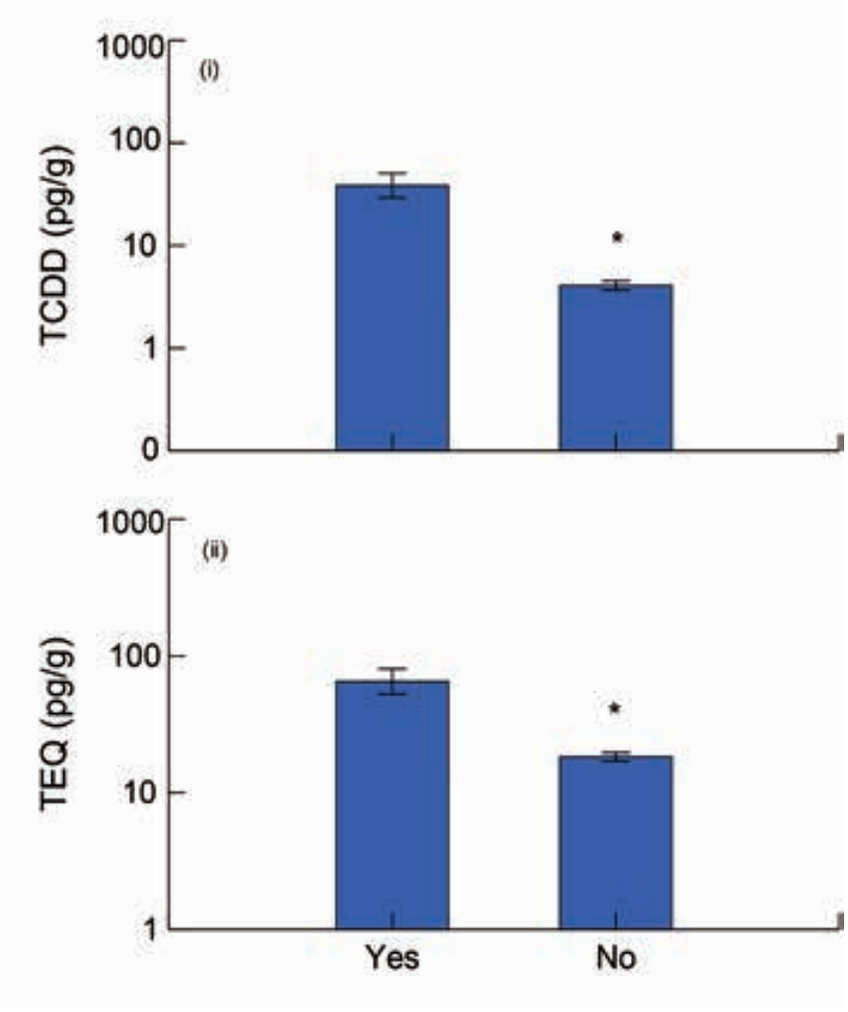

Figure 5.3 Mean TCDD (i) and TEQ (ii) ± SE grouped by the question "Have you ever worked on the Airbase" for An Khe, Khue Trung and Thuan Tay wards (excludes Sen Lake and West Airbase workers); asterisk notes significant difference.

2.2.2 Result of Dioxin Contamination in Breast Milk Samples

The 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 Airbase. 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 second infant, two were with their third infant, and one was unknown. The mother sampled in 2006 was breastfeeding her first infant.

One milk sample (09VN343A) collected from a relocated Sen Lake worker, who resided in Thanh Khe District in 2009, exhibited very high TCDD (232 pg/g) and TEQ (263 pg/g) levels relative to all other samples. 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.

The WHO acceptable standards (1 to 4 pg TEQ/kg body weight/day) cover the range of established Tolerable Daily Intake

PCDD/F exposures for several countries. The most highly exposed part of the population is the breastfed infant, where exposures to PCDDs and PCDFs via ingestion can be higher, on a body weight basis, than during other periods in a person's life.

To assess the impact of TEQ levels 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%.

All individual ADI values from Da Nang study exceeded the 4 pgTEQ/kg bw /d. 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 ADI calculated with actual milk fat (lipid) for the young Sen Lake mother (09VN343A) is extremely high (2,320 pgTEQ/kg bw/d), followed by the West Airbase mother's samples. ADIs greater than 100 pgTEQ/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 Ward, Thanh Khe District, mother was calculated as 192 pgTEQ/kg bw/d.

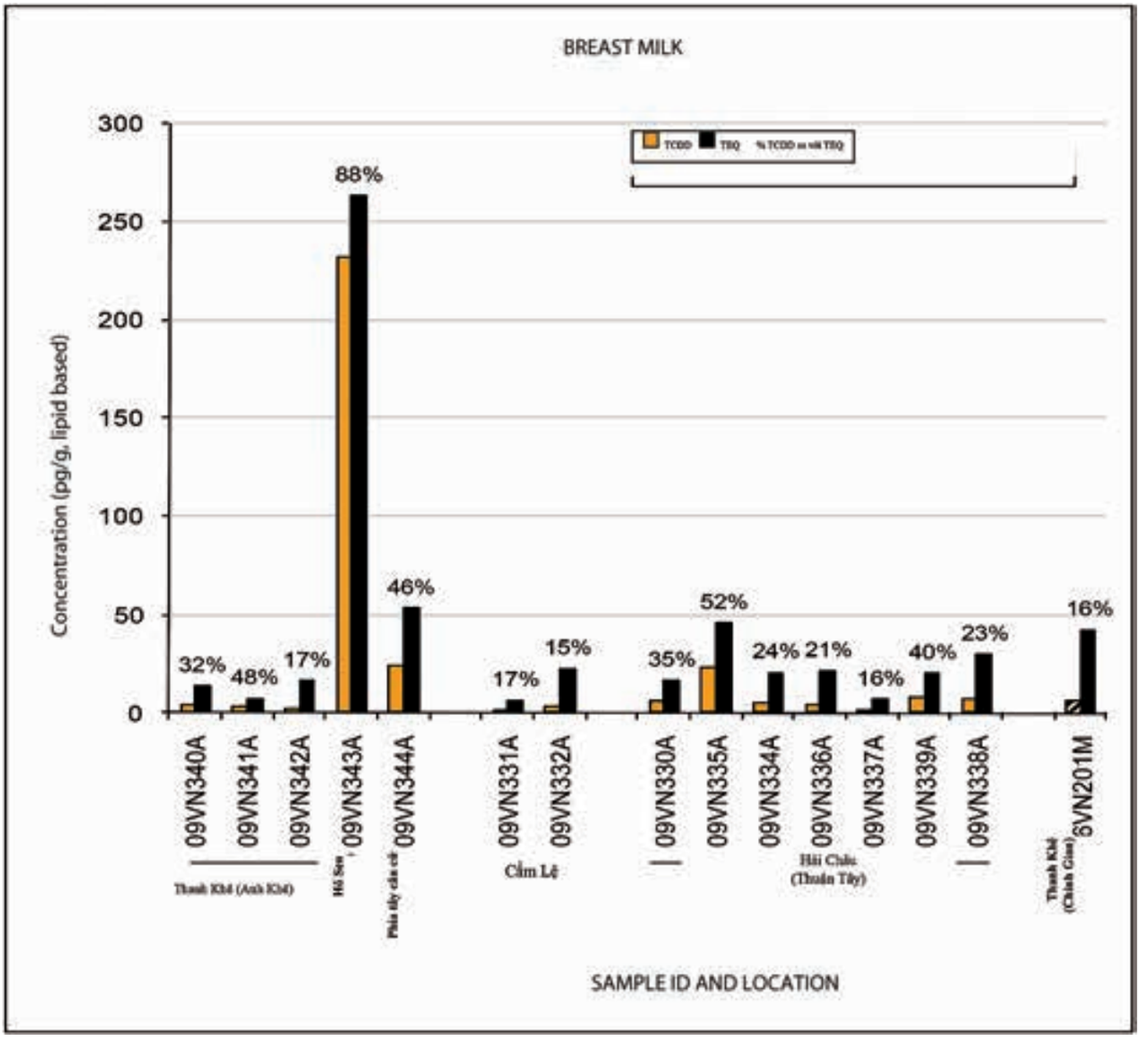

Fig.1.4.TCDD and total TEQ (pg/g [ppt], lipid wt) for human breast milk from females in the vicinity of Da Nang Airbase, April 2009 and December 2006.

2.2.3.Conclusions

- The blood dioxin concentrations recorded in the 2006 study (n=55 blood donors sampled) for Da Nang residents directly associated with the Airbase were the highest concentrations in Viet Nam at the time of survey. These concentrations also exceeded all international standards for these chemicals. The people who harvested fish and plants from Da Nang Airbase had dioxin concentrations in their blood more than 100 times globally acceptable levels (Office 33/Hatfield Consultant 2007). The highest TCDD concentration in fat is 1,150 pp (1,220 ppt TEQ; 94% TCDD) was recorded in a 42-year old male sample who actively harvested fish and plants from the Da Nang Airbase; two other people 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.
- Sen Lake and West Airbase Workers that were retested in 2009 demonstrated no statistical difference in blood TCDD or TEQ levels (lipid based) from those recorded in 2006. The Sen Lake workers have been relocated and all fishing and agricultural activities in the north Airbase have been halted (with the exception of the West Airbase Ponds, which are still in operation).
- The people most affected by direct exposure to dioxins from the Da Nang Airbase 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 Airbase lakes, although exact numbers are presently unknown.
- The analyzed results of blood and breast milk dioxin/furan levels from different communities surrounding the Airbase in 2009 confirmed high concentrations in people living north and east of the Airbase. 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 Airbase. The results indicate that a large proportion of dioxin contamination results from direct exposure to, and working on, the Airbase. Although the contamination levels in people living around the airbase is clearly from a variety of sources, working on the airbase significantly increases blood TEQ and TCDD level, higher than that of background levels in the people exposed from other sources.
- The analysis of blood dioxin levels in people randomly selected in wards surrounding the airbase (An Khe, Khue Trung, and Thuan Tay) show that working on the base is the strongest predictor of blood dioxin levels in these 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. The 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 all lower than 15 pg/g. The low percent TCDD of TEQ values (none exceeded 40%) also indicate that it is unlikely that these participants are directly impacted by Agent Orange exposure in soils, sediment, water or food supplies. This was also true for individuals sampled in 2006 from Thuan Phuoc Ward, Hai Chau District (reference area).
- In contrast, some, but not all, individuals sampled from other wards or areas surrounding the Airbase exhibited TCDD concentrations greater than 10 pg/g. These include residents from An 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 Airbase, within 1 km of the boundary.
- The dioxins and furans were also detected in all breast milk samples analyzed in 2009. The highest levels were recorded in a young primaparous female (232 ppt TCDD) who previously consumed fish from Sen Lake. The 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 Airbase.

3. THE RESULTS OF HUMAN HEALTH ASSESSMENT OF DIOXIN CONTAMINATION AT BIEN HOA AIRBASE, APRIL 2011

3.1. Human blood serum

42 residents living in Tan Phong and Trung Dung ward provided blood samples for study. All of the sampled residents were involved in various occupations inside the Airbase (airport workers, working for MOD, fishing, cultivating). Blood data were collected from 37 male and five female workers.

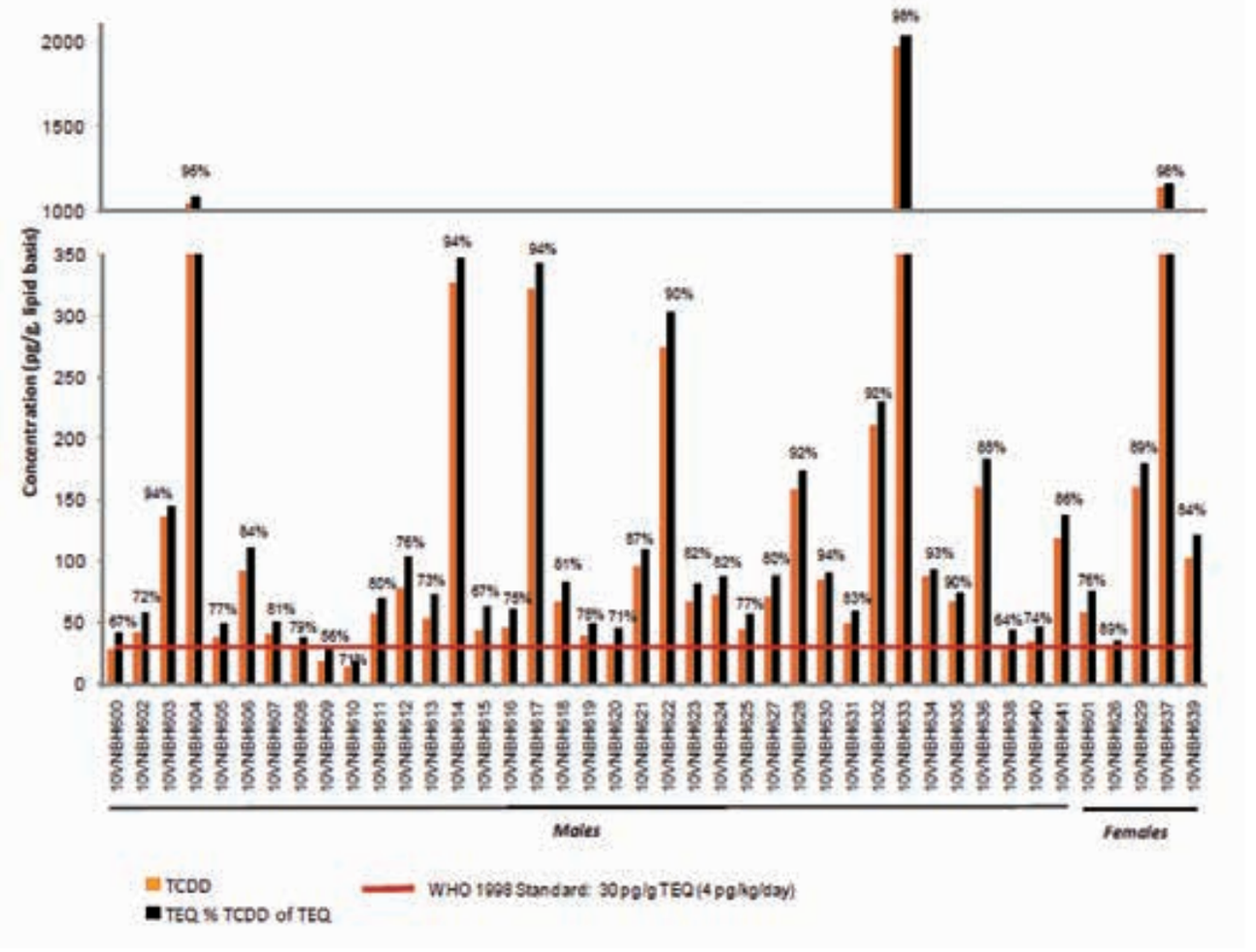

Figure 5.5.Dioxin/furan concentration in human blood serum in Bien Hoa, 2010

Among the 42 serum samples analyzed, three (3) samples recorded extremely high TCDD concentrations. The highest one was recorded in blood sample 10VNBH633 (1970 ppt TCDD; 2,020 ppt TEQ), belonging to an airbase worker involved in aquaculture and fishing near Pacer Ivy area, Bien Hung Lake, South Lake, and Z1 lake, and wetlands. His wife (10VNBH637) was recorded with the second highest dioxin concentration of 1,130 ppt (1,150 ppt TEQ). A serum sample collected from another worker in airbase (10VNBH604) have high dioxin concentration either (1,040 ppt TCDD and 1,080 ppt TEQ). TEQ in these three samples was 35 time higher than WHO 1998 standard (30 ppt); and proportion of TCDD in TEQ was over 96%, indicating Agent Orange was the cause of contamination.

Other 38 blood samples exhibited TEQ higher than standard of WHO 1998, ranging from 31.2 to 347 ppt. Only one sample (10VNBH610) was recorded with TEQ concentration lower than WHO 1998 standard (19.3 ppt).

Percentage of TCDD in TEQ in these 38 samples ranged from 56.4 to 98.3%. In general, donors with low TCDD, also exhibited low TCDD in TEQ.

There was no statistically significant difference in either serum TCDD or serum TEQ between males and females. The length of residence or employment at Bien Hoa Airbase and its vicinity also does not affect the dioxin levels in blood serum. Age was also not the determinant factor of dioxin concentration in blood serum.

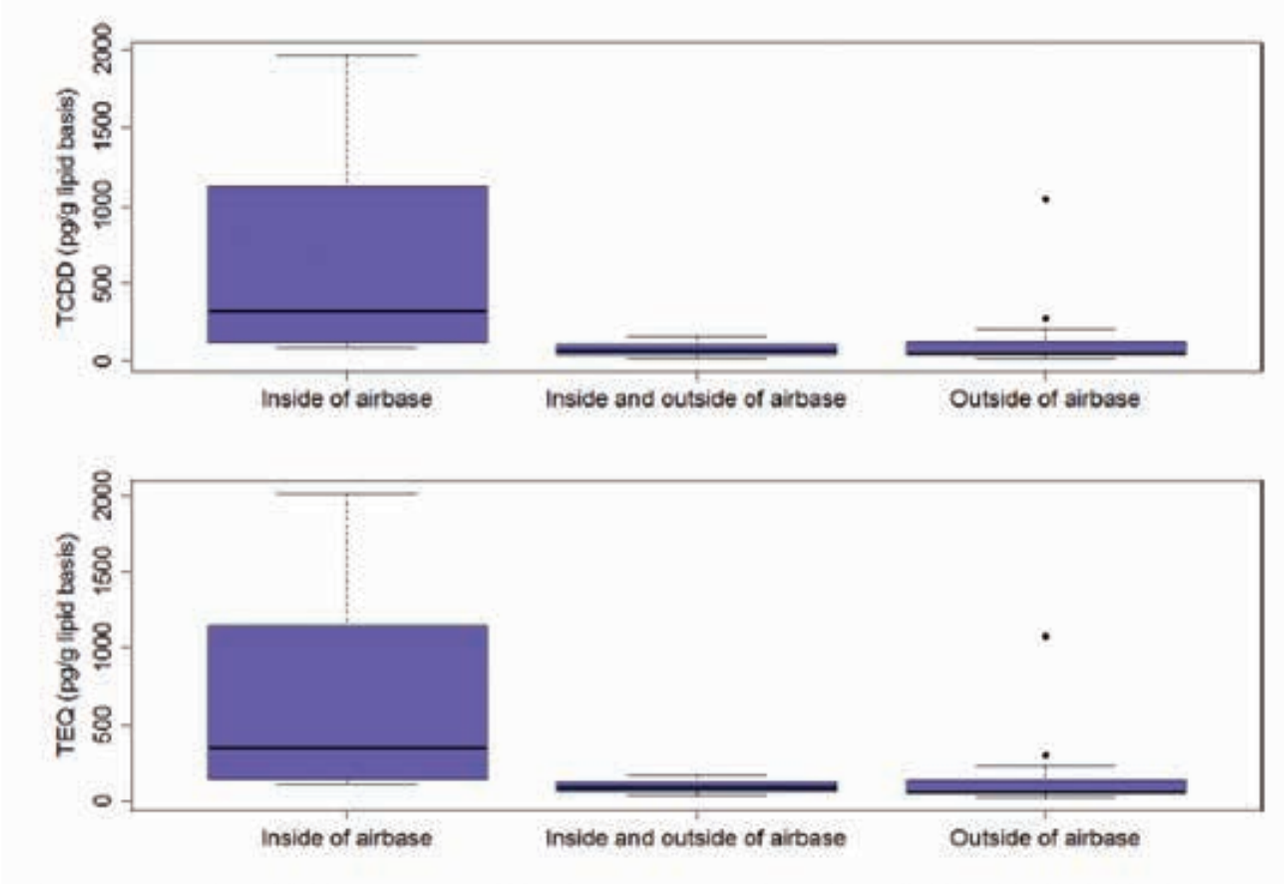

Figure 5.6. Location of fishing sources and blood serum TCDD and TEQ (pg/g, lipid basis) of individuals in Bien Hoa, November 2010

The study found high levels of dioxin contamination in Tilapia fat tissues sampled from lakes inside and immediately to the south of the Airbase. A statistically significant difference was found in both TCDD and TEQ concentrations in individuals fishing in lakes inside the Airbase, both inside and outside the Airbase, and only outside the Airbase (p_{TCDD}=0.0098; p_{TEQ}=0.0093). Figure 5.6 shows that individuals fishing exclusively inside the Airbase exhibit higher average TCDD and TEQ concentrations compared to the other two groups.

3.2. Breast milk Sample

22 breast milk samples were collected from 18 donors in Trung Dung Commune, 2 donors in Tan Phong ward, 1 in Tan Tien and 1 in Hoa An wards. Among 22 breast milk donors, 12 mothers were breastfeeding their first infant, 8 were breastfeeding the second infant, and 2 were breastfeeding the third infant.

A milk sample (10VNBH803) collected from a mother in Tan Phong Ward (inside airbase) exhibited relatively high TCDD and TEQ levels (30.3 ppt and 36.9 ppt, respectively) compared to other samples collected. 76.5% TCDD of TEQ

indicated that Agent Orange is the main contributor of dioxin. This woman had consumed fish from Gate 2 Lake and Z1 Lake, these two lakes were recorded high dioxin concentration in tilapia in the study.

Breast milk samples collected from two donors in Trung Dung ward also exhibited remarkable dioxin concentration. TCDD and TEQ in sample 10VNBH804 were 22.5 ppt and 28.6 ppt, 78.7% TCDD of TEQ. Sample 10VNBH814 exhibited TCDD of 13.8 ppt and TEQ of 31.8 ppt, 43.4% TCDD of TEQ, indicating that not only Agent Orange but also other dioxin sources contributed dioxin contamination in this sample.

15 breast milk samples were recorded TCDD lower then 4 pg/g. Percentage of TCDD in TEQ in all these samples are smaller than 50% (excluding sample 10VNBH808). Sample 10VNBH821 collected in Trung Dung ward exhibited lowest TCDD in TEQ (12.2%). This indicated that Agent Orange was not the solely dioxin source in breast milk in this area.

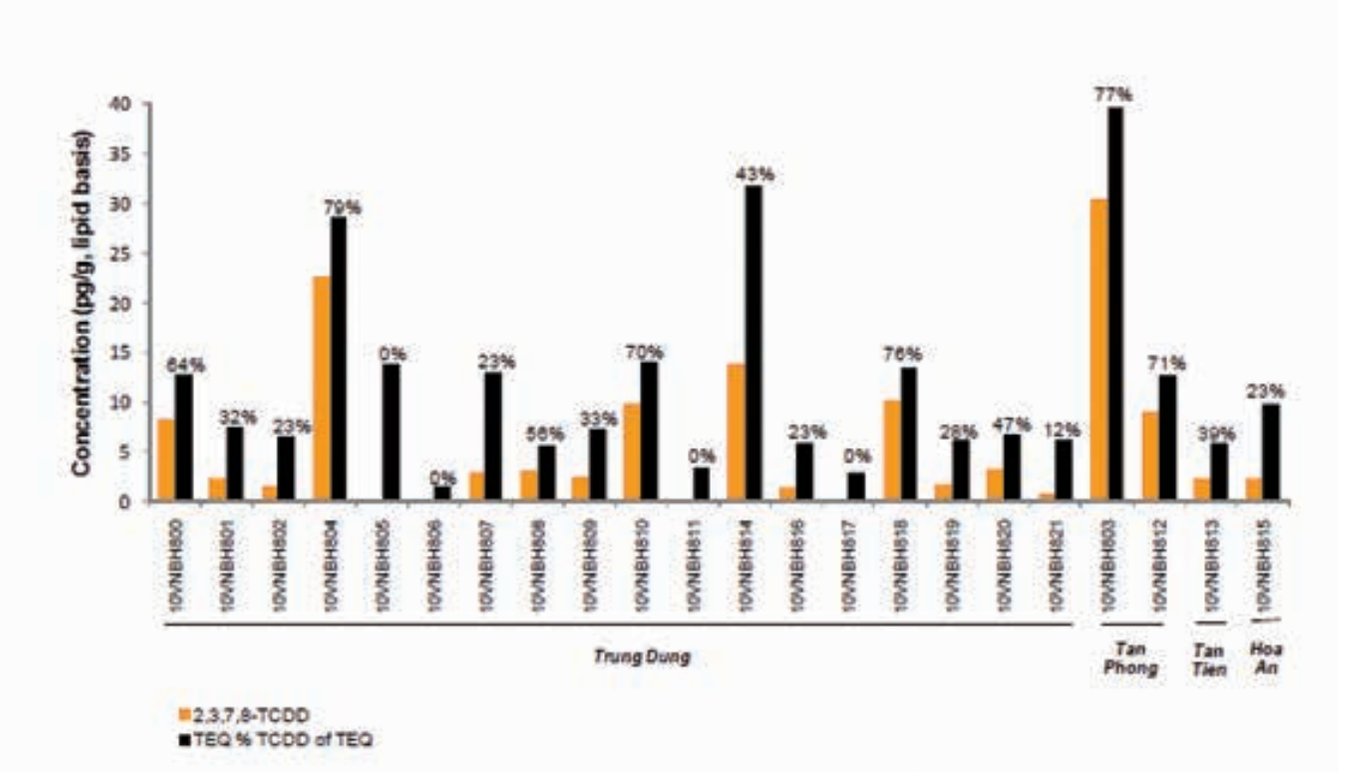

Figure 5.7.TCDD and Total TEQ (pg/g, lipid basis) in human breast milk in Bien Hoa, November 2010

There is some report that the first child is exposed to higher concentrations of PCDDs/Fs than second and later children (Fürst et al., 1989). In Bien Hoa, no significant differences in the TCDD and TEQ were found between these groups. Residing inside the Airbase was also not statistically significant impact to dioxin in their breast milk. Likewise, the length of stay in the Airbase, relatives in the Airbase, and amount of fish consumption did not show.

3.3 Comparison with Da Nang Results (2007 and 2009)

Dioxins and furans were analyzed in human breast milk collected from a total of 14 female donors in Da Nang during the Office 33/Hatfield (2009) study. On average, the TCDD concentrations in breast milk samples collected in Da Nang were higher than samples analyzed in Bien Hoa (2010). The samples from Bien Hoa exhibited a mean TCDD concentration of 6.49 ppt with a standard deviation of 7.71 ppt, while samples from Da Nang exhibited a mean TCDD of 22.24 ppt with a standard deviation of 58.46 ppt. Distribution of TCDD and TEQ concentrations in Da Nang and Bien Hoa breast milk samples are shown in Figure 5.8.

A milk sample collected from a relocated Sen Lake Worker from Da Nang exhibited very high TCDD (232 ppt) and TEQ

(263 ppt) values; the highest TCDD and TEQ values observed in Bien Hoa are 30.3 ppt and 39.6 ppt, respectively. The ADI values calculated based on actual milk fat (lipid) percentages by donors exceeded the WHO acceptable standard (1-4 pg TEQ/kg bw/d) for all donors from the Da Nang 2009 Study (Office 33/Hatfield 2009) and the Bien Hoa 2010 Study. Five donors from Bien Hoa had ADI values exceeding 100 pg TEQ/kg bw/d, the highest recorded being 172 pg TEQ/kg bw/d. In Da Nang, nine (9) of the 15 breast milk samples analyzed exhibited ADI values exceeding 100 pg TEQ/kg bw/d, and the highest average daily intake was as high as 2,320 pg TEQ/kg bw/d for the same relocated Sen Lake worker.

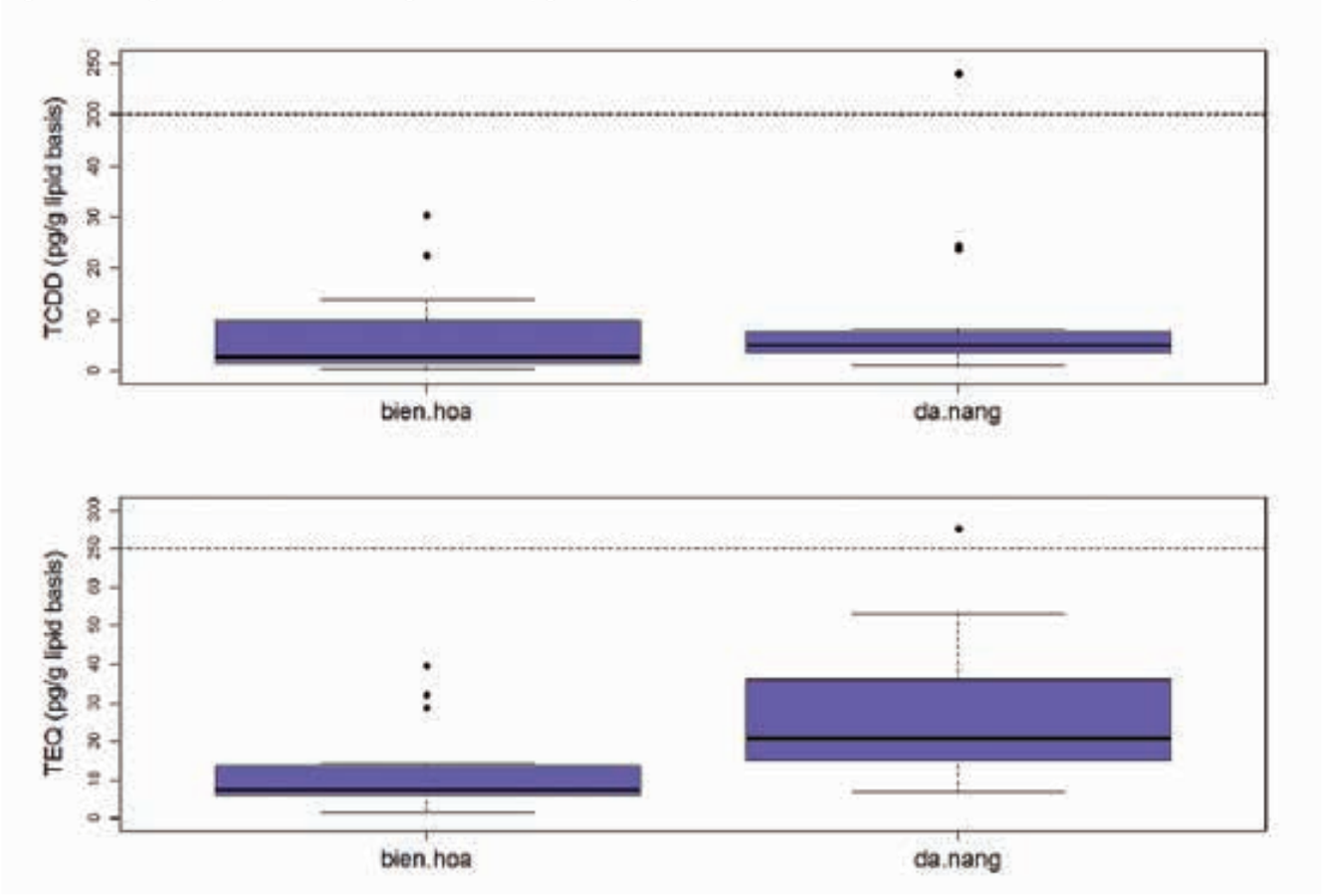

Figure 5.8 Box plot of breast milk TCDD and TEQ (pg/g, lipid basis) in Bien Hoa (2010) and Da Nang (2007 and 2009)

3.4. Conclusion

TCDD and TEQ in human blood serum in Bien Hoa Airbase were relatively high, TEQ ranging from 19.3 to 2,020 pg/g. TCDD in TEQ was high (56.4-98.3%), indicating that Agent Orange is the source of dioxin. All blood serum samples exhibited results exceeding the WHO 1998 guideline (excepting one sample).

Residents who only consumed fishes in airbase exhibited higher mean TCDD and TEQ in blood serum than who consumed fish both in and out of airbase.

Dioxin and furan was detected in all breast milk samples collected in study 2010. The highest dioxin concentration was recorded in a mother consuming fish from Z1 Lake and Gate 2 Lake. TCDD and TEQ in all samples exceeded WHO guideline.

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Part C

PART D

GENERAL EVALUATION AND RECOMMENDATIONS

I. GERNERAL CONCLUSION

1.Classification of dioxin contaminated areas

In order to evaluate the extent of contamination and migration of dioxins in the environment of South Vietnam, two types of contaminated areas have been identified: these are the sprayed areas and the former storage, loading and washing areas in airbases.

The spayed areas cover about 2.63 million ha (~15% total area of Southern Vietnam) and include spraying of more than 95,000 tons of herbicides (consisting of 63,000 tons Agent Orange), with a spraying density of 37.5 kg/ha. The sprayed areas are widely distributed over the entire area of South Vietnam in which the strategic region III (north of Sai Gon) was a key area.

The second areas, including former storage, loading and washing areas, are main airbases. The dioxin contaminated areas in each airbase are much smaller comparing with the former area, about 20 - 40 ha in Da Nang, Bien Hoa airbases and a few ha in Phu Cat airbase.

The results of the extent of dioxin contamination and migration since 1980 indicated a substantial difference between two types of contaminated areas.

The sprayed areas (SA)

The residue and spread level of toxic substances including dioxin depend on the following factors:

- The characteristics and physical-chemical properties of toxic materials, such as water solubility, vapor pressure, persistency, absorbed capability, etc.;
- The natural conditions of soil, water, and hydro-meteorological parameters such as temperature, rainfall, wind velocity, solar radiation, etc.; and
- The extent and magnitude of change to the natural environment by human activities.

The characteristics and physical-chemical properties of dioxin: Dioxins are a group of aromatics and chlorine-containing organic compounds, which have high melting temperature, hydrophobicity, low vapor pressure, high persistency against temperature, acids, alkalis and strong oxidizing agents, and other biological agents, and high adsorbed capability. Therefore, dioxins are persistent substances in the environment.

The Southern Vietnam is located entirely in the tropical belt, which is characterized by high temperature, high humidity and heavy rainfall. In this region, the average temperature is in the range of 25 - 27^{o}C with strong solar radiation, which is a favorable condition for degradation of this type of chemical contaminants. The density of rivers and streams system is relatively high with an average of 1 km/km^2; most of rivers and streams are short, and directly flow into the South China Sea. In this region, heavy rain, typhoons, and floods are very common every year. These hydro-meteorological characteristics cause soil erosion, and the soil is consequently washed out along with stream runoff and finally reaches the sea. Dioxin compounds, which are easily adsorbed onto soil particles, can be migrated to the coastal areas through this pathway. As a result, their concentrations could have decreased every year since spraying operation occurred. These two natural conditions have had remarkable impacts on the transport and fate of dioxins in South Vietnam, showing a dramatic decline in residue concentrations and migration towards coastal areas.

The investigations conducted during the last decades on the contamination of dioxins in soil, sediment, blood and human breast milk, fat tissues and foods in sprayed areas have shown that dioxin concentrations are generally at or below international standards, and significantly lower than those found in hotspot areas.

The former storage, loading and washing areas at US Airbases (Hotspots)

The results of surveys indicated that the dioxins levels in the sprayed areas are lower than the standard level. However, at

the former storage, loading and washing areas at Bien Hoa, Da Nang and Phu Cat Airbases, the dioxins were recognized at relatively to very high concentration. Therefore, those areas are named three 'hotspots' of contaminated dioxin in Southern Vietnam, which require the remediation. The dioxin concentration in soil at the storage areas of the airbases significantly exceeds the permitted level. At the Bien Hoa Airbase, the Z1 region has been contained by Vietnamese Ministry of Defense by using the landfill process with an area of 4 hectares at a depth of 1.2 to 1.4 m. West end of runway where Pacer Ivy Operation took place is another large-scale contamination recently identified. The area and dioxin level of the Pacer Ivy site are comparable or even higher than those of Z1 site. At Bien Hoa, there are a few more locations that require treatment of the sediment; including Lake 1 (area of 0.67 hectare), Lake 2 (area of 2 hectares), Lake Gate 2 (area of 1 hectare). In Da Nang Airbase, the mixing and loading areas, Sen Lake, former Storage area and Pacer Ivy site, with a total volume of 73,000 $m^{3,}$ are contaminated with dioxin, which require immediate remediation. In Phu Cat Airbase, the main area need be treated was Z3 site with the area of approx. 1 ha, and depth 0.3 – 1.2 m. Total volume of contaminated soil at Phu Cat airbase is 7,500 m^3.

2. The transport of dioxins in the environment

The major pathway of dioxin transport from contaminated areas of Southern Vietnam is erosion of contamination soils caused by rain, flood, and storm. This extent of migration depends on the topography and direction of surface water flow. The detection of dioxin residue in canals and rivers in Ho Chi Minh City and Nha Trang City shows such assumption.

The difference in concentrations of dioxins in Lake 1, 2, and Lake Gate 2, Bien Hung Lake, Dong Nai River is the result of dioxin migration from contaminated areas in Bien Hoa Airbase. At Da Nang Airbase, the situation is similar, as dioxin migrates from the contaminated areas into Sen Lake and farther points such as Phu Loc River where sediment contained (although relatively low) dioxin.

Dioxins have high affinity with organic humus in soil particles, and therefore they may have low mobility in deeper soil layers in the sprayed areas. In areas where herbicides were stored and used in massive quantities such as Ranch Hand sites, the herbicide mixed with the solvent fluid created favorable conditions for dioxin to penetrate into deeper soil layers. In fact, dioxins were detected at relatively deeper levels in soils from the depth of 150-180 cm and even more. The extent of dioxin migration depends on nature and condition of soils, type of solvent and the volume of spillage. Due to this dioxin migration, the quantities of soil that requires treatment have greatly increased.

3. The sources of dioxins

The investigations on dioxins in Southern Vietnam in both sprayed areas and hotspot areas in the Airbases demonstrated that the origin of dioxins is herbicides used during US-Vietnam War. US Army used a huge quantity of dioxin-contained herbicides, mainly Agent Orange (63,000 tons). This conclusion is proven by the high contribution of 2,3,7,8-TCDD to total TEQ in most of the analyzed samples. The TCDD percentages in soil, and sediment samples were over 90%, that in blood and breast milk was 66%, and in fat tissue was 80%. For comparison, the percentage in blood of occupational exposed workers at 2,4,5-T manufacturing in Germany and Russia was reportedly approximately 78%.

4. Dioxin contamination trendl

In sprayed area, throughout the time dioxin concentration decreased remarkably. By 90s, dioxin in soil, sediment, bio species, human blood and breast milk became at low level. Meanwhile, at hotspots e.g. storage area, loading and washing area, dioxin concentration in soil and sediment stayed at high levels. At Z3 storage area in Phu Cat airbase, Z1 area in Bien Hoa Airbase, and northern part of Da Nang Airbase, dioxin level remains high, exceeds standard for dioxin in soil (1000 ppt TEQ) by as high as 900 times. Although direct exposure of surrounding residents to dioxin has been decreased, it is still high. Dioxin load to people working at Sen Lake in Da Nang Airbase ranged from 18 to 1,220 pg-TEQ/g in 2006 , and from 40 to 1,410 pg-TEQ/g in 2009, lipid based. In Bien Hoa, as high as 2,020 pg-TEQ/g was reported in 2010. Especially, survey of fish samples in Da Nang in 2009 showed that dioxin in fish collected in Sen Lake was higher than that in samples collected in the same lake in 2006. Aqua ecosystem (ponds, lakes) in the hotspots played the role of dioxin storage. Exposure of residents in this area to dioxin is getting lower, but still remains high, and may risk these people.

II. ACITIVIES CARRIED OUT IN HOTSPOTS

In the past years, many efforts to remediate/mitigate dioxin in three hotspots have been implemented. Contaminated soil in Phu Cat Airbase was contained by landfill method which helps to eliminate the exposure of dioxin. This is considered as the typical environmental achievement in 2012 in Vietnam. Da Nang hotspot is to be remediated by thermal desorption method and the work is planned to be completed in 2016. In terms of Bien Hoa Airbase, comprehensive remediation plan is in the final preparatory step and is planned to be submit for approval of MOD.

1. Phu Cat Airbase

With the support by GEF and UNDP, more than 7,500 m^3 of contaminated soil in Phu Cat Airbase was contained in landfill in 2012. Monitoring system in this area will be developed (planned in 2013) with the support by Czech Republic Government. This landfill was handed over to MOD.

Construction of landfill

Dioxin contaminated soil from storage area (Z3), buffer zone, sedimentation tank and Z9 (southeast and northeast of airbase) was excavated and transported to landfill. Landfill was technically designed by High Command of Chemistry – MOD. The landfill is half underground with the depth of 3.7m below the ground level with the effective internal area of 2,000 m^2. Landfill has square shape, with each internal side has 45 m, and has a separated cover at the height of 2.5 m from the current ground surface. Landfill wall (both internal and external) has slopes to avoid water stagnation and soil erosion. Initial estimated volume of dioxin contaminated soil was 5,400 m^3, however the actual volume contained was increased to be 7,500 m^3.

Landfill was installed on the structure of two insulation layers at the bottom and another cover layers. Cover layers includes (from the surface down): grass vegetation, clean surface soil (40 cm), sand layer (40 cm), HDPE layer (2 mm), geo-textile layer 1,clay (20 cm), geo-textile layer 2, and then contaminated soil. Bottom layers includes (from the bottom up): Compacted base soil, clay layer 1 (bentonite 10%, 20 cm), geo-textile layer 1, HDPE 1 (2mm), water filtering layer 1 (30 cm), geo-textile layer 2, HDPE 2 (2mm), water filtering layer 2 (30 cm) and geo-textile layer 3.

Excavating and transporting contaminated soil to landfill was carried out according the strict guideline on hazardous waste transportation. Methods to prevent soil or dust from spreading to surrounding environment were applied according to design and guideline. After completing landfill, backfill of excavated area was carried out. Landfill area included buffer zone, fences and maintenance pathways to ensure the maintain landfill conveniently.

Monitoring system

Monitoring plan in Phu Cat Airbase is developed in the scope of Project "Support Overcoming consequences of herbicides/dioxin in Vietnam" by Development Department, Czech Republic. At the date of this publishing, this plan was approved by authority and will be developed in 2013.

2. 2. Da Nang Airbase

In 2007, with the support from Ford Foundation, Office 33 installed mitigation work in Da Nang Airbase. Nearly 6,900 m^2 in mixing and loading area at the end of taxiway was concrete-capped to reduce the dioxin spread to surrounding environment. Sedimentation tanks and overflow weir was constructed to reduce dioxin from entering Sen Lake.

In 2010, USAID was carried out Environmental Assessment and evaluated some remediation technologies. Thermal desorption was proven to be the effective dioxin remediation method that reduces the risks to human health and environment. Soil and sediment are to be excavated and transported into close pile containment in two batches. Soil and sediment are then to be heated at high temperature for several months to destroy and remove dioxin. When analytical result confirmed that soil and sediment are clean, then the first batch is to be removed out of pile

containment and the second one will be filled in for the same heating process. In theory, at least 95% of dioxin will be destroyed during heating process. The remaining dioxin which is vaporized will be collected and treated by post treatment system. This post-treatment system adsorbs vapors and liquid from pile containment to ensure that dioxin and other toxic chemicals are not spread into surrounding environment.

In April, 2011, MOD Vietnam cooperated with USAID announced the implementation of project "Environmental remediation of dioxin contamination at Da Nang Airport" in the period of 2012 to 2016, including: screening and demining part, designing, excavating and transporting part, designing and remediating contaminated materials by thermal desorption method with 73,000 m^3 soil and sediment for remediation, and environmental recovery. Remediating areas include: Sen Lake, drainage ditches, eastern wet land, former storage area, mixing and loading area, Pacer Ivy.

The schedule of project includes:

• **2013:** construction of structure to hold contaminated soil for treatment; excavation (phase 1): storage area, mixing and loading area, southern end of drainage ditch, south end of eastern wetland; and Pacer Ivy storage area; installation of treatment system (Phase 1).

• **2014:** phase 1 treatment. sampling of soil treated in Phase 1 to confirm treatment effectiveness, phase 1 treated soil transferred from treatment structure.

• **2015:** excavation (Phase 2) and dewatering of sediment from Sen Lake, Northern end of drainage ditch, Northern end of eastern wetland, and area between eastern wetland and drainage ditch; installation of treatment system (Phase 2).

• **2016:** phase 2 treatment; sampling of soil treated in Phase 2 to confirm treatment effectiveness; phase 2 treated soil from transferred from treatment structure; site restoration.

Project was launched on August 9th, 2012, and started field work on August 8th, 2012. After launching, contractors investigated and clear surface where the pile containment is to be installed, investigated biodiversity of this area to ensure that no rare species are in danger. At the date of this publication, the walls of pile containment structure are being built out of concrete masonry unit (CMU) blocks manufactured. Besides, a dry pad was constructed to hold dioxin contaminated sediment excavated from Sen Lake and wetland. High density polyethylene (HDPE), a very strong, thick plastic material, lined the bottom of the drying pad to prevent water draining from the contaminated sediments into the environment. All water will be captured in a sump inside the drying pad and tested before it is discharged. MOD Vietnam is evaluating and finalizing the design.

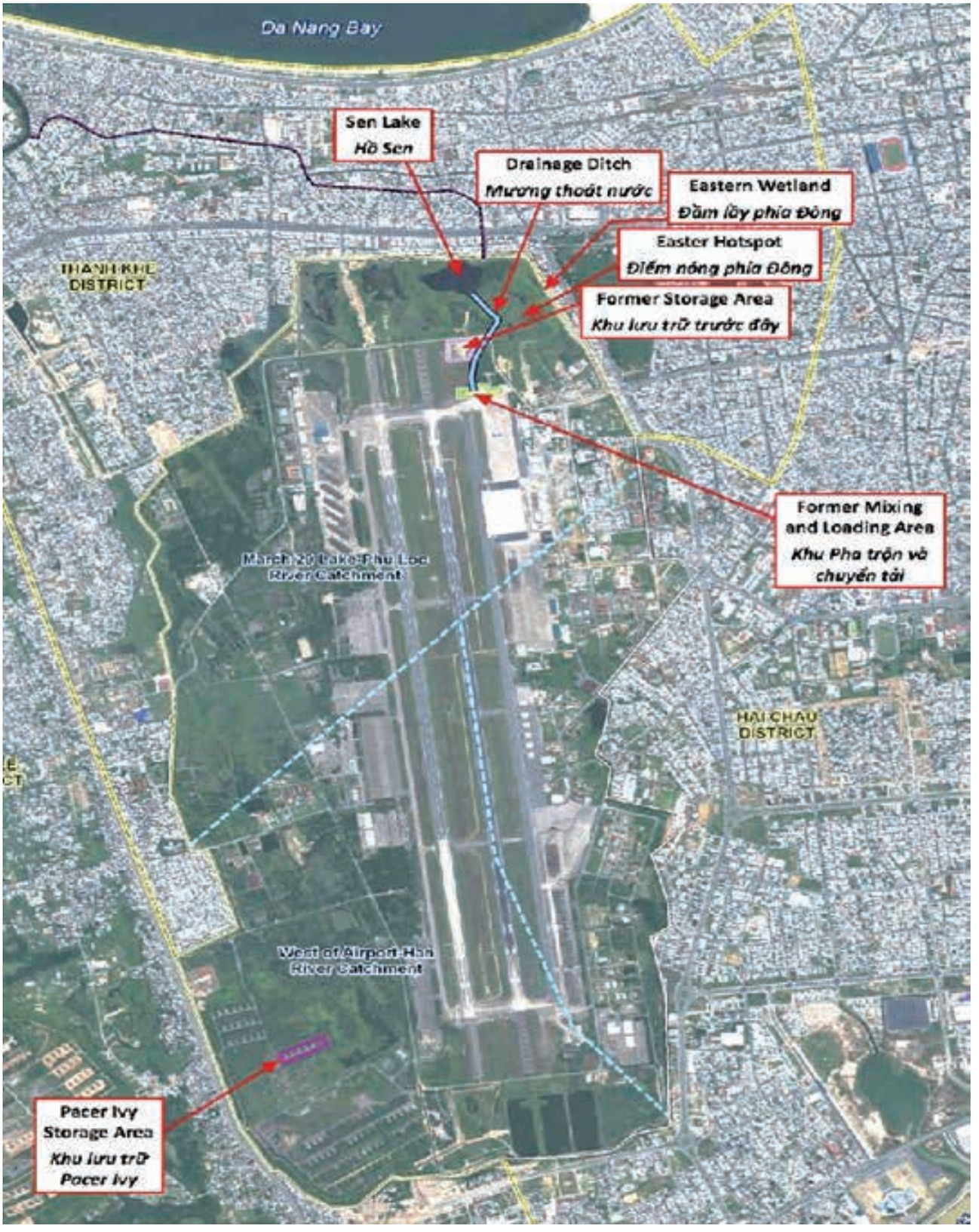


Figure 1.1. Remediated areas in scope of Project by USAID-MOD Vietnam

3. Bien Hoa Airbase

In 2009, MOD completed remediation in Z1 area by landfill method which comprises 23 cell compartments of dioxin contaminated soil. Landfill located on 4.7 ha area and is filled with 94,000 m^3 soil, in which 4 compartments were applied biotechnology which is called "active landfill".

Reports on dioxin contamination in Bien Hoa Airbase suggested that the volume of dioxin contaminated soil is needed to be re-calculated. Based on these results, Comprehensive Remediation Plan in Bien Hoa Airbase will be developed and will be submitted to MOD for approval in the near future.

At the time of this publication, hydraulic isolation of dioxin contaminated soil in Pacer Ivy Area is implemented by the Project "Environmental remediation of dioxin contaminated hotspot in Vietnam" in cooperation with MOD. This work was commenced in March 2013 and scheduled to be complete in 2013. This is the most suitable method to prevent immediate dioxin mitigation into environment with minimum intervention.

Monitoring system will be developed with the support from Czech Republic in the project "Support overcoming consequences of herbicides/dioxin in Vietnam"

III. RECONMENDATIONS

1. Environmental remediation:

- Project "Environmental remediation of Dioxin contamination in Da Nang Airbase" need to complete as scheduled; and must implement environment assessment as approved during the remediation process.
- Need additional surveys to identify volume of contaminated soil and sediment in Bien Hoa. In terms of contaminated soil in Z1 area which was contained in Z1 area, further remediation is necessary
- Need to study more on dioxin remediation technologies, and select the most suitable technologies based on international competitive selection.
- When area of contamination and appropriate technology are identified, remediation of dioxin contaminated soil and sediment should be implemented in Bien Hoa Airbase as soonest.
- Monitoring activities should be developed in three hotspots to ensure the safety for human and environment.

2. Human health researches:

- Beside environmental researches, further studies on environmental health in neighbors of three hotspots need to be implemented, and to suggest the detailed policy for residents living this in this area.
- Implementing and maintaining containment facilities and restricting contact of residents with contaminated areas.
- Improving public knowledge on Agent orange/dioxin in neighboring communities.

PART E

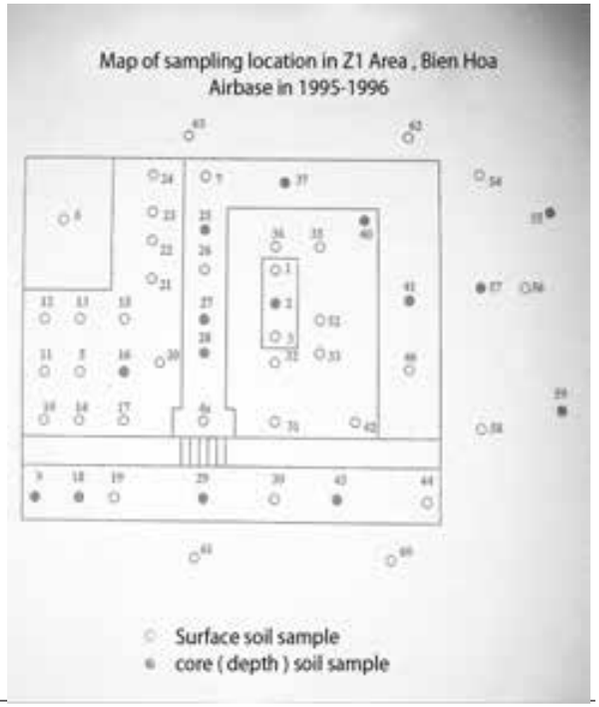
APPENDIX

APPENDIX E1 THE DIOXIN CONCENTRATIONS IN SOILS AND SEDIMENT SAMPLES COLLECTED FROM BIEN HOA AIRBASE

Table E1.1 Data from project Z1 conducted by Vietnamese Ministry of Defense (MOD) in 1995-1996
(coordinates not available, estimation done by MOD & presented in the map).

Location/ sample ID	TEQ (ppt, dry wt)	Soil layer (Depth)	Location/ Sample ID	TEQ (ppt, dry wt)	Depth
Soil Cores (Max depth 120 cm)			**Surface soil (Max depth 30 cm)**		
Nr-27.1	2.698	0-20	Nr. 7	3	0-20
Nr-27.2	1.091	20-40	Nr.42	871	0-20
Nr-27.3	399	40-60	Nr.6	nd	0-20
Nr-27.4	2.088	60-80	Nr.23	16.702	0-20
Nr-40.1	48	0-20	Nr.4	8.349	0-20
Nr-40.2	46	20-40	Nr.28	12.480	0-20
Nr-40.3	472	40-60	Nr.20	1.320	0-20
Nr-40.4	6.514	60-80	Nr.13	21.070	0-20
Nr-29.1	2	0-20	Nr.5	1.015	0-20
Nr-29.2	7.531	20-40	Nr.14	2.761	0-20
Nr-29.3	7.865	40-60	Nr.17	492	0-20
Nr-29.4	5.972	60-80	Nr.19	11.575	0-20
Nr-9.1	409.818	0-20	Nr.44	55.591	0-20
Nr-9.2	2.457	20-40	Nr.53	393	0-20
Nr-9.3	1.433	40-60	Nr.1	12.798	0-20
Nr-9.4	547	60-80	Nr.3	1.100	0-20
Nr-2.1	2.893	0-20	Nr.52	67.672	0-20
Nr-2.2	0	20-40	Nr.26	27	0-30
Nr-2.3	1	40-60	Nr.61	2.374	0-30
Nr-41.1	3.856	0-20	Nr.36	65	0-30
Nr-41.2	24.856	20-40	Nr.15	281	0-30
Nr-41.3	8.488	40-60	Nr.35	nd	0-30
Nr-25.1	3.336	0-30	Nr.32	2.933	0-30

Nr-25.2	4.222	30-60	Nr.33	214	0-30
Nr-25.3	196	60-90	Nr.46	1.396	0-30
Nr-25.4	245	90-120	Nr.21	439	0-30
Nr-59.1	1.408	0-30	Nr.30	7.724	0-30
Nr-59.2	4.120	30-60	Nr.24	2.396	0-30
Nr-59.3	2.930	60-90	Nr.10	58	0-30
Nr-59.4	197	90-120	Nr.63	79	0-30
Nr-57.1	4.460	0-30	Nr.60	2,135	0-30
Nr-57.2	2.550	30-60	Nr.22	930	0-30
Nr-57.3	1.113	60-90	Nr.56	1.839	0-30
Nr-57.4	769	90-120	Nr.31	688	0-30
Nr-55.1	208	0-30	Nr.62	1.571	0-30
Nr-55.2	76	30-60	Nr.58	84.110	0-30
Nr-55.3	63	60-90	Nr.54	58.515	0-30
Nr-55.4	74	90-120	Nr.12	175	0-30
Nr-28.1	1.464	0-30	Nr.41	7.025	0-30
Nr-28.2	293	30-60			
Nr-28.3	3.148	60-90			
Nr-28.4	153	90-120			
Nr-16.1	nd	0-30			
Nr-16.2	71	30-60			
Nr-16.3	25	60-90			
Nr-16.4	nd	90-120			
Nr-43.1	13.290	0-30			
Nr-43.2	269	30-60			
Nr-43.3	114	60-90			
Nr-43.4	161	90-120			
Nr-18.1	12.386	0-30			
Nr-18.2	364	30-60			
Nr-18.3	336	60-90			
Nr-37.1	237	0-30			
Nr-37.1	16	30-60			
ND: not detected					



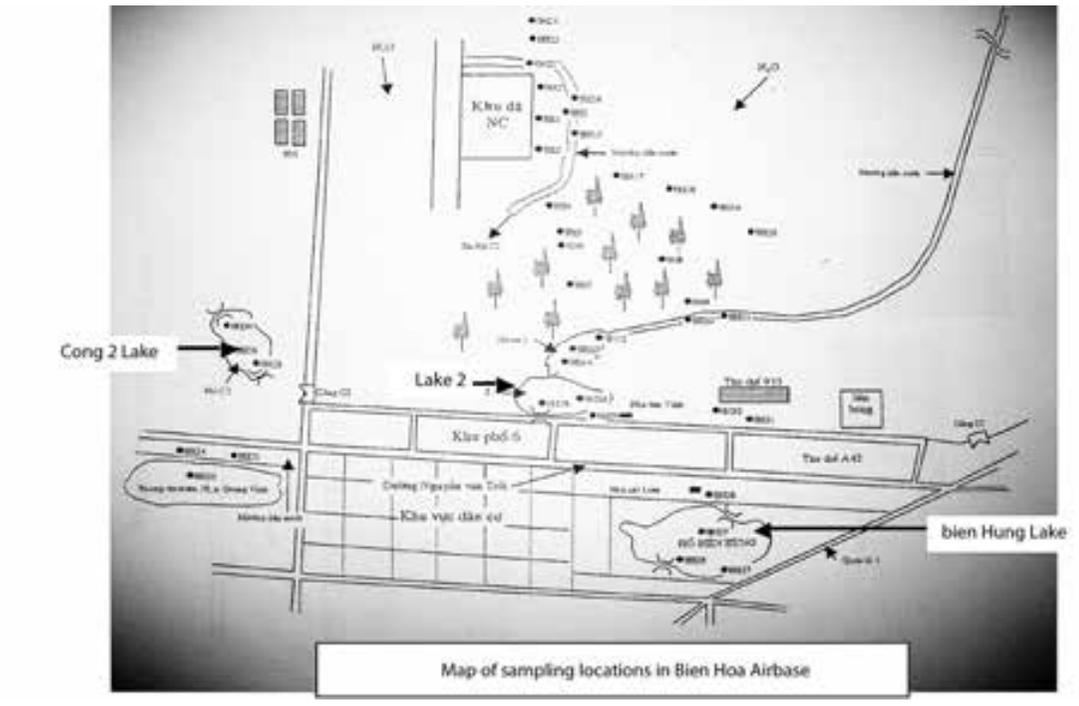
Part E

Table E1.2 Data from research project conducted by Vietnam – Russia Tropical Center (VRTC) in 2000

Z1 Area	TEQ (ppt, dry wt)
BH1	1753
BH2	12244
BH3	11882
BH15	2119
BH16	1381
BH21	150
BH22	5466

Z1- Perimeter Area	TEQ (ppt, dry wt)
BH4	689
BH5	111
BH6	12310
BH7	6
BH8	8,9
BH9	1,7
BH10	4,7
BH11	4,9
BH17	137
BH18	24
BH19	40
BH20	16,2
BH23	193
BH24	89
BH31	1,5
BH32	11

Ponds in vicinity of Z1	TEQ (ppt, dry wt)
BH12	16
BH13	274
BH14	325
BH25	282
BH26	281
BH27	168
BH29	914
BH30	432
BH33	149
BH34	148
BH35	98

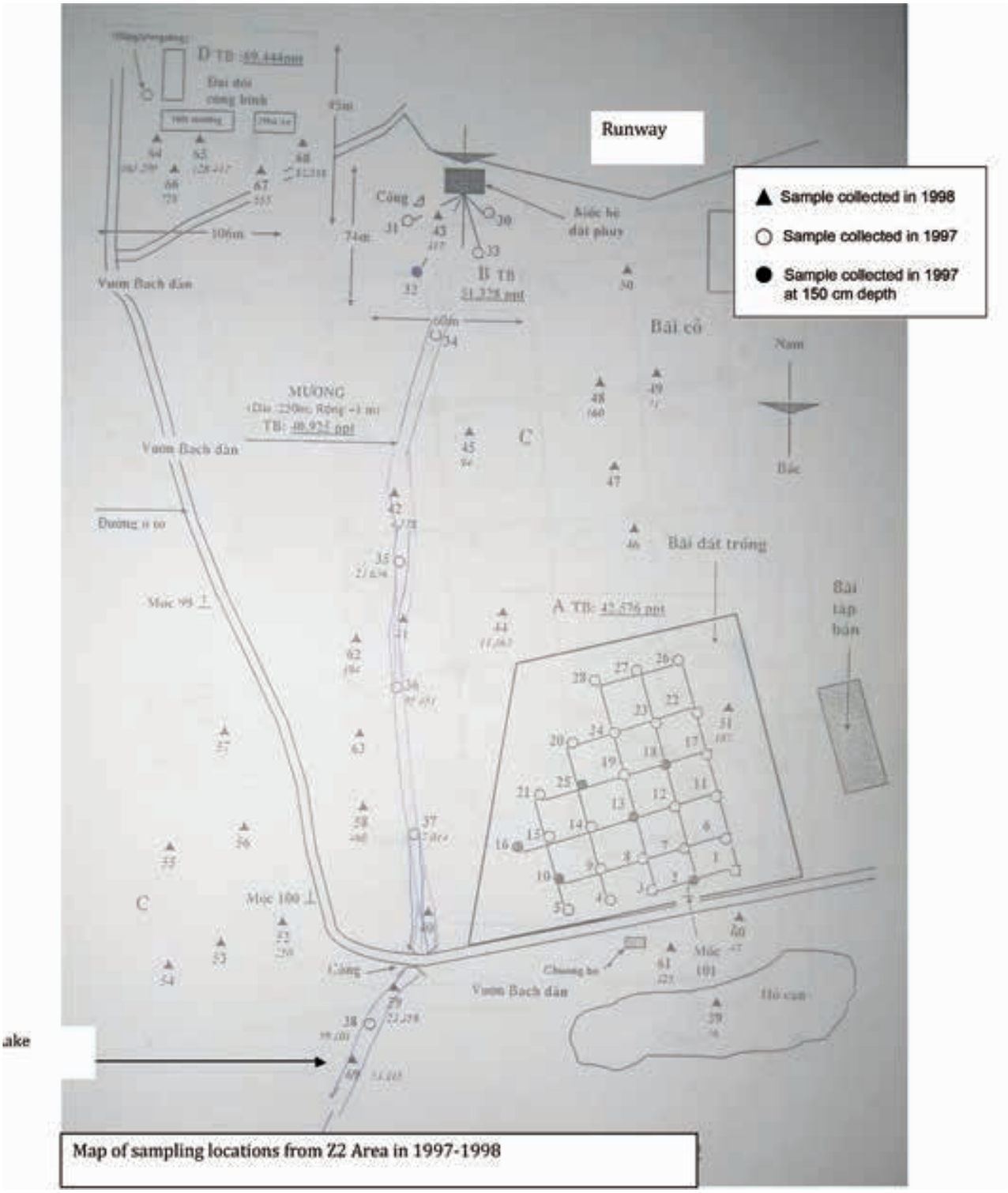


Map of sampling locations in Bien Hoa Airbase

APPENDIX E2 THE DIOXIN CONCENTRATIONS IN SOILS AND SEDIMENT SAMPLES COLLECTED FROM DA NANG

Table E2.1 Data from Project Z2 conducted by MOD in 1997-1998.

Former storage area			Former storage area			Mixing & loading (B)			Drainage Ditch	
Sample ID	ppt TEQ	Remark	Sample ID	ppt TEQ	Remark	Sample ID	ppt TEQ	Remark	Sample ID	ppt TEQ
Nr-1	183		Nr-13.1	116,610		Nr-33.1	1,253	0-30-60 cm	Nr-35	23,656
Nr-2.1	106,900		Nr-13.2	11,830	Soil core (0-30-60-90-120-150 cm)	Nr-33.2	648		Nr-36	95,451
Nr-2.2	16,403	Soil core (0-30-60-90-120-150 cm)	Nr-13.3	660		Nr-43	317		Nr-37	7,014
Nr-2.3	757		Nr-13.4	1,020		**Mixing & loading (D)**			Nr-38	79,101
Nr-2.4	670		Nr-13.5	1,360		Nr-64	165,205		Nr-59	23,358
Nr-2.5	563		Nr-14	-		Nr-65	128,417		Nr-69	53,315
Nr-3			Nr-15	-		Nr-66	728		**Southwest Wetland around Sen Lake (F)**	
Nr-4.1	44,641	0-30-60 cm	Nr-16.1	86,800	Soil core (0-30-60-90-120 cm)	Nr-67	553			
Nr-4.2	5,174		Nr-16.2	2,580		Nr-68	52,318			
Nr-5	134,802		Nr-16.3	1,060		**Between Storage & loading (C)**			Nr-60	47
Nr-6	10,730		Nr-16.4	328					Nr-61	325
Nr-7.1	16,282	0-30-60 cm	Nr-17	692		Nr-42	4,578		**Sen Lake (Lake A)**	
Nr-7.2	710		Nr-18.1	79,221	Soil core (0-30-60-90-120-150 cm)	Nr-44	11,567			
Nr-8	-		Nr-18.2	29,010		Nr-45	94			3520
Nr-9	-		Nr-18.3	20,294		Nr-46	-			1290
Nr-10.1	13,300	Soil core (0-30-60-90-120-150 cm)	Nr-18.4	1,886		Nr-47	-			750
Nr-10.2	1,570		Nr-18.5	708		Nr-48	160		**Other side of the road**	
Nr-10.3	810		**Mixing & loading (B)**			Nr-49	71			
Nr-10.4	820		Nr-30	19,386		Nr-50	-		Nr-52	250
Nr-10.5	1,510		Nr-31	126,413		Nr-58	460		Nr-53	-
Nr-11	1,020		Nr-32.1	58,244	Soil core (0-30-60-90-120 cm)	Nr-62	394		Nr-54	-
Nr-12			Nr-32.2	52,570		Nr-63	-		Nr-55	-
			Nr-32.3	45,947					Nr-56	
			Nr-32.4	29,460					Nr-57	-



Map of sampling locations from Z2 Area in 1997-1998

Table E2.2 Data from project conducted by United States Environmental Protection Agency (US EPA) and Vietnam Academy of Science and Technology (VAST) in 2005.

Former storage area				Mixing & loading (B & D; Mix data CALUX and GC/ MS-HR			
Sample ID	**ppt TEQ**	**NORTHING**	**EASTING**	**Sample ID**	**ppt TEQ**	**NORTHING**	**EASTING**
SA-B1	2811	1777656	200326	ML-B1	10998	1777429	200472
SA-D1	2280	1777635	200327	ML-A2.1	8560	1777415	200458
SA-A2	11577	1777670	200333	ML-B2.1	11061	1777427	200459
SA-B3	11934	1777659	200349	ML-B2.2	6678	1777427	200459
SA-C3	11934	1777649	200348	ML-C2	10998	1777439	200456
SA-D3	2280	1777636	200351	ML-D2	10998	1777451	200455
SA-A4	11934	1777674	200358	ML-A3.1	11061	1777414	200446
SA-H4.1	1861	1777593	200364	ML-B3	10998	1777426	200445
SA-H4.3	6928	1777593	200364	ML-C3.1	9119	1777438	200445
SA-B5.1	4841	1777663	200370	ML-C3.2	9119	1777438	200445
SA-B5.2	2311	1777663	200370	ML-D3	10998	1777450	200443
SA-B5.3	2128	1777663	200370	ML-A4.1	8560	1777412	200435
SA-C5.1	5290	1777652	200372	ML-B4.1	11061	1777425	200434
SA-C5.2	3630	1777652	200372	ML-B4.2	11061	1777425	200434
SA-C5.3	6285	1777652	200372	ML-C4.1	9119	1777436	200430
SA-G5.1	5131	1777606	200378	ML-C4.2	9119	1777436	200430
SA-G5.2	47	1777606	200378	ML-C4.3	5737	1777436	200430
SA-G5.3	79	1777606	200378	ML-D4.1	11577	1777449	200434
SA-A6.1	1889	1777677	200387	ML-D4.2	6890	1777449	200434
SA-A6.2	0	1777677	200387	ML-D4.3	7699	1777449	200434
SA-A6.3	2549	1777677	200387	ML-A5	8560	1777410	200419
SA-A6.4	8429	1777677	200387	ML-C5	10998	1777433	200428
SA-B6	11934	1777664	200384	ML-A7.1	8560	1777442	200545
SA-C6.1	11991	1777654	200386	ML-B7.1	30	1777442	200532
SA-C6.2	11991	1777654	200386	ML-B7.2	33	1777442	200532
SA-F6.1	51	1777619	200391	ML-B7.3	16	1777442	200532
SA-F6.2	39	1777619	200391	ML-A8	8560	1777442	200551
SA-F6.3	17	1777619	200391	ML-B8.1	10222	1777444	200545
SA-A7	11934	1777679	200394	ML-B8.2	6682	1777444	200545
SA-D7	4770	1777642	200399	ML-B8.3	1547	1777444	200545

Table E2.2 Data from project conducted by United States Environmental Protection Agency (US EPA) and Vietnam Academy of Science and Technology (VAST) in 2005.

Former storage area				Mixing & loading (B & D; Mix data CALUX and GC/MS-HR			
Sample ID	**ppt TEQ**	**NORTHING**	**EASTING**	**Sample ID**	**ppt TEQ**	**NORTHING**	**EASTING**
SA-G7	8560	1777609	200402	ML-C8.1	9119	1777448	200542
SA-B8	11934	1777666	200408	ML-C8.2	9119	1777448	200542
SA-C8.1	18	1777656	200411	ML-C8.3	5737	1777448	200542
SA-C8.2	7	1777656	200411	ML-A9	10998	1777444	200555
SA-C8.3	15	1777656	200411	ML-B9.1	11061	1777446	200550
SA-A9	11934	1777679	200417	ML-B9.2	11061	1777446	200550
SA-D9	8560	1777648	200420	ML-B9.3	11061	1777446	200550
SA-E9.1	5207	1777636	200421	ML-C9.1	9119	1777448	200547
SA-E9.2	35	1777636	200421	ML-C9.2	11577	1777448	200547
SA-E9.3	156	1777636	200421	ML-C9.3	4725	1777448	200547
SA-B10	11934	1777672	200430	ML-B10.1	11061	1777447	200555
SA-A11	11934	1777686	200440	ML-B10.2	5174	1777447	200555
SA-A12	11934	1777685	200447	ML-B10.3	2860	1777447	200555
Hồ Sen (Hồ A)				ML-C10.1	9119	1777449	200554
OP-A2	10999			ML-C10.2	11577	1777449	200554
OP-C2	5499			ML-C10.3	4725	1777449	200554
OP-B1	10999			ML-B11.1	11061	1777447	200559
				ML-B11.2	5174	1777447	200559
				ML-B11.3	2860	1777447	200559
				ML-C11.1	11577	1777450	200557
				ML-C11.2	6890	1777450	200557
				ML-C11.3	7699	1777450	200557
				ML-B12	10998	1777448	200563
				ML-C12	10998	1777448	200534
				ML-B13	10998	1777451	200565
				ML-B14	10998	1777437	200490
				ML-B18	10998	1777440	200508
				ML-B20	10998	1777442	200535

Table E2.3 Data from project conducted by VRTC under Office 33 Program in 2006

Mixing & loading (D)		Between Storage & loading (C)		Southeast Wetland around Sen lake (E)		Southwest Wetland around Sen Lake (F)		Sen Lake (Lake A)		Lake B		Lake C	
Sample ID	**ppt TEQ**	**Sample ID**	**ppt TEQ**	**Sample ID**	**ppt TEQ**	**Sample ID**	**ppt TEQ**	**Sample ID**	**ppt TEQ**	**Sample ID**	**ppt TEQ**	**Sample ID**	**ppt TEQ**
DN31	6,1	DN15	345	DN16	43.6	DN22	6	DN1	1035	DN12	30	DN21 (đất)	2.9
DN32	1032	DN16	214	DN17	17.8	DN23	57.6	DN2	4137	DN13	44.9	DN14 (Bùn)	42
DN33	2490	DN17	316	DN18	28.3	DN24	11.6	DN3	2947				
DN34	4015	DN18	-	DN19	11.8			DN4	4884				
		DN19	121	DN20	2.2	DN26	8.2	DN5	4668				
				DN29	57.5	DN27	4.8	DN6	2904				
						DN28	4.3	DN7	2043				
								DN8	700				
								DN9	12393				
								DN10	1057				
								DN11	282				

APPENDIX E3 THE DIOXIN CONCENTRATIONS IN SOIL AND SEDIMENT SAMPLES COLLECTED FROM PHU CAT

Table E3.1 Data from Project Z3 conducted by MOD in 1999-2000

Z3: Storage Area	ppt TEQ	Remark	B: Perimeter Area (Z3.3)	ppt TEQ	Remark	KDrain & sedimentation basin (in Z3 area)	Tppt TEQ	C: Washing/L area (Z3.2)	ppt TEQ	Remark	Lakes	ppt TEQ	Remark
PC 21.1	15,907	0-30-60 cm	PC 1.1	8.5	0-30-60 cm	B4	419	PC 51.1	19.0		B1	0.01	Lake A
PC 21.2	541		PC 1.2	0.2		B5	64	PC 17.1	26.2		B2	87	Lake A
PC 22.1	44,740	0-30-60-90-120-150-180 cm	PC 2.1	2,452	0-30-60-90 cm	B6	120	PC 18.1	40.4	0-30-60-90 cm	B3	54	Lake A
PC 22.2	2,537		PC 2.2	71				PC 18.2	8.5		PC 41	20	Lake A
PC 22.3	682		PC 2.3	35				PC 18.3	1.2		PC 44	45	Lake A
PC 22.4	606		PC 3.1	19				PC 29.1	218.0		PC 81	45	Lake A
PC 22.5	215		PC 6.1	57				PC 32.1	21.3		PC 84	59	Lake A
PC 22.6	6		PC 8.1	11				PC 38.1	17.0		PC 88	75	Lake A
PC 25.1	49,462	0-30-60-90-120-150-180 cm	PC 10.1	13				PC 38.2	21.0		PC 90	15	Lake A
PC 25.2	4123		PC 12.1	-							PC 93	58	Lake A
PC 25.3	1665		PC 45.1	253							PC 42	127	Lake B
PC 25.4	686		PC 60.1	98							PC 43	3.6	Lake B
PC 25.5	26		PC 65.1	-							PC 96	47	Lake B
PC 25.6	4.3		PC 70.1	142							PC 102	196	Lake B
PC 26	723		PC 72.1	175							PC 103	56	Lake B
PC 27.1	12005	0-30-60-90-120 cm									PC 97	8.5	Lake C
PC 27.2	841										PC 98	1.7	Lake C
PC 27.3	731										PC 99	6.5	Lake C
PC 27.4	226												
PC 30	3043												
PC 51.1	5258	0-30-60-90-120 cm											
PC 51.2	483												
PC 51.3	-												
PC 51.4	-												
PC 56.1	2437	0-30-60 cm											
PC 56.2	212												
PC 59	2673												
PC 19	152												

APPENDIX E4 THE DIOXIN CONCENTRATIONS IN HUMAN SAMPLES

Table E4.1.Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) from residents of Da Nang, Viet Nam, December 2006.

Sample ID	Sex	Age	% Lipid	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD /TEQ (2005)
Sen Lake						
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	M	39	0.24	< 1.62	135	-
06VNB052	M	29	0.26	33.4	62.9	53
06VNB053	F	23	0.26	14	39.3	36
06VNB058	F	35	0.26	25.5	57.5	44
06VNB060	F	34	0.26	36	79.3	45
06VNB050	M	39	0.33	20.3	34.7	59
06VNB054	M	27	0.31	41.8	78	54
06VNB055	F	24	0.29	41.1	93.6	44
06VNB056	F	52	0.19	71.4	165	43
06VNB057	F	35	0.31	6.71	15.9	42
06VNB059	M	42	0.19	77.7	142	55
Thanh Khe District (random)						
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

Sample ID	Sex	Age	% Lipid	2,3,7,8-TCDD	TEQ (WHO 2005) ND=1/2DL	TCDD/TEQ (2005)
Hai Chau District (random)						
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
Thanh Khe District (non-random)						
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
Hai Chau District (non-random)						
06VNB061	F	44	0.35	44.2	77.7	57
Thanh Khe District (non-random)						
06VN201M	F	30	3.24	6.76	42.4	16

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.

Table E4.2. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt), Da Nang, Viet Nam, April 2009

Table E4.2.1. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Anh Khe Ward, THanh Khe District, Da Nang, 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/ 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	2.73	2.76	6.91	27.9	28.2	263	< 0.994	< 0.994	7.18	28.7	25.7	NDR 1.57	0.36	19.5	18.1	15
09VNB-187	M	22	13.3	13.3	5.89	23.1	17.9	169	0.82	< 0.794	7.94	19	14.9	NDR 1.05	0.39	28	26.4	50
09VNB-194	M	51	12.1	12.1	5.89	20.2	11.2	130	< 1.15	< 1.15	7.29	14.6	7.01	NDR 1.29	0.36	25.4	24	50
09VNB-195	F	44	18.8	18.8	6.56	26.8	31.6	271	< 1.19	< 1.19	8.35	31.3	18.2	< 1.19	0.34	36.1	34.4	55
09VNB-204	F	50	21.6	21.6	25.5	91.8	112	871	1.58	3.01	19.5	54.2	30.6	1.72	0.43	72.2	68.8	31
09VNB-205	M	44	123	123	17.2	71.8	45.9	692	2.35	2.33	21	58.4	17.4	< 0.699	0.47	164	160	77
09VNB-206	F	33	17.6	17.6	3.33	12.2	19.1	179	0.888	0.925	3.89	11.1	9.07	< 0.666	0.54	25.6	24.8	71
09VNB-207	M	42	54.9	54.9	9.65	35.1	59.5	328	2.36	2.29	11.9	27.7	14.2	< 0.889	0.39	77.3	75.2	73
09VNB-208	M	21	7.39	7.53	4.35	15.1	13.6	169	< 0.956	< 0.956	5.51	14.8	10.1	< 0.956	0.35	17.8	16.7	44
09VNB-209	M	23	5.9	5.83	9.55	38.4	67.1	375	1.1	1.17	9.79	45	34.3	1.14	0.43	29.4	27.8	21
09VNB-210	F	37	3.91	3.86	1.59	5	8.63	50.9	0.886	0.909	2.95	6.14	4.32	< 0.750	0.44	8.34	7.77	50
09VNB-211	M	42	11.8	11.7	7.34	30.6	22.8	183	1.25	1.22	11.3	25.7	18.6	< 0.856	0.41	30.6	28.6	41
09VNB-212	M	34	2.89	2.99	3.22	13.5	16.8	372	< 0.781	< 0.781	7.35	23.7	22.7	1.72	0.44	13.5	12.3	23
09VNB-213	M	42	17.7	17.7	5.69	24.5	29.6	184	1.05	1.2	6.88	20.1	12.9	< 1.02	0.33	32.1	30.7	58
09VNB-214	F	37	11.2	11.2	4.06	17.8	26.2	160	< 1.15	1.25	7.18	22.8	28.4	< 1.15	0.32	22.9	21.8	51

ND = không phát hiện thấy; Nếu không phát hiện, thì lấy giá trị ½ giới hạn phát hiện để tính tổng TEQ
NDR = Phát hiện được pic, nhưng không đủ tiêu chuẩn để định lượng; NDR lấy giá trị bằng giới hạn phát hiện để tính tổng TEQ

Table E4.2.2. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Khue Trung Ward, Cam Le District, Da Nang, 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/ 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	M	38	< 5.64	< 5.64	9.85	25.2	< 5.64	1220	< 5.64	52	< 5.64	59.1	64.6	NDR 7.25	0.25	25	24.7	-
09VNB-101	M	39	3.47	3.51	< 1.27	45.9	60.6	822	< 1.27	1.27	11.8	60.9	37.3	NDR 1.66	0.31	32	29.8	12
09VNB-102	M	56	2.96	2.86	5.2	17.7	38.8	260	< 0.858	< 0.858	7.02	35.4	26	NDR 0.884	0.38	17.8	16.5	18
09VNB-103	F	42	NDR 1.94	< 1.15	5.87	23.8	40.2	341	< 1.15	< 1.15	6.75	32.6	28.2	1.73	0.34	16.5	15.1	-
09VNB-104	F	44	2.25	2.18	6.77	35.8	46.2	486	1.06	0.967	< 0.798	73.7	77.1	3.65	0.41	21.5	21.5	10
09VNB-105	M	37	1.5	1.58	3.16	11.9	20.6	254	< 0.870	< 0.870	5.27	24.5	21.6	1.66	0.38	11.5	10.5	14
09VNB-106	F	50	2.58	2.67	5.57	19.6	17.1	285	0.846	0.891	8.46	34.5	23.4	< 0.735	0.45	18.4	16.8	15
09VNB-107	M	52	2.52	2.45	6.6	19.8	18.3	239	< 0.807	< 2.03	9.29	42.5	30.3	< 0.807	0.41	20.6	18.8	13
09VNB-108	M	23	4.27	4.33	6.22	22.5	19.7	189	< 1.00	< 1.00	7.58	19.5	13.3	< 1.00	0.37	18.9	17.4	25
09VNB-109	M	47	NDR 3.49	< 0.942	5.98	12.2	11	174	1.52	4.6	< 0.759	6.67	1.38	NDR 2.44	0.44	9	8.95	-
09VNB-110	F	45	1.97	2	4.99	38.7	109	679	NDR 0.848	< 0.848	7.73	41.7	29.4	< 0.848	0.4	20.1	18.8	10
09VNB-111	M	22	3.16	2.99	7.99	35.3	31.3	492	< 1.26	< 1.26	< 1.26	35.9	28.9	5.32	0.3	19.3	19.3	16
09VNB-112	M	37	NDR 0.978	< 0.896	1.9	5.16	9.51	112	< 0.896	< 0.896	< 0.896	8.15	6.79	0.951	0.37	4.29	4.21	-
09VNB-113	M	28	2.15	2.03	5.22	13.4	14.8	221	< 1.13	< 1.13	7.84	31.6	30.5	NDR 1.89	0.34	16.7	15.1	14
09VNB-114	F	41	4.69	4.72	8.69	28.5	21.6	233	1.04	0.993	11.4	70.2	42.2	1.94	0.4	29.9	27.7	17
09VNB-115	Nữ	56	2.69	2.72	6.95	28.7	30.5	287	< 0.967	< 0.967	10.9	43.5	31.1	< 0.967	0.33	23	20.9	13

Table E4.2.2. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Khue Trung Ward, Cam Le District, Da Nang, 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/ 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-116	F	23	1.4	1.4	< 0.984	2.39	12.9	177	NDR 1.04	< 0.984	< 0.984	23	13.2	NDR 1.58	0.34	5.24	5.17	27
09VNB-117	M	31	2.81	2.81	< 1.15	18.8	31.4	294	< 1.15	< 1.15	9.06	42	28.4	< 1.15	0.34	14.9	13.1	21
09VNB-118	F	34	< 1.06	< 1.06	5.16	15.5	44.5	239	< 1.06	< 1.06	< 1.06	19.1	12.6	1.55	0.31	10.2	10.1	-
09VNB-119	F	30	3.88	3.88	13.9	107	150	1240	3.76	3.76	21.6	98.4	76.5	5.21	0.24	51.9	47.8	8
09VNB-120	M	33	1.2	1.2	1.73	6.95	16.2	223	< 0.767	< 0.767	1.08	8.72	20.6	NDR 1.70	0.42	5.33	5.28	23
09VNB-121	F	38	2.66	2.66	8.14	39.4	37	274	1.96	1.96	10.9	57.9	35.9	NDR 1.02	0.46	26.9	24.7	11
09VNB-122	M	39	1.71	1.71	5.53	15.6	30.1	336	< 1.17	< 1.17	10.2	61.8	33.9	NDR 1.33	0.37	21	19	9
09VNB-123	F	20	2.31	2.31	< 0.923	< 0.923	15.3	263	< 0.923	< 0.923	< 0.923	26.5	20.4	< 1.36	0.35	6.34	6.29	37
09VNB-124	M	32	6.76	6.76	< 0.858	22.2	22.8	236	< 0.858	< 0.858	10	40.5	28.6	NDR 1.48	0.38	19.2	17.2	39
09VNB-125	M	20	NDR 2.58	< 0.861	< 0.861	7.65	12.3	189	< 0.861	< 0.861	6.5	10.9	12.8	< 0.861	0.38	6.52	5.25	-
09VNB-126	F	46	5.11	5.11	5.19	23	30.4	256	1.16	1.16	7.58	39.8	28.5	1.32	0.37	21.2	19.7	26
09VNB-127	M	43	< 0.987	< 0.987	< 0.987	2.63	25.7	299	< 0.987	< 0.987	2.84	20.6	43.7	NDR 1.85	0.33	5.72	5.21	-
09VNB-128	F	41	2.44	2.44	5.5	24.5	30.3	367	1.42	1.42	9.04	35.4	25.2	2.44	0.37	19.2	17.5	14
09VNB-129	F	39	2.05	2.05	3.99	17.3	24.1	247	< 0.982	< 0.982	5.84	25.2	22.8	1.59	0.35	13.8	12.7	16
09VNB-130	M	40	NDR 4.10	< 1.61	11	65.4	76.6	659	2.29	2.29	18.9	51.7	29.4	NDR 3.17	0.2	34.4	30.7	-
09VNB-131	F	30	3.11	3.11	9	26.2	19.7	325	< 0.859	< 0.859	9.61	33.8	18.9	1.34	0.37	23.4	21.6	14

Table E4.2.2. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Khue Trung Ward, Cam Le District, Da Nang, 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/ 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-129	F	39	2.05	2.05	3.99	17.3	24.1	247	< 0.982	< 0.982	5.84	25.2	22.8	1.59	0.35	13.8	12.7	16
09VNB-130	M	40	NDR 4.10	< 1.61	11	65.4	76.6	659	2.29	2.29	18.9	51.7	29.4	NDR 3.17	0.2	34.4	30.7	-
09VNB-131	M	30	3.11	3.11	9	26.2	19.7	325	< 0.859	< 0.859	9.61	33.8	18.9	1.34	0.37	23.4	21.6	14
09VNB-132	M	18	1.44	1.28	< 1.06	9.85	8.67	156	< 1.06	< 1.06	5.46	18	< 1.06	< 1.06	0.31	7.88	6.79	21
09VNB-133	M	43	3.07	3.02	7.65	25.8	14.9	222	< 0.661	< 0.661	12.3	47.1	40.1	NDR 1.82	0.5	24.5	22.2	14
09VNB-134	M	28	NDR 1.87	< 1.24	< 1.24	5.4	14.9	233	1.65	1.59	6.98	18.7	15.6	< 1.24	0.31	7.94	6.56	-
09VNB-135	F	37	1.74	1.67	< 1.38	13.8	< 1.38	331	NDR 1.48	< 1.38	< 1.38	23.4	22.6	NDR 1.74	0.42	7.08	6.99	25
09VNB-136	M	37	4.13	4.13	10.6	33.4	30.4	348	1.36	1.36	10.6	43.5	27.9	NDR 1.51	0.4	28.6	26.6	16
09VNB-137	F	46	5.91	6.04	< 1.11	66.5	95.4	819	1.65	1.65	< 1.11	114	99.4	3.86	0.3	27.1	27.2	22
09VNB-138	F	41	2.47	2.58	6.89	40.5	58.6	781	NDR 1.06	< 0.947	10.9	88.7	96.2	NDR 3.44	0.35	29.6	27.6	9
09VNB-139	M	52	6.92	6.92	12.3	36.5	23	244	1.51	1.52	16.5	48.6	19	NDR 0.996	0.72	36.6	33.4	21
09VNB-140	F	38	NDR 2.03	< 0.957	< 0.957	4.79	40.1	258	1.5	1.5	7.78	39.2	32	1.02	0.33	10.3	8.75	-
09VNB-141	F	62	2.51	2.51	7.29	27.6	26.1	200	1.38	1.38	12.1	44	18.4	< 0.844	0.39	23.2	21	12
09VNB-142	M	39	3.06	3.06	7.32	34	41.1	588	NDR 1.17	< 0.765	13.8	55.2	40.9	NDR 1.24	0.42	26.6	24.2	13
09VNB-143	M	46	1.5	1.41	< 0.904	15.2	37.3	384	NDR 0.904	< 0.904	7.62	27.4	20.3	NDR 1.27	0.35	10.8	9.38	16
09VNB-144	M	23	2.1	2.04	6.41	30.3	46.9	615	1.66	1.75	11.9	59.7	45.4	1.66	0.34	24.9	22.6	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.

Table E4.2.3. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Thuan Tay Ward, Hai Chau District, Da Nang, 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/ 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	9.31	9.42	9.96	35.8	32.6	632	< 1.10	< 1.10	12.9	61.4	39.8	NDR 1.78	0.37	36.4	33.9	27
09VNB-146	F	48	44	44	5.78	16.9	42	236	< 1.81	< 1.81	8.05	26.9	32.2	8.65	0.4	59.2	57.6	76
09VNB-147	M	54	23.7	23.7	9.8	38.5	36.8	306	1.53	1.43	16.5	54.7	38	1.22	0.42	50.9	48.1	49
09VNB-149	M	27	4.78	4.86	4.08	16.5	18.3	193	< 1.48	< 1.48	5.44	22.1	23.3	NDR 2.33	0.51	16.1	15.1	32
09VNB-151	F	49	30	30	8.92	33.3	30.8	223	< 1.20	2.84	11.4	37.9	17.8	< 1.20	0.49	51.7	49.8	60
09VNB-152	F	50	4.99	5.1	5.98	27.9	25.5	139	< 1.29	< 1.29	10.9	66	31.5	< 1.29	0.45	26.4	24.3	21
09VNB-157	M	51	25.1	25.1	6.04	18.6	30.9	228	< 2.74	3.72	8.6	22.1	14.4	< 2.74	0.43	40.6	38.8	65
09VNB-158	M	22	38.3	38.3	4.63	12.3	18.3	265	< 1.52	1.54	5.91	13.9	12.6	< 1.52	0.39	49.2	48.1	80
09VNB-161	M	44	10.3	10.4	11.2	64.2	70.3	1010	< 1.08	< 1.08	12.9	40.9	27.7	< 1.08	0.53	39	36.8	28
09VNB-164	F	19	NDR 3.47	< 0.875	5.08	19.3	41.5	534	< 0.875	1.13	4.32	22.6	25.7	1.16	0.35	12.8	12	-
09VNB-165	M	26	2.51	2.51	6.44	28.8	31.1	531	1.26	2.04	13	41.5	34.7	NDR 1.73	0.64	22.7	20.4	12
09VNB-166	F	57	3.08	3.02	5.85	19.8	20.8	127	0.755	0.755	11.5	38	16.1	NDR 0.699	0.53	20.5	18.4	17
09VNB-167	M	34	5.75	5.67	7.22	26	12.6	139	NDR 1.11	< 0.902	9.54	20.4	13.1	0.98	0.39	22.8	20.9	28
09VNB-168	F	48	13.7	13.7	3.96	14	12.6	214	< 1.98	< 1.98	6.05	17.7	11.9	< 1.98	0.43	24.5	23.3	59
09VNB-169	F	33	1.11	3.12	2.84	11.9	17.3	240	3.75	9.65	7.38	23.3	30.4	2.7	0.35	10.9	9.87	11
09VNB-170	M	47	3.27	3.21	5.18	11.8	16.4	168	0.678	0.714	8.03	23.6	14.6	NDR 1.73	0.56	16.5	14.9	22
09VNB-172	M	19	1.44	1.49	< 0.701	7.22	13.6	150	0.701	< 0.701	3.4	15.3	16.1	NDR 2.17	0.47	6.2	5.54	26
09VNB-173	M	54	24.9	25	5.62	18.4	18.4	208	NDR 1.37	< 0.999	6.87	16.2	11.9	< 0.999	0.32	37.8	36.5	68
09VNB-174	F	53	15.8	15.7	16.1	57.2	48.7	412	< 0.720	< 0.720	12	55.9	36.4	NDR 2.62	0.46	50.1	47.8	33
09VNB-175	M	53	2.89	2.79	10.1	51.6	50.2	527	< 1.78	< 1.78	17.1	86.1	57.9	NDR 1.88	0.29	36.8	33.5	9
09VNB-176	M	24	21.1	21.2	3.16	12.2	16.8	153	2.26	2.19	4.14	11.9	10.7	< 1.10	0.41	29.3	28.5	74
09VNB-177	M	69	43.1	43.1	9.32	37.1	39.8	302	3.92	3.94	8.7	30.9	11	1.04	0.48	64.6	62.9	69
09VNB-178	M	43	6.5	6.44	8.34	34.8	35.6	360	NDR 1.29	< 0.483	12.4	49.9	33.5	1.16	0.68	29.5	27.4	24
09VNB-179	M	39	25.5	25.5	8.3	16.4	27.4	148	1.81	1.89	11.5	20.4	10.4	< 0.604	0.53	42.9	41	62

Table E4.2.4. Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) in Thuan Phuoc Ward, Hai Chau District, Da Nang, December 2006

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDD (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ 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

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.

Table E4.3 Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) 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)						PCDD (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ 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	271	271	23.7	75.9	35	323	1.51	1.44	24.9	96.1	39.1	1.94	0.42	325	320	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	539	539	15.7	41.5	37.2	459	7.79	7.85	11.3	44.5	38	1.53	0.5	570	568	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	361	361	23.1	85.2	70.3	769	2.63	2.68	21.8	101	31.1	2.32	0.71	414	411	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	120	120	7.48	23.3	19.1	218	< 2.08	< 2.08	6.85	27.4	< 2.08	2.24	0.48	137	135	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	170	170	9.29	32.4	38.1	324	0.881	0.953	14	53.6	33.3	1.98	0.42	195	193	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	8.36	8.28	4	17.4	41.7	982	< 0.970	< 0.970	6.28	24.8	19.7	1.37	0.35	20.5	19.5	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	4.59	4.7	9.17	45.2	40.1	434	< 0.761	< 0.761	14.8	87.9	44.5	1.5	0.45	34.9	32.3	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	24	23.9	5.35	27.3	14.6	400	< 0.901	< 0.901	7.6	40.5	40.5	2	0.36	40.6	39.2	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	6.24	6.15	4.49	16.1	15.8	230	< 0.780	< 0.780	7.8	34.5	28.6	1.13	0.42	20.1	18.6	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	52.4	52.4	9.99	38.1	16.5	456	< 0.999	< 0.999	13.5	58.1	74.8	2.89	0.37	79.9	77.2	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	22.2	22.3	7.52	27.9	26	279	< 1.13	< 1.13	14.7	21	18.8	< 1.13	0.32	42.8	39.9	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.
06VNB### = 2006 sample number; 09VNB-### = 2009 sample number.

Table E4.4 Concentrations of PCDDs and PCDFs in human blood (pg/g, lipid wt) 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)						PCDD (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ 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	< 1.62	357	75.9	265	174	1620	NDR 6.09	< 1.62	56.4	139	89.2	14.2	0.24	144	135	-
09VNB-183	M	42	97.3	97.3	22.3	79.6	45.6	555	1.13	1.05	14.7	34.2	20.8	1.29	0.66	138	136	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	26.7	26.7	7.06	23.7	25.7	136	< 0.832	< 0.832	12.4	16.4	8.57	< 0.832	0.4	44.5	42	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	9.84	9.94	7.03	26.9	24.2	296	< 0.897	< 0.897	7.76	17	17.9	1.07	0.41	25.8	24.3	40
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	12.1	12.1	6.59	33.2	58	534	0.857	0.879	8.13	38.2	34.3	2.53	0.46	30.5	29.2	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	18.9	18.9	10.3	37.6	33.9	265	0.698	< 0.637	10.1	22.8	14.2	< 0.637	0.49	40.8	38.9	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	21.9	21.8	10.7	40.6	15.7	169	< 0.854	< 0.854	14.7	14.7	7.11	< 0.854	0.42	45.9	43	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.
06VNB### = 2006 sample number; 09VNB-### = 2009 sample number.

Table E4.5 Concentrations of PCDDs and PCDFs in human breast milk from districts near the Da Nang Airbase (pg/g, lipid wt), Viet Nam, April 2009 and December 2006

Sample ID	District	Ward	Age	PCDD (pg/g lipid basis)						PCDD (pg/g lipid basis)						% Lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ TEQ (2005)	TCDD/ 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	An 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	32%
09VN341A	Thanh Khe	An 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	48%
09VN342A	Thanh Khe	An 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	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	88%
09VN344A	South of 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	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	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	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	35%
09VN335A	Hai Châu	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	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	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	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	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	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	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	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.

Table E4.6 Concentrations of PCDDs and PCDFs in human blood serum (pg/g, lipid wt) from residents of Bien Hoa, Viet Nam, November 2010

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDD (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				
10VNBH600	M	45	27.8	27.8	5.87	28.4	62.1	402	<0.709	<0.709	6.78	19	16.7	NDR 0.732	0.86	42.7	41.5	67
10VNBH601	F	46	58	58	10.7	32	25.6	282	1.52	1.52	8.15	18.9	10.5	<0.72	0.86	78	76.6	75.7
10VNBH602	M	48	42.1	42.1	8.33	28.8	17.2	225	0.978	0.978	9.29	22.3	11.3	<0.595	0.94	60.7	58.8	71.6
10VNBH603	M	47	137	137	<0.701	27.6	29.3	319	NDR 1.4	<0.701	7.49	17.5	12.1	NDR 0.724	0.87	146	145	94.5
10VNBH604	M	42	1040	1040	25.1	46.7	39.4	275	1.57	1.57	14.1	17.4	23.6	NDR 0.902	0.81	1080	1080	96.3
10VNBH605	M	47	37.7	37.7	5.05	18.5	25.7	346	NDR 1.21	<0.564	5.88	20	15	<0.564	1.1	50.1	49	76.9
10VNBH606	M	50	92.8	92.8	9.81	33.3	29.4	249	NDR1.32	<0.752	9.93	22.1	17.7	NDR 1.8	0.89	113	111	83.6
10VNBH607	M	47	40.9	40.9	6.21	17.9	11.6	105	1.34	1.34	<0.564	13.1	6.3	<0.564	1.1	50.7	50.7	80.7
10VNBH608	M	48	29.9	29.9	4.22	7.27	18.6	109	NDR 0.867	<0.667	4.71	11.8	7.12	<0.667	0.9	38.8	37.9	78.9
10VNBH609	M	48	17.6	17.6	7.45	20.7	<1.12	280	1.55	1.55	6.56	16.3	9.82	<1.12	0.78	32.5	31.2	56.4
10VNBH610	M	46	13.7	13.7	<1.09	12.9	25	212	NDR 1.6	<1.09	5.56	14	11.4	<1.09	0.63	20.3	19.3	71
10VNBH611	M	45	56.5	56.5	6.53	25.5	33.4	214	NDR 1.27	<0.67	7.24	18.9	13	<0.67	0.82	71.7	70.2	80.5
10VNBH612	M	47	79	79	11.8	50.8	72.6	596	1.8	1.8	12.8	30.6	22.2	<0.688	0.9	106	104	76
10VNBH613	M	48	53.3	53.3	9.52	47.2	21.6	370	0.526	0.526	9.99	22.3	12.5	NDR 0.666	1.5	75	73.2	72.8
10VNBH614	M	43	327	327	9.04	29.5	72.1	596	3.05	3.05	10.3	35.4	23.4	1.22	0.9	349	347	94.2
10VNBH615	M	46	42.8	42.8	9.82	36.9	42.5	377	2.36	3.11	12.2	28.8	17.1	<0.61	1	66.2	63.9	67
10VNBH616	M	48	45.9	45.9	8.55	33.6	66.2	558	NDR 1.12	<0.754	<0.754	23.3	12.9	<0.754	1.1	61.3	61.3	74.9
10VNBH617	M	47	322	322	12.1	43.2	61.4	547	NDR 1.24	<0.903	9.81	8.58	29.6	<0.903	0.71	345	343	93.9
10VNBH618	M	45	67.8	67.8	8.37	25.2	42.4	331	1.53	1.53	8.62	10.5	15.6	<0.654	0.98	84.9	83.3	81.4

Table E4.6 Concentrations of PCDDs and PCDFs in human blood serum (pg/g, lipid wt) from residents of Bien Hoa, Viet Nam, November 2010

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDD (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				
10VNBH619	M	46	38.9	38.9	5.19	18.8	17.5	223	NDR 1.01	<0.711	5.75	14.6	13.1	<0.711	0.8	50.8	49.7	78.3
10VNBH620	M	48	32.4	32.4	7.26	22.7	20.4	202	<0.913	1.1	6	14.1	11.3	<0.913	0.7	46.8	45.7	70.9
10VNBH621	M	45	95.8	95.8	7.66	22.2	28.6	237	1.01	1.59	6.61	14.4	7.68	0.791	1.2	111	110	87.1
10VNBH622	M	48	274	274	14.9	57.9	77.8	663	NDR 2.64	<1.04	14	35.5	35	NDR 1.73	0.71	306	303	90.4
10VNBH623	M	47	67.7	67.7	7.6	23.9	14.1	211	1.4	1.4	8.15	18.8	1.01	<0.719	0.89	84	82.4	82.2
10VNBH624	M	45	72.1	72.1	8.8	36	45	314	NDR 1.47	1.25	<1.09	22.8	23	<1.09	0.64	87.9	87.8	82.1
10VNBH625	M	46	44.1	44.1	6.62	22.3	27.4	208	2.29	2.29	7.35	18	<0.5	0.55	1.2	59	57.5	76.7
10VNBH626	F	46	31.9	31.9	<0.989	17.5	15.2	261	1.91	3.26	<0.989	7.5	10.1	<0.989	0.76	35.8	35.8	89.1
10VNBH627	M	48	71	71	8	31.5	28.8	330	1.98	1.98	10.5	28	19	<1.44	0.52	91.1	89	79.8
10VNBH628	M	53	159	159	9.43	33.2	33.9	295	4.09	4.09	<1.02	<1.02	<1.04	<1.02	0.73	173	173	91.9
10VNBH629	F	61	160	160	11.8	31.6	34	260	4.66	4.66	7.02	8.96	8.21	<0.781	1.1	180	179	89.4
10VNBH630	M	45	85.4	85.4	<1.49	24.7	28.2	240	NDR 1.99	<0.864	<0.864	14.8	14.1	<1.13	0.8	90.9	90.8	94.1
10VNBH631	M	50	49.5	49.5	4.57	16.9	15.8	182	1.07	1.07	7.26	17.2	8.8	<0.692	1.1	61.1	59.9	82.6
10VNBH632	M	48	211	211	10.7	30	35.4	311	1.75	1.75	9.07	19.2	10.1	<0.527	1.5	232	230	91.7
10VNBH633	M	49	1970	1970	34.2	61.4	21.6	163	1.51	1.51	11.4	14.2	8.57	NDR 0.763	0.89	2020	2020	97.5
10VNBH634	M	45	87	87	<0.97	13.5	24.1	158	1.8	1.8	6.52	16.1	11.8	<0.97	0.64	94.4	93.1	93.4
10VNBH635	M	47	67.1	67.1	4.75	12.4	12.8	131	2.38	2.38	<0.536	9.83	5.09	<0.536	1.7	74.7	74.7	89.8
10VNBH636	M	48	161	161	13.4	44	54.3	449	2.76	2.76	<0.969	28.3	14.5	<0.969	0.67	183	183	88
10VNBH637	F	38	1130	1130	17.6	44.3	32.8	332	3.24	4.88	<1.2	10.7	17.6	NDR 1.41	0.51	1150	1150	98.3
10VNBH638	M	48	28.1	28.1	6.79	26.3	36.2	392	NDR 1.03	<0.989	9.11	29.9	18.5	1.03	0.8	45.8	44.1	63.7
10VNBH639	F	47	102	102	9.54	38.2	60.8	802	1.13	1.13	6.99	19	17.3	1.31	0.77	122	121	84.3
10VNBH640	M	48	34.4	34.4	5.98	22.8	33.3	339	1.78	1.78	6.43	12.3	20.6	<0.892	0.73	48	46.7	73.7
10VNBH641	M	48	119	119	8.52	38.1	44.3	486	1.13	1.13	8.5	31	22.9	NDR 0.978	0.85	140	138	86.2

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

Table E4.7 Concentrations of PCDDs and PCDFs in human breast milk from districts near the Bien Hoa Airbase (pg/g, lipid wt), Viet Nam, November 2010

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDD (pg/g lipid basis)						% lipid	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ 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				
10VNBH800	Trung Dung	34	8.21	8.21	2	6.17	7.12	44.7	0.584	0.699	3.79	8.95	4.03	0.146	9.61	13.4	12.8	64.1
10VNBH801	Trung Dung	27	2.39	2.39	1.74	7.39	10	113	NDR 0.456	0.765	3.89	13.9	8.79	<0.306	6.14	8.22	7.54	31.7
10VNBH802	Trung Dung	30	1.48	1.48	2.01	7.17	7.82	44.7	0.564	0.722	4.02	10.4	5.09	0.229	5.7	7.24	6.53	22.7
10VNBH804	Trung Dung	21	22.5	22.5	2.7	6.53	14.1	106	NDR 0.917	13.4	3.74	13.3	1.32	<0.479	4.25	29.3	28.6	78.7
10VNBH805[1]	Trung Dung	39	<12.3	NC	NC	NC	NC	70.3	<6.74	NC	NC	NC	NC	<0.22	3.68	14.3	13.7	NC
10VNBH806[1]	Trung Dung	21	<0.246	NC	NC	NC	NC	48.3	<2.33	NC	NC	NC	NC	<0.246	3.58	1.86	1.55	NC
10VNBH807	Trung Dung	28	2.94	2.94	5.07	16.3	17.3	153	<0.787	0.812	5.99	11.6	8.88	<0.482	1.97	14.2	13	22.6
10VNBH808	Trung Dung	28	3.11	3.11	<0.434	2.87	8.17	54.2	NDR 0.837	0.518	3.39	7.61	<0.558	0.398	2.51	6.25	5.58	55.7
10VNBH809	Trung Dung	25	2.45	2.45	2.27	2.52	6.89	49.2	0.732	<0.252	3.91	9.79	5.78	<0.252	3.96	8.16	7.39	33.2
10VNBH810	Trung Dung	29	9.85	9.85	2.4	6.43	6.03	35.2	NDR 1.17	<0.705	<0.705	7.91	1.02	<0.705	1.96	14.1	14	70.4
10VNBH811	Trung Dung	24	NDR 1.64	<0.359	1.14	6.94	20.5	77.5	NDR 0.629	0.729	2.02	6.54	<0.325	0.431	6.04	3.88	3.49	NC
10VNBH814	Trung Dung	27	13.8	13.8	13.1	29.8	10.4	116	1.01	0.781	<0.344	15.7	4.91	0.781	3.46	31.8	31.8	43.4
10VNBH816[1]	Trung Dung	23	1.37	NC	NC	NC	NC	35.4	<5.38	NC	NC	NC	NC	<0.417	3.64	6.58	5.86	23.4
10VNBH817[1]	Trung Dung	27	<0.815	NC	NC	NC	NC	47.5	<8.71	NC	NC	NC	NC	<1.51	1.24	3.23	2.99	NC
10VNBH818	Trung Dung	34	10.2	10.2	1.74	3.94	5.61	30	NDR 0.744	0.992	1.86	5.09	2.18	<0.263	4.03	13.9	13.5	75.6

Table E4.7 Concentrations of PCDDs and PCDFs in human breast milk from districts near the Bien Hoa Airbase (pg/g, lipid wt), Viet Nam, November 2010

Sample ID	Sex	Age	PCDD (pg/g lipid basis)						PCDD (pg/g lipid basis)						% Lipip	TEQ (WHO 1998) ND= 1/2DL	TEQ (WHO 2005) ND= 1/2DL	TCDD/ 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				
10VNBH819	Trung Dung	38	1.72	1.72	2.21	5.76	7.48	60.8	NDR 0.592	<0.425	2.74	7	4.14	<0.425	1.86	6.79	6.25	27.5
10VNBH820	Trung Dung	25	3.2	3.2	1.17	6.22	12.9	111	0.361	0.509	2.55	8.68	6.96	<0.168	4.7	7.19	6.78	47.2
10VNBH821	Trung Dung	24	0.773	0.773	1.87	11.2	18.2	94.9	0.244	0.378	3.12	13.9	6.09	0.218	11.9	6.92	6.32	12.2
10VNBH803	Trung Dung	29	30.3	30.3	4.25	28.7	113	182	NDR 0.437	0.714	4.84	9.88	0.873	<0.314	2.52	40.4	39.6	76.5
10VNBH812	Tan Phong	26	8.99	8.99	1.67	5.72	7.88	63.2	NDR 0.818	1.04	3.08	5.87	3.57	<0.312	2.69	13.1	12.7	70.8
10VNBH813	Tan Tien	34	2.27	2.27	1.46	5.51	6.68	58.4	0.859	0.978	2.81	6.34	4.84	<0.274	4.19	6.33	5.87	38.7
10VNBH815	Hoa An	28	2.31	2.31	3.11	10.1	23	104	NDR 0.854	0.552	5.22	14.8	8.14	<0.397	1.99	10.9	9.83	23.5

[1] Additional clean up was not successful; therefore, only the 2,3,7,8-TCDD and -TCDF values were reported with confidence. As the reported congeners have non-zero TEFs, the TEQ for each sample remains unaffected.
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.
NC = Not calculated.

Designed by **Hoalan Studies**

COMPREHENSIVE REPORT

2013

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