

Comprehensive Assessment of Dioxin Contamination in Da Nang Airbase and Its Vicinities: Environmental Levels, Human Exposure and Options for Mitigating Impacts

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Abstract—This study investigated contamination of dioxin in environment, food chains and human blood of communities living in and around Da Nang military airbase. Significant quantities of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), a contaminant in Agent Orange, were detected in over 80% of analyzed soil samples collected in December 2006. The maximum soil TEQ concentration recorded in this study was 365,000 ppt, from samples collected from the former Mixing and Loading Area; this is 365 times the globally acceptable maximum standard of 1,000 ppt. The maximum TCDD level recorded in fish fat in this study was 3,000 ppt (wet weight basis), which is 100 times the acceptable fish consumption level established by Health Canada. Blood dioxin levels recorded in this study ($n = 55$ patients sampled) for Da Nang residents directly associated with the Airbase were the highest reported for Viet Nam to date, and exceed all international standards for these chemicals. Those individuals who work on the Da Nang Airbase in Sen Lake (harvesting fish and lotus) and in the Airbase gardens (which are often flooded) were found to have dioxin concentrations in their blood more than 100 times globally acceptable levels. The maximum concentration was recorded in a 42-year old male, who had a TCDD level of 1,150 ppt lipid (1,220 ppt TEQ; 94% TCDD). A number of other contaminants, including PCBs, were also recorded in blood samples analyzed, and contributed significantly to the Total TEQ. In 2007, five construction/measures have been implemented in order to prevent continuous spread of dioxin-contaminated soil and sediment to wider environment and thus may cause impacts to larger population.

Keywords: Agent Orange, Vietnam, dioxin, human blood, fish, soil

INTRODUCTION

Agent Orange has been described as the last remaining vestige of the war to be resolved between the US and Viet Nam. Since the US-Viet Nam war, Vietnamese living in the vicinity of key former Ranch Hand sites (Bien Hoa, Da Nang, Phu Cat and others) have been exposed to contaminated soils, sediments and foods; these areas are referred to as dioxin “hot spots” (Dwernychuk *et al.*, 2002;

Dwernychuk, 2005). Due to the chemical stability of dioxins, contaminated lands have potential to expose the general population to dioxin for many decades, well beyond initial aerial applications and spillages during wartime Ranch Hand operations.

The presence of dioxin in the environment in and around former US military sites in Viet Nam is a direct result of storage and use of herbicides by the US and Army of the Republic of Viet Nam (ARVN) forces, spillage, and from improper disposal of empty herbicide barrels. Despite the fact that dioxins are known to be a significant environmental hazard, to date there have not been adequate measures taken to properly assess the extent and impact of contamination around known hot spots in Viet Nam. Protection of human health in the vicinity of these dioxin hot spots is of key concern.

The Da Nang Dioxin Assessment and Mitigation Project was conducted by Hatfield Consultants (West Vancouver, Canada) in association with the Ministry of Natural Resources and Environment Office of the National Steering Committee 33 (Ha Noi, Viet Nam) between October 2006 and April 2007. The project objective was to investigate the issue of residual dioxin contamination on the Da Nang Airbase and in the surrounding environment and local communities, and to recommend mitigation measures to help prevent the local population from future exposure.

MATERIALS AND METHODS

Sampling procedures followed those previously developed and applied by Hatfield for Agent Orange dioxin assessment projects in Viet Nam (Dwernychuk *et al.*, 2002; Dwernychuk, 2005). Sampling activities were undertaken in cooperation with Office 33 and relevant Vietnamese Government agencies, especially the Ministry of Defense, Ministry of Health and local Da Nang authorities. All soil and sediment sampling sites were screened for landmines and unexploded ordnance (UXO) in advance of sampling.

Figure 1 shows the map of the north part of Da Nang airbase which is considered as “area of concern” due to potential dioxin contamination. Soil and sediment sampling locations were determined during a pre-field desktop review of existing topographic maps and remote sensing information available for the study area, in conjunction with historical sampling results from areas within and surrounding the Da Nang Airbase. All soil sampling was conducted in a similar manner to previous Hatfield programs in Viet Nam (i.e., composite of 10 soil samples; Dwernychuk *et al.*, 2002; Dwernychuk, 2005). Soil sampling was conducted to a maximum of 50 cm depth.

A number of fish species, including Nile Tilapia (*Oreochromis niloticus niloticus*), were sampled from waterbodies on the Da Nang Airbase and were tested for dioxins and furans. Human blood and breast milk sampling was undertaken according to protocols employed in previous Hatfield/10–80 Division investigations in Viet Nam (Dwernychuk *et al.*, 2002). Hatfield personnel supervised all sample collections, and consent forms were obtained in advance from all donors.



Fig. 1. Map showing area of concern in the north of Da Nang airbase.

All samples were kept cool (4°C), or frozen within 2 hours of collection and shipped to Canada immediately after completion of the field program. Samples were analyzed by AXYS Analytical Laboratories in Sidney (British Columbia) using a Micromass Ultima high resolution mass spectrometer equipped with an HP 6890 gas chromatograph, a CTC autosampler and an Alpha workstation running VG software (AXYS, 2007). Standard quality assurance and quality control procedures for all Hatfield field sampling programs in Viet Nam were applied.

RESULTS AND DISCUSSION

Agent Orange and other herbicides were stored in large quantities at Da Nang Airbase during the US-Viet Nam war; more than 100,000 45-gallon (208-litre) barrels of herbicide were used on the Da Nang Airbase. These herbicides

Table 1. PCDD/Fs concentration in soil and sediment collected in and near-by the north part of Da Nang Airbase (pg/g TEQ on dry weight, following WHO-1998 TEFs).

| Location | Media | Sample No. | Easting | Northing | pg/g TEQ dry weight |
|---|----------|------------|---------|----------|---------------------|
| Da Nang Airbase | | | | | |
| <i>Former Mixing and Loading Area</i> | | | | | |
| Site 2 - Centre | Soil | 06VN058 | 200458 | 1777421 | 365,000 |
| Site 2 - Centre | Soil | 06VN059 | 200458 | 1777421 | 333,000 |
| Site 1 - West | Soil | 06VN063 | 200432 | 1777422 | 1,200 |
| Site 1 - West | Soil | 06VN064 | 200432 | 1777422 | 8,770 |
| Site 3 - NE | Soil | 06VN065 | 200457 | 1777447 | 27,900 |
| Site 3 - NE | Soil | 06VN068 | 200457 | 1777447 | 37,000 |
| Perimeter - S of Former Barracks | Soil | 06VN066 | 200585 | 1777394 | 899 |
| Perimeter - N of Former Barracks | Soil | 06VN067 | 200561 | 1777452 | 4,980 |
| Perimeter - W of Former Barracks | Soil | 06VN069 | 200546 | 1777448 | 167,000 |
| <i>Former Storage Area (SA)</i> | | | | | |
| Site 1 - NW | Soil | 06VN075 | 200353 | 1777668 | 5,200 |
| Site 1 - NW | Soil | 06VN076 | 200353 | 1777668 | 783 |
| Site 1 - NW | Soil | 06VN077 | 200353 | 1777668 | 20 |
| Site 2 - NE | Soil | 06VN078 | 200392 | 1777672 | 106,000 |
| Site 3 - Centre | Soil | 06VN083 | 200377 | 1777643 | 62,200 |
| Site 3 - Centre | Soil | 06VN084 | 200377 | 1777643 | 346 |
| Site 3 - Centre | Soil | 06VN085 | 200377 | 1777643 | 142 |
| Site 4 - SW | Soil | 06VN070 | 200346 | 1777611 | 3,520 |
| Site 5 - SE | Soil | 06VN074 | 200390 | 1777620 | 64,600 |
| <i>Between Storage Area and Mixing and Loading Area</i> | | | | | |
| S of SA/W of Ditch | Soil | 06VN043 | 200345 | 1777573 | 169 |
| SE of SA/E of Ditch | Soil | 06VN047 | 200449 | 1777573 | 6,520 |
| N of MLA/W of Ditch | Soil | 06VN048 | 200414 | 1777516 | 4,150 |
| <i>Drainage System</i> | | | | | |
| Water Treatment Basin | Sediment | 06VN072 | 200435 | 1777660 | 27,700 |
| Ditch d/s of Storage Area | Sediment | 06VN081 | 200495 | 1777701 | 8,580 |
| Da Nang Airbase Perimeter | | | | | |
| Old Munitions Dump | Soil | 06VN035 | 200581 | 1777614 | 150 |
| Military Garden | Soil | 06VN036 | 200759 | 1777448 | 31 |
| S of Airlines Staff Residence | Soil | 06VN037 | 200672 | 1777735 | 272 |
| S of Airlines Staff Residence (Dup) | Soil | 06VN038 | 200672 | 1777735 | 255 |
| N of Airlines Staff Residence | Soil | 06VN042 | 200607 | 1777768 | 1,830 |
| NE of SA/E of Ditch | Soil | 06VN045 | 200521 | 1777719 | 673 |

were loaded primarily onto C-123 aircraft for aerial spraying in central Viet Nam and Lao PDR; herbicides were also dispensed by truck, backpack spray devices and helicopter. Significant spillage occurred from improper handling and disposal of herbicides; this is well documented in US military records from the war period (US Army documents, declassified - 1969; Cecil, 1986; Hatfield, 2005). Significant quantities of TCDD, a contaminant in Agent Orange and other war-time herbicides, were detected in samples analyzed from the Da Nang Airbase in December 2006. Chemical analyses performed in this study confirm that the main source of dioxin contamination at Da Nang Airbase was Agent Orange and other dioxin-containing

Table 1. (continued).

| Location | Media | Sample No. | Easting | Northing | pg/g TEQ dry weight |
|------------------------------------|----------|------------|---------|----------|---------------------|
| Da Nang City | | | | | |
| March 29 Lake | Sediment | 06VN093 | 200910 | 1778130 | 27.5 |
| N of Airbase/Dien Bien Phu Street | Soil | 06VN091 | 200108 | 1778118 | 5.3 |
| NE of Airbase/Dien Bien Phu Street | Soil | 06VN092 | 200525 | 1778134 | 5.0 |
| Garden near Xuan Lake | Soil | 06VN087 | 199660 | 1777909 | 5.9 |
| Xuan Lake (N) | Sediment | 06VN088 | 199590 | 1777925 | 16.2 |
| Xuan Lake (S) | Sediment | 06VN090 | 199395 | 1777625 | 15.5 |
| Thanh Khe Garden (1) | Soil | 06VN099 | 199901 | 1778482 | 36.2 |
| Thanh Khe Garden (2) | Soil | 06VN100 | 199945 | 1778494 | 3.8 |
| Thanh Khe Garden (3) | Soil | 06VN101 | 199468 | 1778499 | 5.2 |
| Hai Chau Garden | Soil | 06VN102 | 202361 | 1780265 | 3.1 |
| Sen Lake | | | | | |
| Outlet to Da Nang City | Sediment | 06VN030 | 200466 | 1778115 | 289 |
| Centre | Sediment | 06VN031 | 200452 | 1777984 | 193 |
| Centre | Sediment | 06VN032 | 200452 | 1777984 | 2,980 |
| SE | Sediment | 06VN033 | 200485 | 1778000 | 63 |
| NE | Sediment | 06VN052 | 200533 | 1778079 | 5,950 |
| NWA | Sediment | 06VN053 | 200374 | 1778067 | 6,820 |
| Centre-W | Sediment | 06VN055 | 200333 | 1778007 | 3,510 |
| Inlet from Ditch | Sediment | 06VN040 | 200406 | 1777958 | 1,290 |
| Other Airbase Lakes | | | | | |
| <i>Lake B</i> | | | | | |
| North | Sediment | 06VN024 | 200020 | 1778086 | 38.80 |
| South | Sediment | 06VN029 | 200037 | 1777908 | 69.70 |
| <i>Lake C</i> | | | | | |
| North | Sediment | 06VN021 | 199829 | 1777956 | 18.90 |
| North (Dup) | Sediment | 06VN022 | 199829 | 1777956 | 14.70 |
| South | Sediment | 06VN023 | 199818 | 1777888 | 7.56 |
| <i>West Airbase Pond</i> | | | | | |
| Centre | Sediment | 06VN080 | 199465 | 1777458 | 6.92 |

herbicides. TCDD contributed over 90% of the TEQ (i.e., total sample toxicity) in soil and sediment samples collected from the former Agent Orange Mixing and Loading Area, former Storage Area and Sen Lake, all of which are located on Da Nang Airbase (Table 1). Samples collected downstream of the Airbase in Da Nang City contained lower levels of Agent Orange dioxin. Other contaminants (including polychlorinated biphenyls, organochlorine pesticides and hydrocarbons) were also shown to be present in the environment, both inside and outside the perimeter of Da Nang Airbase. TCDD levels recorded in this study exceeded all international standards and guidelines for these toxic chemicals.

The maximum soil TEQ concentration recorded in this study was 365,000 ppt, from samples collected from the former Mixing and Loading Area (Table 1); this is 365 times the globally acceptable maximum standard of 1,000 ppt (ATSDR, 1997) Over 99% of the TEQ in the sample was TCDD (361,000 ppt). This represents extremely high contamination, and confirms Da Nang Airbase as a significant dioxin “hot spot”.

Table 2. PCDD/Fs Concentrations in human blood of those work in Sen Lake (pg/g TEQ, lipid basis).

| Sample ID | 2,3,7,8-TCDD | Total P5CDD | % Lipid | TEQ (pg/g) | %TCDD/TEQ |
|-----------------|--------------|-------------|---------|------------|-----------|
| 06VNB001 (F-72) | 567 | 45.7 | 0.28 | 671 | 86 |
| 06VNB002 (M-42) | 1150 | 38.2 | 0.28 | 1230 | 94 |
| 06VNB003 (F-44) | 430 | 30.7 | 0.37 | 506 | 86 |
| 06VNB004 (F-17) | 294 | 17.6 | 0.23 | 334 | 89 |
| 06VNB005 (M-54) | 366 | 23.8 | 0.22 | 433 | 86 |
| 06VNB006 (M-28) | 9.42 | <1.09 | 0.28 | 20.1 | 51 |
| 06VNB007 (F-52) | 6.36 | 16.2 | 0.31 | 56.4 | 12 |
| 06VNB008 (M-20) | 62.1 | 11.1 | 0.28 | 94.2 | 68 |
| 06VNB009 (M-24) | 19.7 | <1.97 | 0.21 | 44.8 | 48 |
| 06VNB010 (M-22) | 343 | 39.8 | 0.15 | 453 | 77 |
| 06VNB011 (M-23) | 70.8 | 11.2 | 0.23 | 111 | 66 |

F for Female; M for Male; Figure following F & M indicating age.

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.

Soil dioxin levels recorded in this study are the second highest reported in Viet Nam to date (the highest being >1 million ppt TEQ in soils at Bien Hoa Airbase (Schechter *et al.*, 2001), although the exact geographical position, origin, and method of extraction of this Bien Hoa Airbase soil sample is unknown, and has never been reported). Soil TCDD levels from this study confirm contamination data previously obtained by the Vietnamese Government and US EPA (unpublished data).

The present study (and previous work by Hatfield/10–80 Division) has verified that the highest concentrations of Agent Orange dioxin in soils/sediments in Viet Nam are found in the top 10 cm layer; some contamination is found at deeper strata (e.g., >30 cm), but only in limited areas on the former Mixing and Loading Area and former Storage Area at Da Nang Airbase. The movement of dioxin from the former Mixing and Loading Area and the former Storage Area, into Sen Lake, and ultimately into humans (via ingestion of contaminated fish and direct contact with soils and sediments) is without doubt, and is directly linked to historical Agent Orange use on the Airbase. The resulting high dioxin levels in the environment and food chain pose an unacceptable health risk to exposed populations in the vicinity of the Airbase. Lower dioxin levels were recorded in Da Nang City itself, suggesting that most contamination is restricted to the Airbase.

The maximum TCDD level recorded in fish fat in this study was 3,000 ppt (wet weight basis), which is 100 times the acceptable fish consumption level established by Health Canada (2004). Fish originating from the Airbase are contaminated with dioxins, and are consumed by fishermen (and likely some members of the general public) at considerable distances from the point of herbicide release to the environment; there is a direct connection between Sen

Lake and areas outside the Airbase through the local drainage system.

Blood dioxin levels recorded in this study ($n = 55$ patients sampled) for Da Nang residents directly associated with the Airbase were the highest reported for Viet Nam to date, and exceed all international standards for these chemicals. Those individuals who work on the Da Nang Airbase in Sen Lake (harvesting fish and lotus) and in the Airbase gardens (which are often flooded) were found to have dioxin concentrations in their blood more than 100 times globally acceptable levels (Table 2). The maximum concentration was recorded in a 42-year old male, who had a TCDD level of 1,150 ppt lipid (1,220 ppt TEQ; 94% TCDD); two other individuals who were fishing and farming inside the Da Nang Airbase perimeter had >500 ppt TEQ. Previous studies at Bien Hoa recorded a maximum blood TCDD level of 413 pg/g lipid (Schechter *et al.*, 2002). Low blood TCDD concentrations (<8.5 ppt lipid) were recorded at the Hai Chau reference site. A number of other contaminants, including PCBs, were also recorded in blood samples analyzed, and contributed significantly to the Total TEQ.

People most affected by direct exposure to dioxins from the Da Nang hot spot are members of an extended family fishing and harvesting lotus from Sen Lake and gardening along its banks. At present, it is believed that only a small proportion of the general population of Da Nang City is adversely affected. Others may also be affected by eating fish and other aquatic animals harvested from the Airbase lakes, although exact numbers are presently unknown. Exact numbers of highly exposed people needs to be verified and monitored.

Results from this study support those from previous Hatfield/10–80 Division studies (Dwernychuk *et al.*, 2002; Dwernychuk, 2005), namely that dioxins are transported from soils to aquatic sediments to fish and other aquatic organism tissues, and ultimately into humans, as shown by blood and breast milk analyses. The high levels of TCDD contributed almost all of the total toxicity of the samples analyzed, indicating that Agent Orange was the principal source of this dioxin congener. Immediate action is therefore necessary at Da Nang and other former Ranch Hand sites to prevent further human health risks from exposure to dioxins.

It is clear that certain health effects are linked to Agent Orange exposure, and that the precautionary principle should apply when dealing with dioxin contamination in the environment and human food chain. This is particularly true at Da Nang Airbase, where concentrations of dioxins in excess of 300,000 ppt have been recorded in soils, and where levels greater than 3,000 ppt are known to occur in fish tissues taken from Sen Lake. Blood dioxin levels in people known to consume fish and other aquatic organisms from the Airbase were the highest dioxin level recorded in Viet Nam to date. Protection of the local residents known to work on Airbase lakes harvesting fish and other aquatic organisms is therefore paramount, and mitigation measures need to be adopted immediately at Da Nang Airbase. Possible measures are suggested as: Institution of an immediate ban on fishing, aquaculture, consumption of aquatic organisms harvested in contaminated lakes within the airbase; Installation of more secure, permanent fence around the perimeter of the Airbase to prevent public access; Carrying out awareness raising program for prevention of dioxin exposure in local communities and development

of alternate livelihoods for individuals currently earning their living from harvesting fish, lotus and other aquatic organisms and vegetables from Da Nang Airbase; Appropriate engineered solutions require refining and rapid implementation to prevent further spread of dioxin-contaminated soils and sediments into Sen Lake, and, ultimately, into the human population of Da Nang.

More than 40 years have elapsed since Agent Orange was introduced to the environment of Viet Nam, and the resultant chemical contamination continues to enter the environment, the food chain and the human population living in close proximity to Da Nang Airbase. Similar situations can be expected at other major Ranch Hand sites in Viet Nam, in particular, Bien Hoa. Time is of the essence to move forward with this issue, to protect Vietnamese living in the vicinity of such hot spots from further contamination and associated health impacts. These circumstances pose a significant public health threat, particularly when considering elevated dioxin levels in relation to global guidelines for protection of the environment and human health.

To date, five construction have been implemented in order to prevent continuous spread of dioxin-contaminated soil and sediment to wider environment and thus may cause impacts to larger population. The constructions are a 20 cm concrete cap over a part of the contaminated area; a 300 m² sedimentation/ filtration basin to remove contaminated particles from runoff water and 3 other constructions to prevent people from harvesting fish in Sen Lake which is a sink of runoff water from the contaminated areas. Besides, culturing and fishing in the contaminated Sen lake was also completely banned by the local authority.

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