DEVELOPMENT OF IMPACT MITIGATION STRATEGIES RELATED TO THE USE OF AGENT ORANGE HERBICIDE IN THE ALUOI VALLEY, VIET NAM

Hatfield Consultants Ltd., West Vancouver, Canada
10-80 Committee, Ha Noi, Viet Nam

April 2000

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VOLUME 1: REPORT

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Hatfield Consultants Ltd.
201-1571 Bellevue Avenue
West Vancouver, BC
Canada V7V 1A6
Tel: (604) 926.3261
Fax: (604) 926.5389
Email: hcl@hatfieldgroup.com
Website: www.hatfieldgroup.com

National Committee For Investigation of the Consequences of the Chemicals Used During the Viet Nam War (10-80 Committee)
Tôn Thất Tùng Street
Dong Da
Ha Noi
Viet Nam
Tel: 84.48.522.479
Fax: 84.48.523.514

HATFIELD
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10-80 Committee

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Front Cover Photos
- Top: C-123 applying herbicide over upland forest in Viet Nam. Photo courtesy of Dr. E.W. Pfeiffer, Missoula, Montana.
- Bottom: Elders and children living in the Aluoi Valley, Viet Nam (Hatfield Consultants Ltd. Photos, 1999).

Back Cover Photo
- Landslide along the road from Hue to the Aluoi Valley, Viet Nam, March 1999 (Hatfield Consultants Ltd. Photo).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

VOLUME 2

..2

PREFACE

Since 1994, Hatfield Consultants Ltd. (West Vancouver, Canada) and the 10-80 Committee (Ha Noi, Viet Nam) have collaborated on scientific investigations to assess and remediate areas of southern Viet Nam that were subject to aerial spraying of Agent Orange and other military herbicides between 1965-1970. Our results have shown that residual dioxin, a manufacturing by-product of Agent Orange, is still present in the environment of Viet Nam, and is being taken up by humans that consume dioxin-contaminated food. Following the publication of our preliminary report in 1998, we have continued our investigations to develop solutions for the residual dioxin contamination of Aluoi District. This report provides the results from research carried out in 1999, as well as a Health and Environmental Impact Mitigation Plan for the area.

Findings of our 1998 preliminary report on the environmental impacts of Agent Orange (AO) herbicide applications in Viet Nam generated significant news media and scientific interest. We have responded to interview and information requests as much as possible. Hard copy and CD-ROM versions of our reports are available to interested parties at reproduction cost (NGO aid organizations have been given free CD-ROM copies).

The main purpose in distributing our reports as widely as possible is to help develop mitigation plans for AO dioxin contamination and war rehabilitation problems in Viet Nam, and Indochina as a whole. Results of our dioxin research in the Aluoi Valley (Thua Thien Hue Province, central Viet Nam) should also be of interest to international scientific and regulatory agencies. Many global and national jurisdictions are in the process of setting or revising standards related to dioxin levels in the environment and food. The recent incident of dioxin contamination of food in Belgium (June/July 1999) illustrates this need.

Dioxin contamination is not the only environmental problem resulting from war activities in areas like the Aluoi Valley; war-related impacts continue to affect large areas of central and southern Viet Nam, particularly in border areas with Lao PDR and Cambodia. There is a significant unexploded ordnance (UXO) problem in the valley, particularly in the vicinity of the three former US Special Forces bases in the area. These areas may also have buried munitions and chemicals of unknown composition, which adds to concerns regarding the contamination problem in Aluoi. An UXO removal program is therefore an essential phase of a long-term AO impact mitigation program in the valley.

There are also many indirect war-related environmental impacts in the region resulting from AO herbicide usage, including landslides due to erosion, and loss of biodiversity and forest resources. These problems have resulted in severe economic hardship and poverty to local Aluoi residents, since they continue to affect their ability to live off the land, carry on agricultural/forestry production, and often block the transportation routes to markets in Hue.

Some mountain slopes bordering the valley are now being clearcut of remaining trees and planted with agricultural crops. UXO and AO dioxin presence in more suitable flat agricultural lands in the valley bottom prevents their use as cropland. This leads to more on-slope soil erosion, poor crops and a return to the poverty cycle. Firewood is also in short supply in the area, which is primarily the result of herbicide applications that destroyed forests.

Regardless of remaining questions related to human health effects resulting from AO applications, it is clear local people need assistance to deal with dioxin contamination in the valley, and rehabilitate their war-damaged environment to break the poverty cycle. During our 1994-1999 work, it was established that soils in some areas of the valley are contaminated at levels considered to be unacceptable for residential and agricultural use in most western jurisdictions. Food chain components are contaminated with dioxin which renders them unsuitable as major diet items. Blood of Aluoi Valley residents has elevated levels of dioxin compared to data from most other areas of the world. Dioxin levels in breast milk of young nursing mothers is also elevated when compared to world levels. For these reasons, we believe preventative and mitigative action to reduce the risk to human health must be taken in the Aluoi Valley, and where warranted, other areas of Viet Nam.

To date, the Canadian International Development Agency (CIDA) has provided our project team with the majority of the funding to investigate the AO issue in Viet Nam, and to initiate a mitigation plan addressing AO impacts in the Aluoi Valley. The financial assistance has been a lever for minor funding from other Canadian government agencies, and has formed the basis for in-kind contributions from the 10-80 Committee, Thua Thien Hue Provincial Government agencies and our Company to enable the continuation of this work.

International cooperation is key to addressing the issue of AO and dioxin contamination in the environment and human population of Viet Nam. Additional funding from international donor agencies, international financial institutions (e.g., ADB, World Bank), UN organizations, US government agencies, North American foundations and non-government organizations (NGOs) is required to help address this issue. Many of the personnel we have met from these agencies recognize the need for mitigation programs in Viet Nam addressing war-related environmental impacts.

There are sensitive issues involved in resolving Agent Orange dioxin contamination and other war impact issues in Indochina. It is important that the focus of programs related to war rehabilitation remain scientific, and that data be collected and utilized according to internationally-accepted protocols. However, the human dimension cannot be divorced from this scientific endeavor. Our team of Canadian and Vietnamese scientists have been affected by the plight of Aluoi Valley residents, and feel the need to find practical ways to provide assistance.

The local Aluoi Valley population continues to experience chemical contamination of their environment and food, death and maiming from UXO, negative impacts from destruction of forests and soils, and poor economic conditions resulting from war impacts.

On moral and humanitarian grounds, sincere efforts are required to help those least able to help themselves. The international community has a responsibility to ensure that combatants, once the primary conflict is over, are supported in efforts to rehabilitate ravaged environments and economies. To ignore these realities is to endorse a future of continued war-related environmental degradation, entrenched poverty, and political instability for large populations throughout the world.

Chris Hatfield
President

HATFIELD CONSULTANTS LTD.

April 2000

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Financial and In-kind Support

The project team gratefully acknowledges the financial contributions of Canadian government agencies and the in-kind support from Vietnamese agencies involved in the 1999 component of the study. Without these contributions, this program could not have been carried out.

The 1999 component of our Agent Orange program in Viet Nam received funding assistance from two Canadian government programs (Table 1.1). The Canadian International Development Agency (CIDA) was the major contributor. The budget for such high cost items as dioxin sample analyses was limited. Participating Canadian and Vietnamese agencies, titles of programs and objectives, and the role of each agency are summarized in Table 1.1.

We wish to acknowledge the assistance of many Vietnamese, too numerous to name here; various Thua Thien Hue provincial People's Committee, Department of Health, Department of Planning and Investment, and Department of Science, Technology and Environment, Aluoi district and commune Peoples' Committee officials, Aluoi Valley health services centres and local police provided information, logistical support, permits to sample and encouragement during this study.

We are also particularly grateful for the assistance of Mr. Gerd Willkommen from the German "Gerbera Demining Team, Viet Nam". Mr. Willkommen worked with our field team during soil sampling to sweep areas that we proposed to sample with metal detection equipment in order to determine unexploded ordnance (UXO) locations prior to collecting soil core samples.

Mr. Don Price, a masters student at James Madison University, College of Integrated Science and Technology, Harrisonburg, Virginia, assisted our staff in the use of Aluoi Valley CORONA (spy satellite) imagery which was declassified in 1999. He also assisted with UXO detection during soil sampling.

During 1999, discussions were held with the following expatriate and North American based individuals who provided advice, comments and assistance related to our investigation:

- Mr. Marius R. Grinius – former Ambassador; Canadian Embassy, Ha Noi;
- Mr. Pete Peterson – Ambassador; Embassy of the United States of America, Ha Noi;
- The Honorable Raymond Chan – Secretary of State (Asia Pacific); Government of Canada;
- Mr. David C. Dix – former Counselor; Canadian Embassy, Ha Noi;

- Mr. Peter Hoffman – Counselor, Canadian International Development Agency; Canadian Embassy, Ha Noi;
- Mr. John W. Salminen – Head, Chemical Evaluation Division, Food Directorate, Health Canada, Ottawa, Ontario;
- Mr. G. Fox – Senior Risk Assessment Officer, Ministry of Environment, Victoria, BC, Canada;
- Mr. Michael D. Eiland – First Secretary Science, Technology, Environment; Embassy of the United States of America, Ha Noi;
- Mr. Chuck Searcy – Director of Viet Nam Programs; Viet Nam Veterans of America Foundation, Ha Noi;
- Ms. Lady Borton – Field Director; Quaker Service Viet Nam, American Friends Service Committee, Ha Noi;
- Brigadier General John S. Brown – US Army Chief of Military History;
- Mr. Clifford Snyder – Modern Military Records, Textual Archives Services Division, National Archives and Records Administration; and
- Dr. Ronald Spector – Military Historian; Professor of History and International affairs, Chair, Dept. of History, George Washington University.

Support staff from the 10-80 Committee and Hatfield Consultants Ltd. were integral to the completion of various phases of this investigation; we gratefully acknowledge their efforts.

EXECUTIVE SUMMARY

1.0 BACKGROUND

Approximately 76 million litres of herbicides were sprayed over 10-14% of southern Viet Nam during the Viet Nam war. Agent Orange, a 50/50 mixture of 2,4,5-T and 2,4-D herbicide was the main herbicide formulation. Dioxin was a contaminant by-product of the manufacturing process present in Agent Orange (AO) and other herbicides. Dioxins are a family of chemicals which have been associated with serious health effects in humans.

Hatfield Consultants Ltd. (HCL) of West Vancouver, Canada, the government of Viet Nam 10-80 Committee based in Ha Noi, Viet Nam, have cooperated in an assessment of health and environmental impacts related to spraying of Agent Orange herbicide during the war in the Aluoi Valley (formerly named the A Shau Valley). The University of British Columbia (Department of Health Care and Epidemiology) collaborated with HCL and the 10-80 Committee on health and nutrition assessments in the valley. The investigation to date has been carried out during the period 1994-1999. The results of the 1996/97 field programs are reported in a Hatfield Consultants Ltd. and 10-80 Committee report (HCL/10-80 1998). Results of the 1999 work are reported in this document.

The Aluoi Valley, 65 km west of Hue, near the Laos PDR border, was selected as the main dioxin study area, in order to minimize the potential complicating influences of the more urbanized or intensive agricultural areas farther south. The valley was an integral part of the Ho Chi Minh Trail during the war, and was heavily sprayed from approximately 1965 to 1970, principally with Agent Orange, and to a lesser extent, with Agents Blue and White. Inhabitants of the valley are primarily hill tribes living "off the land" at a more or less subsistence level.

Data from a 1996 field program showed that the commune of A So (recently renamed Dong Son), situated in the southern sector of the Aluoi Valley, contained soils and fish tissues contaminated with dioxin (specifically 2,3,7,8 – Tetrachlorodibenzo-*p*-dioxin or 2,3,7,8-T4CDD [TCDD], known to be the congener specific to Agent Orange).

Data from 1996 formed the basis for a more focussed expedition in 1997 at A So and a former US Special Forces base in the area (formerly known as Special Forces A Shau base). The 1997 study was designed to follow the pattern of dioxin movement through the food chain in this relatively localized area. Soil contamination levels determined in 1997 in A So commune, if found in a western jurisdiction, would result in the area being declared a "contaminated site". Dioxin levels found in fish in 1997, if they were found in Canada, would trigger a consumption advisory process (i.e., risk assessment/risk management activities with recommendations on maximum human consumption levels), and possibly prohibitions against consumption.

Whole human blood samples taken in 1997 also showed elevated levels of Agent Orange dioxin. The detection of TCDD in the younger generation provided evidence that the valley environment remains contaminated from the use of Agent Orange, and that TCDD was moving through the food chain into humans.

In the Aluoi Valley, other environmental impacts caused by herbicide use were also clearly documented by the project team during the 1994-1998 program. Such impacts as the destruction of forests, erosion of soils, and landslide damage to infrastructure (e.g., roads and communications) are facts of life in the sprayed areas of the valley. These impacts have led to severe poverty, malnutrition, disease and other socioeconomic problems.

2.0 1999 PROGRAM

Hatfield and the Vietnamese scientists involved in the 1994-1998 program believed that the preliminary information on Agent Orange impacts indicated an urgent need to examine further the extent of the Agent Orange-related problems in the Aluoi Valley, and to implement mitigation strategies to address health risks. Consequently, a further project in the area was designed and implemented in 1999.

The program had the following components.

1. Component 1 – Formulation and implementation of a health protection plan.
2. Component 2 – Delineation of dioxin contamination.
3. Component 3 – Investigation of relationships between contaminated soil and food chain data and human health effects.
4. Component 4 – Development of a forest and wildlife biodiversity rehabilitation plan.

Most accepted global standards/guidelines for dioxin have been developed for western lifestyles and assume quality housing, low direct contact with soil, availability of a wide variety of food sources, good potable water quality and the populations are relatively free from serious disease, malnutrition or chronic illnesses (e.g., water-borne diseases, vitamin deficiencies, etc.).

Minority peoples in the Aluoi Valley do not have the lifestyles of most westerners. In fact, they live in continuous close contact with the soil, generally consume a narrow variety of foods grown locally, and experience numerous health problems related to water-borne disease and malnutrition.

Western dioxin standards/guidelines for health and environmental protection are likely not conservative enough to determine risk to health in the Aluoi Valley. Given the Aluoi Valley socioeconomic situation, such standards should be more stringent. However, developing new standards for application in developing countries (where people are still living off the land), would be a long and likely controversial process. The study team therefore believes short-term action based on existing western standards should be taken immediately to reduce risks to human health in the Aluoi Valley.

If the levels of dioxin found to date in the environment and people of the Aluoi Valley were found in an area in Canada, the United States or Europe, an immediate health protection program would be initiated to limit and/or resolve the problem. A shortage of funds and political sensitivities has delayed agencies and research teams from taking action in Viet Nam. These delays have resulted in a continuation of serious health risks to the mainly minority peoples of the Aluoi Valley, and likely many other areas of Viet Nam. The Vietnamese people whose health is at risk require financial and technical assistance to achieve resolution of this issue.

Accordingly, the project team formulated a comprehensive Health and Environmental Impact Mitigation Plan, which is outlined in this document.

The Agent Orange problem was caused by impacts from the application of western technology. Risk for humans through dioxin exposure can be reduced significantly by means of inexpensive changes to diet and human use of contaminated areas.

Dioxins may amplify negative effects of other diseases or health conditions in the area (e.g., malaria, poor nutrition, etc.), given that immuniological disruptions may be linked to dioxins (ATSDR 1998). Knowledge gained in Viet Nam, related to mitigation of health risks due to Agent Orange, would also have application to resolving long-delayed issues of war-related health problems of veterans from the United States, Korea, Australia and Thailand who were involved in the Viet Nam war.

There is evidence that other contamination and impact problems, related to the presence of herbicide dioxins, exist in many other areas of southern Viet Nam and Indochina. A mitigation strategy developed for the Aluoi Valley will be transferable to other regions of Viet Nam, Lao PDR and Cambodia.

3.0 CONCLUSIONS

A. SOILS

1. A "hot spot" for Agent Orange dioxin contamination (specifically TCDD) was found at the former A So US Special Forces base in the Aluoi Valley in 1997 and was confirmed in 1999. Some composite soil samples from the base area exceeded agriculture and residential land use standards for human health protection in Canada (350 ppt Total TEQ).
2. No additional hot spots were found in 1999, although AO dioxin (TCDD) was found in soils throughout the valley. Composite soil samples analyzed from two other US Special Forces bases in the Aluoi Valley did not exceed Canadian residential/agricultural land use standards (350 ppt Total TEQ based on protection of human health); many exceeded

Canadian agriculture rehabilitation standards (i.e., 10 ppt Total TEQ) based on environmental protection criteria.

3. There was no correlation between TCDD levels and soil particle size, and total organic carbon in the Aluoi Valley.

4. Most soil contamination was clearly associated with the 2,3,7,8-T4CDD Agent Orange congener, not industrial sources of dioxin.

B. HUMAN FOOD CHAIN

1. Domestic ducks in the A So base area had AO dioxin levels in their fat which would, in western jurisdictions, trigger a human consumption advisory process (including risk assessment/risk management) and/or probable prohibition of selling such ducks. The contamination contributed to the human diet by ducks adds to that found in 1997 for fish (up to 52 ppt).

2. Samples of pig, cow fat and chicken egg that were tested had AO dioxin levels below western standards for human consumption.

3. Rice and manioc components of the food chain did not have detectable levels of AO dioxin.

C. HUMAN BLOOD

1. Testing in 1999 confirmed the elevated levels of AO dioxin in whole human blood from the A So area, previously found in 1997.

2. People from the area of the A So base area have significantly higher TCDD levels than people from more distant areas in the valley.

3. TCDD levels were higher in the blood of A So area residents than most reported background levels for unexposed people from industrialized countries.

4. TCDD levels in blood of A So residents are higher than most residents of industrial countries who have been exposed to TCDD (e.g., herbicide plant workers, metal plant workers, chemists, etc.).

5. Tests in 1999 confirmed 1997 findings of elevated levels of AO dioxin in blood of people from the A So area who were born after the war.

6. Males had clearly higher levels of AO dioxin in their blood than did females whether born before or after the war. The difference is likely due to females eliminating TCDD through breast milk. Higher levels in males probably result from greater contact with contaminated earth while ploughing, planting, and digging fish ponds. Males also have a higher caloric intake.

D. HUMAN BREAST MILK

1. There were elevated levels of AO dioxin in human breast milk from the A So base area in 1999 (up to 19 pg/g).
2. There were significantly higher AO dioxin levels in breast milk from the area of the A So base, relative to the reference areas situated at greater distance from the former base.
3. Samples from the A So area were generally higher in TCDD than levels reported in studies elsewhere in the world.
4. A wide range of AO dioxin levels was found for individual breast milk samples, suggesting that such a range probably exists in individual blood samples.
5. Levels of DDT and its metabolites in breast milk were similar to other areas of the world. Such levels are not expected to contribute significantly to increased risk to health in the valley.

E. ENVIRONMENTAL AND HUMAN TISSUE RELATIONSHIPS

1. Elevated levels of AO dioxin in human blood and breast milk in the A So region are correlated with high levels in soil, fish, and ducks.
2. Food chain contamination appears to be a significant contributor of TCDD in A So residents who were born after the war.
3. Local contaminated foods likely contributed to breast milk contamination.
4. Other probable contributing factors for high levels of AO dioxin in blood and breast milk were contact with contaminated soil as a result of living in dwellings with dirt floors, ploughing fields, and digging and operating fish ponds.
5. With increasing distance from the A So base, there is a general decrease in AO dioxin in soils, domestic fish and ducks, and human blood and breast milk. The Hong Van commune, at greatest distance from A So, had the lowest levels of environmental, human blood and milk AO dioxin contamination.

F. HUMAN HEALTH EFFECTS

1. Health data compiled from four communes in the Aluoi Valley show a higher rate of birth defects in people living closest to the A So commune, compared to people living in communes more distant from the former US Special Forces base at A So.
2. Multi-elemental analysis of water samples indicated that parameters are within Canadian drinking water guidelines for all resident groups in the valley.
3. Analyses of potential contaminants in cooking oils eliminated this food item as a confounding factor in the study of dioxin exposure.

4. Pesticide use is low in the valley; pesticide levels are low in soils and breast milk; it is unlikely they are a confounding factor in this dioxin investigation.
5. There do not appear to be significant nutritional differences between the communes studied in the Aluoi Valley.
6. Public health data collected to date appear to be consistent with a dioxin effect, whereby dioxin exposure is hypothesized to cause elevated rates of birth defects. However, more research related to dioxin health effects, and further elimination of other confounding factors, is required before definitive conclusions can be reached.

G. GENERAL SUMMARY CONCLUSIONS

1. The presence of elevated concentrations of Agent Orange dioxin (TCDD) in the blood and breast milk of certain residents of Aluoi District, including contemporary animal food products (e.g., duck fat and fish fat), confirms that dioxin contamination and uptake is a present-day and not a historical phenomenon. Further, the occurrence of Agent Orange dioxin in the blood of younger residents (<25 years old), born long after the end of herbicide spraying, confirms ongoing human uptake of dioxin. Continuing dioxin contamination in Aluoi District is most prevalent in the vicinity of A So commune, adjacent to the former US Special Forces base.

2. Mitigation measures are required to manage dioxin contamination to reduce future exposure of residents in A So commune. The Health and Environmental Impact Mitigation Plan presented in Section 4.0 provides a practical approach that outlines various short-, medium-, and long-term strategies that can be implemented to reduce human exposure and public health risks.

3. New, cost-effective technologies are needed to decontaminate large volumes of dioxin-contaminated soils in Viet Nam. High temperature incineration is not a practical and economical mitigation approach, due to the large volume of contaminated soil requiring treatment.

4. Most Aluoi District soil samples contained measurable traces of dioxin which can be attributed to Agent Orange spraying, 1965 - 1970. However, with the exception of samples adjacent to former US Special Forces bases, most soil samples were below 10 pg/g (ppt), the dioxin concentration in BC Canada that serves as the remediation standard to define safe agricultural soils. Based on this observation, residual dioxins in non-base areas of southern Viet Nam that were sprayed with military herbicides, are probably safe for human habitation and growing food crops; however, confirmatory investigations are recommended.

5. There are hundreds of former US and south Vietnamese military installations and base sites in southern Viet Nam where herbicides were handled, stored, sprayed along base perimeters, and possibly buried. In order to protect present-day public health adjacent to

these areas, a systematic dioxin survey of all former military installations where Agent Orange and other herbicides were utilized is recommended, including areas where residual contamination may be present.

6. There is an opportunity to build on the comprehensive environmental work that has been carried out in Aluoi District since 1994, and to further develop environmental assessment and mitigation approaches that can be widely applied in other war-affected areas of Viet Nam, Lao PDR, and Cambodia. The objective would be to enhance development opportunities through the mitigation of war impacts. There is much additional work that is required in Aluoi District; for example, there are currently no plans to deal with the very large volume of unexploded ordnance that continues to injure and kill Aluoi District residents. Viewed from this perspective, Aluoi District is a pilot area for environmental improvement designed to alleviate war-related poverty through increasing economic and social development opportunities.

7. Viet Nam provides the best natural laboratory in the world to refine our understanding of the environmental and human health impacts of dioxins. Comparative studies of dioxin-contaminated sites in southern Viet Nam with similar (non-sprayed) sites in northern Viet Nam, can be carried out to refine our scientific understanding of dioxin effects.

4.0 RECOMMENDATIONS

1. The Agent Orange Health and Environmental Impacts Mitigation Plan developed for the Aluoi Valley should be fully implemented immediately.

2. Further assessments of dioxin contamination are required in the vicinity of all former US and south Vietnamese military bases/facilities in southern Viet Nam, where use/storage of Agent Orange during the war likely occurred; these assessments would determine the level of dioxin contamination related to Agent Orange, and ultimately reduce human exposure. Studies of other geographical areas in Viet Nam over which heavy Agent Orange spraying occurred (aerial and land-based applications) are also required. Such studies should consist of comprehensive food chain assessments, including human populations.

3. Where additional sites are identified as being contaminated with dioxin, health and environmental impact mitigation plans should be developed and implemented.

4. Studies of human health should be carried out in communes/villages near areas where soils or the human food chain are found to be contaminated with Agent Orange dioxin. Comprehensive epidemiological studies are required in Viet Nam to assist in determining the relationship between environmental contamination with Agent Orange dioxin and human health effects.

5. If higher than normal birth defects, cancers or other health effects are found to occur in contaminated areas, special health clinics or treatment centers should be established to treat people affected by dioxin contamination. In the Aluoi Valley, the existing health clinic at A Ngo should be consolidated and improved to support adjacent villages, rehabilitate any handicapped people and provide advice to local people on health issues related to dioxin contamination.

6. Where clearing programs for unexploded (UXO) ordnance are underway in Viet Nam, parallel studies on soil contamination should be carried out to ensure that disturbance of contaminated soils in these areas does not result in the creation of unacceptably high dioxin levels through re-mobilization of the contaminant in the environment. Such disturbance could make dioxin more accessible to elements in the local food chain and humans.

7. Sediment cores should be collected and analyzed from coastal areas which drain heavily sprayed regions of former major US and south Vietnamese military bases/facilities in southern Viet Nam. Sediment core analyses in British Columbia (Canada) have shown stratified deposition of dioxins over time. Activities such as dredging or trenching in deposition areas could resuspend dioxin into the water column and potentially into the food chain.

8. Vietnamese foresters have developed sound techniques for rehabilitating upland forests sprayed with Agent Orange in southern and central Viet Nam. Some upland forest rehabilitation is now taking place in the country. These activities should be expanded significantly with funding from international agencies. Community forestry projects and flora/fauna biodiversity programs should be integral to these rehabilitation efforts in upland forests. Programs have been successful in other regions of Viet Nam where local people have been given ownership and management control of land and forest areas, in return for commitments not to destructively cut or burn forests for farmland. Such undertakings could include planting trees for lumber and industrial use, and managing grasslands for livestock. The government of Viet Nam is prepared to provide complimentary financial and temporary food source support for families willing to participate in such forest rehabilitation programs.

9. Viet Nam, with its heavily sprayed areas in the south and reference areas in the north (where no spraying took place), represents an excellent location for the study of human health and environmental effects caused by exotic chemicals, such as Agent Orange dioxin. Present world standards for soil and human food contaminated with dioxin represent only best estimates for human health safety. However, billions of dollars of industrial investment decisions, clean-up requirements, and decisions regarding human health protection, are being based on these estimates. These standards would be more effective and credible if they were based on more comprehensive, hard scientific data. Viet Nam may be considered one of the best locations in the world to find solutions to the

many questions and concerns regarding dioxins in the environment, and their effects on human health.

10. Based on the levels of environmental contamination by Agent Orange dioxin found during this investigation, there is an urgency to carry out further programs to reduce the risk to human health posed by contaminated sites in Viet Nam.

Many of the recommendations presented above were also presented in the HCL/10-80 1998 report. Studies in 1999 have confirmed initial results, and further delineated dioxin contamination in the environment and human food chain. Results of this recent investigation confirm the urgent need for implementation of an impacts mitigation strategy in the Aluoi Valley, Viet Nam.

1.0 INTRODUCTION

1.1 BACKGROUND

Hatfield Consultants Ltd. (HCL) of West Vancouver, Canada and the government of Viet Nam 10-80 Committee based in Ha Noi, Viet Nam, have cooperated in a preliminary assessment of environmental impacts related to spraying of Agent Orange herbicide during the Viet Nam war. The investigations covered the period 1994-1998. The work included determining dioxin levels in the environment of Viet Nam and assessing impacts on forests.

Approximately 76 million litres of herbicides were sprayed over 10-14% of southern Viet Nam. Dioxin was a manufacturing contaminant present in Agent Orange, a 50/50 mixture of 2,4,5-T and 2,4-D herbicide. Dioxins are a family of chemicals which have been implicated in serious health effects in humans (IOM 1994, 1996, 1999).

The Aluoi Valley (formerly named the A Shau Valley), 65 km west of Hue, near the Lao PDR border, was selected as the main dioxin study area in order to minimize anthropogenic influences of the more urbanized or intensive agricultural areas farther south. A greater degree of industrialization may be accompanied by recent environmental input of dioxin and other contaminants (e.g., waste-water discharges, air emissions) which may confound data interpretation.

The Aluoi Valley was an integral part of the Ho Chi Minh Trail during the war, and was heavily sprayed from approximately 1965 to 1970, principally with Agent Orange and to a lesser extent with Agent Blue and Agent White. Inhabitants of the valley are primarily hill tribes living "off the land" at a more or less subsistence level.

A 1996 sampling expedition consisted of wide-spectrum sampling throughout the valley. The commune of A So, situated in the southern sector of Aluoi Valley, contained soils and fish tissues contaminated with dioxin; that is, 2,3,7,8–Tetrachlorodibenzo-*p*-dioxin or 2,3,7,8-T4CDD (or TCDD), known to be specific to Agent Orange. This is subsequently referred to as Agent Orange dioxin.

Data from 1996 formed the basis for a more focussed expedition in 1997 in A So (now renamed Dong Son commune), and a former US Special Forces base in the area. The study was designed to follow the pattern of dioxin movement through the food chain in this relatively restricted area. Farmer's soil, former Special Forces base soils, fishpond sediment, cultured fish and duck tissues and human blood were collected. As in the 1996 survey, former US Special Forces base soils contained the highest levels of dioxin. Fish and pond sediment also contained elevated levels of dioxin in this area.

If dioxin levels in soils found in 1997 occurred in a western jurisdiction, the area would be declared a "contaminated site". Dioxin levels in fish would trigger a consumption advisory process (i.e., risk assessment/risk management and recommendations on maximum human consumption levels), and possibly prohibitions against consumption if they were from a location in Canada.

Human blood samples taken in 1997 were contaminated with Agent Orange dioxin. Elevated levels were recorded in pooled blood from males and females >25 years of age, and males and females 15 to 25 years of age. Dioxin in the younger generation provides evidence that the valley environment remains contaminated and dioxin is presently moving through the food chain into humans.

A primary receptacle for dioxin moving through the local environment near A So is human beings. In the valley, both the older and younger generation have significant levels of dioxin in their blood relative to data from northern Viet Nam where Agent Orange was not applied. Deformities and early cancers have been noted in the valley. Vietnamese health studies have indicated that birth defects are an order of magnitude higher in the A So area compared to similar areas of unsprayed northern Viet Nam.

Hatfield and the Vietnamese scientists involved in the 1994-1998 work concluded, following the project, that there was a strong urgency to implement health risk mitigation plans and to further examine the extent of the Agent Orange contamination in the Aluoi Valley. The project reported herein was formulated and implemented in 1999 by the HCL/10-80 team, in collaboration with the University of British Columbia (Department of Health Care and Epidemiology). This report documents results of the 1999 investigation.

1.2 RATIONALE FOR PROJECT

War often continues to affect human health and the environment long after cessation of armed conflict. Fundamental ecological processes and cycles can be altered so that significant health and environmental impacts occur. Alteration of the bio-physical environment may result in the inability to sustain traditional day-to-day pre-war activities. There are subsequent short- and long-term consequences on socioeconomic parameters, which can have devastating effects on production and development in countries like Viet Nam.

Many war-related environmental effects are known, such as those caused by unexploded ordnance (UXO) and landmines, which limit the use of land for productive activities, reduce forest resources and associated bird and wildlife biodiversity, and cause chemical contamination and damage to socioeconomic infrastructure (e.g., dikes and canals, access roads, communications, etc.).

In the Aluoi Valley, a variety of environmental impacts caused by herbicide use were clearly documented by the project team during the 1994-98 work (HCL/10-80 1998). Impacts such as the reduction of forests and arable land, erosion of soils, and landslide damage to infrastructure are facts of life in the sprayed areas of the valley. These impacts have led to severe poverty, malnutrition, disease and other socioeconomic problems.

Some mitigation techniques to reduce the environmental effects of herbicide use are being practised in Viet Nam, such as forest replanting, erosion control and infrastructure reconstruction. However, no comprehensive methodology has yet been developed for assessing herbicide-related environmental damage and the associated human health impacts, or for mitigating their effects. If a systematic methodology is developed for this purpose, Indochina countries such as Viet Nam where herbicides were used, can be more efficiently returned to productive states, and affected populations more quickly released from poverty caused by this war activity.

As documented in HCL-10/80 (1998), the health of Aluoi Valley people who live near the former A So (Dong Son) base area is at serious risk, based on dioxin standards/guidelines of western jurisdictions and the World Health Organization (WHO). Agent Orange dioxin resulting from herbicide use in the valley during the war is clearly the source of the health risk problem.

Assessments of the quantitative levels of dioxin contamination in the environment and human tissue which may cause increased cancer rates and birth defects are ongoing in North America and Europe. However, present western dioxin standards/guidelines are designed by the best scientific minds in the world in the exotic chemical assessment and impact prevention field. Our project team believes there is no alternate practical or moral choice but to apply these dioxin criteria in Viet Nam to determine elevated health risks and initiate steps to mitigate these risks.

It is therefore necessary to take action in the Aluoi Valley to reduce the health risk as much as possible. This can be started by implementing short-term mitigation measures immediately. To further reduce or eliminate herbicide-related impacts, longer-term environmental mitigation measures should be implemented over the next few years.

Some mitigation strategies currently practiced in Viet Nam can actually result in exacerbating impacts. UXO destruction in areas where herbicides have been used can increase contamination through re-mobilization. Construction of fish ponds in contaminated areas can exacerbate human health risk problems. A methodology that screens out such potentially harmful practices will substantially aid in re-establishing sustainable living in post-conflict areas of Viet Nam and other regions of Indochina.

Many agencies in Viet Nam have the goal of reducing poverty through assessment and mitigation of war-related impacts. These agencies include Vietnamese government departments, foreign aid organizations, international finance institutions and NGO. A well-designed methodology for assessing and mitigating human health and environmental impacts from herbicide use will improve the efficiency of these agencies in solving war-related problems and provide much greater benefits to the people of the country.

A mitigation strategy related to the impacts of herbicides in the Aluoi Valley will be largely transferable to other regions of Viet Nam and Indochina affected by defoliants used during the war.

1.3 SPECIAL CONSIDERATIONS RELATED TO THE ALUOI VALLEY

Most dioxin standards/guidelines in the world have been developed for western lifestyles and assume residents have relatively high quality housing, low direct contact with soil, availability of a wide variety of food sources, potable water, and populations relatively free from serious disease, malnutrition and chronic illnesses (e.g., water-borne diseases, vitamin deficiencies, etc.). Minority peoples in the Aluoi Valley do not enjoy the lifestyle of most westerners. In fact, they live in continuous close contact with the soil, generally consume a narrow variety of foods grown or raised locally, and have health problems related to disease and malnutrition.

Western health and environmental protection standards/guidelines are likely not conservative enough for conditions in the Aluoi Valley. However, formulating more stringent criteria for developing countries where people live close to the land, would be a long and likely controversial process, meanwhile the health of people in Aluoi and other dioxin-contaminated areas would remain at serious risk, even using existing western standards/guidelines. The study team therefore believes immediate action should be taken to reduce risks to human health in the Aluoi Valley, based on existing western standards/guidelines.

1.4 RESPONSE OF HEALTH AND ENVIRONMENTAL PROTECTION AUTHORITIES IN WESTERN AND OTHER JURISDICTIONS

Most credible worldwide agencies view dioxin contamination as a serious human health threat. Specific standards, contamination assessment procedures and mitigation practices which are legally required in western jurisdictions have been outlined in some detail in Section 2.0. These procedures for dealing with the dioxin problem have been developed by qualified and experienced scientists in Canada, the USA, Europe, and other countries. They are generally being made more stringent as improved scientific data on the negative effects of dioxins are documented. Significant financial expenditures are being made to reduce levels or eliminate dioxins in the environment, especially in human food and contaminant sources.

In British Columbia, for example, over 1.5 billion US dollars have been spent by the pulp and paper industry over the last ten years, to improve internal processes, waste-water treatment facilities and reduce dioxins in effluent. This effluent was found to be contaminating fish resources in receiving waters near many mills in the province. Since such resources were harvested by commercial, sport and native fisheries, there was a calculated risk to human health posed by dioxins which bioaccumulated in local fish species. No direct effects to human health caused by dioxin were demonstrated in these areas, however, regulatory agencies took preventative action to reduce human health risk.

Recently, in Belgium, health and food safety authorities acted decisively when consumer food items were contaminated or thought to have been contaminated with dioxins from animal feed. Over one billion US dollars have been committed to date to deal with the problem.

In Korea, Agent Orange spraying in the DMZ in the late sixties has resulted in human health concerns today. Over 4.5 billion US dollars are being claimed by Korean veterans for the compensation of health effects.

In Thailand, barrels of herbicide were found buried near Bo Fai airstrip used by US military forces during the Viet Nam war. These containers have been systematically dug up and destroyed in an environmentally acceptable manner; contaminated soil was also disposed of in a safe manner. The US Environmental Protection Agency (EPA) was an overseeing agency for the Thailand clean-up which took place in 1999.

In the USA, the Department of Veterans Affairs (DVA) presently pays compensation to certain American Viet Nam veterans for nine cancers and one birth defect (spina bifida) judged to be related to exposure to Agent Orange herbicide. The DVA takes its compensation direction from the US National Academy of Sciences, Institute of Medicine on this issue. The NAS has a standing scientific committee which reports annually on cancers and birth defects which are related to dioxin exposure based on the weight of scientific evidence.

It has recently been reported by the US Air Force that there is a strong association between Agent Orange exposure and diabetes (News Release, Office of the Assistant Secretary of Defense, Washington, DC, March 29, 2000; Media Release, Congress of the United States, March 29, 2000).

1.5 NEED FOR IMMEDIATE ACTION

If the levels of dioxin found to date in the environment and people of the Aluoi Valley were found in an area in Canada, the United States or Europe, an immediate health protection program would be initiated to limit and/or resolve the problem. A shortage of funds and political sensitivities has delayed agencies and research teams from taking action in Viet Nam. These delays have resulted in a continuation of the serious health risks to the mainly minority peoples of the valley, and likely many other areas of Viet Nam. The Vietnamese people, whose health is at risk from this problem, require financial and technical help to resolve these issues.

Therefore, action should be taken to further assess and mitigate dioxin contamination problems in the Aluoi Valley resulting from Agent Orange, where conventional standards/guidelines for dioxin contamination have been exceeded.

Viet Nam has many other health, poverty and development problems. However, the Agent Orange problem was caused by impacts from application of western technology in the country. Dioxin contamination and exposure risks for humans can be reduced significantly by means of inexpensive changes to diet and restricted use of contaminated areas.

Dioxin effects on human health may amplify the negative impacts of other diseases or health conditions in the area (malaria, poor nutrition, etc.), therefore, there is an urgency for their mitigation. Knowledge gained in Viet Nam, related to mitigation of Agent Orange related health risks, would also have application to resolving long-delayed issues regarding war-related health problems in United States, Korea, Australia, Thailand and the Philippines whose veterans were involved in the Viet Nam war.

1.6 GOALS OF THE PROJECT

The mitigation program for the Aluoi Valley was designed as follow-on work from previous HCL/10-80 Committee studies regarding Agent Orange.

The program had the following goals.

1. To protect people in the valley from health risks posed by dioxin contamination of soils and the food chain.
2. To better define the area(s) of contamination in the valley.
3. To better establish the link between dioxin contamination in the environment and human health effects in the valley.
4. To establish a forest and wildlife biodiversity rehabilitation plan for the valley.

Availability of further funding will determine the magnitude of longer term programs in the valley.

1.7 PROGRAM COMPONENTS AND SPECIFIC OBJECTIVES TO ACHIEVE THE PROGRAM GOALS

The mitigation program had the following components and objectives.

1.7.1 Component 1 – Formulation and Implementation of a Health Protection Plan

a) To design a dioxin health protection plan for the Aluoi Valley.

b) To implement a dioxin health protection plan for the Aluoi Valley.

1.7.2 Component 2 – Delineation of Dioxin Contamination

a) To design and implement a soil sampling project in the A So area to better determine the extent of contamination by dioxin in the vicinity of the former Special Forces bases.

b) To design and implement a soil sampling program for Agent Orange dioxin in other areas in the Aluoi Valley where contamination "hot spots" could occur (around other former military bases, at heavy herbicide spray concentration points, etc.).

c) To design and implement Agent Orange dioxin studies involving human blood and breast milk in other communes in the Aluoi Valley to better determine correlations between soil, food chain and human contamination.

1.7.3 Component 3 – Investigation of Relationship Between Contaminated Soil and Food Chain Data, and Human Health Effects

a) To review and evaluate existing health data collected by 10-80 Committee medical personnel from A So, Huong Lam, and other communes in the valley.

b) To design and implement a medical health evaluation project to enable valid scientific conclusions to be drawn regarding linkages between soil and food chain contamination, and health effects.

1.7.4 Component 4 – Formulation of a Forest and Wildlife Biodiversity Rehabilitation Plan

To design a plan for forest, and wildlife resource rehabilitation in the Aluoi Valley. Implementation of this plan would be dependent on future funding.

1.8 PROJECT TEAM

The project was carried out by members of Hatfield Consultants Ltd., a Canadian environmental consulting company, and the 10-80 Committee, a Vietnamese government agency established in October 1980 to investigate the consequences of the chemicals used during the Viet Nam war on human health and the environment. The Peoples' Committees of Thua Thien Hue province, Aluoi Valley district and Aluoi communes also participated in the program. A project advisory panel was invited to participate in the project early in 1999 to review project plans and reports, and provide advice to the project team based on their experience. A human health assessment component from the University of British Columbia (UBC) was part of the project in 1999.

Hatfield staff consists of environmental biologists and chemists with inter-disciplinary experience in carrying out environmental assessment projects in Canada and Asia. Hatfield has been carrying out dioxin environmental contamination studies in Canada for approximately twelve years. The company is based in West Vancouver and maintains offices in Indonesia and Thailand. The 10-80 Committee consists of medical doctors and chemists who, since 1980, have been carrying out assessments of potential human health problems related to Agent Orange use during the war. The 10-80 Committee has previously collaborated with Japanese, French and American investigators who have also carried out some preliminary work related to determining levels of Agent Orange dioxin, primarily in human populations in Viet Nam.

The UBC medical team has carried out chemical contaminant health studies in Canada for approximately 25 years. They participated in project team workshops in Hue and two field trips to the Aluoi Valley.

The project team consisted of the following personnel.

- **Hatfield Consultants Ltd. (HCL)**

➤ Chris Hatfield, M.Sc.	Canadian Project Manager
➤ Wayne Dwernychuk, Ph.D.	Senior Dioxin Contamination Specialist
➤ Dave Levy, Ph.D.	Senior Ecological Specialist
➤ Thomas Boivin, M.Sc.	Senior Dioxin Sampling Specialist
➤ Martin Davies, M.E.S.	Remote Sensing Specialist
➤ Andrew Allan, B.A., Post Dip. N.R.M.	Dioxin Field Sampling Specialist
➤ Garth Taylor, B.Sc.	Dioxin Field Sampling Specialist
➤ Sue Cho, B.Sc.	GIS/Graphics Specialist

- **10-80 Committee**

➤ Hoang Dinh Cau, M.D.	Vietnamese Project Manager
➤ Tran Mahn Hung, M.D.	Vietnamese Assistant Project Manager
➤ Phung Tri Dung, M.D.	Field Sampling and Logistical Coordinator/ Technical Assistant
➤ Ngugen Huu Duc, Ph. D.	Fisheries Specialist
➤ Mr. Thai, M.Sc.	10-80 Analytical Laboratory Chemistry Specialist/Field Assistant
➤ Tran Thanh Xuan, M.D.	Ho Chi Minh City Project Coordinator

- **University of British Columbia (UBC)**

➤ Christian van Netten, Ph.D.	Environmental Toxicologist/Epidemiologist
➤ Ralph Brands, M.D., MHSc.	Epidemiologist/Statistician

- **Project Advisory Panel**

➤ Gail D. Bellward, Ph.D.	Associate Dean Research and Graduate Studies Faculty of Pharmaceutical Studies University of British Columbia
➤ Allan B. Okey, Ph.D.	Professor and Chair, Dept. of Pharmacology Faculty of Medicine University of Toronto
➤ John B. Sprague, Ph.D.	Aquatic Toxicology Specialist Sprague Associates Ltd. Professor Dept. of Zoology (retired) University of Guelph
➤ Chris van Netten, Ph.D.	Associate Professor and Toxicologist Department of Health Care and Epidemiology Faculty of Medicine University of British Columbia

[Full CV's of all project team and advisory panel personnel are available on request.]

- **Project Participants**

The following personnel from Thua Thien Hue provincial Peoples' Committees and agencies also participated in the project.

➤ Mr. Nguyen Van Me	Chairman, Peoples' Committee of Thua Thien Hue Province, Hue, Viet Nam
➤ Mr. Le Viet Xe	Vice Chairman, Peoples' Committee of Thua Thien Hue Province, Hue, Viet Nam
➤ Mr. Nguyen Due Hue	Director Health Dept., Thua Thien Hue Province
➤ Mr. Duong Huu Than	Chief of Cabinet, Health Dept., Thua Thien Hue Province
➤ Mr. Dinh Pruish	Chairman, Peoples' Committee of Aluoi District

2.0 DELINEATION OF DIOXIN CONTAMINATION

2.1 BACKGROUND

Studies in the Aluoi Valley (formerly named the A Shau Valley), Viet Nam were initiated by the Hatfield/10-80 Committee team in 1994. The report entitled "Preliminary Assessment of Environmental Impacts Related to Spraying of Agent Orange Herbicide during the Viet Nam War" was released in 1998 (Hatfield Consultants and 10-80 Committee [HCL/10-80] 1998). The 1998 document provides a detailed account of the historical aspects of Agent Orange applications during the Viet Nam conflict. It also summarizes information on ecological impacts, dioxin contamination in soils, the human food chain, and in human blood. Comparisons are made between HCL/10-80 data and other international studies, including studies specific to Viet Nam. Cau *et al.* (1994a) provide an extensive overview of various aspects of Agent Orange impacts on man and the environment of Viet Nam.

Three abandoned US Special Forces bases are situated in the Aluoi Valley (Aluoi, Ta Bat and A So [formerly named A Shau Special Forces Base]). Aluoi and Ta Bat Special Forces bases were deemed untenable and were abandoned on December 8, 1965 following intelligence reports of a large north Vietnamese build-up in the area. The Aluoi Valley was considered an important region by US military strategists, given its position along the Ho Chi Minh Trail (Stanton 1985). The A So base was overrun and abandoned on March 9-10, 1966. (A graphic account of the final days/battle of the A So base is vividly presented in Stanton [1985].) Subsequent to abandonment, there was heavy bombing, artillery barrages from mountain top fire bases, herbicide spraying and fighting in the area between US and north Vietnamese troops.

The Aluoi Valley is the location of Ap Bia Mountain, known as Hill 937 by the US military during the war. Subsequent to May 1969, following a 10-day battle for the hill, the mountain was labelled "Hamburger Hill" by US ground combatants (Summers 1995).

Brigadier General John S. Brown (US Army, Chief of Military History, *pers. comm.*) provided the following account of the Special Forces bases in the Aluoi Valley:

> *"The first camp established was Ta Bat, opened in March 1963, soon followed by A Shau* [A So] *the next month. Ta Bat was closed in March 1964, but General William C. Westmoreland, commander of the Military Assistance Command, Viet Nam, then decided that one Special Forces camp in the valley was not enough. In May 1965 he established more camps in the A Shau-A Luoi and Ta Bat (the new Ta Ba base being in a slightly different location than the first). The North Vietnamese regarded these camps as a serious threat to their logistical pipeline and put heavy pressure on them. In December 1965 we abandoned A Luoi and Ta Bat as indefensible. That left only the camp at A Shau, which the North Vietnamese massed against and attacked in March 1966. The Special Forces then abandoned this camp as well. There was no further attempts* [sic] *to*

place Special Forces camps in the A Shau Valley, although several temporary firebases were established there during operations from 1966 through 1969."

Brigadier General Brown also indicated that their files contain no information on the use, storage and/or application of any "chemicals" at either A So, Ta Bat or Aluoi Special Forces bases.

Figure 2.1 shows the distribution of aerial applications of herbicide throughout Viet Nam 1965-1971. Within the Aluoi district in central Viet Nam, the herbicides orange, blue and white were applied (Figures 2.2 and 2.3). Agent Orange was the principle herbicide utilized in the Aluoi Valley.

Along the road into the Aluoi Valley from Hue, the landscape clearly shows evidence of herbicide applications (Plates 2.1A and 2.1B). Herbicides removed thick forests which served as efficient soil stabilizers. Along the 65 km road into the valley, numerous landslides are evident resulting from soil erosion and reduced soil stability (Plate 2.2).

HCL/10-80 investigations in 1996 and 1997 were followed by additional field programs in 1999 subsequent to release of the 1998 report. The earlier investigations in the Aluoi Valley enabled the HCL/10-80 team to further refine the sampling design/program for 1999. Figure 2.4 depicts the areas sampled in Viet Nam by the HCL/10-80 team from 1996 through 1999.

2.2 METHODS

2.2.1 Nomenclature

During the course of discussions in this document, a variety of terms and abbreviations will be used to simplify presentation; the following is a listing of the more common terms/phrases that will appear:

- PCDD - polychlorinated dibenzo-*p*-dioxin;
- PCDF - polychlorinated dibenzofuran;
- TCDD - 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD), the dioxin congener that was a contaminant in the 2,4,5-T portion of the 50/50 mixture which constituted Agent Orange (2,4-D was the remaining 50% of the mixture);
- TDI - Tolerable Daily Intake is the rate of contaminant intake that is deemed unlikely to cause adverse health effects in humans (the rate is presented as "units/kg body weight/day" or "units/kg bw/d";
- TEF - toxic equivalency factor, which is the multiplication factor applied to each concentration of dioxin/furan congener determined in a sample in order to normalize the concentration level to the level of toxicity that would be produced by an equivalent amount of 2,3,7,8-T4CDD (the most toxic dioxin congener) (NATO a,b,c);

- T-TEQ - total toxic equivalence, which is a normalized level of toxicity when the TEFs are applied to the PCDD/PCDF congeners in a given sample; if a ND (non-detect) or NDR (peak detected during laboratory analysis that did not meet laboratory quantification criteria) is reported, one-half of the detection level (Startin 1994, WHO/EURO 1989) for that congener was used in the calculation of T-TEQ; and

- Agent Orange dioxin (AO dioxin) - TCDD; the PCDD congener characteristically found in Agent Orange (Schecter 1994a).

2.2.2 General Sampling Design

Sampling methods used during this study were developed in previous dioxin/furan monitoring programs conducted by Hatfield Consultants Ltd. in Viet Nam (HCL/10-80 1998) and for the pulp and paper industry in British Columbia (see references by Dwernychuk, and Dwernychuk *et al*. 1990-1998, *cited in* Appendix A3 HCL/10-80 1998). Field personnel for this program consisted of Hatfield and Vietnamese biologists, chemists, technicians, and medical doctors, all of whom have experience in contaminant studies in Viet Nam and/or Canada.

Prior to commencing field programs, the study team held meetings with representatives of the 10-80 Committee, Hue Peoples' Committee, Provincial Health Department and other representatives of the Aluoi Valley Peoples' Committee to explain the purpose of our program, obtain permission and permits to collect samples, and to recruit local personnel to assist with logistics. In Aluoi District, the A Ngo Health Centre was designated as a key contact, and provided assistance in the form of transportation, lab space, freezer facilities, personnel (for collection of blood and milk samples), and liaison with the local Peoples' Committee in each commune.

Field supplies transported from Canada included all stainless steel sampling equipment (core samplers, pans, dissecting equipment, etc.), pre-cleaned glass jars with Teflon lids, heat-treated foil, electronic balances (+/- 0.1 g), a Garmin hand-held global positioning system (GPS), pre-numbered labels, data sheets, Vacutainer blood tubes, blood sampling needles, medical supplies and other miscellaneous items. Acetone and hexane were obtained in Ha Noi (HCL maintains a supply in Viet Nam), since it was not possible to transport these with the sampling equipment from Canada.

For soil sampling in March 1999, the Aluoi District was divided into sampling regions based on the presence of former US Special Forces bases and location of aerial herbicide applications (Figures 2.1, 2.2, 2.3 and 2.4). Samples were collected in a grid-like pattern in the vicinity of the former US bases at A So, Ta Bat and Aluoi (hereafter referred to as 'base soil samples'), given the likelihood that these areas contained higher levels of dioxin. Sprayed area samples (i.e., non-base soils) were collected randomly from south to north in the valley, primarily in the vicinity of the road axis where herbicide applications were more intense.

Selection of soil sampling locations was assisted by an examination of existing topographic maps, including remote sensing information (i.e., CORONA [see Section 2.2.3] and

RADARSAT [*c.f.,* HCL/10-80 1998] imagery) available for the study area (Plates 2.3, 2.4, 2.5 and 2.6). All sampling areas were swept for presence of landmines and unexploded ordnance (UXO) by Gerberra demining personnel (Germany) prior to sample collections. HCL/10-80 personnel followed the direction and advice of Gerberra personnel regarding safe locations for sample collection.

Environmental samples (soils, fish pond sediments, fish tissues, animal tissues, and rice) and human blood and human breast milk were collected from four communes in the Aluoi Valley in June 1999: A So, Huong Lam, Hong Thuong and Hong Van. These four communes were selected to represent a gradient of high, medium and low-intensity Agent Orange exposure from the southern to northern areas of the Aluoi Valley (Figures 2.2, 2.3, and 2.5).

Given the relatively low level of Agent Orange applications in Hong Van in northern Aluoi Valley, this area was selected as the reference site in the 1999 study. That selection was made after careful consideration of environmental and social factors in the region. Although reference (control) areas sampled in January 1996 in Con Cuong and Chi Khe in northern Viet Nam (Figure 2.4) may also be used to provide comparative data from an area which was not sprayed with herbicides during the war, communes in northern Viet Nam are culturally and economically somewhat different from those in the Aluoi Valley. Hence, the study team and advisory panel chose Hong Van as a more suitable reference area for the 1999 program.

All samples were split into subsamples, one for archiving and analysis in Viet Nam, and one for transport to Canada for analysis and archiving. On occasion, random duplicate samples were collected as part of the quality assurance/quality control (QA/QC) program.

Samples were kept in coolers subsequent to collection, frozen within three hours of collection and kept frozen in freezers in Aluoi Valley, Hue, and Ho Chi Minh City prior to export from Viet Nam. Appropriate arrangements were made with air carriers and couriers to ensure samples remained frozen during transport to Canada.

Total numbers of environmental and human blood and milk samples collected are summarized below. Soil samples collected from the vicinity of the former Special Forces bases, and fish fat, duck fat, whole human blood and breast milk samples, were the priority samples analyzed for dioxins/furans; fish pond sediments and other animal tissues were archived.

Summary of soil, sediments, food and human blood/milk samples collected in Aluoi Valley, March and June, 1999.

Sample Media	Number Collected
Former US Special Forces base soils	27*
Sprayed area soils (the rest of Aluoi Valley)	20*
Whole human blood	688
Human breast milk	102
Fish muscle	87
Fish liver	88
Fish fat	48
Duck fat	8
Pig fat	4
Cow fat	1
Rice	6
Chicken eggs	2
Cooking oil	4
Fish pond sediments	18
Other animal tissues	50**
Duplicates (fish and soil)	5
TOTAL	**1158**

* Composite of ten individual soil samples.
**Duck, pig, cow liver and muscle tissue.

2.2.3 CORONA Satellite Imagery

Intelligence imagery acquired by the first generation of US photo-reconnaissance satellites, code-named CORONA, was de-classified on 22 February 1995. More than 860,000 images of the earth's surface, collected between 1960 and 1972, were made publicly accessible. The CORONA system provides an impressive level of 2-metre ground resolution with coverage available worldwide.

Early imagery collections were driven, in part, by the desire to confirm Soviet strategic missile capabilities. Worldwide photographic coverage was also used to monitor military ground, naval and air activities, including operations in Viet Nam, Lao PDR and Cambodia.

The CORONA satellite imagery offers a unique look back in time and offers a considerable amount of data for those who research human health and the environment. The de-classified imagery can be used to produce maps, charts and photographic images of environmental conditions over three decades ago. These images recorded much of the baseline data needed to measure, assess and investigate the ecosystem in Viet Nam today, and was used as an information source in designing the 1999 soil sampling program in the Aluoi Valley.

CORONA imagery has strong potential for identifying and assessing herbicide-contaminated areas. Its high resolution and physical attributes allow it to be modified or enhanced to display specific information.

Typical CORONA images were used to locate and identify suspected herbicide contaminated ground, particularly in the vicinity of former Special Forces bases in the valley (Plates 2.3, 2.4 and 2.5).

CORONA imagery, in general, is well suited for assessing hazardous areas of former military bases. Images show base infrastructure, battle activity and perimeter mine fields. The 2-metre resolution is helpful in assessing point source contamination and locating suspected waste dump areas for chemical/munitions. CORONA images are a useful tool in assessing military base information. Ground areas can be categorized and classified into groups such as runway, hanger, maintenance, parking and storage facilities.

2.2.4 Soils and Sediments

2.2.4.1 Overview of the Special Forces Bases

The March 1999 sampling program included the collection of soils from the three abandoned US Special Forces bases situated in the Aluoi Valley (Figures 2.2 and 2.3). Remnants of some of the original infrastructure were present at each facility.

The runway of the A So base is visible in Plate 2.7. Local inhabitants live near the northern area of the base (Plate 2.8). The northern end of the runway served as our north centre quadrant, with north west and north east quadrants flanking the north centre at a maximum distance of approximately 500 metres. The centre series of quadrants (centre west, centre, centre east) were situated mid-way along the longitudinal distance from the northern to southern end of the runway. South west, south centre and south east quadrants were situated at the southern extreme of the runway.

Within each of the nine quadrants, ten random soil core samples (replicates) were taken. Prior to collection of each sample replicate, marker flags were positioned in areas deemed safe following a sweep for UXO (Plate 2.9). This safety procedure was repeated for every core sample collected in the valley (i.e., 470 cores).

A portion of the runway also remains visible at the abandoned Ta Bat Special Forces base (Plate 2.10). UXO was a significant problem during soil coring at Ta Bat. Plates 2.11, 2.12, 2.13 and 2.14 show UXO on the surface within the base area. Extreme caution was taken when walking throughout the region during soil sampling.

As a result of the UXO problem, there was a slight deviation from the quadrant approach of soil cores that was applied at A So. Similar positionings were attempted (i.e., north, central, and south, with east and west flanking quadrants in each region); however, it was often necessary to follow well trodden cattle and human paths throughout, and venture only short distances from these paths to select soil sampling areas (Plate 2.15). It was extremely difficult to obtain an area that did not emit a signal from the sweeping device, which was indicative of potential UXO presence. Sampling of the Ta Bat base required a significant time investment.

Many locals have been killed or maimed by UXO in the valley; Plate 2.16 is a 22-year-old man who attempted to pick up a suspected cluster bomb. In the ten communes in the valley (out of 21) for which statistics are available, 274 people have been killed and 225 injured by UXO since the war.

Throughout the valley, including the bases, numerous bomb craters are visible within the scrub vegetation in the valley bottom (Plate 2.17).

The Aluoi Special Forces base presently lies within a settled area with homes and rice fields in the vicinity. The old runway now serves as a soccer field and general playground for local children (Plate 2.18). No other remnants of former infrastructure were visible.

The Ta Bat and A So Special Forces bases, and their perimeters, are very sparsely populated because of UXO presence. This problem was most evident at Ta Bat. Although other areas in the valley where core sampling occurred did not have highly visible UXO, the field team was assured by local residents that UXO was present.

Some homes are situated near bomb craters that serve as garbage pits and also contain UXO (Plate 2.19). Frequent casualties continue to occur in the Aluoi Valley as a result of UXO contact.

2.2.4.2 Soils

A total of 46 soil samples were collected from the Aluoi Valley in 1999 (Figure 2.5; Plates 2.20, 2.21 and 2.22). Nine samples were collected from the immediate vicinity of each of the three former bases at A So, Ta Bat and Aluoi (for a total of 27 base soil samples). Sampling locations near the bases were determined from examination of existing topographic maps for the area and CORONA imagery.

Nineteen additional soil samples (sprayed area samples) were collected randomly from the southernmost (A Dot) to northernmost (Hong Van) communes in Aluoi Valley (Figure 2.5). The main road through the valley served as the primary axis along which soil sites were selected.

Each soil sample consisted of a composite of ten replicates. Samples were collected using a hand-held, stainless steel core sampler. The sampler contains a stainless steel sleeve which was thoroughly cleaned with hexane and acetone between sampling sites. Surface soils (from 0 cm to 10 cm depth) were collected for analyses, as this soil fraction was found to contain the highest dioxin concentrations in previous Viet Nam dioxin studies (HCL/10-80 1998).

At each site, soil samples were placed into a stainless steel tray for compositing. Composites were thoroughly mixed and placed into appropriately labeled hexane/acetone washed and heat-treated jars with Teflon-lined lids. All samples were split; one jar was destined for Canada, the other for the 10-80 Committee laboratory in Ha Noi. All samples were placed in coolers for storage and transportation.

Laboratory analyses of soils (in Canada) included:

- total organic carbon (TOC);
- particle size (sieve method; gravel, sand, silt and clay); and
- dioxins/furans.

Methodology used for analysis of soil samples followed that described by PTI Environmental Services (1989; for US EPA) in: *Recommended guidelines for measuring organic compounds in Puget Sound sediment and tissue samples*.

2.2.4.3 Fish Pond Sediments and Bomb Crater Pond Sediments

Fish-pond and water-filled bomb-crater sediments were collected from a depth of approximately 60 cm below the water surface. The collector slowly waded into the pond until the desired depth was reached, and scooped sediments directly into sampling jars. Two individual samples were collected at each site. Composite samples were not collected in fishponds and bomb craters to avoid extensive disturbance of bottom sediments. These samples were archived.

2.2.5 Fish and Animal Tissues

2.2.5.1 Fish Tissues

Fish sampling concentrated on locally-grown Grass carp (*Ctenopharyngodon idella*), which are raised in fish ponds excavated throughout the Aluoi Valley. Other cultured fish species were also collected, including Indian carp (*Cirrhinus mrigala*), Common carp (*Cyprinus carpio*) and Nile Tilapia (*Oreochromis niloticus*). In some cases, these ponds were bomb craters, which have subsequently been stocked with fish to supplement local food supplies. Over 150 hectares of fish ponds are presently in use in the valley. Fish were sampled in each of the four target communes (Figure 2.5; A So, Huong Lam, Hong Thuong and Hong Van).

At each fishpond sampled, a maximum of four fish was collected using a hand seine (Plates 2.23 and 2.24). All target fish species were handled by personnel wearing latex gloves and placed in clean, well-labeled polyethylene bags. Fish were dissected within two hours of capture. Fork length (mm), whole weight (g), and sex (visual inspection of gonads) were recorded for each specimen. Muscle tissue (skin removed) was collected from the left side of each fish, above the lateral line, and between the dorsal and caudal fins. Liver samples were also collected (entire livers were removed from each specimen), as was fish fat (collected from the viscera), and on occasion, fish roe (eggs). Samples were placed in individual jars for each type of fish tissue, and frozen immediately after dissections were completed. Fish fat was the main tissue analyzed for dioxin and furan content.

Attempts were also made to collect wild fish samples at two locations on the A Sap River in Aluoi Valley: A So (Dong Son) and Xa Nham. Large, carnivorous fish species were the target using multi-filament gillnets of 3.8 cm and 5.1 cm stretched measure. The study team was unsuccessful in obtaining sufficient numbers of specimens for analysis. Individual muscle, liver and fat samples were collected from some wild fish, retained in individual jars, and archived.

2.2.5.2 Livestock, Fowl and other Animal Specimens

Two markets in the Aluoi Valley were the key locations for sampling of livestock (pig and cow): #91 market (A Ngo village) and Bo Dot market (Hong Thuong). Pigs and cows were sampled immediately after slaughtering to ensure samples were not contaminated by other food items in the markets (Plate 2.25). Liver tissues were removed from the lower left lobe; fat was collected from around the chest area. Approximately 50 g of each tissue type was collected, placed in individual glass jars, and frozen subsequent to collection.

Ducks were purchased from local residents in each of the four target communes (Plates 2.26 and 2.27). Muscle (breast meat), liver and fat tissues were collected, weighed (+/- 0.1 g), placed in individual glass jars, and frozen.

2.2.6 Rice, Cooking Oil and Chicken Eggs

Rice samples were collected from households in each of the four communes (Plates 2.28 and 2.29). Rice was collected randomly from up to three households in each commune, and placed in heat-treated glass jars. Care was taken to ensure that the rice sample originated in each of the communes, and was not purchased externally.

Cooking oil samples were also collected from households in A So (Dong Son) and from the #91 Market. The cooking oil originated in Ho Chi Minh City, and was a commercial brand commonly sold in Aluoi Valley. The oil was poured directly from the original container into a heat-treated glass jar. A composite of three individual oil samples was analyzed.

Chicken eggs were also collected from one household in A So (Dong Son). The eggs were carefully broken using a scalpel, and contents placed directly into a heat-treated glass jar.

All rice, cooking oil and egg samples were immediately stored at -4°C after collection.

2.2.7 Whole Human Blood and Breast Milk

In collaboration with the 10-80 Committee and medical authorities in Hue, human blood and breast milk samples were collected from the four target communes in the Aluoi Valley. Blood and milk sampling was conducted by staff of the Aluoi Health Centre, with assistance from 10-80 Committee medical doctors, and the HCL/10-80 team. Blood donor clinics were established following consultation with the Peoples' Committee and Health Department of Aluoi District, in order to organize sample collections.

Blood samples were taken (Plate 2.30) from select groups of villagers according to the following age and sex categories:

- Males >25 years of age, representing residents born before or during the war;
- Males <25 years of age, (i.e., 15-25 years of age, representing "post war" residents);
- Females >25 years of age, representing residents born before or during the war; and
- Females <25 years of age, (i.e., 15-25 years of age, representing "post war" residents).

Each volunteer donor was interviewed by the study team to determine name, age and personal medical history. Due to health and cultural issues, a maximum of 3.5 cc of blood was removed from each patient using a syringe, and placed in an individual vial (one per patient). Whole blood samples were kept cool on ice packs during the sampling procedure, and frozen within one hour of collection.

The key components of the human blood sampling and breast milk sampling program include:

- all potential blood donors, breast milk donors, and persons participating in the human health survey in each of the four communes were provided with a personal identification number (medical wrist band), which was used to assist the study team identify each individual sampled;
- detailed interviews were conducted with each blood/milk donor prior to collection of blood samples;
- blood donors were segregated based on sex and age, as in previous programs;
- a minimum of 150 donors was sampled in each of the four communes;
- individual blood samples were collected from each donor; these were placed in plastic Vacutainer hemogard tubes with sodium heparin as a preservative; samples of the Vacutainer tubes were pre-analyzed for presence of dioxins and furans prior to use in the field;
- individual blood samples were kept cool on ice packs following sampling, and were frozen within one hour of sample collection; and

- there was no compositing of blood or milk samples in the field; all compositing of samples was performed at the AXYS laboratory, Sidney BC, Canada, under Hatfield direction.

In Canada, blood samples were composited according to sex, age group and commune, and were analyzed for dioxin and furan content. A total of 16 blood analyses were performed (4 communes x 2 age classes x 2 sexes).

The cost of carrying out dioxin analyses was a major factor in guiding the program. Although it would have been desirable to analyze many individual samples rather than composites, financial considerations did not allow that at this time. A single dioxin analyses cost approximately $1,000 CDN.

Breast milk samples were also collected from volunteer donors (Plate 2.31). Mothers were asked to provide information on age, number of children and number of children which they have breastfed (including children of relatives, etc.). Breast milk sampling was conducted at the same time as the blood sampling program; some mothers donated both blood and breast milk samples. Volunteer patients donated 15-50 cc of breast milk sample; milk was expressed by individual mothers directly into the sample jar. A minimum of 20 milk samples were collected from each of the four target communes (total of 102 samples). Analyses were conducted on 17 samples; five from A So and four from each of the other three target communes; remaining samples were archived.

The breast milk phase of the Aluoi Valley program was targetted to serve two purposes:

- given the close relationship between blood and breast milk PCDD/PCDF levels, single milk samples (four individual samples per commune) were analyzed to provide an indication of PCDD/PCDF variability in the commune; these data were to provide another indication of the relative degree of variability that may occur in blood on an individual sample basis, given blood analyses were performed on composite samples only; and

- given that breast milk constitutes a significant portion of the diet of infants in the Aluoi Valley (breast feeding for children up to three years of age was reported), and given that other infants in the commune may be fed by the same mother, knowledge of breast milk contamination would serve to clarify an additional route of human contamination in addition to that caused by the ingestion of other contaminated foods and/or dermal exposure through contact with contaminated soils.

A summary of blood and milk samples collected is presented in Appendix A1.

2.2.8 Field Quality Assurance (QA)/Quality Control (QC)

Important components of the study include ensuring standard QA/QC protocols were followed during all sample collection activities, in addition to training of Vietnamese scientists in ultra-trace contaminant sampling. The field team has expended considerable time training Vietnamese counterparts in environmental sampling techniques during previous expeditions, and have emphasized the importance of minimizing potential contamination of samples. Some important QA/QC considerations are:

- disposable latex gloves were used to handle all samples and specimens, and were dipped in hexane prior to sample collection and/or dissection; gloves were changed between samples and specimens;
- stainless steel trays and tools (spoons, forceps, etc.) were rinsed in ambient water, then acetone and hexane, before each use and between sample collections;
- sample jars were pre-cleaned by the Canadian analytical laboratory prior to shipment to Viet Nam;
- duplicate samples were collected at all stations;
- all samples were placed in 250 mL heat-treated, wide-mouth glass jars and sealed with lids lined with heat-treated aluminum foil. Samples were appropriately labeled, stored in a cool/dark area, and transported to refrigerator facilities within three hours of collection;
- tools and gloved fingertips which touched the skin or external organs of sampled animals was not allowed to touch internal tissues; any tissue suspected of being contaminated in this manner was discarded;
- the location of each sampling station was recorded using a hand-held GPS; still photography and video was used to record sampling locations and activities;
- detailed records were kept of the name of the owners of local farms, fields, fish ponds and animals sampled. Interviews with local residents provided essential data on the source of animals sampled (i.e., sex, age, origin);
- livestock (pigs, cows) were sampled immediately after being slaughtered by the local butchers (i.e., samples were not "purchased" from the market);
- field blanks and blind duplicates were included in the samples analyzed;
- smoking was not permitted in the vicinity of sampling activities; and
- all samples were secured with adhesive tape and given individual markings to prevent tampering during transport and storage in Viet Nam.

2.2.9 Laboratory Procedures/Analytical Methods

2.2.9.1 General

Samples arriving in Canada from Viet Nam were forwarded to AXYS Analytical Services Ltd. (AXYS) for dioxin analyses. AXYS was one of approximately 25 laboratories from around the world participating in a World Health Organization (WHO) interlaboratory comparison study of PCBs and dioxins in human plasma and breast milk samples. WHO officials presented the study results to all participants at a meeting in Prague in late 1998. According to the criteria set by WHO, AXYS is one of two laboratories in the world meeting the requirements for analyzing dioxins in blood, and one of three for dioxins in breast milk. AXYS was also one of three laboratories in the world meeting the criteria for PCB analysis in blood and breast milk. These results are to be confirmed in an official summary report expected to be released by the WHO in 2000. These results are unofficial, pending release of the WHO report (*pers. comm.* Dr. C. Hamilton, AXYS).

The following is a brief topical itemization of laboratory methods applied during this investigation. Appendix A2 provides additional information on laboratory procedures involving:

- sample handling;
- extraction;
- chromatographic cleanup (i.e., silica gel column, alumina column, carbon/celite column, alumina column [from the carbon/celite column], and preparation for GC/MS analyses);
- high resolution GC/MS analyses (gas chromatograph/mass spectrometry);
- quantitation protocols;
- GC/ECD analyses (gas chromatograph/electron capture);
- quality assurance/quality control (QA/QC);
- procedural blanks;
- duplicates;
- surrogate standard recoveries;
- laboratory reference samples;
- detection limits;
- calculations;

- data reporting;
- soil particle size determination; and
- determination of Total Organic Carbon (TOC) in soil samples.

2.2.9.2 Polychlorinated Dioxins and Furans in Soil and Biological Tissues

All samples were spiked with ^{13}C-labelled surrogate standards (tetrachlorodioxin, tetrachlorofuran, pentachlorodioxin, pentachlorofuran, hexachlorodioxin, hexachlorofuran, heptachlorodioxin, heptachlorofuran, and octachlorodioxin) prior to analysis. Soil samples were soxhlet extracted. Tissue samples were ground with sodium sulphate, loaded into a glass chromatographic column and eluted with solvent. All extracts were subject to a series of chromatographic cleanup steps prior to analysis for polychlorinated dibenzodioxins and dibenzofurans by high resolution gas chromatography with high resolution mass spectrometric detection (HRGC/HRMS).

2.2.9.3 Polychlorinated Dioxins and Furans in Whole Human Blood and Breast Milk

All samples were spiked with ^{13}C-labelled surrogate standards (as listed above) prior to analysis. Samples were liquid/liquid extracted by shaking with solvent. All extracts were subject to a series of chromatographic cleanup steps prior to analysis for polychlorinated dibenzodioxins and dibenzofurans by high resolution gas chromatography with high resolution mass spectrometric detection (HRGC/HRMS).

2.2.9.4 PCBs and Chlorinated Pesticides in Human Breast Milk

All samples were spiked with a suite of ^{13}C-labelled surrogate standards (hexachlorobenzene, gamma-BHC, p,p'-DDE, p,p'-DDT, Mirex, PCB 101, PCB 180, and PCB 209) and perdeuterated alpha-endosulphan. Samples were solvent extracted. The final extracts were separated into two fractions on a Florisil column. One fraction was analyzed by high resolution gas chromatography with detection by either quadrupole or high resolution mass spectrometry for PCBs (as Aroclors) and non-polar and moderately polar chlorinated pesticides. A second fraction was analyzed for the most polar chlorinated pesticides by gas chromatography with election capture detection (GC/ECD).

2.3 RESULTS AND DISCUSSION

2.3.1 Perspective

Our earlier report (HCL/10-80 1998) provides a detailed account of the historical aspects of Agent Orange applications during the Viet Nam conflict. Readers are referred to that report for additional background information. Where useful and relevant, information from the 1998 document has been extracted and placed in the context of the 1999 database in the present report.

To acquaint the reader with the existing Viet Nam database which was generated through HCL/10-80 studies (1994-1998), Tables 2.1 and 2.2 are presented. Accompanying the Aluoi Valley data in these tabulations are dioxin concentrations from other regions of Viet Nam that were sampled during these initial investigations. In 1996, for example, a reference area was selected in northern Viet Nam to serve as a comparison to Aluoi Valley results. In 1997, samples were also collected and analyzed from the vicinity of the Ma Da forest in southern Viet Nam (north east of Ho Chi Minh City); the Ma Da forest region was a major combat theatre during the conflict (Figure 2.4).

A complete analysis and assessment of the 1996/1997 database (i.e., Tables 2.1 and 2.2) is presented in HCL/10-80 (1998).

Raw data sheets for all laboratory analyses are presented in Appendix A2.

2.3.2 Soil

2.3.2.1 General

In 1996, soil from the A So commune, situated in the vicinity of the former US Special Forces base, had the highest TCDD and Total TEQ (T-TEQ) level (110 pg/g and 112.6 pg/g, respectively; Table 2.1). In 1997, soils collected in the vicinity of the 1996 samples within the perimeter of the base, had significantly higher TCDD and T-TEQ values relative to 1996 (897.85 pg/g and 901.22 pg/g, respectively; Table 2.2). Given that the TCDD level, and in turn T-TEQ, were the result of analyses on samples that consisted of a composite of ten subsamples, it was concluded that some individual concentrations probably existed in the subsamples that exceeded the "average" values obtained in the composite analysis. Conversely, some individual TCDD levels were probably below the "average" composite value. For comparative assessment and remediation purposes, some understanding and appreciation of the probable range, in addition to actual, contaminant concentrations has merit, particularly when mitigation measures are being considered.

2.3.2.2 1999 Dioxin Levels in the Aluoi Valley

Soil collections during the 1999 program extended from the southern to northern regions of the Aluoi Valley (Figure 2.5). As recorded during previous sampling expeditions, those soil samples originating from the US Special Forces base at A So had the highest TCDD concentrations (220 pg/g - 360 pg/g; Table 2.3).

Figure 2.6 presents TCDD concentrations (and T-TEQs) in soils throughout Aluoi Valley, 1996-1999. The northern quadrants of the A So base had the highest TCDD levels. Levels at A So decreased towards the southern quadrants of the base. The 1999 TCDD values were lower than the 1997 level determined at the A So base (897.85 pg/g, Figure 2.6), suggesting a high degree of variability throughout the site.

TCDD was the principle dioxin congener in the analytical spectrum. The T-TEQ values, particularly at the Special Forces bases consisted to a high degree of the TCDD congener (Table 2.3). The TCDD congener is specific to Agent Orange; its presence in the concentrations recorded, relative to other congeners, supports the conclusion that Agent Orange was the mechanism introducing TCDD to the bases and Aluoi Valley, in general.

Given the high TCDD concentration at A So, in particular, and to a lesser degree Ta Bat, it is clear that Agent Orange application, storage and/or use at these bases did, in fact, occur. The continued occupation by military personnel of the A So base until March 1966, beyond the closure period of Ta Bat and Aluoi, undoubtedly contributed to the higher readings of TCDD.

The variable TCDD concentrations in soils near the A So base (1996, 1997 and 1999), indicates that sectors of the base are highly contaminated and, probably in some areas, in excess of levels reported herein.

Generally, there is a low level presence of TCDD throughout the Aluoi Valley, apart from those at the former A So base. Centres of concentrated military activity (i.e., the Special Forces bases) had the highest TCDD concentrations.

TCDD was detected at 46 of the 47 sites tested throughout the Aluoi Valley. Thirty-six of the 47 samples tested (77%) contained T-TEQ values for which TCDD comprised more than 75% of the total.

Other soils throughout Aluoi Valley were markedly lower in TCDD concentrations relative to the bases (Table 2.3, Figure 2.6). The highest concentration recorded was 15 pg/g TCDD at the existing Aluoi market site. Other levels throughout the valley ranged from non-detect in Huong Lam to 7.9 pg/g TCDD in Hong Quang. A So area had the highest level of dioxin contamination, probably as a result of both ground and aerial use of Agent Orange around and probably within the base perimeter. Storage of Agent Orange on-site probably occurred; however, attempts to obtain plans, sketches and/or photographs of the A So Special Forces base have proved unsuccessful. Brigadier General Brown (*pers. comm.*) indicated no information regarding A So (including Ta Bat and Aluoi bases) was available at the US Army Centre of Military History. Efforts to secure such information from other military archives have also proved unsuccessful.

Highest octa-dioxins (O8CDD) concentrations were from areas of the Aluoi Valley where human activity was more pronounced and the burning of refuse common (e.g., Hong Thuong commune, 2,200 pg/g total O8CDD; Bo Dot market 1,100 pg/g total O8CDD; Son Thuy commune, 1,800 pg/g and 1,100 pg/g total O8CDD; Table 2.3).

The south-centre quadrant of the Ta Bat Special Forces base had a total O8CDD of 1,100 pg/g. Human activity in this region, in general, was markedly less than in those areas noted above; however, the southern most perimeter of the Ta Bat base/airstrip was near the Ho Chi Minh Trail, which, at present, is utilized extensively by locals as a route of travel. This activity pattern along the Ho Chi Minh Trail may contribute to the higher total O8CDD in this southern Ta Bat quadrant.

Matsuda *et al*. (1994) and Quynh *et al*. (1994) measured TCDD levels in soils from Viet Nam. A TCDD range of 1.2 pg/g to 59.2 pg/g was reported by Matsuda *et al.* (1994) from various regions in southern Viet Nam (collection period 1989-1991; Phu Loc [Thua Thien Hue Province], 4.37 pg/g-16.8 pg/g; Ho Chi Minh City, 2.98 pg/g-59.2 pg/g; Tay Ninh Province, 1.23 pg/g-38.5 pg/g; and Song Be, 6.0 pg/g). Only 20% of their sample complement of 106 samples yielded detectable levels of TCDD. Leaching and run-off were considered the processes that reduced TCDD levels to the point of non-detection.

Quynh *et al*. (1994) reported a TCDD level of 1.0 pg/g from the Aluoi Valley (20 cm depth). A 62.7 pg/g TCDD level (10 cm depth) was reported by Quynh *et al*. (1994) in soils from Bach Ma (situated between the cities of Hue and Da Nang). The 10-20 cm depth fraction yielded a TCDD concentration of 17.3 pg/g.

Previous HCL/10-80 (1998) studies in Viet Nam revealed that the 0-10 cm depth fraction contained higher concentrations of dioxin, relative to the 10-30 cm fraction. Matsuda *et al.* (1994) indicated that dioxins were not detected at soil depth greater than 10 cm. Quynh *et al*. (1994) and HCL/10-80 (1998) have shown that dioxins are, in fact, detectable at greater depths; however, it appears that concentration is reduced as depth is increased. On the basis of these findings, only the 0-10 cm depth fraction was tested during the HCL/10-80 1999 program.

Nestrick *et al.* (1986) reports several TCDD concentrations in soils from typical industrialized areas in the United States. A group of mid-western and mid-Atlantic states were the focus of this investigation. Soil samples were collected near major steel, automotive or chemical manufacturing facilities or near municipal solid-waste incinerators. Nestrick *et al.* (1986) reported that soils from these typical industrialized areas contained TCDD levels that were below 10 pg/g, with a range of non-detectable (ND) to 9.4 pg/g.

Nestrick *et al.* (1986) also reported TCDD soil levels near a Dow Chemical plant in Midland, Michigan (involved in the manufacturing of chlorophenolic compounds). TCDD levels in soils from this area ranged from 22 pg/g to 450 pg/g. The Agency for Toxic Substances and Disease Registry (ATSDR 1998) reports on a number of studies in Missouri (including Times Beach) where TCDD levels ranged from 30 pg/g to 2,200 x 10^3 pg/g. These areas were considered highly contaminated. The ATSDR (1998) summarizes by stating that soil TCDD concentrations are typically greater in urban areas, with industrial soils clearly exhibiting the highest levels of contamination.

Soil TCDD levels in the Aluoi Valley, and specifically near the A So Special Forces base, were well above the typical soil level of <10 pg/g, as noted above. Soils near the A So base show TCDD levels that are more characteristic of soils found near highly contaminated industrialized urban areas in the US.

2.3.2.3 *Particle Size and Total Organic Carbon*

A portion of the composite sample from each soil location was analyzed for particle size and Total Organic Carbon (TOC) (Table 2.4). These data were graphed to show the relationship of the physical characteristics of the soil sample (i.e., particle size and TOC) and the T-TEQ value recorded for that particular composite (Figures 2.7 and 2.8).

No statistically significant (regression analyses, $p>0.05$) relationship existed between either percent sand, percent silt or percent clay and T-TEQ values. Similarly, T-TEQ was not associated statistically (regression analyses, $p>0.05$) with TOC in the sample.

Soils have a tendency to facilitate the adsorption of TCDD to particulate matter (Webster and Commoner 1994). Larger particle sized materials would encourage percolation and leaching (e.g., during heavy rains), thereby "flushing" contaminants to greater soil depths (or stimulate lateral dispersion) but these phenomena were not seen.

If Agent Orange applications throughout the Aluoi Valley were uniform, in terms of application rate per unit area, a relationship between T-TEQ and certain particle size(s) and TOC would likely have been observed. It is apparent that distribution of Agent Orange (and in turn TCDD and T-TEQ) was uneven and concentrated in specific locations during military activities in the valley.

Current data from the valley indicate there is a strong probability that the "loading" of Agent Orange in the A So commune area was significantly greater than in other areas of the valley. If the A So base during operation likely experienced ground spraying of Agent Orange (i.e., truck mounted and/or backpack sprayers), in conjunction with aerial applications (helicopter and/or fixed-wing aircraft), and also contained reserves and caches of Agent Orange within the base parameter, it is logical to assume the TCDD in the base area would be elevated (relative to other sites in the valley). Any correlation between contaminant concentration and physical characteristics of local soils (e.g., particle size and TOC) would therefore be negated by excessive loading on/near the actual base facility.

2.3.2.4 *Environmental Protection and Human Health*

Dioxins in general, and TCDD in particular, in soils from industrialized countries are expected to be detected at varying concentrations. The production of dioxin and dioxin-like compounds (e.g., PCBs) essentially began during World War I as a result of large-scale industrialization (Webster and Commoner 1994).

Historically, soils near specific industries and certain materials treatment processes have a high probability of containing dioxins, particularly if chlorine was involved in the process (e.g., bleaching of pulp and paper with elemental chlorine; incineration of chemical waste, hospital waste and sewage sludge; processing of certain metals) (Webster and Commoner 1994).

Given their low water solubility and resistance to rapid degradation, dioxins (particularly TCDD) tend to partition into soil; consequently, this medium serves as a "reservoir" for the contaminant and effectively serves to facilitate the contamination of other media long after cessation of a contaminating activity and/or process has occurred (Webster and Commoner 1994).

In the United States, the ATSDR (1998) reports that TCDD is not generally detected in rural soils; however, in industrialized regions of the US, TCDD levels typically range from 1.0 pg/g to 10 pg/g. The International Agency for Research on Cancer (IARC 1997) provides a detailed summary of 42 studies in 18 industrialized countries presenting over 150 TCDD data points. TCDD concentrations presented in this overview ranged from ND to 9.6×10^9 pg/g; the highest concentrations recorded in the IARC (1997) summary were determined in highly contaminated soils from Missouri (e.g., a horse arena and farm soil, Kimbrough *et al.* 1997 and Viswanthan *et al.* 1995, both *cited in* IARC 1997). Other very high TCDD levels (i.e., >1,000 pg/g) were recorded in soils collected from heavily industrialized sites; these sites included manufacturing plants for tetrachlorophenol, pentachlorophenol, chlorophenolics and herbicides (e.g., 2,4-D) and incineration facilities.

Regulatory agencies addressing human health protection have employed various protocols to address the issue of dioxin contamination (e.g., in Canada, Health Canada and provincial health ministries and environmental departments; in the US, the Environmental Protection Agency [EPA] and state health agencies).

In British Columbia (BC), Canada, legislation addresses the issues of contaminated sites and legal standards directed at site remediation. The definition of a "contaminated site" (i.e., soil) in BC is one in which:

> *"…the concentration of any substance in the soil at the site is greater than or equal to… the lowest value of the applicable matrix numerical soil standards…"* (BC Waste Management Act 1996).

For soils contaminated with polychlorinated dioxins and polychlorinated furans (PCDD and PCDF, respectively), legal T-TEQ standards are set, which if exceeded would designate a site to be a "contaminated site". For example, in BC, the land categories of "agricultural and residential/park" are recognized in the legislation. The site-specific receptors that define the legal threshold contaminant level for the land categories considered above are "human health protection" and "environmental protection" (i.e., ecological health). The following is the BC PCDD/PCDF (expressed as T-TEQ) soil standards for agricultural and residential/park soils (source: BC Waste Management Act 1996):

Matrix Numerical Soil Standard (pg/g Total TEQ).

Site-Specific Factor/Receptor	Agricultural Land	Residential/Park Land
Human Health Protection[1]	350	350
Environmental Protection	10	1,000

[1] An adult is used as the critical receptor, and related to intake (ingestion) of contaminated soil.

When addressing the issue of ecological health (environmental protection), the agricultural land and residential/park categories have different levels, 10 pg/g and 1,000 pg/g T-TEQ, respectively.

When addressing human health protection in BC, T-TEQ for agricultural and residential/park soils is 350 pg/g for both categories. This value is calculated on the basis of oral ingestion of soils alone, and does not make provision for dioxins that may be taken into the body through other avenues (e.g., foods, drinking water, exposure to commercial products, etc; BC Environment 1996).

These values focus on adult individuals with an assumed soil ingestion rate of 20 mg/day (BC Environment 1996). The following provides a summation of typical soil ingestion rates for the general population in Canada (source: Angus Environmental 1991, Newhook 1992 and MENVIQ 1992, *cited in* BC Environment 1996):

Typical Average Receptor Characteristic Values for the Canadian General Population.

Age Classes (years)	Soil Intake (mg/day)
0-0.5	20
0.6-4	80
5-11	20
12-19	20
20+	20

It should be noted here that young children are believed to ingest more soil materials and, generally, have greater exposure to soil contaminants relative to adults. Their lower body weight is also a factor. The above table would undoubtedly be magnified for young children in the Aluoi Valley as they are more intimately associated with soil as a result of dress (e.g., usually they lack footwear) and play habits (particularly the very young living in poor villages who spend time on bare ground), which increase the opportunity to ingest soil. In addition, many houses have dirt floors.

When a given area is to be assessed and categorized as to whether or not it constitutes a contaminated site in BC, two receptor categories (human health and ecological health, see table on previous page) are always considered. However, if a land category is designated as contaminated by either standard and remediation is contemplated, the BC Waste Management Act (1996) stipulates that the "lowest" matrix numerical soil standard be applied; that is, if a property is to be remediated for agricultural purposes, the 10 pg/g T-TEQ level for PCDDs/PCDFs is the target (remediation measures must reduce the soil contaminate level below 10 pg/g T-TEQ). Similarly, if land is to be remediated solely for the purposes of residential/park use, 350 pg/g T-TEQ is the target criterion.

The question may be posed: if the ecological health receptor level is 10 pg/g T-TEQ for agricultural land, and the human health receptor level is 350 pg/g T-TEQ, is not more importance being placed on the ecological elements as opposed to human elements of the environment? The rationale for the difference in T-TEQ relates to the issues of bioaccumulation and biomagnification. Agricultural areas are used for raising food (crops and livestock); these foods are ultimately consumed by humans, therefore, directly facilitating dioxin bioaccumulation and biomagnification processes. Since it is important to protect crops, livestock, and human health, a more stringent standard has been designated for ecological health.

A similar rationale is in place for residential/park lands. Given that residential/park areas are not major food producing regions, the ecological health standard is set at 1000 pg/g T-TEQ. The direct ingestion of soil contaminants is considered a greater probability (and greater potential hazard) in residential/park situations relative to the possibility of ingestion from foods produced in these areas. The quantity of foods produced in a residential/park area is markedly less than on agricultural lands, hence the 1000 pg/g and 10 pg/g levels, respectively.

The Canadian Council of Ministers of the Environment (CCME 1999), a joint federal-provincial Canadian agency, has set a guideline for PCDDs and PCDFs (T-TEQ) for land used in agricultural areas at 10 pg/g T-TEQ, and for residential/park land at 1000 pg/g T-TEQ; only a single value is presented for each land category. In Canadian provinces, where contaminated site legislation is available, the provincial regulatory standards take precedence over CCME guidelines. The CCME (1999) T-TEQ values for agricultural and residential/park land use are recommended for remediation quality (i.e., remediation should be equal to or less than the value).

Given legal agricultural standards defining contaminated sites in British Columbia (noted above), the majority of soils from the A So Special Forces base in the Aluoi Valley are considered contaminated from the perspective of human health protection and environmental protection. Data were also obtained from the A So base which indicate that human health protection is compromised when comparing data (in Figure 2.6) to the residential/park soil standard (i.e., 350 pg/g T-TEQ).

Soils in other areas of the valley (excluding the Special Forces bases) were generally below 10 pg/g T-TEQ, therefore within the BC standard. The only exception was the 17 pg/g T-TEQ recorded in soils from the Aluoi market (Table 2.3).

Given that land near the A So Special Forces base is used for agriculture, aquaculture, and residential purposes, the issue of remediation arises in order to address the protection of human health. Recommendations for soil remediation in the Aluoi Valley are presented in Section 4.0; however, to place the Aluoi Valley and the Special Forces bases (particularly A So) in perspective, an example of a remediation approach in BC Canada is presented here.

A four-hectare (approximately nine-acre) parcel of land in BC was considered contaminated with chemical residues, including dioxin. A remediation approach of soil removal and incineration was estimated to cost 170 million US dollars. Consequently, in lands that are contaminated, and an exorbitantly high expenditure is necessary to remediate to legal contaminant levels, the approach in BC is one of *in situ* risk management. In the example above, contaminated soils were covered with an impermeable membrane and clay; the area was subsequently converted to an urban park (*pers. comm.* Mr. Dave Clark, Dillon Environmental).

In the US, the Environmental Protection Agency (EPA) works to protect public health and the environment. Regarding soils and contaminant levels, for example, the US EPA Region III (Delaware, Maryland, Pennsylvania, Virginia, West Virginia and District of Columbia) has set a TCDD level (not T-TEQ level as in BC Canada) of 4.3 pg/g as a residential soil guideline (a level for agricultural soil does not exist) and 38.0 pg/g for industrial soil (US EPA 1999a). If soil values exceed these guidelines, a risk assessment is required.

In US EPA Region IX (Arizona, California, Nevada, Hawaii, US Territories of Guam and American Samoa, and the Commonwealth of the Northern Marianna Islands, and other unincorporated US Pacific possessions), the soil guidelines for TCDD are 3.9 pg/g and 27 pg/g for residential and industrial soils, respectively (US EPA 1999b).

Some differences related to assumed dioxin exposure, and thus guideline values, exist between Regions III and IX; however, it can be accepted that the residential soil guideline is relatively low (4.3 pg/g and 3.9 pg/g TCDD, respectively).

In the context of Aluoi Valley soils (Figure 2.6), the majority of sites, if they existed in US EPA Regions III and IX, would require a risk assessment, and in all probability subsequent risk management.

The ATSDR (1997) guideline for dioxin and dioxin-like compounds in residential soils has been set at 50 pg/g T-TEQ. The guideline states that in residential regions where soil T-TEQ levels exceed 50 pg/g, a further site-specific evaluation is required. The ATSDR (1997) indicates that if a soil dioxin level is <50 pg/g T-TEQ, a more detailed site-specific assessment may still be required based on overall community health concerns and a health assessor's concerns regarding other combinations of potential contaminants. In addition, if an exposure pathway is identified (e.g., food chain pathway, as in Aluoi Valley), the extent of exposure and public health implications are required to be further evaluated. The likelihood, frequency, routes and exposure levels to the contaminant, and information on human populations that are exposed, would require assessment.

The ATSDR (1997) guideline recommends that an area with a soil concentration of >50 pg/g to <1,000 pg/g T-TEQ should experience the following evaluation:

- bioavailability;
- ingestion rates;
- pathway analyses;
- soil cover;
- climate;
- other contaminants;
- community concerns;
- demographics; and
- background exposures.

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

- surveillance;
- research;
- health studies;
- community;
- education, and
- exposure investigations.

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

Many of the soil samples near the A So Special Forces base area are >50 pg/g and <1,000 pg/g T-TEQ; site-specific evaluations (ATSDR 1997) are therefore required. Given the soil samples collected and analysed in the Aluoi Valley were a composite of ten sub-samples, there is a high probability that values >1,000 pg/g T-TEQ exist, particularly at the A So base. If these values were recorded in the United States, the processes as described by the ATSDR (1997), and in US EPA Regions III and IX, would be initiated to protect human health.

2.3.2.5 AXYS Analytical and 10-80 Committee Interlaboratory Comparison

Soil samples were analyzed in Canada at AXYS Analytical (AXYS). Split samples were provided to the 10-80 Committee following field collections in the Aluoi Valley, March 1999. These split samples were analyzed at the 10-80 Committee laboratory in Ha Noi.

Eighteen results from the 10-80 Committee laboratory were compared to AXYS results. The following provides the data comparison.

Comparison of AXYS and 10-80 Committee Laboratory Dioxin/Furan Concentrations (pg/g) in Split Soil Samples, Aluoi Valley, 1999.

Sample #	2,3,7,8-T4CDD		Total TCDD		2,3,7,8-T4CDF		Total TCDF		Total TEQ	
	AXYS	10-80	AXYS	10-80	AXYS	10-80	AXYS	10-80	AXYS	10-80
1	220	178.45	220	178.45	3.7	ND	11	ND	220	178.83
2	260	199.19	280	199.19	20	ND	35	ND	260	199.5
3	25	37.34	37	37.34	1.6	ND	6.1	13.44	27	51.18
4	45	59.94	54	59.94	2.7	5.22	11	56.72	46	101.37
5	15	18.82	20	18.82	0.9	ND	6.0	59.18	16	19
6	5.4	12.71	7.6	12.71	0.4	ND	2.3	10.72	5.6	12.72
7	4.2	<2	5.1	<2	0.4	ND	2.4	695.8	4.8	<2.7
8	1.0	ND	1.0	ND	0.3	<2	1.7	70.09	1.6	<2.5
9	6.7	9.23	8.4	9.23	0.4	ND	2.6	12.07	7.2	9.77
10	9.4	11.47	15	11.47	1.4	ND	11	54.91	11	11.81
11	11	13.51	16	13.51	0.7	ND	5.7	67.73	13	15.09
12	35	13.21	40	13.21	1.0	ND	5.3	76.39	36	14.51
13	4.3	<2	8.8	<2	0.3	ND	2.7	169.1	5.5	<3.85
14	7.7	<2	12	<2	0.6	ND	4.4	ND	8.9	<2.6
15	12	<2	15	<2	0.5	ND	2.2	137.78	13	<2.2
16	19	10.87	26	10.87	0.7	ND	3.4	83.42	20	11.02
17	10	17.39	14	17.39	0.6	ND	3.6	52.27	11	17.95
18	11	10.92	16	10.92	0.5	ND	2.7	24.73	12	11.13

AXYS reviewed the two data sets and provided comments. The following is a brief review of their assessment (*pers. comm.* Dr. Coreen Hamilton, Vice-president Analytical Services, AXYS Analytical, Sidney, BC Canada).

- Reasonable agreement between the two sets of data was obtained for 2,3,7,8-T4CDD values. The more significant differences may be sample related (i.e., related to the compositing process).

- The comparability of 2,3,7,8-T4CDD results is poorer for low concentrations as 10-80 did not readily detect low levels in samples; this is to be expected as AXYS uses more sensitive high resolution GC/MS technique while 10-80 uses low resolution GC/MS.

- Total TEQ values reported by the two labs also show good general agreement. Again, the lowest level samples show poorer correlation.

- Data from both laboratories show that the 2,3,7,8-T4CDF concentration is very low in all samples except one, Sample #2, for which AXYS reports 20 pg/g while 10-80 reports ND. The TCDD results from the two laboratories for this sample generally agree. AXYS' chlorinated furan data for this sample suggests that there may be some combustion input to this sample and, therefore, the difference in results could be related to AXYS' subsample having a small quantity of ash or other carbon-related material.

- 10-80 reports higher furan "totals" compared to AXYS. For example, Sample #7, AXYS' Total TCDF concentration is 2.4 pg/g while 10-80's result is 695.8 pg/g. This difference could be explained by the lower specificity of the low resolution GC/MS method used by 10-80. This can lead to false positives and, therefore, to higher total values if the total includes peaks that appear to be dioxins or furans, but actually are not. Some other sample components, such as chlorinated diphenylethers, can appear to be chlorinated furans and may not be resolvable by the low resolution GC/MS method.

Consideration has been given to using the 10-80 Ha Noi laboratory as an analytical screening mechanism to facilitate the selection of those samples, contaminated areas, etc., that could warrant further comprehensive analyses in Canada. Given the high cost of dioxin analyses, a more cost effective screening mechanism may prove beneficial in programs where a high number of samples require dioxin analyses.

2.3.3 Biological Media

2.3.3.1 Overview and Human Health Concerns

Contaminants such as dioxins and furans (polychlorinated dibenzo-*p*-dioxins [PCDDs] and polychlorinated dibenzo furans [PCDFs]), are highly persistent, ubiquitous chemical compounds in the environment (McLachlan 1993). Given their hydrophobic nature and high affinity for fatty tissues, PCDDs/PCDFs have a high tendency to accumulate (and biomagnify) in the human food chain (Jensen 1987).

Over 90% of the human body-burden of PCDDs/PCDFs in the general population is the result of food consumption (Patandin *et al.* 1999a, Harrison 1998, Vartiainen *et al.* 1998, IARC 1997, Alawi 1996, Dahl *et al.* 1995, Huisman *et al.* 1995a, Pluim *et al.* 1993, 1992, Rappe 1992). Foods which are rich in fats tend to be the principle sources of PCDDs/PCDFs; these are primarily meat, fish and dairy products (Albers 1996, Pluim *et al.* 1993, 1992).

In most vertebrate animals, the ingestion of foods contaminated with PCDDs/PCDFs results in the retention of those congeners containing primarily the 2,3,7,8-substituted PCDDs (IARC 1997). The most toxic of the various dioxin congeners is 2,3,7,8-T4CDD (TCDD) (Hu and Bunce 1999, Dwyer and Flesch-Janys 1995 and Bacci *et al.* 1992). Numerous toxic effects in humans have been associated with TCDD exposure. The literature regarding dioxin effects on humans and experimental animals is too voluminous to summarize here; the reader is referred to ATSDR (1998), IARC (1997) and Schecter (1994a) which summarize in considerable detail various investigations focussing effects that are immunological, neurological, reproductive, circulatory, pulmonary, developmental, genotoxic, carcinogenic, gastrointestinal, thyroidal, hepatic and integumental. In addition, the above citations examine the topics of toxicokinetics (i.e., absorption, bioavailability, distribution, metabolism, elimination/excretion and pharmacokinetics/dynamics), mechanism of action/carcinogenicity (e.g., binding of TCDD to the Ah receptor; TCDD has the highest affinity of the PCDDs/PCDFs for human receptors [IARC 1997]).

The toxicity of TCDD specifically, and PCDDs/PCDFs in general, has prompted organizations such as the World Health Organization (WHO) and various countries to develop and adopt tolerable daily intake (TDI)[1] or allowable daily intake (ADI) levels for PCDDs/PCDFs in foods, based on TCDD toxic equivalents (NATO 1998a,b,c).

The Canadian and the Japanese governments are presently applying a TDI value of 10 pg TEQ/kg body weight/day (10 pg TEQ/kg bw/d) (IARC 1997, Health Canada 1996, Government of Canada 1993). This value was originally recommended by the WHO (WHO/EURO 1991) based on liver toxicity, reproductive effects and immunological effects, in addition to employing information on kinetics in humans and experimental animals.

In Germany, 10 pg TEQ/kg bw/d is also being used at present, wherein if a daily intake exceeds this value for an extended period of time, immediate actions are necessary to counter exposure (Shultz 1994).

The Netherlands uses a more restrictive TDI of 2-3 pg TEQ/kg bw/d (Birnbaum and Slezak 1999). Patandin *et al.* (1999a) indicate that the TDI for the Netherlands is, in fact, lower than that reported by Birnbaum and Slezak (1999); they report the TDI as being 1 pg TEQ/kg bw/d. The US Environmental Protection Agency (US EPA) has proposed a virtually safe dose of 0.0064 pg TEQ/kg bw/d (Patandin *et al.* 1999a, McLachlan 1993), a markedly lower value relative to those quoted above.

The WHO has recently revised the recommended TDI, reducing the value from 10 pg TEQ/kg bw/d to a range of 1-4 pg TEQ/kg bw/d (WHO/EURO 1998a,b) based on new epidemiological and toxicological data, particularly information focussing on neurodevelopment and endocrinological effects.

The WHO has stressed that the upper value of the range (i.e., 4 pg TEQ/kg bw/d) should be considered the <u>maximum</u> TDI, and that *"the ultimate goal is to reduce human intake levels below 1 pg TEQ/kg bw/d"*. They also indicate that there may well be subtle effects of dioxin exposure in the general population in developed countries even at current background levels. WHO/EURO (1998b) summarizes by stating:

> *"The consultation therefore recommended that every effort should be made to limit environmental releases of dioxin and related compounds to the extent feasible in order to reduce their presence in the food chains, thereby resulting in continued reductions in human body burdens. In addition, immediate efforts should be made to specifically target exposure reductions towards more highly exposed sub-populations."*

The following is presented as an example of a TDI application for assessing whether a given level of contamination warrants initiation of a risk assessment/risk management process, which could involve food consumption advisories.

[1] TDI = an intake rate considered safe for humans.

In Canada, the 10 pg TEQ/kg bw/d is the upper threshold which, if exceeded on a regular basis, triggers implementation of a risk assessment/management process. For foods, a standard weight of an individual consumer is set at 60 kg. The probable daily intake (PDI) of animal liver/fat tissues is set at 20 g tissue/day; for animal muscle tissue the PDI is set at 40 g tissue/day. Therefore, if one wishes to determine the concentration (i.e., Total TEQ) of PCDDs/PCDFs in a given tissue sample that equates to 10 pg TEQ/kg bw/d (which constitutes the upper threshold level), the following approach is applied:

Liver and Fatty Tissues

$$\frac{(x)(20\ g/d)}{60\ kg} = 10\ pg\ TEQ/kg\ bw/d$$

$$(x)(20\ g/d) = (10\ pg\ TEQ/d)(60)$$

$$(x)(20\ g/d) = (600\ pg\ TEQ/d)$$

$$x = \frac{600\ pg\ TEQ/d}{20\ g/d}$$

$$x = 30\ pg\ TEQ/g$$

where: x = Total TEQ of a liver/fat sample which would be equivalent to 10 pg TEQ/kg bw/d for a 60 kg person consuming 20 g of tissue per day.

A similar calculation using muscle tissue at a set consumption rate of 40 g/day results in a Total TEQ of 15 pg/g as the upper threshold level.

Therefore, if either the 30 pg/g Total TEQ in liver or fat, or 15 pg/g Total TEQ in muscle tissue is exceeded for a tissue sample, the risk assessment/management process is activated in Canada.

Given the now-revised and recommended WHO level (1-4 pg TEQ/kg bw/d), it is evident that much reduced threshold levels of tissue contamination would trigger a consumption advisory process if these were implemented in Canada (this value is presently being reviewed by Health Canada, *pers. comm.* Mr. John Salminen, Head Chemical Evaluation Division, Health Canada). As an example, if the revised WHO level of 4 pg TEQ/kg bw/d were applied to the above example of liver/fat tissues, the 30 pg/g threshold level would be reduced to 12 pg/g, and for muscle tissue it would be reduced from a threshold level of 15 pg/g to a TEQ of 6 pg/g.

DeVito and Birnbaum (1994) stated that *"the available data indicate that humans are sensitive to the toxic effects of these chemicals* [dioxins]*"*. Kerkvliet (1994) indicates there is a general acceptance that dioxins (TCDD) *"alter multiple cellular targets within the immune system"*. Undoubtedly, many countries are reviewing the TDIs in light of these and similar views on TCDD.

The exact relationships between dioxin and human health remain unclear; researchers also agree that more studies are required in order to generate a clearer understanding of the effects of TCDD on humans.

In Canada, federal legislation governing dioxin/furan releases into the environment became law in 1992 (CEPA[1] 1992). By 1994, all pulp mills in Canada were releasing final effluents with virtually non-measurable concentrations of 2,3,7,8-T4CDD or 2,3,7,8-T4CDF. Costs to the British Columbia pulp and paper industry for dioxin cleanup of pulp mill effluent, and internal process changes, exceeded $1.5 billion US dollars between 1988 and 1993 (MOE 1994). The speed at which government and industry reacted to address the dioxin/furan contamination problem in Canada indicates the perceived health hazard that dioxins and furans pose to the environment and human health.

Several medical studies have attempted to evaluate health effects of dioxin contamination associated with herbicide spraying during the Viet Nam war. In 1991, the US Secretary of Veterans Affairs requested the US National Academy of Science to conduct a major review of health effects on US veterans exposed to Agent Orange and other herbicides used in the war. A review of the scientific data was undertaken during which the committee weighed these data from the perspective of inherent strengths and limitations – essentially a weight-of-evidence approach.

The resulting report by the Institute of Medicine (IOM 1994) concluded that there is sufficient evidence for an association between Agent Orange exposure and several medical conditions, including soft tissue sarcoma, non-Hodgkin's disease, Hodgkin's disease, chloracne, and porphyria cutanea tarda (PCT; symptoms being a thinning and blistering of the skin when exposed to the sun). The report also concluded that there was "limited/suggestive evidence of an association" between Agent Orange exposure and respiratory cancers (lung, larynx and trachea), multiple myeloma (bone marrow cancer), and prostate cancer.

The US Institute of Medicine in their 1996 update (IOM 1996), has determined that there is "limited/suggestive evidence of an association" between Agent Orange exposure and the birth defect spina bifida and peripheral neuropathy (acute and subacute); the latter condition being a nerve disorder which can cause pain, numbness and weakness in limbs. The 1996 IOM document also downgraded PCT from "sufficient evidence" to "suggestive evidence" of a relationship to Agent Orange. The IOM (1999) update has resulted in no change from the 1996 update in the association between specific health outcomes of US Viet Nam Veterans and their exposure to herbicides.

It is clear from publications in the international community that dioxins in the environment are considered a significant potential threat to the health of human populations. The following sections review data on dioxin contamination in the food (plant and animal matter), blood and breast milk of human inhabitants of the Aluoi Valley, central Viet Nam.

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[1] Canadian Environmental Protection Act.

2.3.3.2 Plant Matter

Orazio *et al.* (1992) has reported that the degradation of tetra- through octachlorinated dioxin congeners (P5CDD through 08CDD) in soil is minimal over time, relative to the di- and trichlorinated congeners. The presence of these (and other) PCDDs/PCDFs in soil results in the potential for vegetation and food plants to become contaminated with these compounds. Contamination of crops by soil particles is an avenue for human contamination, particularly if washing and peeling of vegetables prior to eating is not undertaken (Startin 1994, Hulster and Marschner 1993). It is generally accepted that the ability for uptake of PCDDs/PCDFs through the systemic system of plants is virtually absent in most species (IARC 1997). McLachlan (1999) states that atmospheric deposition is the principle pathway of PCDDs/PCDFs entering the human food chain through agricultural crops.

Although PCDDs/PCDFs possess a high affinity to the soil organic fraction and are extremely hydrophobic, which would limit their mobility in soil and translocation in plants, recent studies have demonstrated soil-plant transfer of PCDDs/PCDFs (Neumann *et al.* 1999, Hulster *et al.* 1994).

Hulster *et al.* (1994) has shown uptake of PCDDs/PCDFs in zucchini and pumpkins; these results were unexpected and have prompted a recommendation for more research in the area. However, they also concluded that the primary mode of PCDD/PCDF contamination in plant materials is through atmospheric deposition.

In the Aluoi Valley, samples of manioc root (tapioca) and rice were analyzed for PCDDs/PCDFs in 1996/1997 (Tables 2.1 and 2.5 and Figure 2.9); TCDD was not detected. The only congener that was detected in manioc was 08CDD (Table 2.1, 1.1 pg/g). Rice samples yielded 08CDD and H7CDD (Table 2.5, 1.8 pg/g and 0.8 pg/g, respectively). These values are extremely low and considered inconsequential from a toxicological perspective. Total TEQs for plant materials ranged from 0.14 pg/g (rice sample No. 99VN332, Table 2.5) to 0.20 pg/g (manioc sample No. VN9606, Table 2.1). Total TEQ values do appear, given that calculations of the Total TEQ proceed using one-half the detection level (Startin 1994); these values are also considered inconsequential. The least toxic congener of the PCDDs/PCDFs is 08CDD/08CDFs (0.001 of TCDD).

A composite of vegetable cooking oil showed low levels of H6CDD, H7CDD, 08CDD, H7CDF and 08CDF (Table 2.5). IARC (1997) reports studies where the results for cooking oils were similar to those found in the Aluoi Valley (i.e., primarily hepta/octa chlorinated congeners). These values are considered very low and inconsequential in terms of overall toxicity.

Pesticide and PCB analyses were also performed on the oil composite. Analyses indicate that p,p'-DDE, p,p'-DDT, alpha-Endosulphan and Arcolor 1260 were detected in minute quantities (i.e., 6.0 ng/g, 1.4 ng/g, 2.3 ng/g and 72 ng/g, respectively; Appendix A2).

2.3.3.3 Animal Tissues

Foods play a significant role in the transfer of PCDDs/PCDFs from the environment into the human food chain (Pohl *et al.* 1995). Foods such as fish, poultry, beef and pork may become contaminated to varying degrees, given their level of association with the contaminated lands on which they are produced.

In Viet Nam, Dai *et al.* (1994b) and Cau *et al.* (1994b) reported on dioxin levels in human food items (e.g., fish, chicken, pork), stating that by 1988 dioxin levels had decreased significantly and were considered comparable to food stuffs in other nations. However, both Dai *et al.* (1994b) and Quynh *et al.* (1994) offer the generalization that residual dioxin contamination nonetheless remains a threat to human health in Viet Nam.

The HCL/10-80 (1998) report summarizes a variety of food samples collected in 1996 and 1997 from the Aluoi Valley (Tables 2.1. and 2.2 herein). Conclusions of the HCL/10-80 report were that levels of dioxin recorded in fish grown in ponds excavated from contaminated soils (at the A So Special Forces base) would trigger a risk assessment/management process with potential food consumption advisories, if these values were recorded from a location in Canada or other western jurisdiction. The highest Total TEQ recorded in 1996/1997 was 53.7 pg/g (carp fat) (Table 2.1). In 1999 (Table 2.5), the A So Special Forces base also had the highest level of dioxin contamination in animal tissues; (duck fat at 56 pg/g and 87 pg/g Total TEQ). These values exceed the 30 pg/g Total TEQ threshold level set in Canada that would trigger risk assessment/management processes with possible consumption advisories. Figure 2.9 depicts levels of TCDD contamination (including Total TEQs) in foodstuffs throughout various communes in the Aluoi Valley.

People living in the Aluoi Valley consume animal fat regularly to supplement their diet. Given that ducks possess a high level of fat throughout their bodies, the consumption of muscle tissue alone would not totally eliminate the indigestion of fats. The highly contaminated fatty tissues would be difficult, if not impossible, to separate from muscle tissues prior to consumption. Health Canada's comment, when asked, regarding the Total TEQ of duck fat recorded in Aluoi Valley (87 pg/g, Figure 2.9) was that this level would definitely be of concern, with recommendations that no regular consumption of these tissues should occur, pending implementation of risk assessment/risk management strategies to protect human health near the A So Special Forces base (*pers. comm.* Mr. J. Salminen, Health Canada).

It is evident that the highest levels of contamination are in the A So commune, the commune most intimately associated with the highest soil contamination in the Aluoi Valley (those soils found near the A So Special Forces base presented in Figure 2.6). It is noteworthy that TCDD (the congener specific to Agent Orange) comprises a very high percentage of the Total TEQ of the majority of samples collected in the Aluoi Valley (including soils; Tables 2.1, 2.2 and 2.5). These high percentages of TCDD contribution to Total TEQ, confirms that Agent Orange was the mechanism for introducing dioxin contamination to the Aluoi Valley.

Cau *et al.* (1994b), Quynh (1994), Schecter *et al.* (1990c and 1989a) and Olie *et al.* (1989) summarize data on foodstuffs collected throughout Viet Nam in the mid-1980's. The highest levels of TCDD reported (from southern Viet Nam) in these papers was turtle ovaries (250 pg/g), turtle liver (88.0 pg/g), turtle gall bladder (39.0 pg/g) and snake (11.58 pg/g). Other TCDD values reported in these investigations were relatively low, many of them were lower than values determined in foodstuffs from the Aluoi Valley by the HCL/10-80 team (compare, for example, Table 1 in Cau *et al.* 1994b with Tables 2.1, 2.2 and 2.5 herein).

In general, the exposure of elements in the human food chain to TCDD in the Aluoi Valley, in particular near the A So Special Forces base, has continued to the present day. Twenty-nine years following cessation of spraying in the valley, TCDD continues to accumulate in animal tissues used by local human inhabitants for food. Some of the contamination levels recorded would be of concern to western health authorities.

The comparative differences in levels of contamination (soils and food) between the various communes throughout Aluoi Valley (Figures 2.6 and 2.9) indicate a higher level of TCDD exposure for human food produced near the A So Special Forces base. It is suspected that this area received a higher "loading" of Agent Orange through the presence of herbicide storage yards, herbicide spills and perimeter spraying around the base. This situation in the Aluoi Valley may occur in other areas of southern Viet Nam; that is, those areas that functioned as military installations during the war probably received a higher level of Agent Orange usage (loading), relative to non-military facilities where only aerial spraying occurred (e.g., forested and crop areas). Foods produced in the vicinity of other former military installations throughout southern Viet Nam have a high probability of localized contamination, as exemplified by the A So situation in Aluoi Valley, potentially creating numerous "hot spots" through southern Viet Nam. Since many of these former military installations are now occupied as residential/agricultural areas, it is likely these populations are at risk of exposure to dioxins (i.e., TCDD).

2.3.3.4 Whole Human Blood

a) General

Humans are at the top of their food chain and will bioaccumulate and biomagnify certain chemical contaminants. Blood, milk and adipose tissue can serve as monitors of environmental conditions, including the bioavailability of persistent contaminants like dioxins (Schecter *et al.* 1992a and Schecter *et al.* 1991a).

Given that TCDD is considered the most toxic of the PCDD/PCDF congeners (Dwyer and Flesch-Janys 1995), and that TCDD was the dioxin congener characteristically found in the 2,4,5-T portion of the Agent Orange mixture, TCDD has been a primary focus in numerous investigations regarding Agent Orange effects, both in Viet Nam and the United States (Viet Nam veterans) (e.g., Schecter *et al.* 1995, Roumak *et al.* 1995, Phiet *et al.* 1994, Schecter *et al.* 1992b, Schecter *et al.* 1990b, Schecter *et al.* 1989b, Schecter *et al.* 1987, Schecter *et al.* 1985, and other citations by Dai *et al.,* Schecter, and Schecter *et al.* [*cf.*, References section]).

The analytical determination of PCDDs and PCDFs in physical and biological media has made significant progress since the 1970s. The reliability of early dioxin data, in general, is considered somewhat questionable and should be regarded with caution (Jensen and Slorach 1991). Many of the data points presented herein originating from various citations were generated through analytical techniques which varied from present day protocols. It was not until the mid-1980s that reliable standards and ^{13}C-labeled materials became available for ultra-trace dioxin analyses. In addition, it has only been since the early 1990s that high-resolution mass spectrometers became commonly used in the analyses for the various dioxin congeners (*pers. comm.* Dr. C. Hamilton, AXYS Analytical, British Columbia, Canada).

Throughout the following sections (human blood and breast milk), data summaries from various publications are presented spanning nearly two decades which were the result of differing laboratory protocols and analytical equipment; these methods have not been identified herein (many were not reported). In addition, the "N" value (number of individuals involved in an analytical determination) for pooled/composite data originating from various publications was also variable; where available, the "N" value for each determination was reported.

b) Aluoi Valley

In 1999, 556 individuals from the Aluoi Valley were selected for blood PCDD/PCDF analyses. Table 2.6 summarizes sex, age categories and "N" values of participants.

Table 2.7 provides a congener breakdown of PCDDs/PCDFs for each of the four composites in each commune (A So, Huong Lam, Hong Thuong and Hong Van). The communes have been tabulated from the most southerly (A So) to the most northerly (Hong Van). Hong Van received the fewest aerial Agent Orange applications, relative to the other communes (Figures 2.2 and 2.3), and, consequently, was used as a reference area within the Aluoi Valley.

The highest TCDD levels in blood (Table 2.7) were recorded at the A So commune, near the abandoned US Special Forces base. A So males of both age categories (<25 and >25 years of age) had the highest TCDD levels. The lowest levels are in Hong Van; these being either ND or NDR[1]. The use of Hong Van as an Aluoi Valley reference area was verified by these data (Figure 2.10).

The 1999 A So levels also exceeded 1997 levels from this commune (Figure 2.10). The high percentage of TCDD in the T-TEQ (Table 2.7), particularly at A So, indicates significant Agent Orange involvement.

TCDD data in Table 2.7 were tested for statistically significant differences using a three-way ANOVA[2]; results of this analysis are:

- a highly statistically significant difference among TCDD levels recorded from the four communes ($F[3,7]=37.9$, $p=0.0001$);

[1] ND = not detected.
NDR = a peak was detected during laboratory analysis that did not meet laboratory quantification criteria; data treated as ND.

[2] Where ND or NDR appears in Table 2.7, 1/2 the detection level was used in the ANOVA.

- a highly statistically significant difference between TCDD levels recorded for the sexes (F[1,7]=27.4, p=0.001);

- a statistically significant difference between TCDD levels recorded for the age categories (F[1,7]=9.3, p=0.019); and

- a statistically significant interaction between sex and commune location in determining TCDD levels (F[3,7]=7.6, p=0.013).

The following tabulation further illustrates the comparison between TCDD concentration and commune location using the Student-Newman-Keuls test (Hicks 1973):

Comparison	Observed Difference	Level of Significance
A So vs. Hong Van	23.925	p<0.01
A So vs. Huong Lam	16.525	p<0.01
A So vs. Hong Thuong	13.200	p<0.01
Hong Thuong vs. Hong Van	10.725	p<0.01
Hong Thuong vs. Huong Lam	3.325	Not significant
Huong Lam vs. Hong Van	7.400	p<0.05

All comparisons of communes showed significant differences except for the Hong Thuong/Huong Lam comparison. The A So commune, when paired with the remaining three communes, resulted in the highest level of observed statistical difference.

Given the high level of TCDD contamination in the A So commune, through its proximity to the A So Special Forces base, these differences are not unexpected. The greatest difference was between A So and Hong Van (i.e., the reference area), since Hong Van was farthest north in the valley, and received less Agent Orange exposure.

A statistically significant difference was noted between the sexes (p<0.001) where males had the higher concentrations of TCDD in blood. Males' higher caloric intake, greater exposure to soil and their living off the land in areas away from the home (which can extend for days), likely contributed to this sex difference. In addition, females, through breast feeding, possess an avenue for the elimination of TCDD, thereby reducing their overall body burdens.

A statistically significant difference was recorded between ages (p<0.019). This is not unexpected as older people would normally be expected to be exposed for a longer period of time, therefore facilitating the accumulation of TCDD to higher concentrations. However, people <25 years of age (i.e., born after the war) also had elevated TCDD levels. Particularly in A So, there is little difference in TCDD levels between the two female age categories (Table 2.7;

16 pg/g, >25 years of age; 14 pg/g, <25 years of age). The physiological capability of eliminating TCDD by lactating females, regardless of age, through breast feeding may tend to balance out the age variable. Virtually no TCDD difference between females of the two age categories was also recorded in 1997 (Table 2.2; 11 pg/g, >25years of age; 12 pg/g, <25 years of age).

There was a significant interaction between sex and commune location. This interaction indicates that males living in the A So area have a higher level of risk of being contaminated with TCDD relative to males in Hong Van. Figure 2.11 depicts the interaction and the average level of TCDD in blood of males and females living in the various communes. For males, the risk of being highly contaminated with TCDD decreases from A So to Huong Thuong to Huong Lam to Hong Van.

High human exposure through contaminated soils and/or the local food chain in A So account for the observed relationships and the increased risk of contamination in this commune relative to the other three. The markedly lower level of soil and food contamination in the Hong Van area generates the lowest risk of TCDD contamination in human blood, with no difference in risk between the sexes.

In 1997, males in A So >25 years of age (i.e., born before the war ended) had a TCDD level which was equal to that of the A So males in 1999 who were <25 years of age (i.e., born after the war ended) (31 pg/g in each case; Figure 2.10, Tables 2.2 and 2.7). The continued ingestion of contaminated foods by younger inhabitants born well after cessation of hostilities, in A So (and other communes), is strong testament to a TCDD contaminated food chain 29 years following the end of herbicide spraying in the Aluoi Valley, and 33 years subsequent to closure of the A So Special Forces base. It is clear that the local environment is the principle conduit through which TCDD is being transported to humans in the valley. The persistence of TCDD is evident from our results, confirming conclusions of other blood studies in Viet Nam (Schecter 1994b).

The Aluoi Valley is isolated with no industrial development and limited human food sources. This scenario is probably exacerbating TCDD bioaccumulation and biomagnification in the valley. If contaminated foods are being consumed on a regular basis, particularly in A So, with little variety and/or choice, there exists a significant potential for continued contamination with further bioaccumulation of dioxins in local inhabitants.

Blood sampling in the Aluoi Valley may not have been entirely random (i.e., except for the four age/sex categories). Visits to households throughout the valley indicated that many deformed and/or sick people are not mobile; these individuals would not be able to attend blood sampling clinics. Consequently, TCDD levels in the blood of Aluoi Valley inhabitants determined through this investigation are probably conservative.

c) Aluoi Valley and Viet Nam

Figures 2.12 and 2.13 summarize TCDD levels and TCDD as a percentage of T-TEQ in human blood, respectively, throughout Viet Nam. Historical data were combined with the HCL/10-80 database for 1997 and 1999 to provide a geographical depiction of TCDD contamination from the DMZ in Quang Tri province, to Minh Hai (Ca Mau) province in the south. Data from Ha Noi and Thanh Hoa represent regions in northern Viet Nam that were not sprayed with Agent Orange herbicide.

The HCL/10-80 TCDD level of 41 pg/g (Figure 2.12), representative of males >25 years of age, exceeded all other values presented in this graphic summary; the 33 pg/g TCCD level recorded in Tra Noc, Can Tho province, was the nearest concentration to the HCL/10-80 41 pg/g level. It is clear from this graphic representation of human blood in Viet Nam that the commune in closest proximity to an abandoned US Special Forces base in the Aluoi Valley (A So) had individuals with the highest TCDD levels in blood.

The existence of other "hot spots" of TCDD contamination throughout southern Viet Nam is highly probable. Former military installations throughout Viet Nam likely serve as potential "reservoirs" for Agent Orange TCDD. Dai *et al.* (1995) state that high TCDD levels in residents inhabiting areas in the vicinity of former bases may have resulted from their close proximity to these bases.

As a further indication of the potential "reservoir" status of former military facilities, declassified US military documents obtained by HCL report a major Agent Orange spill at the Bien Hoa airbase north of Ho Chi Minh City. These documents itemize several spills/leaks of Agent Orange at the base. On March 1, 1970, a leak of approximately 7,500 US gallons of Agent Orange occurred on-site (*pers. comm.* US Department of the Army, Springfield, Virginia, January 8, 1997). Other spills and leaks in the order of 100-500 US gallons were also reported at the Bien Hoa base.

Agent Orange jettisons from C-123 aircraft are another source of localized high levels of TCDD contamination. Cecil (1986) states that the US Secretary of Health and Human Services reported the existence of 90 emergency jettisons of Agent Orange payloads during the Viet Nam war; of these, 41 were apparently over or near US airbases and other military installations. Cecil (1986) further clarifies that these 41 emergencies near US installations would almost always have involved jettisons off the end of runways at Bien Hoa, Tan Son Nhut, or Da Nang. The on-target jettisons were apparently the result of battle damage which would indicate higher than normal levels of Agent Orange were released over certain areas. C-123 crashes have also probably resulted in high TCDD levels in localized areas.

d) Aluoi Valley and Non-Viet Nam Studies

Blood TCCD levels recorded in the Aluoi Valley were compared to a number of other investigations in other countries throughout the world (i.e., non-Viet Nam studies). Various studies/data points were segregated into the categories of "unexposed" and "exposed" individuals from whom blood was taken and analyzed for PCDDs/PCDFs.

Unexposed participants were those who inhabited industrialized countries, but were not closely associated with an industrial source of contamination from which TCDD, for example, could originate and ultimately accumulate in human blood via exposure through inhalation, oral ingestion, and/or dermal exposure.

It should be restated that no attempt was made to itemize the analytical techniques/instruments used to generate the various TCDD data points presented in the non-Viet Nam studies category. In addition, the N values for each designated sample varied. The intention of the approach is to provide a general comparative overview of contaminant levels in industrial countries and the Aluoi Valley, Viet Nam.

Table 2.8 summarizes data extracted from studies of unexposed participants and/or the reference/control data from investigations involving exposed populations. Figure 2.14 presents a graphic representation of TCDD levels, T-TEQ and percent TCDD of T-TEQ from these studies compared to the Aluoi Valley. TCDD levels in the Aluoi Valley were generally higher than concentrations recorded in other investigations. The lowest recorded TCDD level in the Aluoi Valley, excluding Hong Van, was 5.3 pg/g in females >25 years of age in Huong Lam (Table 2.7); this value exceeded the majority of data points presented for other non-Viet Nam studies (Figure 2.14).

TCDD levels in A So exceeded all other non-Viet Nam TCDD levels in the non-exposed category. In addition, all percent TCDD of T-TEQ in A So samples (the lowest being 84.3%), exceeded all other non-Viet Nam TCDD levels, indicative of an Agent Orange source.

Theoretically, poor agrarian populations inhabiting an isolated valley with no industrialization, and little in the way of mechanization, would be expected to be relatively unexposed to contaminants, compared to a more industrialized region. Data from Figure 2.14 clearly indicate that inhabitants of some locations in the Aluoi Valley cannot be considered "unexposed", particularly those inhabiting the area near the abandoned Special Forces base at A So. Other Aluoi Valley communes (with the exception of Hong Van) also had blood levels which, when compared to the non-Viet Nam studies, could also be classified as exposed (see below).

Hooper *et al.* (1998) and IARC (1997) indicate that the ratio of P5CDD to TCDD in a blood sample can be suggestive of the level of industrialization in an area from which a given blood sample was taken; ratios of approximately 2-3 appeared to be typical of industrialized countries. Figure 2.15 summarizes the P5CDD:TCDD ratios presented in Table 2.8, including ratios calculated from Aluoi Valley data (Table 2.7).

In the majority of the non-Viet Nam investigations, the P5CDD:TCDD ratio in blood is typical of industrialized countries. Aluoi Valley data enabled a ratio calculation in only four of 16 instances due to ND concentrations of P5CDD in 12 blood samples. The origin of dioxins in blood samples from Aluoi Valley overwhelmingly appears to be of a non-industrial source (i.e., Agent Orange).

Table 2.9 summarizes a number of studies that present blood data from exposed populations. This table is segregated into those data points <100 pg/g and those >100 pg/g TCDD. The <100 pg TCDD data with T-TEQs (including the percent of TCDD of T-TEQ) are presented in Figure 2.16, in conjunction with Aluoi Valley data from Table 2.7.

In general, the distribution of TCDD levels in the Aluoi Valley, indicate that these residents are exposed. The lowest A So TCDD blood level (14 pg/g; Table 2.7) was exceeded by only two values from Russia and one from Germany (these involving chlorophenolic industries).

Blood TCDD has been recorded in high concentrations (Table 2.9, bottom tabulation). A value of 331.8 pg/g was recorded in Germany at a chlorophenolic plant. The other high concentrations were also the result of participants being in close proximity to industries that produced agrochemicals (notably 2,4,5-T in which TCDD was a contaminant). Note the high percent TCDD of T-TEQ in the >100 pg/g data. These high percentages are comparable to those recorded in Aluoi Valley data, thereby further corroborating 2,4,5-T involvement (and in turn Agent Orange) in the contamination of the valley.

Perhaps one of the most infamous situations involving TCDD contamination was the Seveso, Italy accident which occurred June 10, 1976 (Bertazzi and di Domenico 1994). A TCP (trichlorophenol; specifically 2,4,5-T) production facility experienced an explosion that released 2,900 kg of organic matter, 600 kg of sodium trichlorophenate and an as yet undetermined amount of TCDD (Bertazzi and di Domenico 1994).

Blood TCDD levels from people in the most contaminated areas near the Seveso incident ranged from 828 pg/g to 56,000 pg/g TCDD[1]; these blood serum levels are among the highest ever reported for humans (Mocarelli *et al.* 1991 *cited in* ATSDR 1998).

When compared to the exceptional circumstances that generated very high single-event TCDD levels, Aluoi Valley numbers are low; however, Aluoi Valley in the context of the majority of the other exposed data is of significance, particularly when considering that the inhabitants of Aluoi Valley have been exposed to residual TCDD for nearly 35 years on a continual basis. The ingestion of contaminated food by Aluoi Valley residents has occurred on an ongoing basis for the past 35 years.

A review of P5CDD:TCDD ratios of exposed non-Viet Nam participants in relation to Aluoi Valley data is presented in Figure 2.17. As noted for unexposed participants (Figure 2.15), the vast majority of the non-Viet Nam data reveal contamination as a result of industrial operations in industrialized countries. The P5CDD:TCDD ratios from Aluoi Valley indicate no industrial involvement, and confirm a specific source of contamination (i.e., Agent Orange).

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[1] Samples were stored shortly following the accident, and recently analyzed.

e) Summary

The science of detecting ultra-trace contaminants like PCDDs/PCDFs in human blood has evolved significantly over the past decade. Detection levels have been reduced, and the amount of sample necessary to produce a reliable result has also decreased. The most up-to-date analytical protocols and GC/MS equipment have been used in our analyses.

Blood data recorded from HCL/10-80 samples collected in the Aluoi Valley in 1999 corroborate a continuation of TCDD passage from the environment to the human population.

TCDD blood levels recorded throughout Aluoi Valley appear to be more characteristic of levels recorded in people inhabiting highly industrialized countries, in particular, people in close proximity to a source of industrial contamination (i.e., an exposed population). A congener analysis using P5CDD:TCDD ratios indicates that the TCDD source in the Aluoi Valley is not industrial, but Agent Orange.

In the Aluoi Valley, the A So commune near the former US Special Forces base had the highest levels of TCDD in human blood, which correlated with the highest soil and food TCDD levels (also recorded in A So). The mobilization of TCDD from contaminated soils into the human food chain is clearly exemplified in these data. Agent Orange use at the A So base is clear; the delineation of the principle reservoir(s) of TCDD on the former base remains to be established beyond the approximate 1 km diameter area at the northern sector of the airstrip.

2.3.3.5 Human Breast Milk

a) General

The class of chemical compounds known as organochlorines, of which PCDDs/PCDFs are a member, have been recognized as teratogens (i.e., involved in the production of abnormal organisms) (Dietrich 1999). PCDDs/PCDFs are considered persistent and toxic with the source being contaminated foods (Patandin *et al.* 1999a). The nursing of infants reduces the maternal body burden of PCDDs/PCDFs at the expense of the infant (Schecter *et al.* 1998, Abraham *et al.* 1998, 1996, Raum *et al.* 1998, Schecter *et al.* 1996, Schecter *et al.* 1990a, Furst *et al.* 1989).

It has generally been concluded that breast-fed infants can be considered a high risk group in the human population for PCCD/PCDF exposure (Dahl *et al.* 1995, Jensen 1987). These compounds have elicited concern for the overall health of infants, particularly if breast milk comprises a high proportion of the infant diet (Raum *et al.* 1998).

The tetrachlorinated dioxin, 2,3,7,8-T4CDD (TCDD), is the most toxic of this family of compounds (Jensen *et al.* 1997). Jodicke *et al.* (1992) reported that the higher chlorinated PCDDs/PCDFs (i.e., hepta- and octachlorinated PCDDs/PCDFs) had a reduced propensity to be absorbed into the human body, thereby, effecting a higher degree of elimination relative to the tetra-/penta-/hexachlorinated PCDDs/PCDFs. They also noted that over <u>90%</u> of the tetra- to hexa- PCDDs/PCDFs were absorbed by the infant. Dahl *et al.* (1995) reported over 95% of the PCDDs/PCDFs were absorbed with a higher level of excretion noted for the hepta- and octa-PCDDs. In general, the retention of the tetrachlorinated PCDDs/PCDFs is greater than the more chlorinated compounds (ATSDR 1998). Dahl *et al.* (1995) states that an infant's body burden of PCDDs/PCDFs is largely a function of nursing and the high absorption rates of these compounds.

A considerable body of literature exists on the biochemical and toxicological responses of laboratory animals and humans exposed through accidents and environmental exposure to PCDDs/PCDFs. With respect to responses related to human breast milk and infant intake, studies have provided information on dermal effects, immunotoxic effects, hepatotoxic effects, carcinogenic effects, teratogenic effects, neurobehavioral effects and other biochemical responses (Nagayama *et al.* 1998a,b, Becher *et al.* 1995, Weisglas-Kuperus *et al.* 1995, Jensen and Slorach 1991). Numerous studies have also reported a relationship between bleeding in infants, Vitamin K deficiencies, and PCDDs/PCDFs (Koppe *et al.* 1991); others have reported on thyroid hormone impacts and Vitamin K and other vitamin deficiencies related to PCDDs/PCDFs (Nagayama *et al.* 1998b, Koppe 1995, Pluim *et al.* 1994, Sauer *et al.* 1994, Koopman-Esseboom 1994, Koppe *et al.* 1989).

Breast milk is a reliable indicator of PCDD/PCDF levels in adipose tissue. This medium provides a reliable matrix for investigations regarding the degree of exposure to contaminants such a PCDDs/PCDFs (Noren 1993, Rappe 1992). Concentrations in breast milk also compare well to those in human blood (Papke 1999a,b, 1998); however, Schecter *et al.* (1991b) found that levels of PCDDs/PCDFs (including T-TEQs) are somewhat higher in blood compared to milk.

In general, PCDDs/PCDFs in human breast milk are higher in industrialized countries (Schecter *et al.* 1996, Schecter *et al*. 1989d), when compared to developing regions of the world. Human breast milk contaminated with PCDDs/PCDFs, essentially reflects levels of local contamination, rather than toxins that may have been associated with atmospheric transport (Schecter *et al.* 1989d).

Little is known about the multi-level integrational effects of long-term exposure to PCDDs/PCDFs (Jensen *et al.* 1997). Consequently, it is important to initiate programs in areas like the isolated Aluoi Valley where, over the past 34 years, the local population has been exposed to PCDDs/PCDFs (principally TCDD from Agent Orange).

b) Aluoi Valley

Table 2.10 provides a summary of primaparous females (first child, single birth) and one multiparous female (multiple children) selected for PCDD/PCDF analyses on individual breast milk samples. Table 2.11 summarizes PCDD/PCDF data for the lactating females presented in Table 2.10; the single multiparous female, presented in Table 2.12, was selected to compare contaminant levels in an older individual; in addition, this female's latest child (the one being breast fed at the time of sampling) was diagnosed with spina bifida. TCDD and T-TEQ data are presented in Figures 2.18 and 2.19.

Breast milk from the A So commune had the highest TCDD levels (19 pg/g; T-TEQ=21.9 pg/g) (Table 2.11). When considering TCDD contribution to T-TEQ in A So, the values range from 85.1% to 96.3%, a further indication (as noted for soils, food and human blood data) that Agent Orange was the principle source of contamination.

Mean TCDD level from each commune was highest in A So (14.6 pg/g); the Hong Van mean was the lowest (3.0 pg/g). The lowest levels of TCDD (and T-TEQ) were recorded in the reference area, Hong Van, where Agent Orange use was less relative to A So.

TCDD levels in breast milk were tested for statistical differences. It was found that differences did exist among the four communes ($F[3,12] = 7.31$, $p=0.005$). The following tabulation clarifies the comparative differences between TCDD levels and commune location (Student-Newman-Keuls test; Hicks 1973).

Comparison	Observed Difference	Level of Significance
A So vs. Hong Van	11.65	p<0.01
A So vs. Huong Lam	7.375	Not Significant
A So vs. Hong Thuong	5.025	Not Significant
Hong Thuong vs. Hong Van	6.625	p<0.05
Hong Thuong vs. Huong Lam	2.350	Not Significant
Huong Lam vs. Hong Van	4.275	p<0.05

Although A So had the highest TCDD levels in breast milk, this commune was not statistically different from levels recorded at Huong Lam and Hong Thuong; Hong Thuong was not different from Huong Lam. Hong Van, the reference commune, was statistically lower in TCDD milk levels than values recorded in the other three communes. These data imply that areas not necessarily exhibiting very high levels of TCDD contamination, may still result in elevated milk levels. This phenomenon probably results from the process of bioaccumulation and, more specifically, biomagnification.

It has been presented above (Section "a) General") that the process of breast feeding serves as a mechanism for the elimination of contaminants from a lactating female. Papke (1998), Vartiainen *et al.* (1998) and Furst *et al.* (1992) state that as the number of children from a given female increases, the level of PCDDs/PCDFs in breast milk will decline. These authors, including Dahl *et al.* (1995), also indicate that the body burden of PCDDs/PCDFs in mothers will decrease with an increasing length of time devoted to breast feeding.

In the instance of the Aluoi Valley data, the single multiparous female (A So commune, Table 2.12), from which breast milk was tested, had a TCDD level of 32 pg/g (approximately two years subsequent to initiation of breast feeding). The relationship of decreasing contaminant concentration with an increasing number of children, and increasing period of nursing, would appear to be most logical and applicable if the mother was not exposed, on a regular basis, to contaminated foodstuffs.

If the relationships discussed above are in fact real, then one can only speculate on what the TCDD level was in this female 20 years ago, prior to the birth of the first of her ten children; in addition, what was the TCDD concentration in milk from this female prior to initiation of two years of breast feeding for her most recent child (the point when her milk sample was collected by the HCL/10-80 team)?

Age is definitely a factor, simply because a greater length of exposure time to contaminants has occurred; however, given only the relationships described above (i.e., applying only the variables of number of children and duration of breast feeding), it would appear that the multiparous female may have had a higher TCDD level two years ago, and a significantly higher level 20 years ago; alternatively, an equilibrium has been established where elimination through breast feeding is "compensated" for by the regular ingestion of foods contaminated with TCDD, or the decline in contaminant level is "slowed" due to contaminant replacement. It is probable that a combination of the above scenarios have been (are) in effect.

Papke (1998) estimated that the average Total TEQ decrease in breast milk per week of nursing is approximately 0.1 pg/g. On this basis, prior to initiating approximately two years of breast feeding, this multiparous female could have had (by a back calculation) a T-TEQ in her milk of approximately 44.5 pg/g (or 41.7 pg/g TCDD, based on a 93.8% TCDD of T-TEQ; Table 2.12), with no replacement through ingestion of contaminated foods. How this back calculated approach may apply to her other children and the time frame of the past 20 years is speculative. Theoretically, if she breast fed ten children for two years each, 20 years ago her milk could have had a T-TEQ level of approximately 138 pg/g (or 129 pg/g TCDD) by a back calculation and no replacement. Given the A So area is contaminated with TCDD, it is probable that this mother has been ingesting foods contaminated with TCDD for an extended period of time, and probably has been replacing, to some degree, contaminants eliminated through breast feeding. Exactly what the relative contribution to the overall toxicity level of her milk due to PCDD/PCDF contamination, based on historical contaminant levels, and those levels being contributed to by replacement and the regular ingestion of contaminated foods, is difficult to ascertain. In general, however, it would appear that certain females in Aluoi Valley may possess (or have possessed) very high TCDD body burden levels, with these levels being passed on to many infants in a commune through non-familial, multi-infant nursing.

The apparent relationship between commune location and level of TCDD contamination in the Aluoi Valley, exemplified by levels in soils, foods and human blood, is again corroborated by elevated TCDD levels in human breast milk. The general data trend tends to link the A So commune and its proximity to the abandoned US Special Forces base, to higher overall levels of TCDD contamination.

The potential for deformed and/or sick mothers not being able to attend the breast milk clinic may also be a factor. Given their reduced mobility, the severely handicapped females (as noted above in the human blood section) were not part of the investigation. Consequently, TCDD levels in human breast milk in the valley may also be considered conservative.

c) Aluoi Valley and Other Studies

In order to provide a frame of reference regarding PCDD/PCDF concentrations in breast milk of Aluoi Valley mothers comparisons have been made with other studies (Table 2.13). These studies are a small proportion of those undertaken on the subject of PCDDs/PCDFs in human breast milk. IARC (1997) and Jensen and Slorach (1991) provide comprehensive summaries on the topic.

No attempt was made to detail the analytical techniques and laboratory equipment used to generate the various PCDD/PCDF data reported in these other investigation; protocols were probably variable throughout the decade these data were generated. Comparisons are included herein to provide the reader with some sense of relative concentrations of TCDD in breast milk in Viet Nam and industrialized countries.

TCDD and T-TEQ values are presented graphically in Figure 2.20 in relation to the Aluoi Valley data. Viet Nam in general, and the Aluoi Valley in particular, had the highest TCDD levels when compared to a sampling of data from industrialized countries (Figure 2.20). The single data point that stands out was recorded by Hooper *et al.* (1998). It was suspected that Russian-produced 2,4,5-T, contaminated with TCDD, was applied to cotton growing areas of Kazakhstan. The high breast milk TCDD level, relative to the T-TEQ is comparable to those in the Aluoi Valley.

Other Viet Nam investigations did not appear to show the high TCDD percentage in T-TEQ as recorded by Hooper *et al.* (1998) and the HCL/10-80 team. Virtually no industrial exposure occurs in the Aluoi Valley as a result of its isolation; this fact, in conjunction with a limited variety of foodstuffs, probably resulted in the high TCDD proportion of T-TEQ in the valley.

As noted for human blood, the P5CDD:TCDD ratio in breast milk provides an indication of sample origin, given that ratios of approximately 2-3 are "typical" of industrialized countries (Hooper *et al*. 1998, IARC 1997).

Tables 2.11 and 2.13 and Figure 2.21 summarize P5CDD:TCDD ratios for breast milk. The Viet Nam ratios in general, and Aluoi Valley data in particular, exhibited P5CDD:TCDD ratios that were less than those calculated for the non-Viet Nam studies. Those with higher ratios are indicative of a higher degree of industrialization, whereas in the isolated Aluoi Valley, five of the 16 ratios could not be calculated, given the below detection values for P5CDD. Note the low ratio for the Kazakhstan data where 2,4,5-T use was suspected (i.e., 2,4,5-T contaminated with TCDD).

In order to further clarify differences regarding PCCD/PCDF levels in the milk sample (Tables 2.11 and 2.13), a congener profile was developed. Figure 2.22 provides a graphic representation of the congener profile of each data point. The percent contribution of each congener group to the T-TEQ of the sample is summarized.

The distribution pattern of the PCDD/PCDF congeners in the Aluoi Valley milk samples confirms the involvement of Agent Orange as the source of contamination in these samples, given the high proportion of TCDD presence, particularly at A So. As one progresses north from A So to Hong Van, the patterns change slightly with other congeners appearing; however, the differences between the non-Viet Nam studies and the 1999 HCL/10-80 data are clear.

Other Viet Nam investigations show less TCDD participation in the profiles relative to Aluoi Valley samples, but generally more TCDD relative to the non-Viet Nam samples. The one exception, again, occurs in the Kazakhstan data where TCDD comprised approximately 80% of the T-TEQ, similar to Aluoi Valley samples; the comparability is related to the use of 2,4,5-T in Kazakhstan and the use of Agent Orange in the Aluoi Valley.

IARC (1997) provides a comprehensive summary of numerous investigations where concentrations of TCDD were reported in human breast milk (pg/g, lipid basis). The IARC (1997) summary shows that of the 125 TCDD data points collected from industrialized countries (i.e., non-Viet Nam studies) the mean concentration of TCDD was 3.17 pg/g, with a mean percent TCDD contribution to the T-TEQ of 17.2%. A minimum of 0.3 pg/g TCDD and a maximum of 13.6 pg/g TCDD was reported; percent TCDD of T-TEQ ranged from 3.8% to 67.7%; the highest levels of TCDD (13.6 pg/g) and T-TEQ (67.7%) were from data provided by Petreas *et al.* (1996, *cited in* IARC 1997) regarding studies in Kazakhstan (suggestive of a 2,4,5-T connection, as noted by Hooper *et al.* 1998).

d) Average Daily Intake of PCDDs/PCDFs

In Canada, a TDI (Tolerable Daily Intake) of 10 pg TEQ/kg bw/d is recognized for the protection of human health. The most recent recommendation of the World Health Organization (WHO) is that the TDI be reduced to a maximum of 4 pg TEQ/kg bw/d, with efforts being made immediately to reduce the level to a maximum of 1 pg TEQ/kg bw/d for the protection of human health.

Tables 2.14 and 2.15 review TCDD levels in the Aluoi Valley breast milk samples; in addition, calculations are presented which are representative of the average daily intake of TCDD and Total PCDDs/PCDFs (expressed as T-TEQ). These calculations are presented based on the actual percent lipid determined in the respective milk sample, and a lipid value of 3.5%.

In order to calculate the average daily intake, the WHO (WHO/EURO 1989) has recommended a constant set of parameters be applied to the calculation; these include milk consumption by the infant at 700 mg/d (700 ml/d), infant weight of 5 kg and a percent milk fat of 3.5%. These constants were applied to the Aluoi Valley data as presented in Tables 2.14 and 2.15, and summarized in Figure 2.23.

In terms of the 10 pg TEQ/kg bw/d (TDI employed in Canada), and utilizing the WHO constants, all individual intake values and the mean (of the four individual tests) exceeded the 10 pg TEQ/kg bw/d TDI.

Milk from A So female No. 2 yielded 107.3 pg TEQ/kg bw/d. Hong Thuong had two females whose milk T-TEQ exceeded 80 pg TEQ/kg bw/d (Table 2.14). On a mean basis (mean of four individual milk samples), A So exhibited the highest average intake based on the WHO recommended approach (80.3 pg TEQ/kg bw/d). The reference area, Hong Van, had the lowest intake figure, but remained well above the 10 pg TEQ/kg bw/d TDI.

When applying the recently recommended WHO TDI value (4 pg TEQ/kg bw/d), all data exceed this criterion. A maximum of a 27-fold increase was recorded for female No. 2 in A So.

The multiparous female (Table 2.15) exceeded the Canadian TDI (10 pg TEQ/kg bw/d) by a factor of approximately 17 (167.1 pg TEQ/kg bw/d), and the recommended WHO TDI (4 pg TEQ/kg bw/d) by a factor of 42. Given that it is common practice for a mother to breast feed other children in a commune, there is a high probability that older multiparous females are passing on relatively high concentrations of PCDDs/PCDFs to other infants in the commune whom are not of their immediate family.

Breast feeding has been recognized as being beneficial to infants (Hooper *et al.* 1998, Huisman *et al.* 1995b, Jensen and Slorach 1991, WHO/EURO 1988); some of these benefits include the passage of immunological factors to the infant, creating a bonding between mother and infant, reducing the risk of allergic reactions, providing virtually all the nutrition necessary during earlier months, and serving as a contraceptive.

The Aluoi Valley, in general, supports a population whose PCDD/PCDF levels in breast milk exceed guideline levels in Canada and those recommended by the WHO. It is accepted that these compounds can be regarded as a potential health risk to breast-fed infants (Jensen 1987).

The food chain in the Aluoi Valley is probably the principle mechanism for the introduction of these contaminants into breast milk; therefore, food habits of mothers in the valley will, for the most part, determine the level of contamination in their milk which is ultimately passed to their infants.

Information on the benefits of breast feeding has resulted in recommendations by numerous researchers that breast feeding continues, given that the benefits appear to outweigh the health risks, at least at this point in time (Patandin 1999b *et al.*, Schade and Heinzow 1998, Lutter *et al.* 1998, Wise 1997, Albers *et al.* 1996, Rogan 1996, 1991, Huismann *et al*. 1995b, Tarkowski and Yrjanheikki 1989). Notably, the added caution accompanying the above recommended continuation of breast feeding is that concerted efforts should be made to reduce exposure to toxic chemicals to further reduce potential health risks; these efforts should include controlling the source(s) of such contaminants (Brouwer *et al.* 1998, Abraham *et al. 1996, Schuhmacher et al.* 1999, Somogyi and Beck 1993).

Economic and cultural conditions in the Aluoi Valley, are not conducive to recommending cessation of breast feeding, particularly since it constitutes an important source of nutrition for infants; however, given that the source of significant PCDD/PCDF (specifically TCDD) contamination, which feeds into the human food chain, has been identified, reducing exposure would appear to be the most favourable/logical avenue to facilitate a reduction in contaminant body burdens in both adults and infants in the valley. A reduction of exposure by humans to TCDD involves either completely eradicating the source, or reducing human contact with contaminated media. In order to address this objective, an impact mitigation plan, based on present PCDD/PCDF contamination levels in the valley, is outlined in Section 4.0.

e) Pesticides/PCBs

Concerns regarding pesticides in human milk have been present since at least 1951, when Lang *et al.* (1951, *cited in* Rogan *et al.* 1991) detected DDT in breast milk. DDT and its metabolites (DDD and DDE) enter the human body primarily through ingestion of contaminated foods. Small amounts may also be taken in through breathing. These compounds are readily stored in fat tissues and, therefore, can be eliminated by mothers during breast feeding.

In terms of toxic effects, DDT, DDD and DDE have been studied in experimental animals where effects are seen in the nervous system, reproductive system, and liver (ATSDR 1994). ATSDR reports that eating food with high concentrations of DDT primarily affects the nervous system; once exposure was removed, symptoms disappeared. ATSDR (1994) also reports that humans given small doses of DDT for 18 months exhibited no toxic effects. In general, ATSDR indicates that DDT has not caused any known permanent harmful effects in humans; however, ATSDR also indicates that DDT is a "probable" human carcinogen with some estrogen mimicking properties (Soto *et al.* 1992, *cited in* Jensen and Shearer 1997).

In the Aluoi Valley, four composites of ten individual breast milk samples were analyzed for pesticides and PCBs. Given that DDT is still used in developing countries for reduction of such diseases as malaria and dengue fever (Schecter *et al.* 1989b), the HCL/10-80 team considered it prudent to obtain some information on relative concentrations of these chemicals.

Malaria and other insect-borne diseases are a significant health problem in the Aluoi Valley. As a consequence, DDT appears to be used to counter these potential illnesses. Other pesticides such as hexachlorobenzene, beta-HCH, mirex and dieldrin were detected, but at very low concentrations.

The highest DDT level recorded was p,p'-DDE at 8,900 ng/g (lipid basis; or 8,900 ppb or 8.9 ppm at A So; Table 2.17). Hooper *et al.* (1997) and Jensen and Slorach (1991) indicate that a p,p'-DDE/p,p'-DDT ratio of <1 to approximately 5 suggests recent exposure to the parent DDT compound, whereas a ratio >5 suggests residues arising from the food chain over an extended period of time. For example, DDT was banned from the United States in 1972 (Arbuckle and Sever 1998, Rogan 1996); Jensen and Slorach (1991) report the following ratios in breast milk from the United States:

Year	p,p'-DDE/p,p'-DDT
1960-61	0.6
1971-72	2.6
1973-75	4.8
1970-80	10.0

With the phasing out of DDT, the ratios calculated in the United States increased from 0.6 to 10.0, which effectively confirms that DDT was decreasing in the environment, thus effecting an increasing ratio when compared to its metabolite DDE.

In the Aluoi Valley, the p,p'-DDE/p,p'-DDT ratios in breast milk are below and slightly above 5. Therefore, recent exposure to DDT has occurred, which is not unexpected given its continued use in the valley for malaria prevention. Although economic conditions in the valley limit the purchase of pesticides, a certain amount is being utilized in order to curb diseases such as malaria. The straddling of the 5 ratio (below and above; Table 2.17) would also indicate that food chain elements are also involved in the realization of observed ratios (i.e., DDE was present from historical use of DDT).

Schecter *et al.* (1989b) report pesticide levels from Viet Nam; DDE and DDT levels from three areas in southern Viet Nam totaled 10,500 ng/g (lipid basis), 12,130 ng/g and 11,400 ng/g. The beta-HCH from these same areas was 22 ng/g, 34 ng/g, and 221 ng/g; dieldrin was 4 ng/g, a non-detect was registered, and 4 ng/g. The total DDT and metabolite levels in Aluoi Valley breast milk were comparable to, or less than, those noted in southern regions of Viet Nam. Other reported pesticides in southern Viet Nam were recorded at a greater concentration relative to Aluoi Valley (e.g., hexachlorobenzene, maximum 10 ng/g; oxy-chlordane 3 ng/g; Schecter *et al.* 1989b).

A So had the highest total DDT/DDD/DDE concentration of the four communes sampled. The age of the mothers that were used to provide a composite sample for analyses (n=10) varied. The mean age of A So participants was higher than at other communes (Table 2.17); however, the average ages are not markedly different (range of means 17.4 - 24.6 years). The most noticeable difference is the presence of a 50-year old woman in the A So composite. This female, who was nearly double the oldest individual from other communes, may have had a higher body burden which skewed the DDT (and metabolite) values. The extra 25 years of life probably resulted in a greater degree of pesticide loading, thereby affecting the overall composite concentration.

Jensen and Slorach (1991) present a comprehensive review of pesticide levels in breast milk reported in the literature. Values in the Aluoi Valley are, in many cases, lower than those reported by Jensen and Slorach (1991) (but higher in some cases). For p,p'-DDE, Jensen and Slorach (1991) report some very high maximum values that were observed throughout Europe, the Americas, Australia, Africa and Asia; some of these values (lipid basis) occurred in Czechoslovakia (14,800 ng/g, 17, 600 ng/g), Germany (13,700 ng/g), Greece (21,800 ng/g), Italy (10,000 ng/g), Poland (18,800 ng/g), Spain (26,400 ng/g), Turkey (25,500 ng/g), USA (Mississippi, 74,000 ng/g), Mexico (30,000 ng/g), China (26,000 ng/g), India (17,000 ng/g), and Kenya (32,900 ng/g). With the gradual phasing out of DDT in many countries throughout the world, levels in breast milk from these and other regions have probably declined over the years. Given that some of the above data points were reported during the late 60's, 70's and 80's, breast milk levels have undoubtedly declined.

Health Canada (1996) and Hooper *et al.* (1997) report the tolerable daily intake (TDI) for DDT and its metabolites at 20 µg/kg bw/d; other TDI levels for pesticides and PCB are presented in Jensen *et al.* (1997) and Health Canada (1996).

Table 2.18 summarizes the average daily intake of pesticides and PCB by infants in the Aluoi Valley through breast milk, and TDI values of chemicals detected in breast milk samples. The total DDT (plus metabolites) in composite breast milk from A So and Hong Van exceeded the TDI of 20 µg/kg bw/d by factors of 2.6 and 1.8, respectively. Given conclusions of the ATSDR (1994) regarding potential effects of DDT and metabolites on humans, the levels observed in breast milk from the Aluoi Valley are not expected to raise significant public health issues; levels of TCDD in breast milk pose a greater level of health concern.

f) Summary

Aluoi Valley had some of the highest TCDD values recorded, relative to breast milk contamination summarized from other investigations. The congener profiles of Aluoi Valley data provide additional evidence that Agent Orange was responsible for levels observed in the valley.

When comparing the tolerable daily intake (TDI) levels recognized in Canada and recommended by the WHO, with the average daily intake of infants in the Aluoi Valley, all samples exceeded the Canadian and WHO thresholds.

Despite potential health risks to infants through exposure to dioxins, the WHO and others recommend the continuation of breast feeding, as the benefits appear to outweigh the risks; however, attempts must be made to reduce exposure and/or minimize/reduce the source(s) of contaminant intake.

Some pesticides and PCBs were identified in breast milk samples from the Aluoi Valley. When compared to the TDIs of these respective chemicals, only DDT/DDD/DDE at A So and Hong Van exceeded the TDI. These exceedences are not considered significant; elevated TCDD levels in the valley are believed to pose a greater health risk.

2.4 CONCLUDING DISCUSSION

Thirty-four years have elapsed since Agent Orange was introduced to the isolated Aluoi Valley, and the indigenous mountain tribes inhabiting the region. Aerial applications throughout the valley, in conjunction with other forms of administering/handling the herbicide near former US Special Forces bases, have resulted in a state of chemical contamination that is affecting the valley to the present day.

The level of 2,3,7,8-T4CDD contamination (TCDD; a component of the 2,4,5-T portion of the Agent Orange mixture) is variable throughout the valley with highest levels being determined near the former A So Special Forces base. The exact extent of contaminated soils near the base (in terms of geographic distribution) has not been fully defined. Information on the A So base during its three-year existence, prior to being abandoned in March 1966, would greatly assist in developing a more precise grid to delineate the zone of contamination. Such a delineation could prove significant in reducing human exposure and ultimately reducing the level of contamination moving up the food chain. It has not been possible, to date, to obtain detailed layout and operations information regarding the A So base – efforts will continue.

Given that the people of the Aluoi Valley effectively live off the land through basic agrarian practices, it is not unexpected that the persistent TCDD contaminant in Agent Orange has been detected in local foods and up the food chain to humans (blood and breast milk), including people born after herbicide spraying and hostilities ceased.

An overview of TCDD contamination throughout the Aluoi Valley is presented in Figure 2.24. For this "snap-shot", the highest TCDD values for each of the principle test media are summarized (i.e., soils, food [animal], human blood [sex/age basis], and human breast milk), employing circle areas that are proportional to recorded TCDD levels.

It is clear that in the region of Aluoi Valley where use/handling of Agent Orange was probably high (A So), the levels of TCDD in the test media were similarly high relative to other communes (notably Hong Van, where Agent Orange applications were lower).

Low levels of TCDD contamination in soils and foods throughout the Aluoi Valley (Figures 2.6, 2.9 and 2.24), apart from the high concentrations recorded at A So, do not necessarily suggest that humans inhabiting areas of lower contamination will, by virtue of commune location, reflect similarly low TCDD levels (e.g., in blood and breast milk). The process of TCDD bioaccumulation enables low or non-detectable environmental concentrations (i.e., in soils and foods) of this compound to be absorbed into the human body. Through the bioaccumulation of low/non-detect quantities of TCDD over extended periods of time, the additive process of the human body accumulating minute quantities of the contaminant eventually culminates in a condition where many low/non-detect loading events result in elevated levels of the compound; overall, this process is the result of "magnifying " the once "low/non-detect" concentrations to a state of "elevation" (i.e., biomagnification).

These processes of bioaccumulation and biomagnification are in effect in the Aluoi Valley. The TCDD levels in human blood and breast milk (Figures 2.10 and 2.18) do not vary throughout the valley to the same extent as TCDD concentrations in soils and foods. These data are probably indicative of the continual association with, and ingestion of, soils and food, containing analytically non-detectable or low levels of the contaminant, which are being ultimately expressed, over time, in the detectable/elevated range.

Many of the TCDD/T-TEQ values for soils and food items in the Aluoi Valley, if recorded in western jurisdictions, would precipitate action regarding risk assessment/risk management for the protection of human health. Contaminant levels in human blood and breast milk from the Aluoi Valley are more similar to those reported in industrialized countries, rather than from an area like the isolated Aluoi Valley which is far removed from the influences of dense human inhabitation, industries in urban areas, and more advanced agricultural practices which occur farther south in Viet Nam.

Other former military installations in southern Viet Nam also have a high probability of being contaminated with Agent Orange TCDD. The microcosm of the Aluoi Valley may serve as a design template for contaminant assessments throughout southern Viet Nam, thus assisting in the progression towards alleviating human health risks near highly contaminated "hot spots" in southern Viet Nam.

HCL/10-80 (1998) postulated that hot spots/dioxin reservoirs could be present near former US and south Vietnamese military installations throughout southern Viet Nam. A 7,500 US gallon Agent Orange spill incident at the Bien Hoa airbase (March 1, 1970) was described in Section 2.3.3.4 (sub-section c)) of this report, and in the HCL/10-80 (1998) document.

Paustenbach *et al.* (1992) has reported that the top 0.1 cm of soil-bound TCDD is subject to photodegredation. Subsurface soils are suspected to have a TCDD half-life of 25-100 years, and surface soils 9-15 years. Such half-life durations foster the presence of dioxin reservoirs in highly contaminated areas for many years into the future.

Speculation that potential dioxin reservoirs, as proposed by HCL/10-80, may be a real phenomenon near former US and southern Vietnamese military facilities (where Agent Orange was dispensed and/or stored), lead "Red Cross Viet Nam" to host the testing of human blood from Bien Hoa (March/June 1999; Dai 2000). Drs. Le Cau Dai and A. Schecter collected human blood from residents living in close proximity to the Bien Hoa base where large quantities of Agent Orange were stored during the war. Samples of human blood were analyzed in Hamburg, Germany in the laboratory of Dr. O. Papke.

Results of these analyses indicate TCDD levels (lipid basis) in the blood of residents near Bien Hung Lake (near the former base) are very high (A. Schecter, *in preparation*). A wide range of TCDD levels were recorded near Bein Hung Lake. These recent data show that within the same region of sampling, a wide variation in TCDD levels can occur. Consequently, levels recorded in the Aluoi Valley could be considered conservative, given the level of variability that probably also occurs in the valley.

Dai (2000) also presents information on cancer rates and congenital malformation rates in the city of Bien Hoa (1993/1994). Twenty-three districts in the city were studied; results suggest that the district in closest proximity to the base had the highest rates of cancer and congenital malformations. Dai (2000) also reports that certain districts, although at greater distance from the base, also had elevated cancer and malformation rates; Dai (2000, and *pers. comm.*) indicates, however, that these districts lie on the flight path of the base airstrip. C-123 pilots would often flush their on-board herbicide tanks prior to landing; in addition Cecil (1986) reports that jettisons of a complete Agent Orange load (approximately 1,000 US gallons) occurred at Bien Hoa shortly following take off if aircraft had mechanical or other problems.

The involvement of Agent Orange in contributing to TCDD levels in human blood near the Bien Hoa base is certain. In addition, these data strengthen the HCL/10-80 speculation that other former US and south Vietnamese military installations throughout southern Viet Nam could serve as dioxin (TCDD) reservoirs; TCDD, in these yet to be determined areas, could be sources of contamination of the food chain, and ultimately local human inhabitants.

3.0 PRELIMINARY REPORT OF THE ALUOI VALLEY HEALTH AND NUTRITION SURVEYS

(Section 3.0 was prepared by Drs. C. van Netten and R. Brands, University of British Columbia, Department of Health Care and Epidemiology, Division of Occupational and Environmental Health, Vancouver BC Canada)

3.1 INTRODUCTION

Environmental sampling for dioxins by Hatfield over recent years has indicated elevated levels of this contaminant in the soil (HCL/10-80 1998). These soil dioxins have since been traced to the use of Agent Orange as a defoliant by the US military during the Viet Nam war. The extent of soil contamination has since been narrowed down to a number of communes in the Aluoi Valley, and in some instances, specifically to areas that coincide with former locations of bases that were in use during the war.

The controversy regarding the impact on health of populations exposed to dioxins has not been clearly resolved for a number of reasons (Booth 1987).

Often, exposure is relatively short-term, such as with US Viet Nam veterans who may have been exposed for a couple of years or less. Others have been exposed during industrial accidents and have experienced acute symptoms. In some environmental settings, dioxins appear to be closely bound to soil particles, such as bentonite, which reduces its bioavailablity (Anon 1985). The known, and potential, health effects from dioxin exposure are numerous and have been addressed and reviewed by various reports (HCL/10-80 1998 and herein).

One of the areas of concern for the Vietnamese government has been the possibility of exposed populations having a higher than expected prevalence of birth defects. This is evidenced by the number of abnormal fetuses which have been recorded over the years. The problems that one faces, in order to make a connection between past/present dioxin exposure and the prevalence of birth defects, are numerous and need to be carefully addressed before such a relationship can be demonstrated or rejected (Booth 1987).

Although dioxins are found in the soils of the Aluoi Valley, one needs to establish exposure of the population and the extent of such exposure. This has now been clearly established, as indicated by the elevated blood and mother's milk dioxin levels that have been measured in the Aluoi Valley communes (HCL/10-80 1998 and herein). These findings indicated food chain transfer as well as bioaccumulation.

In order to obtain a more accurate picture of this food chain transfer, most of the different trophic levels have now been sampled and analyzed for dioxins. It was found (HCL/10-80 1998 and herein) that locally grown fish and ducks in areas with elevated dioxin levels had the highest levels of dioxin associated with their fatty tissues.

Since exposure of the population has now been clearly demonstrated, the question whether these dioxins are associated with the prevalence of birth defects can now be addressed.

When preliminary environmental data became available showing that dioxin levels corresponded closely to the historical records, regarding the frequency of spraying of Agent Orange, it was suggested to the 10-80 Committee at a meeting in Hue on March 3 and 4, 1999 that, based on these records, some communes were likely to be more highly exposed than others. Four communes were therefore selected for a cross-sectional study, with the intend of being able to demonstrate, or reject, a dose-response relationship between dioxin exposure and prevalence of birth defects.

In order to perform an appropriate epidemiological cross-sectional study, one has to be able to control for a number of confounding factors that may be present in the Aluoi Valley, and which independently could affect the prevalence of birth defects. One of the confounding factors that was likely to be present in the past is malnutrition (Stein *et al.* 1975). Malnutrition is well known to be associated with birth defects, specifically the lack of vitamin intake during the first trimester which has been linked to heart defects, limb deficiencies and, neural tube defects (Shaw *et al.* 1995). For this reason, it was important to conduct a nutrition and food survey to assess if there are current nutritional factors which need to be controlled. In addition, one needs to establish if there is a significant variation of these factors between the four communes of interest. Other variables to be considered include the quality of drinking water and the use of pesticides. Pesticide use is perhaps more important in the Aluoi Valley population, compared to any North American setting, because of the lack of personal hygiene facilities such as washrooms, bathrooms, running water, etc., and proper storage facilities for those chemicals. It was also observed that information on the pesticide containers was not always in a language that was understood by the local population.

3.2 METHODS

3.2.1 Environmental Sampling

Based on historical data, regarding frequency and total amount of Agent Orange sprayed on the various regions in the Aluoi Valley, four communes were selected for further investigation. In addition to the environmental sampling from different trophic levels that was conducted by Hatfield, a number of water samples and cooking oil samples were collected. Water samples were obtained from the local wells, river, and in one instance, a rice paddy. Water samples were transported to Canada and analyzed by Inductively Coupled Plasma (ICP) methodology for elemental content (Al, Sb, As, Ba, Bi, B, Cd, Cr, Co, Cu, Pb, Li, Mg, Mn, Hg, Mo, Ni, K, Se, Sr, Tl, Sn, U, V, Zn) by ASL in Vancouver, BC. Cooking oil samples were purchased from the local market, transported to the University of British Columbia (UBC), and analyzed for semi-volatile constituents using gas chromatography mass spectral (GC/MS) analysis in the laboratory of the School of Occupational and Environmental Hygiene. A composite of these three oil samples was analyzed by Hatfield for dioxins, dibenzo-furans, polychlorinated biphenyls (PCBs), and pesticide content.

Information was also obtained from the Mr. Tuanh Huy Son, Deputy of Department of Agricultural and Rural Development of Aluoi District (June 1999), regarding the current and past use of pesticides in the Aluoi District.

3.2.2 Nutrition and Exposure Surveys

A food and nutrition questionnaire was constructed by the UBC and Hatfield team, in collaboration with Drs. Hung and Dung (members of the 10-80 Committee) who translated questions into Vietnamese which was shown next to the English version on the same questionnaire. The four communes were visited by the UBC team, the Hatfield team, and members of the 10-80 Committee over the period of June 7-19, 1999. The food and nutrition questionnaire was administered by members of the 10-80 Committee at the time that the Hatfield team was collecting blood and milk samples for the exposure survey. All participants were volunteers from the local population who were provided with a payment of 15,000 Dong ($1 US is equivalent to 13,500 Dong) in order to cover their costs and efforts. In some communes, it was necessary to solicit the help of a local person capable of translating the Vietnamese questionnaire into one of the local dialects. The questionnaires were collected and taken to UBC for data entry and preliminary analysis. The blood and milk samples were collected by the Hatfield team and taken to Canada for analysis.

3.2.3 Health Survey

A birth defect survey was conducted by Drs. Hung and Dung who constructed a questionnaire and trained ten Vietnamese health professionals (four medical doctors with six years of medical school background), and four para-doctors (with four years of medical school background) to administer questionnaires in a consistent fashion in the various communes of interest. All ten trained individuals would arrive at one of the four communes and ensure that all members of the commune were interviewed.

This procedure took two-three days depending on the commune.

Birth dates were checked against the registration book that each commune resident has in his/her possession. The filled-out questionnaires were collected by members of the 10-80 Committee; the information was translated and transcribed onto a computer database and forwarded to the University of BC team for further analysis.

3.3 Preliminary Results (Descriptive Statistics)

3.3.1 Selection of Communes of Interest

Based on the Agent Orange spraying frequency that was available from war records available and data from Hatfield (HCL/10-80 1998), four communes were selected from the Aluoi Valley to provide the widest possible range of anticipated human dioxin exposure. The A So and Huong

Lam communes, both located in the southern portion of the valley, were selected because they were anticipated to have high dioxin exposure. The Hong Thuong and Hong Van communes, located in the center and northern region of the valley were also selected because they were anticipated to represent medium and low dioxin exposure, respectively.

3.3.2 Environmental Sampling

A total of 11 water samples were collected in the Aluoi Valley, eight of these samples were obtained from surface wells which had generally a depths of 2-4 meters at the time of sampling. All wells were concrete-lined and constructed around 1980. In addition to the well water samples, two river (A Sap River) water samples, and one rice paddy water sample were obtained. The results from a multi-elemental analysis of these water samples have been summarized in Table 3.1.

None of the elements tested for exceed the Canadian Drinking Water health guidelines. Manganese exceeded the esthetics guideline of 0.05 milligrams per liter (HWC 1989).

Only three different cooking oil samples were available from the local market.

- **Sample # 1,** "Golden Carp" vegetable cooking oil SDK:63/98 which was manufactured in Viet Nam by Cai Lam Oils and Fats Industries Ltd., Cai Lan Port, Ha Long City.

- **Sample #2**, "Nakydaco Cooking Oil, vegetable oil all natural and cholesterol free". Produced by Tan Binh Vegetable Oil Factory.

- **Sample #3**, "Tuongan Cholesterol free, a mixture of refined edible oils for: frying, making cakes, vegetarians, protect(sic) you against malnutrition". This oil was manufactured by "Tuong an vegetable oil factory" Ho Chi Minh City. The result of a GC/Mass Spec analysis for semi-volatiles indicate only a few major components. It should be pointed out that the compounds identified by Chemical abstract service (Cas) registry number using GC/Mass Spec are the closest fit to the actual spectrum of that compound in the Mass Spec library. A fit of 1,000 is a perfect match. When the match is not perfect, there is a possibility that another compound could be present instead. The degree of this uncertainty is reflected by the value of the fit.

Sample #1, contained:

- 9,12-Octadecadienoic acid Cas# 60-33-3 fit 769;
- Cholest-5-en-24-one, derivative Cas# 20981-59-3 fit 833;
- Cholest-5-ene, 3-bromo, (-3-beta) Cas# 516-91-6 fit 890;
- Methanone, derivative Cas# 52806-36-7 fit 896; and
- 8,11,14,-Docosatrionic acid, methyl ester Cas # 56847-02-0 fit 716.

Sample #2 contained:

- Butylated hydroxy toluene Cas# 128-37-0 fit 986;
- 9,12-Octadecadienoic acid,methyl ester Cas# 112-63-0 fit 941;
- Ergos-5-en-3-ol 3-beta Cas# 4651-51-8 fit 961;
- Campesterol Cas# 474-62-4 fit 932; and
- Gamma-Sitesterol Cas # 83-47-6 fit 975.

Sample #3 contained:

- cyclo hexadiene,1-4 dione, derivativeCas# 3602-55-9 fit 914;
- Butylated hydroxy toluene Cas# 128-37-0 fit 986;
- Ergos-5-en-3-ol 3-beta Cas# 4651-51- 8 fit 945; and
- Gamma-Sitesterol Cas # 83-47-6 fit 973.

3.3.3 Nutrition Survey

The descriptive statistics of the population that participated in this study have been summarized in Table 3.2. The results of the nutrition and food survey have been summarized in Tables 3.3 to 3.7.

Table 3.2 indicates that the average age of volunteers in Huong Lam was considerably younger than in the other communes. More females volunteered in A So than males. This trend was reversed in the other three communes.

It can be observed from Table 3.3 that all four communes were highly dependent on locally grown fruit and vegetables. Little was purchased and none was obtained from the wild.

A large part of the population was 100% to 75% dependent on locally cultured fish. The source of meat was not as localized and more appeared to be purchased.

Table 3.4 illustrates the different food items used by each commune. Duck consumption is quite low, followed by chicken and fish. It is apparent that fish is a major food source in most of the valley.

Similarly, pork appears to be an additional important source of meat. Goat meat is of lesser importance, and beef and buffalo even less.

The reliance on wild animals as a food source was most important in A So. This was also the case in all other communes, but to a lesser degree.

Table 3.5 provides an overview of the types of foods eaten during a typical week in June 1999. All communes were highly dependent on rice, chili peppers, fish, banana and sugar cane. Manioc was important during this week in A So, but not to the same extent in the other communes.

Table 3.6 provides an overview of the fish pond ownership in the four communes as well as an assessment of how this resource is utilized. A So and Huong Thuong communes had a high percentage of fish pond owners (76% and 74%, respectively), whereas the other two communes were in the 40% and 50% range. Fish appeared to be an important commodity for selling and trading.

Table 3.7 identifies the reported use of pesticides within the four communes. Hong Thuong appeared to be by far the major user of pesticides, followed by Hong Van, Huong Lam and A So, the latter reported the lowest use. It is also important to note that most individuals questioned did not know the name of the pesticide they were using.

A number of pesticides were found to be for sale at a local supplier including:

- **Sofit 300ND,** containing 300 grams per Liter of Pretilachlor and 100g/L Fenchlorin, Produced by Novartis from Nguy Hiem;
- **Olfatox 400EC** containing O,O, -Dimethyl-0,4-nitro-m-toyl phosphoratethioate 200g/kg, supplied by Dong Da, Hanoi; and
- **Vifosat 480DD,** produced by Vipesco and contained Glyphosate-isopropylamine.

Information obtained from the Agricultural and Rural Development Office of the Aluoi District, regarding the historical and present use of pesticides, has been summarized in Table 3.8 and shows past and current use. It appears that Fenobucarb (Vibam 5H) is the major pesticide currently in use. Pretilachlor was second in importance. It is important to note that DDT is still used for mosquito control in the valley. Of similar interest was the visit by Monsanto representatives in 1998 to the agricultural office of the Aluoi District with the purpose of promoting the use of the herbicide "Roundup".

3.3.4 Health Survey

The prevalence of birth defects in living individuals in the four communes of interest has been summarized in Table 3.9. A So had the highest percentage followed by Hong Van, Huong Lam, and Hong Thuong.

The results from the health survey regarding the pregnancy outcomes have been summarized in Figures 3.1-3.6. Figure 3.1 indicates an increase in spontaneous abortion in the four communes in the Aluoi valley collectively over the period between 1961-1971.

The number of pregnancies that ended in a child being born dead with a birth defect peaked around 1961-1965 for the same four communes has been summarized in Figure 3.2.

When the information is visualized for each commune separately (Figure 3.3), it can be observed that A So appeared to be associated with a larger percentage of total birth defects (birth defects in living offspring and birth defects in term death) after 1970, and some elevated levels were observed in Huong Lam prior to 1970.

The same trend was observed in Figure 3.4 which only examines live offspring with birth defects. The period starting in 1973 to present appears to correspond to the increases observed.

When A So is compared to the other three communes, the increases in total births with birth defects (Figure 3.5), and birth defects in live offspring (Figure 3.6) is even more clearly visible starting in 1971.

3.4 DISCUSSION

The participation of the population from each of the four communes was better than expected, as a target of 150 individuals was anticipated. The average age of the volunteers was also very similar except for the Huong Lam commune. This was not a reflection of the demographics of this commune, but rather what appeared to be the result of poor communication between the commune administrators and health officials.

The water analyses results were quite interesting in their relatively low values of elemental constituents. Lead concentrations in river and well water were often two orders of magnitude below what can be expected in Canada. The low lead concentrations observed in Aluoi Valley well water compared to Canadian water supplies could be a reflection of not only the lack of lead-based plumbing materials, but also a lack of industrial pollution. The exception was Hong Van, which had comparable levels. It was noted at the time of sampling in the rice paddy in this commune that there was a significant discolouration of rust in the water, which could be a reflection of the presence of war-related materials as a source of contaminants.

Individual cooking oil sample analyses revealed few medium volatile agents in their composition. Samples #2 and #3 appeared to be derived from rape seed oils and /or soy bean oils, as was apparent from the presence of specific sterols, campesterol (found in rape seed oil) and gamma – sitesterol (found in soy bean oil) (TMI 1996). Sample #1 did not contain any of these sterols either, because it was more highly refined, or was produced from a different source.

Viet Nam still uses DDT, which is reflected in its presence in the composite oils investigated. DDT and DDE were found at levels of 1.4 and 6.0 ppb. Aroclor 1260 was present at a level of 72 ppb (Appendix A2).

Dioxin levels of the 2,3,7,8 congener were below the detection limit of 0.04 pg/g. Some of the higher chlorinated dioxin congeners were found in the picogram range. Dibenzo-furans were generally below the detection limits of 0.03-0.06 pg/g. As this was a composite sample, the origin of the contaminants that were found cannot be identified unless each individual oil sample is analyzed. In addition, the possibility exists that all contaminants are from a single oil, in which case the concentration of the contaminants in that oil would be three times higher.

In A So, perhaps the least affluent commune, 43% of the population was totally dependent on their fishponds as a source of fish. A larger proportion of meat was home grown in A So, which was apparently not sufficient; additional meat needed to be purchased elsewhere. Compared to the other communes this was less than the average.

The Hong Thuong population purchased meat well above the average, compared to that observed in the other communes which may be a reflection of its standard of living (which appeared to be better than average).

Results from the questionnaire, regarding foods eaten over the previous week, provide an interesting snapshot of the various foods consumed in the valley in early June 1999. These data should be interpreted with caution, as it would likely be highly dependent on seasonal availability of various food items. It appears that A So and Hong Thuong use their fish production as a trading or selling commodity more than the other two communes, and reflects the economic importance of this resource.

The reported elevated use of pesticides in the Hong Thuong commune compared to the others is perhaps a reflection of the location of this commune at the centre of the valley, situated at the main road to Hue making its availability more direct. This commune also has the appearance of being more affluent compared to the other three. In contrast, it appears that residents in A So either did not have ready access to pesticides or could not afford to buy them. The latter appeared to be the case when this was discussed with the local population.

The collective blood dioxin levels representing various sectors of the local population has been summarized in Section 2.4.3.4 of this report, and was discussed at the expert panel meeting on December 8, 1999. The anticipated difference in levels of 2,3,7,8-Dioxins and the Total Toxicity Equivalents (T-TEQs), based on the spraying frequency data, appear to be substantiated with the measured blood levels. It is interesting to note that the pattern of higher dioxin levels in males vs. females was consistent for the three communes that have 2,3,7,8,- dioxin exposure. This pattern did not hold for the fourth commune (Hong Van), which did not show any 2,3,7,8,-dioxin in blood samples and showed similar levels of T-TEQs for both sexes. One possible explanation for this observation is that T-TEQs exposure is related to smoke exposure from wood fires for cooking to which woman are likely to be more highly exposed than men. Based on the observed gradient in dioxin exposures between the four communes, it appears that the prerequisite to demonstrate a possible dose response relationship between dioxin exposure and prevalence birth defects is satisfied.

The result of the prevalence of pregnancy outcomes, for the four communes combined, that resulted in term death and spontaneous abortion indicate a sharp increase in the prevalence of spontaneous abortion, which started in 1961 and declined somewhat in 1973. This time period coincides exactly with the one during which Agent Orange was sprayed over the valley. In order to identify a causal relationship many factors need to be controlled for including malnutrition. Detailed information is not available from this time period to be able to control for all the confounding factors and support a causal relationship. At present, however, as shown in this report, many of the potential confounding factors have been evaluated or are controlled. The different exposure patterns in the four communes are important in showing a possible dose-response relationship. It is already apparent that A So has the highest dioxin exposure levels and also has an elevated prevalence of total birth defects (alive as well as born dead), which started in around 1971. Data, prior to this date, do not seem to be available. This might be due to the lack of survivors in the A So commune, which was devastated during the war, or due to some other cause.

The reported pesticide exposure in this commune (i.e., based on the food questionnaire) is virtually non- existent. When the number of birth defects in this commune is compared to the other communes, an increase is observed. This relative increase is likely a conservative estimate of birth defects due to dioxin exposure, given the other communes may already have an increase in birth defects due to pesticide use, in addition to those caused by dioxins. The fact that A So, which has the least pesticide exposure, still shows an increase in birth defects upon comparison, strengthens the argument of a possible causal relationship with dioxins.

In order to demonstrate the degree of dioxin involvement in the observed birth defect data, the nutrition data needs to be linked to the health questionnaire data as well as exposure data.

4.0 HEALTH AND ENVIRONMENTAL IMPACTS MITIGATION PLAN

4.1 INTEGRATED SETTING OF ENVIRONMENTAL/HUMAN CONTAMINATION AND THE DEVELOPMENT OF IMPACT MITIGATION STRATEGIES

The Aluoi Valley, in central Viet Nam, remains to this day an isolated enclave of mountain tribes living by means that probably have not changed significantly for several generations. With gradual population pressure in the province, as in other regions of Viet Nam, the need for inhabitable/agricultural land is escalating.

One of the most significant impediments to expanded utilization of land in southern Viet Nam, is the potential human health risk caused through the historical use of Agent Orange in the valley, in concert with a significant UXO presence.

Since cessation of spraying in the valley in 1970, and the war's end in 1975, little has been accomplished which addresses items of rural development and poverty reduction. In recent years, recognition of the needs of the area has occurred; gradually certain infrastructural elements have been added (e.g., electricity within the past four years).

Throughout other regions of southern Viet Nam a variety of programs have been initiated to rehabilitate the forests; for example, the planting of indigenous trees among plantation trees to facilitate the growth of the more sensitive indigenous species.

Problems faced by inhabitants of the Aluoi Valley, are generally shared by many throughout the country; however, in light of increasing attention to rural development/infrastructural issues, the valley serves as a valuable microcosm. Potential mitigation strategies that would prove successful in the valley could be exported to other regions of Viet Nam that are faced with similar herbicide/war related impacts.

Recent studies in the Aluoi Valley have provided a foundation for a mechanism to be applied that addresses significant development issues in Viet Nam. Investigations in the valley focussed on the delineation and quantification of Agent Orange effects.

Health statistics for the valley form a further foundation for the launch of an impact mitigation plan. Discussions regarding this phase of the program follow as a lead into an itemized impact mitigation plan that is directed at the Aluoi Valley, and has the capability of being selectively applied, with appropriate modifications to other regions of Viet Nam that display impacts similar to those identified in the valley.

4.2 METHODS EMPLOYED FOR DEVELOPMENT OF THE PLAN

4.2.1 10-80 Committee Courses

In February 1999, at the start of our field program, medical personnel from the Vietnamese 10-80 Committee presented a one-week duration course on health assessment techniques, and advice based on the HCL/10-80 (1998) report findings that some aquaculture-raised fish in Aluoi Valley were contaminated with dioxin. These courses trained 63 Aluoi Valley medical technicians and provided continuing basic salary support for them to disseminate diet advice information and examine as many people as possible in each commune for health problems.

Sixty-three basic medical examination tools and treatment materials kits, provided by funding from CIDA, were used by these technicians when conducting their work (Plate 4.1). Feedback and data from these courses, and follow-up work, were used in formulating the Health and Environmental Impacts Mitigation Plan.

4.2.2 Workshops with Hatfield / 10-80 Committee / Thua Thien Hue Province and Aluoi Valley Representatives

A workshop attended by sixty people from the above organizations was held in Hue, March 2 and 3, 1999 to review study designs related to forthcoming studies directed at Agent Orange use in the Aluoi Valley. Ecological and human health assessment plans were discussed. A further workshop on March 1 and 2, 2000 reviewed 1999 data and results, and finalized a Health and Environmental Impacts Mitigation Plan developed for the valley. A strategy to implement this plan in the Aluoi Valley was also agreed upon at this workshop. A decision to recommend moving existing residents from the area of the former A So Special Forces base to other areas less contaminated with dioxin was made after considerable discussion. This step will be implemented after fully informing A So base area residents, consulting with the A So commune Peoples' Committee, and providing money to the families involved for relocation.

4.2.3 Consultations Among Hatfield / 10-80 Committee / Thua Thien Hue Province and Aluoi Valley Health Authorities

During the project, medical doctors and other public health specialists and technical personnel from the above organizations were consulted regarding the proposed plans for obtaining human blood and breast milk for dioxin analyses, and compiling health statistics from the minority peoples in the Aluoi Valley.

Medical personnel from the Aluoi Health centre (hospital) and individual communes often accompanied ex-pat personnel during field trips to the valley. Aluoi district nursing and medical technicians carried out the blood and breast milk sampling under Hatfield and 10-80 Committee supervision. Aluoi Valley medical personnel collected medical health data from residents of four valley communes under 10-80 Committee and University of British Columbia direction and supervision. Information collected during these project components was used in the formulation of the Health and Environmental Impacts Mitigation Plan.

4.2.4 Literature Review by Project Team

In order to build on previous dioxin health and environmental impact information from previous scientific studies in Viet Nam and worldwide, project team scientific staff carried out an in-depth review of available published information. Impact mitigation options described in the literature were also reviewed during this process.

Detailed results of this technical literature review have been included throughout Section 2.0 of this report. These information and impact mitigation option alternatives have been combined with the experience of project team members to formulate the Health and Environmental Impacts Mitigation Plan.

This process is evolving, as more technical information related to impact assessment and mitigation experience becomes available both from the HCL/10-80 program in the Aluoi Valley and other worldwide dioxin impact assessment and mitigation programs.

4.2.5 Consultation with Canadian Health Protection Authorities

Through extensive scientific work related to assessing environmental impacts of dioxins in Canada, Hatfield scientists have established many contacts with health and environmental protection authorities in both the Canadian Federal government and British Columbia government. Exotic chemical impact assessment and mitigation scientists and administrators in Health Canada, Environment Canada and BC Ministry of the Environment agencies have been consulted concerning field sampling designs and development of the Aluoi Valley Health and Environmental Impacts Mitigation Plan.

4.2.6 Consultations with External Advisory Panel

To guide the scientific aspects of the Aluoi Valley herbicide impacts mitigation program, a four member advisory panel was appointed in early 1999. The composition of this panel is outlined in Section 1.8. The panel met with the project team twice during 1999 for one-day workshops to review project results, proposed fieldwork designs, and provide input to the Health and Environmental Impacts Mitigation Plan.

In addition to the more formal workshop sessions, members of the panel also provided individual input into field sampling protocols, technical literature sources, Canadian standards information, etc. All members of the panel reviewed report drafts of this 2000 report before it was finalized.

4.3 ORGANIZATION OF SHORT-TERM, MEDIUM-TERM AND LONG-TERM RECOMMENDATIONS

The Aluoi Valley Agent Orange Dioxin Health and Environmental Impacts Mitigation Plan is organized into short-term, medium-term and long-term recommendations based on dioxin contamination and other environmental impact findings to date.

Recommendations are listed for options that should be implemented, and priorities for further assessment work. Short-term recommendations should be implemented immediately, medium-term recommendations within one year, and long-term recommendations over periods up to five years. Mitigation possibilities have been further organized into Feasible Options, Possibly Feasible Options, and Likely Not Feasible Options based on technical, financial and social considerations. The list of mitigation options considered was derived mainly from Hatfield Team experience, but also included mitigation options outlined in the technical literature, by Canadian dioxin contamination mitigation authorities, or suggestions from Vietnamese authorities. The final list of feasible mitigation options recommended for implementation was arrived at subsequent to in-depth consultation between the Hatfield Team and Vietnamese agencies.

All recommended mitigation options would contribute to mitigating Agent Orange impacts in the valley. However, the organization of the recommendations into short-, medium- and long-term blocks reflects implementation priorities which would likely have the most immediate health benefits, would be the most inexpensive to implement, and would not require a lengthy period for planning/implementation.

The success of implementing recommended options would be determined by a follow-up monitoring plan to evaluate if health risks and environmental contamination are being reduced by implementation of the plan. Future modifications to the plan may be necessary if it is found the contamination problem is not being resolved.

4.4 COMPONENTS OF PLAN

4.4.1 Short-Term Mitigation Options[1]

4.4.1.1 A So (A Shau) Base Area

A. Summary of Situation to Date at A So

Soils, pond-raised fish and ducks in the area have been found to have dioxin (T-TEQ) levels which exceed standards for residential and agricultural soils and guidelines for unrestricted human consumption (foods) in many western jurisdictions. AO dioxin levels in human blood and breast milk are higher than those found in most other dioxin studies of these parameters in industrialized countries. The immediate A So base area is not being used extensively for agriculture, forestry or other economically important crops, although some cultivation occurs on the perimeter of approximately 20% of the former base area; livestock graze on this land. The base has not been cleared of unexploded ordnance (UXO). Approximately 12 families live within 500 m of the main base; there are approximately 20 aquaculture fish ponds in this area. A clear airstrip, a number of concrete building foundations, and other remnants of base infrastructure are identifiable in the area.

B. Main Issues of Uncertainty for A So Base Area

a) Exact extent of soil contamination which exceeds western standards.

b) Relative importance of direct soil contact as a pathway for dioxin bioaccumulation/ biomagnification in humans.

c) Suitability of soils in the base area for productive socioeconomic use (e.g., agriculture, forestry).

d) Possible groundwater contamination in the area.

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[1] Feasible options which should be implemented immediately.

C. Feasible Options

1. <u>Consideration of Relocating Present Residents to New Areas</u>

Recommended Mitigation Based on <u>Current Information</u>:

a) It is recommended that households in the A So Base area be relocated to less contaminated areas.

b) Residents within a 500 m radius of the north end of the airstrip should be included in such a relocation.

c) Such relocations should also be carried out if further dioxin work finds other residential lands are contaminated above 350 ppt (the present remediation standard for residential land use in Canada).

d) When advice to relocate is presented to local A So base area residents, a well developed resettlement plan should be in place, and adequate resources provided to assist such resettlement.

e) Local NGOs currently active in development projects in A So should be consulted to assist with resettlement planning.

Recommended Priority for Immediate Further Work in Area to Refine Mitigation Plan;

a) Vietnamese agencies responsible for planning residential areas in the Aluoi Valley, should assess potential locations for resettlement of households presently in the A So base area.

b) Residents presently living in the A So base area should receive assistance from appropriate Vietnamese agencies to ensure they are made aware of food preparation procedures and consumption advisories to reduce further ingestion of contaminated foods.

c) Composite soil samples (ten replicates) should be taken from the yard (within 10 m of house) of each residence outside of the 500 m radius of the north end of the runway (up to a 1,000 m radius) and analyzed for dioxins.

d) Archived US military information related to base layout and activities should be reviewed to determine, if possible, where herbicide and other chemicals (CS gas crystals, PCBs, fungicides, etc.) were stored and used on the base. This information should then be used in future sampling designs related to delineation and remediation of contaminated soils.

2. Consideration of Limiting Further Human Settlement in A So Base Area

Recommended Mitigation Based on Current Information:

a) No further human settlement should be permitted within a 500 m radius of the main A So base area (centre of radius is defined as being at the centre of the northern end of the airstrip, east of concrete abutment remnants).

b) Any activity which further disturbs soil in the base area (e.g., UXO clearance, infrastructure development, water well construction), should not be permitted unless adequate measures are taken to limit the further remobilization of dioxin into the human food chain.

Recommended Priority for Immediate Further Work in Area to Refine Mitigation Plan:

a) A more comprehensive dioxin soil sampling program should be designed and implemented in the base area to fully delineate the extent of the contaminated area.

b) A groundwater dioxin sampling program should be designed and implemented.

c) The A So base area should be accurately mapped to a scale of 1:2000 to show the location of former base airstrip and facility foundations, present local residences, aquaculture ponds and roads, and all dioxin sampling locations.

3. Consideration of Limiting Further Development of Aquaculture Fish Ponds in A So Base Area

Recommended Mitigation Based on Current Information:

a) No further fish ponds should be developed within approximately a 500 m radius of the main A So base area.

b) Local residents who consume fish from ponds in the A So area should be assisted by Peoples' Committees to ensure they are made aware that fat and internal organ tissue from these fish should not be eaten on a regular basis.

c) If further sampling indicates more A So residents should be relocated (through the procedure outlined in recommendation C1.), existing fishponds within the area vacated by residents should be phased out.

Recommended Priority for Immediate Further Work in Area to Refine Mitigation Plan:

a) Five species of fish are stocked in aquaculture ponds in the Aluoi Valley. Some of the aquaculture ponds are fed by groundwater and some by surface water. Present contamination data for fish at A So should be reviewed and, if necessary, additional data collected to determine if there are correlations between certain fish species and higher dioxin contamination. The review should also evaluate if there is any correlation between higher dioxin contamination in fish and pond water supply sources.

If such a correlation is found, it may be possible to continue fish pond aquaculture in the A So area by modifying species or water sources to limit contamination of fish crops.

4. Development of Advisories Related to Consumption of Locally Raised Food from the A So Area

Recommended Mitigation Based on Current Information:

a) Residents of A So should be advised through public information and education programs, to avoid eating fat and internal organ tissue from fish and ducks which have been raised within approximately 500 m of the main base area.

b) A So residents should be advised that locally grown rice, manioc and other vegetable or grain crops do not have potentially harmful levels of dioxin and can, therefore, be safely consumed. Soil associated with harvesting such crops should be thoroughly washed from any consumed root material; such food items should also be peeled.

c) Assessment is ongoing related to possible dioxin contamination of pigs and cows from the A So area. However, since these food items are rarely eaten by A So residents (because of cost), no consumption advisories are thought to be necessary.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

a) Further pig and cow fat and internal organ tissue samples should be taken from animals raised in the A So area.

b) Since the main pathway for dioxin contamination of A So residents is most likely through the food chain in the base area, it is important that local people continue to be promptly informed of any new developments in the delineation and mitigation of the problem. Regular public information meetings should therefore be conducted by appropriate Peoples' Committees to ensure new information is disseminated, and people continue to be advised regarding food preparation and consumption precautions.

5. <u>Consideration of Issuing Advisories for Food Products from A So Area</u>

Recommended Mitigation Based on Current Information:

a) If exports of fish and/or duck products from the A So area to markets outside the Aluoi Valley take place or are contemplated in future, the products should be eviscerated and, to the extent possible, stripped of fat.

b) Some marketing of fish and duck raised in the A So area takes place in the village markets of Aluoi in the valley. Considerable trading and gift giving of these food items from A So to other valley residents also takes place. It is recommended that such food be eviscerated and, to the extent possible, stripped of fat before being sold or exchanged.

c) To protect export markets for other Aluoi Valley products which have no dioxin contamination (e.g., rice, manioc, sugar, coffee, etc.), it is recommended that advisories be issued stating such products have been tested and found to be dioxin-free.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

No recommendations for immediate further work related to this mitigation option are made at this time.

6. <u>Disposal of Contaminated Fish and Duck Fat and Internal Organ Tissue not Consumed by Humans</u>

It is important that recirculation of this material into the human food chain be limited as much as possible since AO dioxin levels were found to be highest in fat and internal organs of these animals in the A So area.

Recommended Mitigation Based on Current Information:

a) Such material should not be fed to any animals consumed by humans in the A So area or Aluoi Valley generally.

b) Such materials should be burned or buried as composting material in rice, cash crop (e.g., coffee, sugar cane, fruit trees) or forest areas well away from houses and yard areas of A So area or other valley residents.

c) Residents presently living in the A So base area should be assisted by local Peoples' Committees, to ensure they are made aware of safe disposal practices for contaminated fish and duck fat and internal organs.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

No recommendations for immediate further work related to this mitigation option are made at this time.

7. <u>Development of Alternate Land Use Plans for Dioxin Contaminated Area</u>

Recommended Mitigation Based on <u>Current Information</u>:

a) A program to remove the present UXO from the A So base area is urgently required before any alternate use of the land related to dioxin contamination is implemented.

b) Plans for such a UXO removal program should include methods to limit remobilization of dioxin in soils of the area (i.e., if UXO is detonated *in situ*, erosion/dispersal of contaminated soil should be controlled).

c) Plans for such a UXO removal program should also include methods to limit potential pollution from disposing of any special ordnance found (e.g., phosphorous materials, incendiary materials, CS gas crystalline material).

d) Plans for alternate land uses should also take into account other chemicals which could have been used at the base and disposed of in the area (e.g., PCBs, pesticides, fungicides, etc.)

e) Soils in the A So base area should be evaluated for their potential for alternate land uses (e.g., agriculture cropland, community or plantation forestry, etc.)

Recommended Priority for Immediate Further Work in Area to Refine Mitigation Plan:

a) UXO removal specialists from Gerbera, Mines Advisory Group (MAG) or other demining teams who have experience with demining in Viet Nam should be retained to design and cost a UXO removal program for the A So base area.

b) Vietnamese agencies responsible for land use planning in the Aluoi Valley should test soils for agricultural and forestry capability, and formulate future land use plans for the A So base area.

D. Options Which Are Likely Not Feasible

1. <u>Consideration of Developing a Plan for Substituting Food from Uncontaminated Areas for Residents of A So</u>

Some foods (including fish) for sale in the markets in the Aluoi Valley is imported from coastal areas of Hue province. It would be possible therefore to increase these imports as food substitutes for A So residents at significant cost. Financial support and sustainability of this option is uncertain.

Recommendation Based on Current Information:

a) It is not recommended that fish importation be done at the present time as other mitigation measures (as outlined in options C3 and C4, above) provide more effective low cost ways of reducing the dioxin contamination problem.

Recommended Priorities for Immediate Further Work to Refine Mitigation Plan:

No recommendations for immediate further work related to this mitigation option are made at this time.

2. Consideration of Alternatives to Breast Feeding for Residents of A So Area

The science of associating specific levels of human breast milk dioxin levels with exact health effects has not advanced to the point where definitive relationships can be quantified at the present time. All technical studies related to breast milk contamination have concluded that although such contamination is undesirable, other benefits of breastfeeding to infant health likely override the risk of negative effects.

Recommendation Based on Current Information:

a) It is therefore recommended that breast feeding of infants of residents in the A So area continue.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

a) Since this issue is an active area of medical/environmental research, results of future worldwide studies should be closely monitored in the technical literature.

b) Breast milk AO dioxin (TCDD) contamination data from 1999 indicated there were higher levels in residents of the A So area compared to other regions of the valley. A number of breast milk samples from residents of the valley were archived (not-analyzed) because of cost constraints. It is recommended that further breast milk samples from this archived group be analyzed to further investigate this issue in the Aluoi Valley.

4.4.1.2 General Parameters for All Aluoi Valley Area (outside of A So base area)

A. Summary of Situation to Date in Aluoi Valley

Most soils, poultry and livestock from other areas in the Aluoi Valley contain low levels of AO dioxin (TCDD). These levels are below standards used in the west to define "safe" areas for residential use and acceptable levels for food consumption. Human blood and breast milk levels in other areas of the valley are, on average, lower than in the A So area. To date, no AO dioxin was found in plant food material in the Aluoi Valley. No soil contamination "hot spots" similar to the A So area were found at former US Special Forces bases at Ta Bat and Aluoi. Land in the area of Ta Bat base is not being used by people because of UXO presence.

B. Main Issues of Uncertainty for Aluoi Valley Area

a) Significance of low background AO dioxin levels found in most soils, environmental tissues and human tissue samples taken in the Aluoi Valley outside of A So area (i.e., do these lower amounts of dioxin accumulate and biomagnify in the human food chain in the valley to levels that are a risk to human health given the limited variety of foods?).

b) Potential agriculture and forestry capabilities of unused land in the vicinity of the former Ta Bat base.

C. Feasible Options

1. <u>Consideration of Issuing Food Consumption Advisories in Communes in the Aluoi Valley Outside the A So Base Area</u>

Ingestion of dioxin by residents of the Aluoi Valley is considered to be undesirable given the unknown risk to health posed by even low levels in food ingested on a more or less continual basis. The recent (1999) international response to the dioxin contamination in Belgium food products is consistent with this premise.

However, many people in the valley are already living at a very basic subsistence level mainly centered around vegetable, fish and poultry foods raised near their own households. Any marketing of surplus food items is at best limited and fragile.

Scientific knowledge related to the health risk posed by low dioxin levels in human food is uncertain at the present time.

Therefore, it is concluded at the present time that the benefits to the health of non-A So base area residents in the valley of continuing their present food consumption practices override the risk of negative effects.

Recommended Mitigation Based on Current Information:

a) It is therefore recommended that no food consumption advisories be issued in the general Aluoi Valley apart form those relating to A So base area residents as outlined in Section 4.4.1.1.

b) A general public information program which would encourage thorough washing and peeling of rooted vegetables should be undertaken in the valley.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

a) Since this is an active area of medical/environmental research, results of future worldwide studies should be closely monitored in the technical literature.

2. Development of UXO Removal Plan for the Valley

Recommended Mitigation Based on Current Information:

a) A UXO Removal Plan should be developed for the valley, particularly in the former Ta Bat base area.

Recommended Priorities for Immediate Further Work in the Area:

a) UXO removal specialists from Gerbera, Mines Advisory Group (MAG) or other teams who have experience with demining in Viet Nam should be retained to design and cost a Level 1 Plan for UXO Removal for the Ta Bat base area and other areas of the valley.

b) Vietnamese agencies responsible for land use planning in the Aluoi Valley should test soils for agriculture and forestry capability and refine future land use plans for the Ta Bat base area.

3. Development of a Soil Erosion Control Plan for Key Areas in Aluoi Valley

Many slopes surrounding the Aluoi Valley and along the main access road to the valley from Hue, are very unstable because of the lack of upland jungle regeneration after the 1965-1970 herbicide spraying in these areas. Ten people were killed by mudslides during typhoon rains in November 1999. Mudslides, particularly during the monsoon season, are common and can result in roads being blocked for periods of weeks. This creates economic hardships for the people in the valley given they cannot market their surplus and cash crops in the Hue area. It also directly affects health emergency evacuations from the valley to Hue hospital related to the numerous UXO and other accidents, and sicknesses which presently occur in the valley.

Many sloping land areas of the Valley are now been cultivated for agriculture and plantations because the valley bottom has many residual serious war damage impacts from spraying, shelling and bombing. UXO is still present in many of these areas.

Recommended Mitigation Based on Current Information:

a) An immediate program should be undertaken to increase the present efforts to stabilize slopes in critical areas along Route 49 which connects the valley to Hue using known engineering techniques (e.g., re-culverting, improved water ditching, upslope matting, retaining wall construction, upslope grass seeding, etc.).

b) Land use plans in the valley should discourage present erosion-causing agriculture on sloped land which is presently taking place (as a result of high UXO risk in many flat areas of the valley).

c) If agriculture cultivation practices need to be continued because of shortages of suitable land for agriculture, it is recommended that appropriate cross slope cultivation and other techniques be used to control erosion.

Recommended Priorities for Immediate Further Work in the Area:

a) A detailed Hue to Aluoi valley road (Route 49) reconstruction plan should be formulated to rectify the main soil erosion problem areas where main blockages occur.

b) A present sloped land use assessment should be carried out to address slope instability problems and erosion caused by agricultural activities.

D. Option Which Is Likely Not Feasible

1. Consideration of Development of Alternate Land Use Plans for the Aluoi Valley

Dioxin reduction and/or breakdown could occur in areas developed for forestry and agriculture crops. Scientific knowledge related to the health risk posed by low dioxin levels in soils is uncertain at the present time.

Recommended Mitigation Based on Current Information:

a) It is concluded that at the present time, it is not necessary for alternate land use plans to take dioxin soil contamination into account for the Aluoi Valley other than in the A So area as outlined in Section 4.4.1.1.

Recommended Priorities for Immediate Further Work in Area to Refine Mitigation Plan:

a) Present impact mitigation land use plans which have been developed by Vietnamese agencies which have land use planning jurisdiction in the Aluoi Valley should be reviewed and updated to ensure they are adequate to attract investment or funding from private sector companies and/or donor agencies having interests in rural development projects.

4.4.2 Medium-Term Mitigation Options[2]

4.4.2.1 A So (A Shau) Base Area

A. Possibly Feasible Options

1. Consideration of Contaminated Soil Removal and Replacement

Since soil incineration to eliminate dioxin contamination is an expensive process anywhere in the world, one practice which is commonly used is the removal and replacement of contaminated soil with clean soil. This practice has been used for a site contaminated with dioxin from industrial practices in the Vancouver area. At this site, contaminated soil has been removed and replaced with soil suitable for residential housing. Dioxin contaminated soil was removed and disposed of 90 miles out to sea in the open Pacific ocean (a practice not presently permitted) or capped.

Recommended Mitigation Based on Current Information:

a) Contaminated soil removal and replacement should not occur for the A So base area in the medium-term because of volume uncertainties and cost.

b) If the area of highly contaminated soil is found in the future to be relatively limited, this mitigation method should be reconsidered.

Recommended Further Work in the Area:

a) An assessment should be carried out once the area of contaminated soil is better delineated in the A So base area, to determine the volume of material which should be considered for removal, possible disposal areas, possible sources of clean soil and costs of carrying out such an operation.

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[2] Recommended options should be implemented within one year.

2. Consideration of Contaminated Soil Site Capping

At the former industrialized site outlined in Option 1 above, and other sites in Canada, highly contaminated sites are capped with clay and impermeable membranes or other suitable soils and developed for uses which do not require excavations or result in direct exposure of people or their food to contaminated soils.

Recommended Mitigation Based on Current Information:

a) Such an option should be considered for the most contaminated area near the A So base.

b) Appropriate Vietnamese agencies should zone such capped sites for uses which would protect the integrity of the capped site (e.g., community forest, forest plantation, pasture land, etc.).

Recommended Further Work in the Area:

a) An assessment should be carried out once the area of contaminated soil is better delineated in the A So base area, to determine the area which could be considered for capping and costs of carrying out such an operation.

B. Option Which Is Likely Not Feasible

1. Consideration of A So Base Soil Decontamination by Incineration

High temperature incineration is the most widely used method for breaking down and eliminating dioxin contamination from soils and other materials at the present time. Incineration equipment for carrying this out is extremely expensive (over $US5 million per mobile unit), highly technical to operate, and limited as to the volume of material which can be treated.

Recommended Mitigation Based on Current Information:

a) It is recommended that such an operation not be undertaken at A So at this time because of cost and the uncertainty of the configuration of the contaminated area.

Recommended Priority for Further Work in the Area:

a) Technical literature should be reviewed and new technologies monitored to assess appropriate methods which may evolve in future for dioxin breakdown and elimination by incineration, chemical or biological processes or other methods which may have application in Viet Nam.

4.4.2.2 General Parameters for Aluoi Valley Area

A. Feasible Options

1. Development of Contingency Plans for Dealing with Future Dioxin Contaminated Areas or Buried Chemicals found in the Aluoi Valley

No other dioxin contamination "hot spots" have been found in the Aluoi Valley outside the A So base area, although some other areas have levels which are higher than background in other regions of the world. However, buried munitions and chemicals have been found in other locations in Thua Thien Hue province.

Recommended Mitigation Based on Current Information:

a) A contingency plan should be developed for reporting the finding of buried chemicals or munitions in the valley and designating appropriate Hue province and Vietnamese central government agencies for dealing with such problems.

b) A public information system should be developed to inform people in the valley on how they should report such finds.

Recommended Further Work in this Area:

No recommendations for further work related to this mitigation option are made at this time.

4.4.3 Long-Term Mitigation Options[3]

A. Feasible Options

1. Improvement of the Health Services Provided in the Valley

A rudimentary health centre (hospital) is operational in the valley centre in the village of Aluoi. Basic medical clinics are functional in several other communes. UXO injuries, birth deformities, malnutrition, diseases and poor living conditions are common in the valley. Many of the medical problems in the area are either directly or indirectly related to the war.

[3] Recommendations which should be implemented over five years.

Recommended Mitigation Based on Current Information:

a) The Aluoi health centre and commune health clinic facilities in the valley should be significantly improved for better treatment of general health issues, UXO injuries, and related conditions. Health clinic facilities should be upgraded at A So (Dong Son) and new health clinic facilities constructed at A Roang, Huong Phong, Phu Vinh, Hong Thuong, Xa, Nham, Hong Thai, Bac Son and Hong Kim.

b) A regional emergency response capability (i.e., ambulance), headquartered in Hue hospital and servicing Aluoi and other remote districts is urgently required for the benefit of the local populaces (e.g., UXO victims, general health conditions, etc.).

c) There should be a major training program designed for medical staff of present and future health facilities in the valley with particular emphasis on UXO injury, birth defect and cancer treatment, and health rehabilitation.

2. Rehabilitating and Improving Infrastructure in the Valley

Some road and water system rehabilitation has taken place in the valley financed by NGO's and the Hue provincial government.

Recommended Mitigation Based on Current Information:

a) Better gravity water systems should be constructed to service eight communes in the valley (Bac Son, Dong Son, Son Thuy, Hong Bac, A Dot, Hong Quang, Hong Thai and Huong Lam). Other villages should have basic well water sources constructed.

b) Such systems should be constructed to be free of AO dioxin contamination.

c) Basic road systems in the valley should be upgraded to be useable during the monsoon season.

3. Development of a Socioeconomic Improvement Plan for the Valley

Through conflicts like the Viet Nam war, the compounding nature of environmental impacts ultimately have one paramount/recognizable human impact – poverty. The end result of human poverty, caused by additive environmental and socioeconomic destruction/disruption throughout the valley, should be viewed with a mitigative strategy in mind that addresses these cumulative impacts. Through integrated design, assessment, planning and implementation of mitigative approaches, the ultimate goal of economic improvement and poverty reduction through appropriate rural development can begin to germinate and continue to expand in the best interests of the valley's residents.

A socioeconomic improvement plan has been outlined by the Thua Thien Hue provincial Department of Planning and Investment (DPI) for the valley. Some war damage impact rehabilitation options as outlined in the Health and Environmental Impacts Mitigation Plan are included in this socioeconomic improvement plan.

Recommended Mitigation Based on Current Information:

a) The DPI socioeconomic plan should be refined and developed in more detail in order that the plan as a whole, or its components, can attract financing.

b) Specific provisions should be included in the DPI plan for private and public sector investment. Corporate and International Financial Institution (IFI) financing, donor agency rural development programs and NGO contributions should be part of this plan, where appropriate.

4. Rehabilitation of Forest and Wildlife Bio-diversity in the Valley

The Thua Thien Hue Department of Planning (DPI) has developed a general environmental plan for replanting of forests in the head waters of the A Sap river watershed (the main river system in the Aluoi Valley). Natural forest plantations and community forests are included as part of this plan. Moving and/or settling poor or landless households as occupants and managers of these new areas are part of the DPI plan. Forest and Wildlife Biodiversity Rehabilitation Plans for the Aluoi Valley are described in more detail in Section 5.0.

Recommended Mitigation Based on Current Information:

a) The general forest and wildlife rehabilitation plan developed by DPI should be developed in more detail to make it as effective as possible in attracting future donor agency and NGO financing and participation.

5. Development of Measures to Control Flooding and Soil Erosion in the Valley

As a result of the removal of the majority of former upland tree cover in the valley, flood frequency and resulting soil erosion has increased substantially; this causes serious problems for roads and bridges, agriculture and residential development.

Recommended Mitigation Based on Current Information:

a) A flood and soil erosion control program should be developed for the valley involving a combination of engineered structures and forest rehabilitation.

6. Development of Measures for Improving Agriculture Soil Quality which has been Impacted by Spraying, Shelling and Bombing

As a result of war activity, significant areas of land in the valley have been rendered less productive because of ordnance craters, herbicide spraying, soil erosion, etc. In some areas, productivity of the land has been reduced to near zero, given changes to soil structure from compaction, reduced nutrient content, etc.

Recommended Mitigation Based on Current Information:

a) A rehabilitation program is required, which would address agricultural objectives of the valley, and how agriculture land could be rehabilitated to further economic development in the agricultural sector.

7. Agent Orange Dioxin Contamination Monitoring in the Valley

Recommended Mitigation Based on Current Information:

a) An AO dioxin monitoring program should be established for soils, groundwater, fish, ducks and human blood in the A So base area and any other "hot spot" identified in the valley in future.

b) Such a monitoring program should be designed to assess whether dioxin levels are bio-magnifying or declining in such hot spots due to the mitigation measures implemented.

B. Possibly Feasible Option

1. Consideration of other Contaminated Soil Treatment for Breakdown or Removal of Dioxin Contamination

There is some evidence that dioxin is broken down when contaminated soils are exposed to light through processes such as ploughing. Using contaminated sites for forest or other types of cash crop plantations could also be considered.

Recommended Mitigation Based on Current Information:

a) Pilot projects to test ways of dioxin contamination reduction such as those outlined above should be developed.

4.5 RECOMMENDED IMPLEMENTATION STEPS

4.5.1 Short-Term Steps[4]

1. Carrying out Meetings with Aluoi District and All Aluoi Valley Commune Peoples' Committee Officials

Recommended Implementation Steps:

a) Appropriate Thua Thien Hue provincial and central government personnel should continue meeting with the above committees to explain the impact mitigation plan, discuss and reach agreement on its details, and plan for its implementation.

b) Budget resources for these meetings should be obtained from the annual allocations of government agencies.

2. Holding of Public Information Meetings in the Aluoi, A So and Hong Van Communes in the Valley

Recommended Implementation Steps:

a) Such meetings should be held to verbally summarize the present AO dioxin contamination situation in the valley and the health and environmental plan designed to mitigate herbicide related impacts.

b) Such information should be conveyed by leaders of the communities in the four ethnic languages in the valley, as necessary.

c) Thua Thien Hue government medical/environmental and planning personnel and 10-80 Committee medical personnel should be present as required.

d) Foreign technical advisors could attend to answer questions from the public if desirable.

3. Carrying Out Further Health-related Short-Term Training Programs in Aluoi Valley

The 10-80 Committee conducted two weeks of training for health service technicians in early 1999. Basic medical kits were also distributed to individual communes during these courses.

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[4] Recommended implementation steps that should be taken immediately.

Recommended Implementation Steps:

a) Regular follow-up courses should be carried out in the valley to update medical technicians with new mitigation plan information related to dioxin ingestion, in order to ensure previous course instructions are being followed, and to replenish basic medical supplies as necessary.

b) Costs for carrying out these further courses and medical kit replenishments should be solicited from donor agencies and/or NGOs having interests in the area.

4. Development of Health and Environmental Impact Mitigation Plan Poster Programs

Recommended Implementation Steps:

a) Newspaper articles should be written for publication in Hue city and any Aluoi Valley newspapers related to the present dioxin contamination situation in the valley and health and environmental plans designed to mitigate herbicide-related impacts.

b) A poster program should be designed and implemented in the valley which encourages proper food preparation procedures to reduce dioxin ingestion from rooted vegetables (i.e., thorough washing and peeling). Extensive use of graphics should be part of these poster displays to emphasize the key points.

c) A poster program should be designed and implemented for the A So area which encourages the discarding of fat and internal organs of fish and ducks before cooking and consumption.

d) A poster program should also be designed and implemented for the A So area which encourages the safe burial or burning of contaminated fat and internal organs from fish and ducks.

5. Participation in Aluoi Valley Radio Programs and Newspaper Articles

Recommended Implementation Steps:

a) Appropriate Thua Thien Hue provincial agency and, if necessary, central government personnel, should be interviewed on local radio outlets to summarize the AO dioxin situation in the Aluoi Valley, and provide information related to the Health and Environmental Impacts Mitigation Plan. These interviews should be translated to the extent possible into the minority languages of the Aluoi Valley.

b) The above interviews should be timed to be part of an overall media and public information plan in implementation steps 1-4 (above).

c) Costs for carrying out the series of meetings, media presentations and poster programs outlined in steps 1-4 should be funded from regular government budgets.

4.5.2 Medium-Term Steps[5]

1. Continuation of Foreign Advisory Team as Advisor and Participant in Rehabilitation of Aluoi Valley Environment and Social Infrastructure Redevelopment

Recommended Implementation Steps:

a) A medium-term consultant advisory arrangement should be continued between Thua Thien Hue provincial agencies, 10-80 Committee and the Hatfield technical team to advise and work on implementing the Health and Environmental Impact Mitigation Plan for the valley. The advisory team would assist Hue province and central government agencies with implementing issues including the following:

- advice related to the short-term mitigation options;
- updating Vietnamese agencies on new technical information related to mitigating dioxin contamination problems in North America and Europe;
- designing and participating in further programs in the Aluoi Valley related to the delineation of AO dioxin contamination;
- assisting in further human health assessment programs in the Aluoi Valley; and
- assisting in efforts to obtain continuing short- and medium-term funding for the initial implementation of the Health and Environmental Impacts Mitigation Plan.

b) Hatfield would work with appropriate Vietnamese agencies to extend the medium-term advisory role into a long-term relationship.

[5] Recommendations to be carried out within one year.

2. Carrying out of Pilot Projects Related to Implementation of the Health and Environmental Impacts Mitigation Plan

Recommended Implementation Steps:

a) Pilot projects should be designed to test and gain experience related to implementation of a number of recommended mitigation options (e.g., erosion control measures, replanting forests, etc.).

b) Such projects should be initiated in the medium-term and, if necessary, extended and/or expanded over the longer term.

c) Aluoi Valley and Hue province personnel should be utilized as much as possible for these projects in order that local expertise on these mitigation techniques be developed.

d) Funding for carrying out such pilot projects should be solicited from International Financing Institutions (IFI), donor agencies, western based NGO foundations, etc.

4.5.3 Long-Term Steps[6]

1. Implementation of Long-Term Impact Mitigation Options in the Aluoi Valley

Long-term mitigation options which should be designed and carried out include plans for forest and wildlife diversity rehabilitation, flood and soil erosion control, infrastructure improvement, socioeconomic improvement and health services improvement. Implementation of such plans are critical to mitigating the continuing war-related impacts in the valley.

Recommended Implementation Steps:

a) Plans listed above should be further refined and implemented over the next five-year period.

b) Funding for implementing these rehabilitation plan components over the long-term should be solicited from international donor agencies and foreign private investors.

[6] Recommended to be carried out over next five years.

2. <u>Application of the Aluoi Valley Health and Environmental Impacts Mitigation Plan Implementation Experience to Other Herbicide Impacted Areas of Viet Nam, Lao PDR and Cambodia</u>

Many other areas of Viet Nam and Indochina experienced major impacts from herbicide spraying during the war. Many of these impacts continue to the present day. Each area will require a contamination assessment and the formulation of impact mitigation plans to reduce the risk to human health posed by herbicide-related dioxin contamination and continuing impacts to the environment.

Recommended Implementation Steps:

a) All results from AO dioxin delineation programs, and experience with mitigating herbicide spraying and other war impacts, should be published in regular annual reports. This will enable technical teams responsible for mitigating impacts in other areas of Viet Nam and Indochina to apply knowledge learned in the Aluoi Valley. Such experience will also be of major interest to agencies working to resolve dioxin contamination issues worldwide.

b) Such reports should be made available to all interested parties at a modest price.

4.6 SUMMARY OF ALUOI VALLEY AGENT ORANGE HEALTH AND ENVIRONMENTAL IMPACTS MITIGATION PLAN

4.6.1 Components of Plan

4.6.1.1 Short-Term Mitigation Options

A. A SO (A SHAU) BASE AREA

Feasible Options

1. Relocating Present Residents to New Areas.
2. Limiting Further Human Settlement in the A So Base Area.
3. Limiting Further Development of Aquaculture Fish Ponds in the A So Base Area.
4. Development of Advisories Related to Consumption of Locally Raised Food from the A So Area.
5. Issuing Advisories for Food Products from A So Area.
6. Disposal of Contaminated Fish, Chicken and Duck Fat and Internal Organ Tissue Not Consumed by Humans.
7. Development of Alternate Land Use Plans for Dioxin Contaminated Areas.

Options Which Are Likely Not Feasible

1. Developing Plan for Substituting Food from Uncontaminated Areas for Residents of A So.
2. Alternatives to Breast Feeding for Residents of A So Area.

B. GENERAL PARAMETERS FOR ALL ALUOI VALLEY AREA (outside of A So base area)

Feasible Options

1. Issuing Food Consumption Advisories in Communes in the Aluoi Valley Outside the A So Base Area.
2. Development of an UXO Removal Plan for the Valley.
3. Development of a Soil Erosion Control Plan for Key Areas in Aluoi Valley.

Option Which Is Likely Not Feasible

1. Development of Alternate Land Use Plans for the Aluoi Valley.

4.6.1.2 Medium-Term Mitigation Options

A. A SO (A SHAU) BASE AREA

Possibly Feasible Options

1. Contaminated Soil Removal and Replacement.
2. Contaminated Soil Site Capping.

Option Which Is Likely Not Feasible

1. A So Base Soil Decontamination by Incineration.

B. GENERAL PARAMETERS FOR ALUOI VALLEY AREA

Feasible Option

1. Development of Contingency Plans for Dealing with Future Dioxin Contaminated Areas or Buried Chemicals found in the Aluoi Valley.

4.6.1.3 Long-Term Mitigation Options

Feasible Options

1. Improvement of the Health Services Provided in the Valley.

2. Rehabilitating and Improving Infrastructure in the Valley.
3. Development of a Socioeconomic Improvement Plan for the Valley.
4. Rehabilitation of Forest and Wildlife Bio-diversity in the Valley.
5. Development of Measures to Control Flooding and Soil Erosion in the Valley.
6. Development of Measures for Improving Agriculture Soil Quality which has been Impacted by Spraying, Shelling and Bombing.
7. Agent Orange Dioxin Contamination Monitoring in the Valley.

Possibly Feasible Option

1. Other Contaminated Soil Treatment to Breakdown or Remove Dioxin Contamination.

4.6.2 Recommended Implementation Steps of Plan

4.6.2.1 Short-Term Steps

1. Carrying out Meetings with Aluoi District and All Aluoi Valley Commune Peoples' Committee Officials.
2. Holding of Public Information Meetings in the Aluoi, A So and Hong Van Communes in the Valley.
3. Carrying Out Further Health-related Short-Term Training Programs in Aluoi Valley.
4. Developing Health and Environmental Impact Mitigation Plan Poster Programs.
5. Participating in Aluoi Valley Radio Programs and Newspaper Articles.

4.6.2.2 Medium-Term Steps

1. Continuation of Foreign Advisory Team as Advisor and Participant in Rehabilitation of Aluoi Valley Environment and Social Infrastructure Redevelopment.
2. Carrying out of Pilot Projects Related to Implementation of the Health and Environmental Impacts Mitigation Plan.

4.6.2.3 Long-Term Steps

1. Implementation of Long-Term Impact Mitigation Options in the Aluoi Valley.
2. Application of the Aluoi Valley Health and Environmental Impacts Mitigation Plan Implementation Experience to Other Herbicide Impacted Areas of Viet Nam, Lao PDR and Cambodia.

5.0 FORESTRY AND WILDLIFE BIODIVERSITY REHABILITATION PLAN

5.1 OVERVIEW OF FOREST COVER TRENDS IN VIET NAM

The following overview of forest cover trends in Viet Nam has been summarized from a recent report by Poffenberger (1998) based on a collaborative study by the Asia Forest Network and the Forest Inventory and Planning Institute (FIPI): ***"Stewards of Viet Nam's Upland Forests"***.

Viet Nam presently has over 75 million people, making it one of Asia's most densely populated countries. The population of Viet Nam is projected to surpass 100 million by the year 2020 (Figure 5.1). Fifty-eight percent (19 million ha) of the 33 million hectares comprising the total land area of Viet Nam is classified as forest under the jurisdictional authority of the Ministry of Agriculture and Rural Development (MARD). Only part of this area actually supports forest vegetation. The total forest cover declined steadily over the 20th century (Figure 5.1); the rate of decline has accelerated in recent decades. Forest cover declined from 14 million hectares in 1943 to 9.3 million hectares in 1995. In 1995, there were over ten million hectares covered by grasses, brush, or a few scattered trees. Only three million hectares are considered to support healthy forests.

Most of the investments in tree planting in Viet Nam to date have focused in lowland and midland areas. Natural forests in upland areas are under mounting extractive pressure. There are presently about two million hectares of old growth natural forest distributed around the country, covering approximately 6% of the land area of the country. Deforestation is presently progressing at a rate of 100,000 to 200,000 hectares annually. Figure 5.2 illustrates the rapid deforestation of Viet Nam over the latter part of the 20th century.

The Central Highlands possess the country's best and most extensive forests, 42% of Viet Nam's total forest cover and its most valuable timber reserves. Migrant and industrial pressures have driven rapid deforestation in the Central Highlands since the 1970's when State Forest Enterprises and resettlement programs were initiated. As recently as the 1960's, up to 90% of the Central Highlands possessed natural forest cover. However, the forests had receded 57% by 1995, with much of the cleared land classified as barren.

In terms of war damage from bombing and herbicides over a 30 year period, an estimated two million hectares of forests were badly degraded by 13 million tons of bombs, and over 75 million litres of herbicides and defoliants. While there has been substantive recovery of many mangrove forests so-affected, due both to the resiliency of mangrove ecosystems and active re-forestation activities by the Vietnamese Army, recovery of many upland areas like the Aluoi Valley, will require massive future investments of time and resources. The following is a plan for the Aluoi Valley designed to rehabilitate the areas affected by Agent Orange herbicide damage, to stabilize the ongoing deforestation in the area, and to generate economic opportunities for local residents.

5.2 OVERVIEW OF WILDLIFE BIODIVERSITY TRENDS IN VIET NAM

One reason that the flora and fauna of Viet Nam is famous around the world is because of its relatively high biodiversity. The following data[1] show the number of species in different taxonomic groups:

Taxa	No. Species in Viet Nam (SV)	No. of Species in the World (SW)	SV/SW %
Mammals	265	4,000	6.8
Birds	800	9,040	8.8
Reptiles	180	6,300	2.9
Amphibians	80	4,184	2.0
Fishes	2,470	19,000	13.0
Plants	7,000	220,000	3.2

Many species are considered to be threatened or endangered, as documented by the World Conservation Monitoring Centre. The following table provides an estimate of the nationally threatened species in Viet Nam:

Taxa/Category	Endangered	Vulnerable	Threatened	Rare	Indeterminate
Mammals	30	23	1	24	-
Birds	14	6	32	31	-
Reptiles/Amphibians	8	19	16	11	-
Fish	6	24	13	29	3
Invertebrates	10	24	9	29	3
TOTAL	**68**	**96**	**71**	**124**	**6**

While there are various reasons for the reduction in biodiversity in Viet Nam, including over-exploitation, pollution and urbanization, probably the most serious threat is caused by deforestation. In addition to war damage, deforestation has resulted from logging, clearance for agriculture, forest fires, shifting cultivation, collection of firewood, and overgrazing.

A further threat to biodiversity in Viet Nam is caused by habitat fragmentation. As habitat patches are encroached and split, their capacity to support species declines. Larger species of

[1] Data from the World Conservation Monitoring Centre.

wildlife, or species with low density or wide range requirements, are especially vulnerable to such effects.

Under the Ministry of Science Technology and Environment (MOSTE), there is a National Programme designed to conserve biological diversity in Viet Nam. The major components of this programme include:

- to set aside a total of at least 5% of the land area as natural reserves representing viable examples of all major ecosystems in the country;
- maintaining a forest cover of at least 40%, of which at least half should be natural forest, to protect the hydrology of the country; this will necessitate the sedentarisation of shifting agriculture and the development of increased forest cover through natural regeneration and reforestation;
- establishing controls to ensure that utilization of biological resources is done in a sustainable manner following the principles of maximum sustainable yield;
- ensuring that illegal harvesting and trade in wildlife are brought under control;
- controlling the emission of harmful pollution into both natural and human ecosystem through firm regulation and application of EIA (environmental impact assessment);
- active efforts to ensure the preservation of the full range of domesticated varieties of plants and animals in Viet Nam;
- improved capacity for management of wild and captive populations of plants and animals based on scientific research;
- an effective monitoring and data management capability to evaluate the status of species and habitats and identify areas of priority for protection or improved management;
- a greater accounting of natural resource values and ecological functions in the costing of development programmes and projects; and
- increased levels of international cooperation and support.

5.3 REVIEW OF HERBICIDE IMPACTS ON FORESTS AND WILDLIFE

It is estimated that over the period of 1961 to 1971, the US military sprayed over 75 million litres of herbicide over an area equivalent to 10 to 14% of the area of southern Viet Nam (HCL/10-80 1998). A variety of vegetation types were targeted, including coastal mangroves, upland forests, and various crops.

The US military's use of herbicides resulted in the destruction of a significant proportion of tropical forest and agricultural land in Viet Nam (Quy 1992 and *pers. comm.*). Herbicide impacts, in conjunction with use of bulldozers, napalm and saturation bombing resulted in the loss of an estimated 20 million cubic metres of timber, 300 million kg of food, 135,000 ha of rubber plantation and the elimination of much of southern Viet Nam's wildlife and fisheries (Quy 1992).

A generation after the war, the World Bank stated:

> *"One of the least understood and potentially most detrimental aspects of the war is how the modification in species distribution that it caused may have permanently changed the biodiversity of Viet Nam"* (World Bank 1995).

Initial environmental impact assessments associated with herbicide spraying and defoliation began during the war (Tschirley 1969, Orians and Pfeiffer 1970). These assessments were, in part, driven by serious misgivings regarding the ethics of chemical warfare as well as concerns regarding unknown ecosystem impacts. Technically, these early assessments evaluated the impact of defoliation and, in particular, the toxic effects of the herbicide constituents on forests and crops. At the time of these early assessments, many of the environmental/health effects of dioxin contamination were unknown.

The US Society for Social Responsibility in Science funded a March 1969 trip of American biologists to learn about the effects of defoliants (Orians and Pfeiffer 1970, Neilands *et al.* 1972). One of their field trips, for example, was to Rung Sat near Ho Chi Minh City. They concluded that the Rung Sat mangroves were "extremely susceptible" to defoliants. Only one application was necessary to "kill most trees". Most of the areas they visited remained "completely barren" although they had been sprayed several years earlier; they speculated that:

> *"The unusual soil conditions of mangrove forests may result in a failure of the herbicides to be decomposed. If the molecules remain bound to the soil particles, they might influence seed germination for a long time."*

Other concerns were expressed by biologists regarding possible long-term direct toxic herbicide effects and indirect ecosystem effects as follows:

> *"The defoliation program has caused ecologic changes. I do not feel that the changes are irreversible, but complete recovery may take a long time. The mangrove type is killed with a single treatment. Regeneration of the mangrove forest to its original condition is estimated to require about 20 years"* (Tschirley 1969, Neilands *et al.* 1972); and

> *"…. it may take decades for some of the damaged* [upland] *forest lands to recover, partly because the invading bamboo and grasses may be difficult to eradicate, and partly because nutrient minerals previously tied up in forest vegetation may have been released and then leached out of sprayed forests by heavy tropical rain"* (Boffey 1971).

Shortly after the war, Bengtsson (1976) identified two immediate research initiatives required in Viet Nam:

- to document the presence of toxic effects and how remediation should proceed; and
- to determine the best land uses for damaged areas and develop restoration/regreening options.

In October 1980, the Government of Viet Nam established the "10-80 Committee" to execute a national research program investigating the long-term effects of war-time herbicides on the environment and human health and to develop remediation measures. The Committee hosted two international conferences on the long-term environmental and human health impacts of the war in 1983 and 1993 (Cau *et al.* 1994a). There has been a significant in-country effort to assess and remediate chemical war-associated damage to forests with the following objectives as reported in FIPI (1991):

- identify affected areas;
- assess changes to damaged forest ecosystems;
- assess natural regeneration; and
- assess prospects of, and methods for, reforestation of damaged areas.

The environmental consequences of the war remain an important domestic Vietnamese issue and a major research area within the 1991 National Plan for Environment and Sustainable Development of Viet Nam (Can 1992). Nation-wide deforestation, caused in part by the war, has reduced total forest cover from ~44% in 1943 to <25% of the total land area at present, including a high proportion of "bare" land accounting for ~37% of the land area (GOVN/GEF 1994).

There are generalizations on residual herbicide impacts on Vietnamese forest ecosystems (Ashton 1986, FIPI 1991, Quy 1992, Hong and San 1993, Boi and Cham 1994, Ha and Boi 1994, Hong *et al.* 1994), for example:

- trees vary in susceptibility, but all forest types have susceptible species with particularly high proportions of species in mangrove and *Melaleuca* forests;
- spray-resistant trees such as *Irvingia malayana* and *Parinari annamense* were among the only large living trees in some areas;
- invasion of opportunistic species such as bamboos and grasses hamper natural reforestation by their thick ground cover and ultimately change forest composition;
- these new grasslands increased the incidents of wild fires, particularly during the dry season, that killed tree seedlings which greatly slowed or prevented reforestation;

- forest wildlife were killed or migrated from damaged forests;
- the destruction of forest wildlife, including predators, led to rat population explosions that spread diseases to people and damaged crops;
- leaf-drop from defoliation of mangroves provided a short-term pulse of organic matter into local food webs but also increased local biological oxygen demand (BOD) and increased turbidity that reduced phytoplankton growth;
- damaged hydrological characteristics of forests caused decreased water retention properties and increased severity of droughts and flooding;
- exposed topsoils eroded, especially during wet season rains;
- exposed mangrove soils experienced increased temperatures, higher evaporation, higher rates of oxidation, desiccation and pH changes towards acidic sulfate conditions;
- regeneration in unflooded mangrove areas has lagged badly behind flooded mangrove areas which were the preferred areas for reforestation; and
- defoliated mangrove areas permitted easier access, often leading to overharvesting of wood.

In terms of the severity of residual impacts, the Aluoi Valley provides an example of an ecosystem in which there has been minimal recovery from herbicide spraying impacts. Today, it is possible to see accurately where the spraying took place due to the locations where the native forest is absent. It is apparent that successional changes associated with the presence of grasses and scrub plants for all intensive purposes prevent the recovery of the native forests in Aluoi. It is only with active human intervention and vigorous reforestation efforts, that it will be possible for the re-establishment of forests in the now de-vegetated areas of Aluoi Valley and other upland ecosystems in Viet Nam.

Given that forests provide the necessary habitat for wildlife, the future rehabilitation of wildlife in Viet Nam is contingent on the re-establishment of forests from sprayed areas, and on the future implementation of effective wildlife protection programs.

5.4 FORESTS OF ALUOI DISTRICT

The total area of forested lands in Aluoi District is approximately 60,095 ha; "bare" land covers 40,950 ha and "non-forest" land 15,598 ha (Table 5.1). The current known forest, bare land and other land cover types in Aluoi District are presented in Figure 5.3. Aluoi Valley is dominated by bare land (cleared grassland and brushland) and agricultural land on the relatively level valley bottom.

Pre-war forest cover was approximately 80% with high species diversity, as the region straddles two climate types (FIPI 1995). The forest types are dominated by moist, evergreen, broadleaf species. FIPI (1991) reported that most forest cover in the valley was destroyed by herbicides, with slow restoration observed after 18 years; they speculated that over 100 years would be needed for full reforestation. A FIPI forest cover map of the Aluoi Valley created in the early 1990s shows most land in the area, particularly on steep slopes surrounding the valley, to be bare or poor forest. FIPI (1991) concluded that the quickest way to rehabilitate sprayed areas was through active reforestation.

There are no natural gas or electric stoves in Aluoi; most families use firewood for cooking and heating in winter. Deforestation is extensive throughout the valley. Villagers travel considerable distances to collect wood. Recently, the government privatized land ownership to allow people to control their forest harvesting practices. Now that people are in charge of forests, they are responsible for conserving and managing their plots. Nonetheless, there is concern that local forests will be seriously depleted if present harvesting levels continue.

Listed in Table 5.2 are the current planned land uses for Aluoi district; Table 5.3 describes the planned land use types used by FIPI. The map in Figure 5.3 presents the distribution of these land use types in Aluoi District. The need for improvement of water resources is addressed with the "protected area watershed" designation. The need to promote reforestation and forest management is evident by the fact that 58.8% of lands have been designated for some form of forest use (FIPI 1995).

Table A1.8 in HCL/10-80 (1998) lists 271 tree species recorded from Aluoi District forests. The District's forests have relatively high species diversity, but remain under threat from human activities.

5.5 WILDLIFE OF ALUOI DISTRICT

Partial species lists of fish, amphibians, reptiles, birds, and mammals in Aluoi valley, are provided in Tables A1.10 –A1.16 in HCL/10-80 (1998). In view of the degraded state of the forests, present-day residual wildlife populations are sparse compared to those which existed prior to war activities in Aluoi Valley.

The reduction in wildlife populations of Aluoi is reflected in data compiled by FIPI (Table 5.4) which compares the pre-1952, 1982, and 1995 occurrence of mammals in the Aluoi Valley. Reductions of large mammals are especially pronounced in the Aluoi Valley due to the decimation of the forests, in concert with ongoing hunting and other human activities.

5.6 HUE PROVINCIAL FORESTRY DEPARTMENT PROPOSED PROJECTS

The Hue Provincial Forestry Department has developed specific proposals for forestry and wildlife projects in Aluoi District and some of the adjacent areas (e.g., adjacent to Route 49 which runs between Hue and Aluoi). To date, only meager financial resources have been allocated to support the implementation of the proposed projects. Rehabilitation of forestry and wildlife biodiversity will form a key component of a future environmental restoration and improvement program for Aluoi District. As a contribution to this effort, HCL has translated and reviewed the relevant Hue Provincial Forestry Department Proposals (presented in Appendix A3).

National forestry initiatives in Viet Nam provide the context for Provincial and District-level activities. The most recent national project, approved by the National Assembly in 1998, is the Five Million Ha Forest Project which will plant five million ha over the period 1998 to 2010. Under the Five Million Ha Project, two of the five million ha of new forests are allocated for protection, while the remainder is allocated for commercial purposes. The project is faced with a number of challenges, the largest of which is the incomplete investigation and planning of forest land use. Inventory data are dated and require updating: in 1992, analysis revealed that Viet Nam had approximately ten million ha of bare land and hills. Funding is also a major problem, as it is estimated that the five million ha forest project will require 35 trillion Vietnamese Dong (VND) ($US 2.6 million). To date, only a small percentage of the preferential credit loans authorized for afforestation in 1999 have been released. Other National forestry programs include Program 135, which has invested VND 30.7 billion ($US 2.2 million) in 521 particularly impoverished communes, including Program 327 which was still in effect in 1999.

Appendix A3 outlines five specific Vietnamese proposals for future forestry rehabilitation work and preliminary biodiversity investigations. The following proposals are described:

Proposal	Implementation Schedule
Reforestation for protection of Aluoi District	1999-2010
Forest construction for protection of A Sap watershed	1999-2010
Afforestation for protection of Route 49	1999-2030
Conservation of animals, plants, and natural forest	1999
Biodiversity investigation of Upper Bo River	1999-2000

5.7 FORESTRY AND WILDLIFE BIODIVERSITY REHABILITATION PLAN

There are several compelling reasons why forestry rehabilitation and biodiversity protection is urgently required in the Aluoi Valley:

- there has been only minimal ecosystem recovery from the devastating impacts of herbicide spraying which occurred over 30 years ago; without some form of active human intervention (e.g., reforestation), there will be prolonged impairment of the ecosystem which will continue to limit social and economic development opportunities in the Aluoi Valley;

- in November of 1999, there was a devastating flood in Hue province in the vicinity of the Huong River, one of the de-vegetated watersheds which has not recovered from herbicide spraying; the severity, duration, and magnitude of flood events in Aluoi and elsewhere in Hue Province, is directly related to the absence of tree cover, and the de-vegetated status of the watersheds;

- landslides, associated with the absence of tree cover in steep areas, are a continuing problem that create economic hardships (e.g., blockage of the key Route 49 transportation route) for residents of Aluoi;

- continuing extractive pressure within existing forested areas needs to be stabilized and managed in order to arrest the continuing deterioration of forest lands;

- improved forestry and biodiversity management methods are required in order to enhance economic opportunities for Aluoi residents; and

- a well-designed and well-monitored forestry rehabilitation and biodiversity protection program in Aluoi, Viet Nam will enable the development of appropriate technology for future rehabilitation of other war-damaged areas of central Viet Nam (e.g., Quang Tri Province).

A 5-year duration environmental mitigation project for Aluoi is described in the August, 1999 document "To invest in environmental rehabilitation and social infrastructure development for the mitigation of war-effects in Aluoi District, Thua Thien Hue Province". This proposal was prepared and approved by the Peoples' Committee of Thua Thien Hue and the Peoples' Committee of Aluoi. Within the proposal, a Forestry Component is presented that would be undertaken to rehabilitate the damaged forests of Aluoi District.

The proposed Forestry Component (total budget of VND 15,000 million [$US 1.1 million]) targets the A Sap River watershed. The A Sap River covers a total of 43,868 ha, of which only 49% is forested. The watershed is subject to alternate drought and flood conditions due to the absence of protective tree cover. The forestry plan involves:

- protection of 17,716 ha;

- rehabilitation of 7,572 ha;

- planting of 1,861 ha;

- establishment of 1,335 ha of forest gardens and farms; and

- resettlement of 278 households to fulfill the four tasks above.

The planting will target vacant lands with slope of $< 25^{o}$. A 5-yr duration project is envisaged for implementation between 2000-2005. The Aluoi Forest Farm is identified as the executing agency responsible for the management of the project.

Restoration of the forests and biodiversity of Aluoi District to a semi-natural status, resembling that which existed prior to intensive herbicide spraying will involve a massive effort in future, and will not be achieved at low cost. It is debatable whether the Aluoi Valley ecosystem can ever be restored to something which closely resembles its previous, pre-sprayed status. A more practical approach involves support of Vietnamese agencies to re-establish forest cover in priority strategic areas within Aluoi District. Accordingly, the A Sap River watershed project, described above, provides a useful focus for future forestry and wildlife biodiversity rehabilitation over the short term.

6.0 CONCLUSIONS

A. SOILS

1. A "hot spot" for Agent Orange dioxin contamination (specifically TCDD) was found at the former A So US Special Forces base in the Aluoi Valley in 1997 and was confirmed in 1999. Some composite soil samples from the base area exceeded agriculture and residential land use standards for human health protection in Canada (350 ppt Total TEQ).
2. No additional hot spots were found in 1999, although AO dioxin (TCDD) was found in soils throughout the valley. Composite soil samples analyzed from two other US Special Forces bases in the Aluoi Valley did not exceed Canadian residential/agricultural land use standards (350 ppt Total TEQ based on protection of human health); many exceeded Canadian agriculture rehabilitation standards (i.e., 10 ppt Total TEQ) based on environmental protection criteria.
3. There was no correlation between TCDD levels and soil particle size, and total organic carbon in the Aluoi Valley.
4. Most soil contamination was clearly associated with the 2,3,7,8-T4CDD Agent Orange congener, not industrial sources of dioxin.

B. HUMAN FOOD CHAIN

1 Domestic ducks in the A So base area had AO dioxin levels in their fat which would, in western jurisdictions, trigger a human consumption advisory process (including risk assessment/risk management) and/or probable prohibition of selling such ducks. The contamination contributed to the human diet by ducks adds to that found in 1997 for fish (up to 52 ppt).

2 Samples of pig, cow fat and chicken egg that were tested had AO dioxin levels below western standards for human consumption.

3 Rice and manioc components of the food chain did not have detectable levels of AO dioxin.

C. HUMAN BLOOD

1. Testing in 1999 confirmed the elevated levels of AO dioxin in whole human blood from the A So area, previously found in 1997.
2. People from the area of the A So base area have significantly higher TCDD levels than people from more distant areas in the valley.

3. TCDD levels were higher in the blood of A So area residents than most reported background levels for unexposed people from industrialized countries.

4. TCDD levels in blood of A So residents are higher than most residents of industrial countries who have been exposed to TCDD (e.g., herbicide plant workers, metal plant workers, chemists, etc.).

5. Tests in 1999 confirmed 1997 findings of elevated levels of AO dioxin in blood of people from the A So area who were born after the war.

6. Males had clearly higher levels of AO dioxin in their blood than did females whether born before or after the war. The difference is likely due to females eliminating TCDD through breast milk. Higher levels in males probably result from greater contact with contaminated earth while ploughing, planting, and digging fish ponds. Males also have a higher caloric intake.

D. HUMAN BREAST MILK

1. There were elevated levels of AO dioxin in human breast milk from the A So base area in 1999 (up to 19 pg/g).

2. There were significantly higher AO dioxin levels in breast milk from the area of the A So base, relative to the reference areas situated at greater distance from the former base.

3. Samples from the A So area were generally higher in TCDD than levels reported in studies elsewhere in the world.

4. A wide range of AO dioxin levels was found for individual breast milk samples, suggesting that such a range probably exists in individual blood samples.

5. Levels of DDT and its metabolites in breast milk were similar to other areas of the world. Such levels are not expected to contribute significantly to increased risk to health in the valley.

E. ENVIRONMENTAL AND HUMAN TISSUE RELATIONSHIPS

1. Elevated levels of AO dioxin in human blood and breast milk in the A So region are correlated with high levels in soil, fish, and ducks.

2. Food chain contamination appears to be a significant contributor of TCDD in A So residents who were born after the war.

3. Local contaminated foods likely contributed to breast milk contamination.

4. Other probable contributing factors for high levels of AO dioxin in blood and breast milk were contact with contaminated soil as a result of living in dwellings with dirt floors, ploughing fields, and digging and operating fish ponds.

5. With increasing distance from the A So base, there is a general decrease in AO dioxin in soils, domestic fish and ducks, and human blood and breast milk. The Hong Van commune, at greatest distance from A So, had the lowest levels of environmental, human blood and milk AO dioxin contamination.

F. HUMAN HEALTH EFFECTS

1. Health data compiled from four communes in the Aluoi Valley show a higher rate of birth defects in people living closest to the A So commune, compared to people living in communes more distant from the former US Special Forces base at A So.
2. Multi-elemental analysis of water samples indicated that parameters are within Canadian drinking water guidelines for all resident groups in the valley.
3. Analyses of potential contaminants in cooking oils eliminated this food item as a confounding factor in the study of dioxin exposure.
4. Pesticide use is low in the valley; pesticide levels are low in soils and breast milk; it is unlikely they are a confounding factor in this dioxin investigation.
5. There do not appear to be significant nutritional differences between the communes studied in the Aluoi Valley.
6. Public health data collected to date appear to be consistent with a dioxin effect, whereby dioxin exposure is hypothesized to cause elevated rates of birth defects. However, more research related to dioxin health effects, and further elimination of other confounding factors, is required before definitive conclusions can be reached.

G. GENERAL SUMMARY CONCLUSIONS

1. The presence of elevated concentrations of Agent Orange dioxin (TCDD) in the blood and breast milk of certain residents of Aluoi District, including contemporary animal food products (e.g., duck fat and fish fat), confirms that dioxin contamination and uptake is a present-day and not a historical phenomenon. Further, the occurrence of Agent Orange dioxin in the blood of younger residents (<25 years old), born long after the end of herbicide spraying, confirms ongoing human uptake of dioxin. Continuing dioxin contamination in Aluoi District is most prevalent in the vicinity of A So commune, adjacent to the former US Special Forces base.

2. Mitigation measures are required to manage dioxin contamination to reduce future exposure of residents in A So commune. The Health and Environmental Impact Mitigation Plan presented in Section 4.0 provides a practical approach that outlines various short-, medium-, and long-term strategies that can be implemented to reduce human exposure and public health risks.

3. New, cost-effective technologies are needed to decontaminate large volumes of dioxin-contaminated soils in Viet Nam. High temperature incineration is not a practical and

economical mitigation approach, due to the large volume of contaminated soil requiring treatment.

4. Most Aluoi District soil samples contained measurable traces of dioxin which can be attributed to Agent Orange spraying, 1965 - 1970. However, with the exception of samples adjacent to former US Special Forces bases, most soil samples were below 10 pg/g (ppt), the dioxin concentration in BC Canada that serves as the remediation standard to define safe agricultural soils. Based on this observation, residual dioxins in non-base areas of southern Viet Nam that were sprayed with military herbicides, are probably safe for human habitation and growing food crops; however, confirmatory investigations are recommended.

5. There are hundreds of former US and south Vietnamese military installations and base sites in southern Viet Nam where herbicides were handled, stored, sprayed along base perimeters, and possibly buried. In order to protect present-day public health adjacent to these areas, a systematic dioxin survey of all former military installations where Agent Orange and other herbicides were utilized is recommended, including areas where residual contamination may be present.

6. There is an opportunity to build on the comprehensive environmental work that has been carried out in Aluoi District since 1994, and to further develop environmental assessment and mitigation approaches that can be widely applied in other war-affected areas of Viet Nam, Lao PDR, and Cambodia. The objective would be to enhance development opportunities through the mitigation of war impacts. There is much additional work that is required in Aluoi District; for example, there are currently no plans to deal with the very large volume of unexploded ordnance that continues to injure and kill Aluoi District residents. Viewed from this perspective, Aluoi District is a pilot area for environmental improvement designed to alleviate war-related poverty through increasing economic and social development opportunities.

7. Viet Nam provides the best natural laboratory in the world to refine our understanding of the environmental and human health impacts of dioxins. Comparative studies of dioxin-contaminated sites in southern Viet Nam with similar (non-sprayed) sites in northern Viet Nam, can be carried out to refine our scientific understanding of dioxin effects.

7.0 RECOMMENDATIONS

1. The Agent Orange Health and Environmental Impacts Mitigation Plan developed for the Aluoi Valley should be fully implemented immediately.

2. Further assessments of dioxin contamination are required in the vicinity of all former US and south Vietnamese military bases/facilities in southern Viet Nam, where use/storage of Agent Orange during the war likely occurred; these assessments would determine the level of dioxin contamination related to Agent Orange, and ultimately reduce human exposure. Studies of other geographical areas in Viet Nam over which heavy Agent Orange spraying occurred (aerial and land-based applications) are also required. Such studies should consist of comprehensive food chain assessments, including human populations.

3. Where additional sites are identified as being contaminated with dioxin, health and environmental impact mitigation plans should be developed and implemented.

4. Studies of human health should be carried out in communes/villages near areas where soils or the human food chain are found to be contaminated with Agent Orange dioxin. Comprehensive epidemiological studies are required in Viet Nam to assist in determining the relationship between environmental contamination with Agent Orange dioxin and human health effects.

5. If higher than normal birth defects, cancers or other health effects are found to occur in contaminated areas, special health clinics or treatment centers should be established to treat people affected by dioxin contamination. In the Aluoi Valley, the existing health clinic at A Ngo should be consolidated and improved to support adjacent villages, rehabilitate any handicapped people and provide advice to local people on health issues related to dioxin contamination.

6. Where clearing programs for unexploded (UXO) ordnance are underway in Viet Nam, parallel studies on soil contamination should be carried out to ensure that disturbance of contaminated soils in these areas does not result in the creation of unacceptably high dioxin levels through re-mobilization of the contaminant in the environment. Such disturbance could make dioxin more accessible to elements in the local food chain and humans.

7. Sediment cores should be collected and analyzed from coastal areas which drain heavily sprayed regions of former major US and south Vietnamese military bases/facilities in southern Viet Nam. Sediment core analyses in British Columbia (Canada) have shown stratified deposition of dioxins over time. Activities such as dredging or trenching in deposition areas could resuspend dioxin into the water column and potentially into the food chain.

8. Vietnamese foresters have developed sound techniques for rehabilitating upland forests sprayed with Agent Orange in southern and central Viet Nam. Some upland forest rehabilitation is now taking place in the country. These activities should be expanded significantly with funding from international agencies. Community forestry projects and flora/fauna biodiversity programs should be integral to these rehabilitation efforts in upland forests. Programs have been successful in other regions of Viet Nam where local people have been given ownership and management control of land and forest areas, in return for commitments not to destructively cut or burn forests for farmland. Such undertakings could include planting trees for lumber and industrial use, and managing grasslands for livestock. The government of Viet Nam is prepared to provide complimentary financial and temporary food source support for families willing to participate in such forest rehabilitation programs.

9. Viet Nam, with its heavily sprayed areas in the south and reference areas in the north (where no spraying took place), represents an excellent location for the study of human health and environmental effects caused by exotic chemicals, such as Agent Orange dioxin. Present world standards for soil and human food contaminated with dioxin represent only best estimates for human health safety. However, billions of dollars of industrial investment decisions, clean-up requirements, and decisions regarding human health protection, are being based on these estimates. These standards would be more effective and credible if they were based on more comprehensive, hard scientific data. Viet Nam may be considered one of the best locations in the world to find solutions to the many questions and concerns regarding dioxins in the environment, and their effects on human health.

10. Based on the levels of environmental contamination by Agent Orange dioxin found during this investigation, there is an urgency to carry out further programs to reduce the risk to human health posed by contaminated sites in Viet Nam.

Many of the recommendations presented above were also presented in the HCL/10-80 1998 report. Studies in 1999 have confirmed initial results, and further delineated dioxin contamination in the environment and human food chain. Results of this recent investigation confirm the urgent need for implementation of an impacts mitigation strategy in the Aluoi Valley, Viet Nam.

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