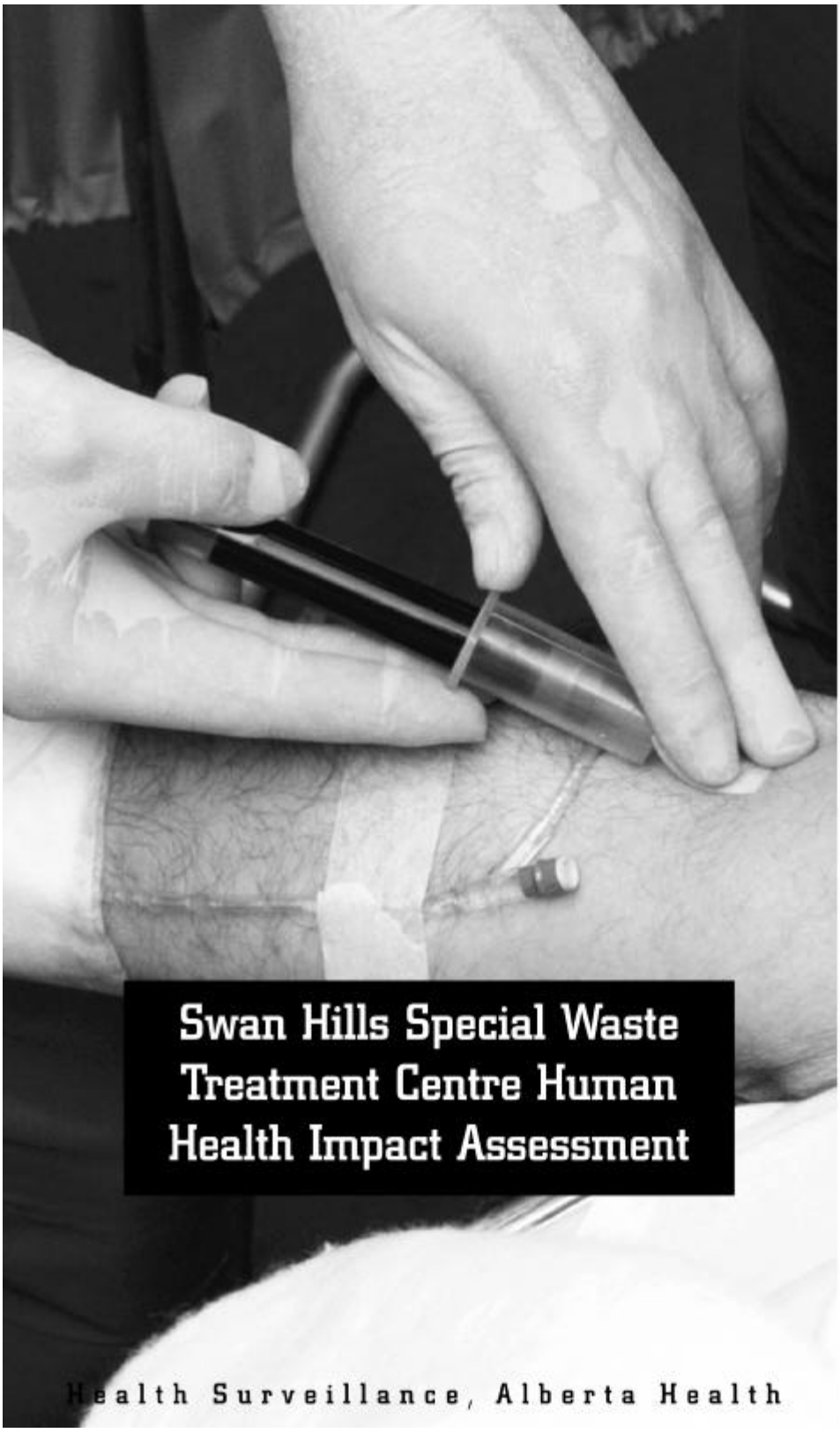

Swan Hills Special Waste Treatment Centre Human Health Impact Assessment

REPORT

October 1997

Health Surveillance, Alberta Health

Swan Hills Special Waste Treatment Center Human Health Impact Assessment

Volume 1: Final Report

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Executive Summary

The Swan Hills Waste Treatment Centre (SHWTC) is a facility for the safe disposal of special wastes located approximately 12 kilometres north-east of the Town of Swan Hills. On October 16, 1996, a malfunction of a transformer furnace was discovered which had caused the flow of a portion of process gases containing polychlorinated biphenyls (PCBs), dioxins and furans (PCDD/Fs) into the ambient air. In order to estimate human exposure to these chemicals, a detailed human impact assessment was carried out by Alberta Health from December 1996 to October 1997. The specific goals were to evaluate the potential for human exposure to PCBs and dioxins/furans through wild game and fish consumption and to estimate the existing levels of these contaminants in the human population.

The current report describes:

1. sampling and chemical analyses of fresh and frozen deer and moose samples, and fish samples collected from the vicinity of the SHWTC;
2. sampling and chemical analyses of target chemicals in human blood samples;
3. a questionnaire interview process and resulting estimates of dietary patterns of the potentially exposed population;
4. the estimation of the daily intake of PCBs and dioxin/furans expected in segments of the population through wild game and fish consumption, comparisons of these figures with relevant guidelines, and consumption limits based upon these guidelines; and
5. recommendations for further monitoring and research activities.

Briefly, the results of the study indicate that :

1. levels of PCBs and PCDD/Fs were elevated in deer and moose from the area immediately surrounding the Swan Hills Waste Treatment Centre;
2. levels of PCBs and PCDD/Fs were elevated in the liver and muscle tissues of brook trout sampled from Chrystina Lake compared to northern pike sampled from Roche Lake and Chip Lake;
3. human blood serum levels of PCBs and PCDD/Fs for study participants were below the levels reported in other jurisdictions, but follow similar age and gender patterns;

4. human blood serum levels of PCBs and PCDD/Fs for residents of Swan Hills and its surrounding communities did not exceed the levels found in Edmonton residents;
5. no differences in levels of PCBs and PCDD/Fs were observed between individuals who consumed wild game and fish from the Swan Hills area and those who did not; and
6. about forty percent of local residents consume local wild game and fish although only a small portion of the residents consume large quantities.

Based on estimated daily intake and exposure ratio calculations, daily and weekly consumption of wild game meat and fish taken near the SHWTC may result in increased exposure and potential health risk over a person's lifetime. Thus, restrictions on the consumption of wild game and fish contaminated with PCBs and dioxins/furans are warranted.

The following consumption guidelines are recommended:

1. limit consumption of wild game taken from a 30 km radius of the SHWTC to 13 ounces (370 grams) per month
2. avoid eating organ meat or using fat harvested from within a 30 km radius of the SHWTC
3. pregnant or breast feeding women should avoid eating wild game taken from within a 30 km radius of the SHWTC
4. young children should avoid eating wild game taken from within a 30 km radius of the SHWTC
5. limit consumption of fish taken from Chrystina Lake to 6 ounces (178 grams) per week
6. avoid eating fish organs or using fat harvested from Chrystina Lake
7. pregnant or breast feeding women should avoid eating wild game taken from Chrystina Lake
8. young children should avoid eating fish taken from Chrystina Lake

The next phase of the Swan Hills health assessment is the implementation of a longer term human health monitoring plan which includes continued environmental monitoring, on-going human health surveillance, and research activities. Alberta Health, Aspen and Keeweetinook Regional Health Authorities, Alberta Environmental Protection and Alberta Labor, in collaboration with Bovar Waste Management, will ensure the implementation of further human-exposure-related activities including fish monitoring, wildlife monitoring, human blood monitoring as warranted, health outcome monitoring (including special risk groups as warranted), specific research initiatives, and the establishment of a joint computerized database of monitoring information. The risk management process will include review and interpretation of information by an independent Science Advisory Committee and by the Provincial Health Officer and Medical Officers of Health, timely dissemination of information, and the ongoing review of fish and game consumption advisories.

ACKNOWLEDGMENTS

To meet the Alberta Health's mandate and in response to public concern on accidental and fugitive emissions of PCBs and dioxins/furans from the Swan Hills Waste Treatment Center, the Health Surveillance branch of Alberta Health conducted the Swan Hills Human Health Assessment between December of 1996 and October of 1997. The study was led by Senior Team Leader Stephan Gabos. The study would not have been possible without the participation and substantial efforts of numerous members from various groups and reviewers (listed below). The final report was prepared by Weiping Chen and Donald Schopflocher. The Alberta Health Study Team conducted the study design, sampling strategies, field collection, data analysis, data interpretation and presentation. The Science Advisory Committee provided direction, technical information, reviews and recommendations throughout the study. The Public Health Advisory Committee, chaired by Dr. John Waters, carried out the health risk management function. The Communications Branch, Alberta Health developed the communication strategies.

Laboratory analysis was conducted by MAXXAM Laboratory under the overall coordination of project manager Dr. Sub Ramamoorthy. Dr. Ken Froese and Dr. Siu Chan provided independent reviews throughout the study. The Alberta Health Study Team was substantially helped in its activities by strong support from Alberta Environmental Protection, Alberta Agriculture, Alberta Labour, the Regional Health Authorities, Health Canada and the Canadian Red Cross Society. The assistance by wild game meat donors, blood donors and all study participants from local communities is gratefully acknowledged. Involvement and cooperation from members of the Swan Hills community, the Lesser Slave Lake Indian Regional Council, BOVAR Waste Management, Edmonton Friends of the North, and local citizens are gratefully appreciated.

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1. INTRODUCTION

The Swan Hills Waste Treatment Centre (SHWTC) is a facility for the safe disposal of special wastes. It is located approximately 12 kilometres (km) north-east of the Town of Swan Hills, at the geographic centre of Alberta (54^{o} N, 115^{o} W) (Figure 1-1). During 1996, several odour incidents, accidental emissions and spills were reported by the management company (BOVAR, Inc.). On October 16, 1996, a malfunction of a transformer furnace was discovered which had caused the flow of a portion of process gases containing polychlorinated biphenyls (PCBs), dioxins and furans (PCDD/Fs) into the ambient air. A preliminary risk assessment indicated that this incident might have resulted in an unacceptable exposure risk to inhabitants in the immediate area. Therefore, as a precautionary measure, Alberta Health issued a food consumption advisory for wild game and fish taken within a 30 km radius of the plant in December of 1996.

In order to estimate actual human exposure and to evaluate the effectiveness of public health interventions, a detailed human impact assessment was carried out by Alberta Health from December 1996 to October 1997. The human impact assessment was designed to document the current status of exposure and to address questions about population exposures arising from accidental and fugitive emissions of PCBs, dioxins and furans from the waste treatment plant. The following questions were specifically addressed:

- To what extent are human food sources in the Swan Hills area contaminated with PCBs and dioxins/furans? What is the geographic range of this contamination?
- To what extent does the consumption of these foods pose health risks?
- Do individuals in the Swan Hills area show evidence of exposure to PCBs and dioxins/furans?
- What public health advisories need to be established for public safety?

Figure 1-1 Location of Swan Hills

2. STUDY FRAMEWORK

A total human exposure model provided the framework for the human impact assessment (Figure 2-1). In general, human exposure is any contact between a substance, biological agent or radiation and an individual or community. While all people are exposed to low levels of contaminants in air, food, drinking water, and consumer products, sufficiently high levels of contaminants can interfere with normal biological functions. Such effects can range from very subtle biochemical changes to clinical disease. Determining the risk posed by environmental contaminants to populations requires knowledge about the following fundamental components:

- source(s) of contaminants;
- transport of agents in the environment;
- exposure of individuals and population to agents;
- doses received by those exposed (biological markers of exposure);
- early biological effects resulting from these doses (biological markers of effect); and
- health outcomes (clinical disease).

Since the output of each component in the chain of events serves as input to the next, the lack of information on any one component impairs the ability to make accurate assessments of the associated population health risks. It should be noted that present knowledge of health effects caused by long term exposure(s) to low levels of contaminants is based on incomplete toxicological and epidemiological information. Thus, many questions cannot be definitively answered by current health assessments.

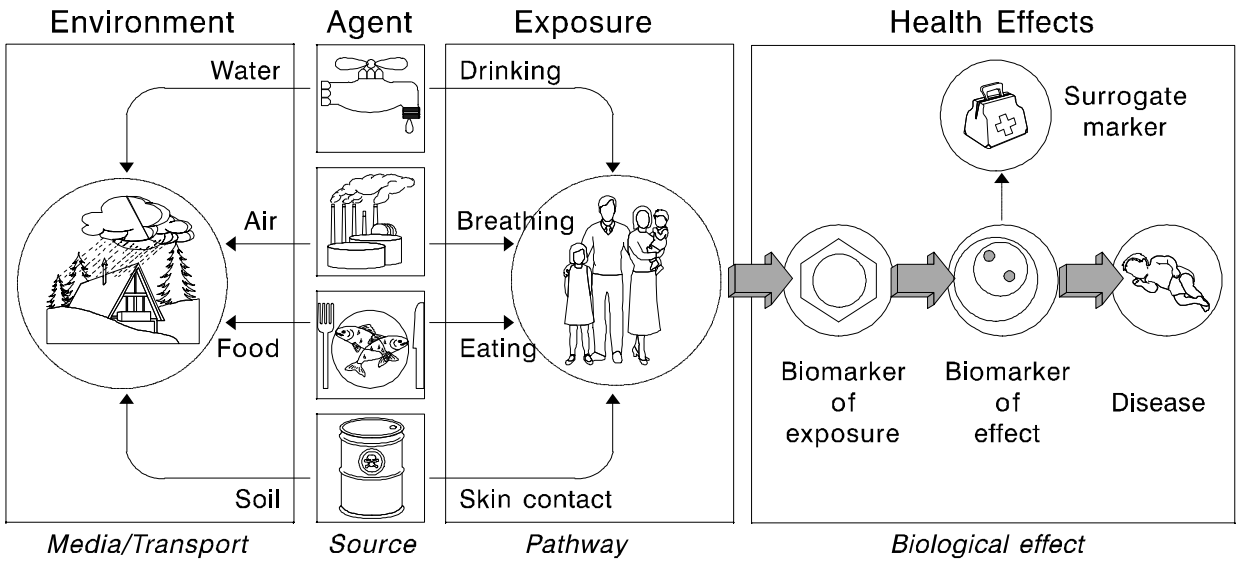

Figure 2-1 Basic Health Risk Assessment Framework

The specific goals of the current study were to evaluate the potential for human exposure to PCBs and dioxins/furans through wild game and fish consumption and to estimate the existing levels of these contaminants in the human population. The study was designed to meet the requirements of public health intervention in the short term. To serve medium and longer term surveillance and research objectives, a plan for further monitoring will need to be developed. In line with the mandate and responsibilities of Alberta Health, assessment emphasized human-related exposure and focused on selected components of a site-specific health risk assessment (Figure 2-2). Separate ecological exposure assessments were carried out by Alberta Environment Protection and by BOVAR Inc. Highlights of these assessments are presented in Appendix A.

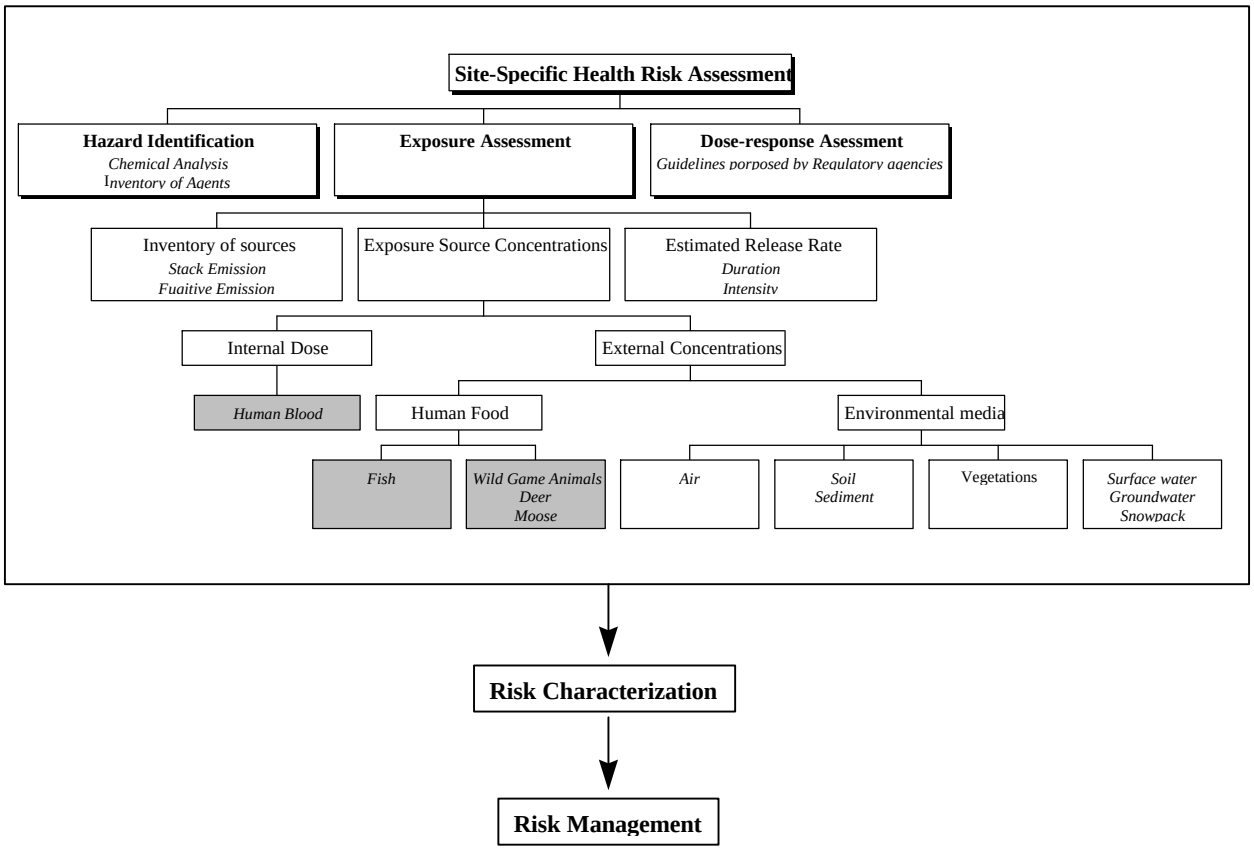

Figure 2-2 Framework of Site-Specific Health Risk Assessment

Three measurement methods were used (Figure 2-3). Environmental concentration measurement was used to assess contaminant concentrations in potentially exposed food sources; human body burden measurement was used to assess contaminant concentrations in the blood of potentially exposed human beings, and survey measurement was used to assess the demographic characteristics, dietary habits and activity patterns of potentially exposed human beings. For the environmental concentration and human body burden components, a sampling strategy was developed, samples were collected, and laboratory analysis of the samples was conducted. Summary measures were then calculated and analyzed using statistical methods. For the survey component, a sampling strategy was developed, interviews were conducted, and the data was analyzed to provide consumption rate estimates for potentially exposed food sources. Finally all information was combined in order to review and revise the current food consumption advisory. The remaining sections of this report present the detailed results of these activities.

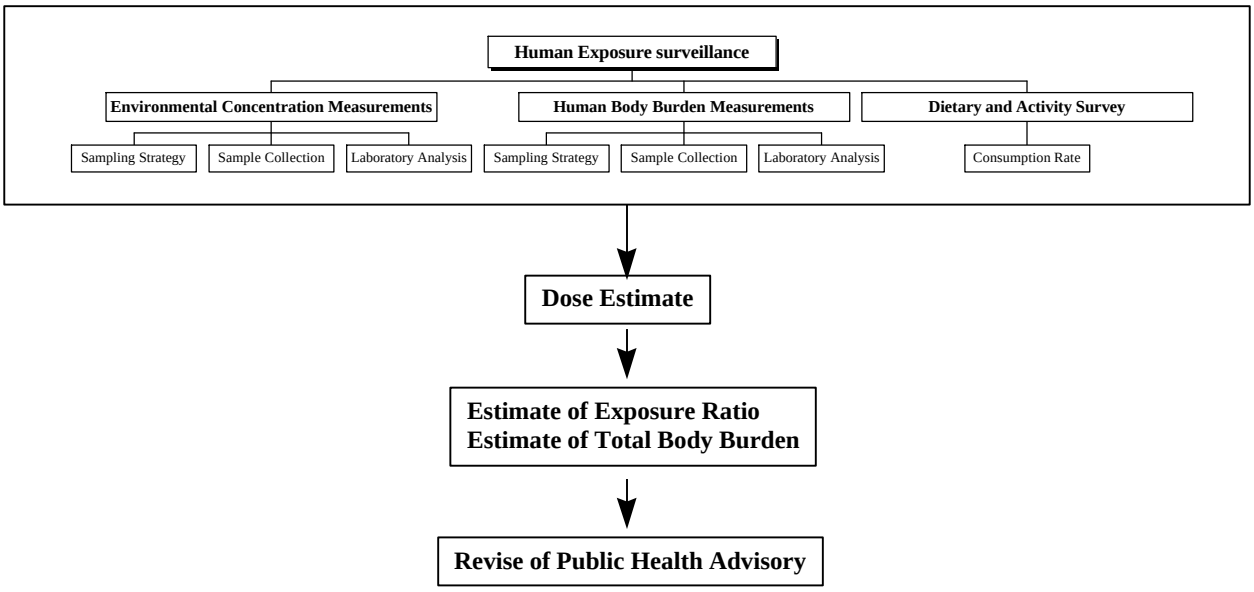

Figure 2-3 Study Design for Measuring Human Exposure

Section 3, *Environmental Monitoring*, describes the sampling and chemical analyses of fresh and frozen deer and moose samples, and fish samples collected from the vicinity of the SHWTC. These analyses were used to develop an estimate of exposure potential through consumption of these foods.

Section 4, *Human Tissue Monitoring*, describes the sampling and chemical analyses of target chemicals in human blood samples. This analysis was used to assess previous exposure and internal doses in the population.

Section 5, *Diet and Activity Survey*, describes the questionnaire interview process and the resulting estimates of dietary patterns of the potentially exposed population.

Section 6, *Estimation of Daily Intake and Exposure Ratio*, combines the information discussed in sections 3,4 and 5 to estimate the daily intake of PCBs and dioxin/furans that would be expected in segments of the population through wild game and fish consumption, provides comparisons of these figures with relevant guidelines proposed by different regulatory agencies, and develops consumption limits based upon these guidelines.

Section 7, *Risk Management and Communication*, describes the context of the current study and discusses specific issues of interpretation of, communication of, and compliance with Public Health Advisories.

Finally, Section 8, *Long Term Monitoring Plan*, presents recommendations and plans for further monitoring and research activities stemming from the study.

3. ENVIRONMENTAL MONITORING: WILD GAME AND FISH

The purpose of environmental monitoring was to estimate the concentrations of contaminants in wild game and fish used for human consumption, and to establish the geographic extent of contamination in wildlife surrounding the SHWTC site.

3.1 Materials and Methods

3.1.1 Samples

3.1.1.1 Fresh Deer

Meat samples from deer (white-tail and mule) collected within a 30 km radius of the plant were selected for wild game monitoring. Animals were obtained from other locations in Alberta to be used as study control samples. Muscle, liver and fat samples were targeted for analysis.

One deer was collected near the fence of the SHWTC by BOVAR, Inc. on November 23, 1996. Field collections of additional deer were conducted by Alberta Environmental Protection in cooperation with local hunters during January and February 1997 under a standard protocol (Appendix B). Three white-tail deer were collected at distance 10 km, 20 km, 30 km to the east of the SHWTC, respectively. Figure 3-1 illustrates the collection locations of deer taken within a 30 km radius of the SHWTC.

One control deer was collected by BOVAR, Inc. in November 1996. Eleven road-kill adult deer carcasses (7 white-tail and 4 mule deer) were collected from outside the Swan Hills area. Collection locations included Alberta Beach, Calgary, Lethbridge, Medicine Hat, Ministik, North of Consort, and Redcliff.

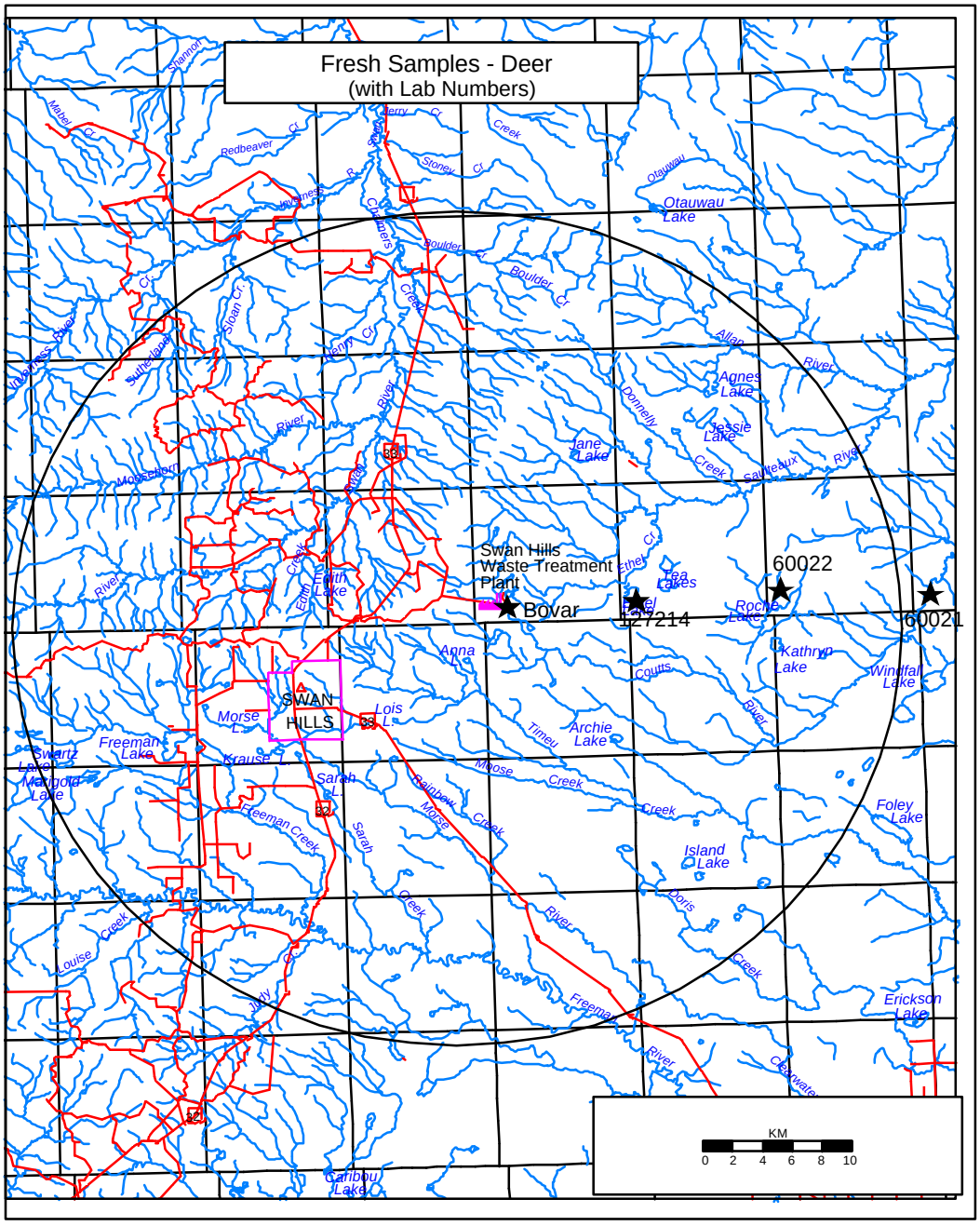

Figure 3-1 **Locations of Fresh Deer Collection in the Swan Hills Area**

For each animal, information was recorded on the species, sex and age, date and location of collection, and the types of specimens extracted. Each specimen weighed approximately 500 g. Teeth were used for aging by tooth cementum analysis. The age of the animals ranged from 2.5 to 6.5 years.

A total of 42 deer specimens were collected (Table 3-1). The six specimens collected by BOVAR, Inc. consisted of a muscle sample, a liver sample and a fat sample from each of two animals. The thirty six deer specimens collected by Alberta Environmental Protection consisted of 14 muscle samples, 14 liver samples and 8 fat sample samples.

Table 3-1 Summary of Fresh Deer Samples

Collection Agency	Scientific Name	Muscle	Liver	Fat	Location	Total
Alberta Health	Whitetail Deer *Odocoileus virginianus*	3	3	2	Swan Hills	8
BOVAR. Inc	unknown	1	1	1	Swan Hills	3
Alberta Health	Whitetail Deer *Odocoileus virginianus* or Mule Deer *Odocoileus hemionus*	11	11	6	Control areas	28
BOVAR. Inc.	Unknown	1	1	1	Control area	3
Total		16	16	10		42

The specimens collected by BOVAR, Inc. were shipped to the Enviro-Test Laboratory for analysis in December 1996. The specimens collected by Alberta Environmental Protection were placed in clean polyethylene bags and kept frozen (at -18 °C) in the Food Laboratory, Animal Health Laboratory Branch, Alberta Agriculture. On March 11, 1997, the specimens were packed with dry-ice and shipped to the MAXXAM laboratory for analysis.

3.1.1.2 Freezer Deer and Moose Meats

Deer and moose collected by hunters from areas surrounding the SHWTC and preserved in home freezers were also selected for analysis.

In December, 1996, Alberta Health issued a public notice requesting that individuals who had hunted in the Swan Hills area after October 1996 notify their Regional Health Authority if they could provide meat samples for analysis. The Environmental Health Service in cooperation with the Regional Health Authority (RHA) undertook wild game meat collection between January and March 1997 under a standard protocol (Appendix C). Approximately 40 people who had offered to provide samples of meat and who had taken animals between

October 1996 and February 1997 from within an approximately 30 kilometer radius of the SHWTC were contacted by RHA Health Inspectors who made an appointment to pick up the samples.

Each sample weighed approximately 500 g. and was packed in an individual zip-lock freezer bag with an identification code. Each meat donor completed a form for each sample submission and marked the sampling location on a map in relation to the SHWTC site (Figure 3-2). Information was recorded on the sample owner (name, date, address and telephone number) and on the sample (species, age and sex of animals, sample weight, cut of meat, conditions of sample e.g. fresh, frozen, thawed, date the animal was killed, location of kill site, and wildlife identification number, if applicable). The completed forms and maps were sent to the Manager, Environmental Health Services, Alberta Health.

A total of 60 deer and moose specimens were collected (Table 3-2). The collected specimens consisted of 14 samples of deer meat (11 muscles, 2 livers and 1 heart) and 46 samples of moose meat (37 muscles, 6 livers, 1 fat, 1 heart and 1 kidney). Thirty four of the 60 samples were collected during October, November and December of 1996. The remaining 26 samples were obtained during January and February of 1997.

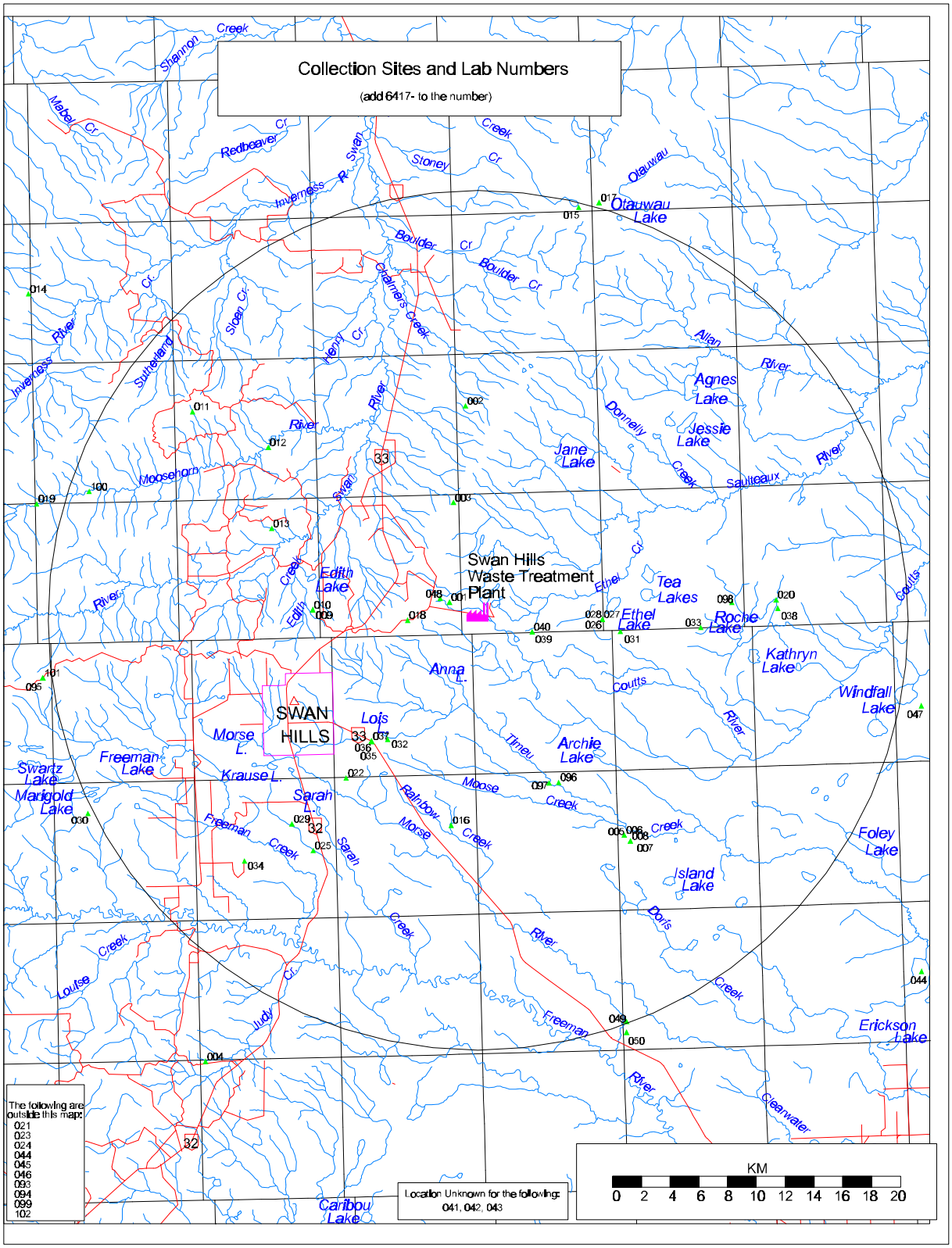

Figure 3-2 **Locations of Freezer Meat Collection in the Swan Hills Area**

Table 3-2 Summary of Freezer Meat Sample

Species	Scientific Name	Muscle	Liver	Fat	Heart	Kidney	Total
Deer	Whitetail Deer *Odocoileus virginianus* or Mule Deer *Odocoileus hemionus*	11	2	0	1	0	14
Moose	*Alces americana*	37	6	1	1	1	46
Total		48	8	1	2	1	60

All specimens were shipped to the Food Laboratory, Animal Health Laboratory Branch, Alberta Agriculture and stored frozen until ready for shipping to the laboratory. Fifty specimens were packed with dry ice and shipped to the MAXXAM laboratory for analysis via next-day courier on February 21 and an additional 10 specimens were shipped on March 11, 1997.

3.1.1.3 Fish

Fish sampling strategies were developed by Alberta Health in cooperation with the Science Advisory Committee and Alberta Environmental Protection. Selection of target species was based on the following considerations:

1) the species of fish consumed most frequently in the Swan Hills area;
2) the species which are of recreational or traditional value;
3) the species which have the potential to bio-accumulate high concentrations of PCBs and PCDD/Fs;
4) the feeding habits of the fish (e.g. bottom feeder, predator); and
5) the lakes which are located near the waste treatment plant.

Two lakes near the plant were selected for fish sampling: Chrystina (Windy) Lake, approximately 1.5 km northeast of the plant, and Roche Lake, approximate 20 km southeast of the plant (Figure 3-3). Chrystina Lake contains a stocked, non-native population of eastern brook trout (*Salvelinus fontinalis*). The lake has been stocked every year with brook trout reared at the Sam Livingston hatchery in Calgary. The latest stocking date was May 1997. Brown trout and white suckers form only a small portion of the lake's fish population. All Alberta brook trout populations feed strictly

on benthic and planktonic invertebrates. Thus, brook trout were selected for chemical analysis. Roche Lake contains northern pike (*Esox lucius*), a predatory fish commonly consumed by local people. This species was selected for monitoring. As a control, northern pike were also selected for analysis from Chip Lake, located between Edmonton and Edson.

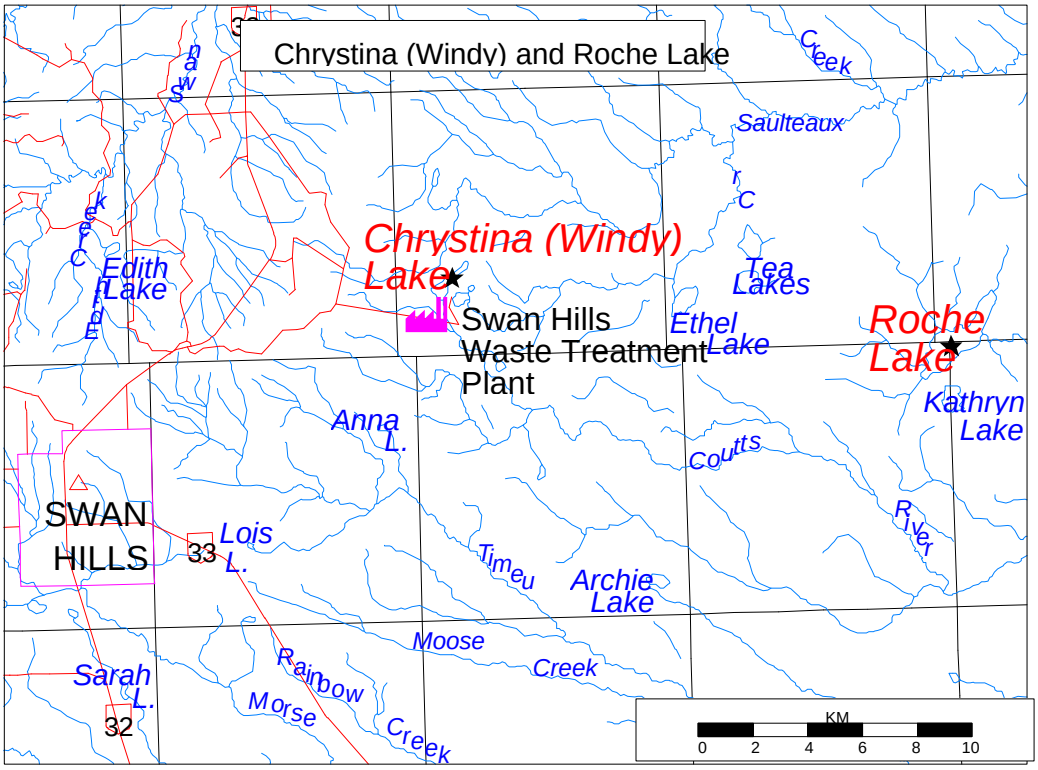

Figure 3-3 **Locations of Fish Collection in the Swan Hills Area**

Field collection was carried out by Alberta Environmental Protection during June and July, 1997 under a protocol developed previously for the Northern River Basin Study [NRBS] (Appendix D). For each fish, the species, length, weight, and age were recorded. A total of 16 brook trout were collected from Chrystina Lake with an average age of 2.0 years and 17 northern pike were collected from Roche Lake with an average age of 4.4 years (Figure 3-3). A total of 32 northern pike were collected from Chip Lake with an average age of 5.4 years. All fish samples were shipped to and stored at -18 ^{o}C at the MAXXAM laboratory in Edmonton.

Both fish fillet and liver were analyzed. For Chrystina and Roche Lake samples, composite samples were formed from 4 (or 5) fish from a single species from the same lake with approximately the same length and weight. For Chip Lake samples, composite samples were formed from 6 or 7 fish. A total of 26 composite samples were formed (Table 3-3).

3.1.1.4 Other Animals

One lynx, one marten and two black bears were killed near the SHWTC. Because control groups for these animals are not available and because of the small number of samples, results of the analysis are not reported here.

Table 3-3 Summary of Fish Samples

Sample ID (composite)	Species	Lake	Location	Tissue	Length (mean, cm)	Weight (mean, g)	Number of fish
7655-1	n. pike	Roche	Swan Hills	Muscle	50.48	906	4
7655-5	n. pike	Roche	Swan Hills	liver	50.48	906	4
7655-2	n. pike	Roche	Swan Hills	muscle	56.22	1090	4
7655-6	n. pike	Roche	Swan Hills	liver	56.22	1090	4
7655-3	n. pike	Roche	Swan Hills	muscle	55.81	1266	4
7655-7	n. pike	Roche	Swan Hills	liver	55.81	1266	4
7655-4	n. pike	Roche	Swan Hills	muscle	59.69	1615	5
7655-8	n. pike	Roche	Swan Hills	liver	59.69	1615	5
7655-9	bk. tr.	Chrystina	Swan Hills	muscle	18.26	71	4
7655-13	bk. tr.	Chrystina	Swan Hills	liver	18.26	71	4
7655-10	bk. tr.	Chrystina	Swan Hills	muscle	19.85	82	4
7655-14	bk. tr.	Chrystina	Swan Hills	liver	19.85	82	4
7655-11	bk. tr.	Chrystina	Swan Hills	muscle	21.59	108	4
7655-15	bk. tr.	Chrystina	Swan Hills	liver	21.59	108	4
7655-12	bk. tr.	Chrystina	Swan Hills	muscle	24.77	187	4
7655-16	bk. tr.	Chrystina	Swan Hills	liver	24.77	187	4
7655-17	n. pike	Chip	outside SH	muscle	45.30	636	6
7655-22	n. pike	Chip	outside SH	liver	45.30	636	6
7655-18	n. pike	Chip	outside SH	muscle	48.26	701	6
7655-23	n. pike	Chip	outside SH	liver	48.26	701	6
7655-19	n. pike	Chip	outside SH	muscle	50.62	745	7
7655-24	n. pike	Chip	outside SH	liver	50.62	745	7
7655-20	n. pike	Chip	outside SH	muscle	53.55	861	6
7655-25	n. pike	Chip	outside SH	liver	53.55	861	6
7655-21	n. pike	Chip	outside SH	muscle	57.33	1156	7
7655-26	n. pike	Chip	outside SH	liver	45.30	1156	7
Total							55

n. pike = Northern Pike, bk. tr. = Brook Trout

3.1.2 Laboratory Methods

The MAXXAM Laboratory, in Mississauga, Ontario, was selected to analyze the samples for PCB and PCDD/F concentrations. The MAXXAM Laboratory is accredited by the Standards Council of Canada to ISO Guide 25. (It should be noted that the fresh deer samples collected by BOVAR, Inc. were tested under a different protocol by Enviro-Test Laboratories. A smaller number of congeners were analyzed. Data from these samples were combined with data analyzed by MAXXAM where appropriate).

3.1.2.1 Selection of Individual Congeners for Analysis

Commercial use, environmental occurrence, abundance in the environmental media and biological matrices, and potential toxicity need to be considered in the selection of specific congeners of PCBs for analysis [McFarland and Clarke, 1989; Sonzogni et al, 1991; Borlakoglu and Walker, 1989; Battershill, 1994; and Seegal, 1996]. According to McFarland and Clarke, a total of 36 of the 209 PCB congeners are environmentally relevant. The Canadian Association of Pest Control Offices recommends 12 specific congeners for regular analysis. Based upon the literature review, the laboratory capacity, and financial considerations, a total of 44 specific congeners of PCBs were selected for analysis:

8, 18, 28, 33, 37, 44, 49, 52, 70, 74, 77, 81, 87, 99, 101, 105, 114, 118, 119, 123, 126, 128, 137, 138, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 191, 194, 201, 202, 205, 209

The composition of PCBs in most environmental extracts does not resemble the composition of commercial products. Individual PCB congeners have different physico-chemical properties that influence their rates of partitioning, uptake and retention in the environmental matrices and their rates of absorption, distribution, metabolism and elimination in the biological matrices [Safe 1994]. Health risk assessment of PCBs should consider the potential adverse impact of individual PCB congeners and their levels in the environmental, food and human blood samples. Health Canada's current policy is to provide congener analyses and also to sum the concentrations of the individual congeners to arrive at a total PCB level [Dr. Jake Ryan. Personal communication]. This policy was also followed in the current study and a total PCB level calculated by summing the concentrations of the 44 selected congeners is reported.

Availability of toxic equivalency factors determined the individual congeners of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) selected for analysis:

PCDD	**PCDF**
2,3,7,8-TCDD	2,3,7,8-TCDF
1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF
	2,3,4,7,8-PxCDF
1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-HxCDF

1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF
1,2,3,7,8,9-HxCDD	
	1,2,3,7,8,9-HxCDF
	2,3,4,6,7,8-HxCDF
1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF
	1,2,3,4,7,8,9-HxCDF
OCDD	OCDF

3.1.2.2 Basic Quality Assurance /Quality Control Criteria

The following QA/QC criteria were in place for the current analyses:

a) Analysis of a certified reference material every batch of samples i.e. 10-20 samples
b) Analysis of blanks every 10 samples
c) Confirmation of standard by another reputable (certified) lab
d) Analysis of a duplicate sample every 20 samples
e) Reporting of internal standard recoveries (added during extraction of the sample)
f) Review and evaluation by an independent chemist

3.1.2.3 Analytical Procedure

The analytical approach for the analysis of PCBs, PCDDs and PCDFs is based on the in-house Standard Operating Procedure SOP# TO.1013.02 (Revised on 08/27/94). This SOP is based on Environment Canada methods EPS 1/RM/19 and EPS 1/RM/23 with specific references to equipment and instrumentation that are used in MAXXAM Laboratory. Methods highlights include:

a) soxhlet or liquid-liquid extraction with methylene chloride/hexane for solids or liquids
b) acid wash
c) four stage Chromatographic clean-up
d) High-Resolution Gas Chromatographic/High Resolution Mass spectrometer Analysis (HRGC/HRMS)
e) built-in Quality Assurance/Quality Control (QA/QC)
f) detection limit:

PCDD/PCDF (HRGC/MS)	0.1 - 1.3 pg/g
PCB congeners (HRGC/MS)	1 - 3 ng/g

After the necessary sample work-up, the extracts are analyzed on a VG AutoSpec Ultima Magnetic Sector, HRMS with a 60 meter DB 5 column. Some AutoSpec capability highlights include: variable mass resolution to 60 000, sub parts per quadrillion (ppq) sensitivity for PCDDs/Fs, EPA dioxin quantitative package and a NIST 49 000 compound library. The published instrument sensitivity for TCDD is 100 femtograms (fg) with a signal to noise ratio of 50:1, three to one signal to noise ratio would therefore equal instrument detection of 6 fg.

Spiking

Prior to the initial extraction, all samples were fortified with fifteen $^{13}C_{12}$-labeled PCDD/F with exception of OCDF and eight $^{13}C_{12}$-labeled PCBs (IUPAC nos. 31, 52, 118, 153, 180, 194, 206 and 209). These internal standards represent each of the PCDD, PCDF and PCB homologues. The solutions were prepared from purified crystaline compounds (chemical: >98%, isotopic: >99%), analyzed by HRGC/HRMS and confirmed to be free of native PCDD/Fs and PCBs. Surrogate recovery limits range from 30% to 130%.

Extraction

A 20 g homogenized sample was extracted with 100 ml of pre-cleaned hydrochloric acid for 30 min in a tared 240 ml extraction jar. Twenty ml of 25% DCM/Hexane (v/v) was added to allow the sample to digest overnight. The extract was centrifuged for 45 minutes and the upper layer removed by suction into a 250 ml filtering flask. The extraction was repeated with 20 ml 25% DCM/Hexane (v/v) solution. The extract was concentrated to approximately 2 ml using a rotary evaporator. The combined and dried extracts were collected in a 40 ml glass VOC bottle. The weight of the lipid portion residue was obtained to determine the percent lipid content.

The extracts were reconstituted with 10 ml hexane and then 20 ml concentrated sulphuric acid. After shaking and allowing the layers to separate, the acid layer was removed. The acid-wash process was repeated until the extract was clear and colorless. The acid-washed extract was concentrated to 2 ml and then fortified with 20 µl of the clean-up surrogate standard.

Clean-up and separation

The extracts were cleaned up using an acid/base silica column. The concentrated extracts were transferred to the column, which was eluted with 30 ml hexane into a 250 ml round-bottom flask. The eluent was concentrated on a rotary evaporator.

The extracts were cleaned up using an alumina column, collecting four separate fractions. The concentrated extracts were transferred to the column, which was eluted with 7 ml hexane into a 15 ml conical test tube (fraction one), 15 ml 4% DCM/Hexane (v/v) into a new 15 ml tube (fraction two), 15 ml 65% DCM/Hexane (v/v) into a

new tube (fraction three) and 15 ml of DCM into a new tube (fraction four). Fractions 1, 2 and 4 were placed in storage. Fraction 3 was concentrated under a gentle stream of nitrogen gas. The concentrated extracts were quantitatively transferred to an autosampler vial and reconstituted to a final volume of 20 µl via the addition of 20 µl of the performance standard.

Identification

A FISONS VG Ultima High Resolution Mass spectrometer is utilized for analysis of ultra-trace levels of organic contaminants. This mass spectrometer is coupled to a Hewlett Packard gas chromatograph. The sample extracts were injected into a Hewlett Packard 5890 Gas Chromatograph via a FISONS A200S automatic sample injection system. The GC is equipped with a split/splitless injection port.

The GC is equipped with a 60 meter, 0.25 mm ID., 0.25 µm film thickness DB-5 capillary column. Alternative column includes a DB-225 (30 m, 0.25 mm ID, 0.25 µm film thickness). Injector temperature was 265 °C. The GC temperature program was as follows: initial temp 80 °C, hold 1 min; ramp to 205 °C @ 40 °C/min; ramp to 220 °C @ 3 °C/min, hold 16 min; ramp to final temp of 310 °C @ 15 °C/min, hold 15 min. The total time of the GC run was 50 min.

The autosampler and gas chromatograph operations are controlled by the analyst from the Vax 4000 work station, using the experiment method "EPA". The retention time windows for the EPA method program were adjusted using the experiment "ZONE CHECK". The run sequence includes a check standard which is analyzed at 12 hour intervals and the end of a run sequence. The host system for mass spectral data collection is the Digital Vax 4000.60 work station. The Vax work station is interfaced with a second personal computer (IBM 486).

Quantitation

Relative response factors (RRFs) were calculated for the native compounds in relation to the C-13-labeled surrogates of the same homologue group. Surrogate compound RRFs were calculated based on their relation to the performance standards. All RRFs fell within ±25% of the mean relative response calculated from the calibration curve. The calculations of concentrations were based on separate quantitation of peak areas for all the homologues and individual isomers corresponding to the amount of the internal standards.

3.1.3 Data Analysis

Data analysis was conducted on both individual and summary measures of PCBs and PCDD/Fs. Additional variables designating species, specimen type, and location were included in analyses where required. Individual

measures included whole weight concentrations, lipid-adjusted concentrations (where applicable), and Toxic Equivalencies (TEQs) for each of the 44 PCB congeners, each of the 7 PCDD congeners, and each of the 10 PCDF congeners. International Toxic Equivalency factors [I-TEFs] (WHO-IPCS for PCBs and NATO-CCMS for dioxins/furans) were used for calculating TEQ values. The concentration of a congener below detection level was assigned a value of 0 ("zero"). Summary measures included

a) *Detect/Non-Detect status* (formed separately for PCBs, PCDD/Fs, and both PCBs and PCDD/Fs together). A sample was designated detect if any congener value was above detection limits, and was designated non-detect if all congeners were below detection limits.
b) *Total PCB Concentration* calculated by summing the values for each of the 44 individual PCB congeners, for whole weight and lipid-adjusted concentrations (where applicable).
c) *Total PCDD/F Concentration* calculated by summing the values for each of the 17 individual PCDD and PCDF congeners, for whole weight and lipid-adjusted concentrations (where applicable).
d) *Total TEQ* calculated by summing the TEQ values for each of the individual PCBs, PCDDs, and PCDFs, for whole weight and lipid-adjusted concentrations (where applicable).

It should be noted that the fresh deer samples collected by BOVAR, Inc. were tested under a different protocol by Enviro-Test Laboratories. These samples were excluded from the analysis of individual congeners. In order to compare the analyses of these samples with the analysis of samples analyzed by the MAXXAM laboratories, summary measures for total PCBs were calculated as the sum of the concentrations of 9 homologous groups (di-, tri-, tetra-, penta-, hexa-, hepta-, octa, nona-, and deca-), and summary measures for total PCDD/Fs were calculated as the sum of the concentrations of 10 homologous groups (octa CDD, total tetra CDD, total penta CDD, total hexa CDD, total hepta CDD, octa CDF, total tetra CDF, total penta CDF, total hexa CDF, total hepta CDF).

Appendices E, F, and G present the summary concentrations of PCBs and PCDD/Fs for the individual samples for fresh deer meat samples, freezer meat samples, and composite fish samples, respectively.

The examination of individual congener distributions can, in the ideal case, serve to locate anomalous analyses as part of a Quality Assurance/Quality Control process and can serve to allow the development of hypotheses about contaminant source localization. In the current case, the small number of individual samples, the large number of congener variables, and the generally skewed distributions of congeners make such examinations speculative. Consequently this analysis is presented primarily for scientific interest and should be interpreted with due caution. Appendix H presents the PCB and PCDD/F congener patterns for selected samples and sample types in graphical form.

3.2 Results

3.2.1 Fresh Deer Meat

The proportion of samples in which measurable levels of PCBs and PCDD/Fs were not detected is shown by sample type in Table 3-4.

Table 3-4 Proportion of Non-detect in Fresh Deer Samples

Parameter	Swan Hills Area	Control Areas in Alberta
Liver		
total PCBs	0/4	4/12
total PCDD/Fs	0/4	1/12
both PCBs and PCDD/Fs	0/4	0/12
Fat		
total PCBs	1/3	4/7
total PCDD/Fs	0/3	0/7
both PCBs and PCDD/Fs	0/3	0/7
Muscle		
total PCBs	2/4	6/12
total PCDD/Fs	1/4	7/12
both PCBs and PCDD/Fs	1/4	4/12

Statistical comparisons of the summary measures were conducted using two non-parametric procedures: the Mann-Whitney U test and a Randomization test. Significance levels are reported for the Randomization test. Because the randomization test was applied to sample means, these were tabulated in Table 3-5. Briefly, all measures for liver are significantly elevated in the Swan Hills samples relative to the Alberta control samples. All measures are significantly elevated for fat (except the PCDD/F whole weight concentration and total PCB lipid adjusted concentration which approach significance); and the whole weight PCDD/F TEQ and both whole weight and lipid adjusted PCDD/F + PCB TEQ measures for the muscle samples are significantly elevated. However, the skewed nature of the data should be considered in the interpretation of these means. Also, caution should be exercised in interpreting the results from fresh deer samples since the sample size was small, the number of comparisons was high, and the tests for liver, fat and muscle were not independent (since the same animals contributed liver, fat, and

muscle samples).

Because the distributions of the summary measures were skewed, selected graphical comparisons are presented in Figures 3-4 to 3-7 which employ box-plots showing the 5th, 25th, 50th, 75th, and 95th percentiles of each distribution and separately indicating extreme values located substantially above or below the outer percentiles. The pattern is similar for whole weight concentrations, whole weight TEQ, and lipid adjusted TEQ.

Table 3-5 Mean Levels of PCBs and PCDD/Fs in Fresh Deer Samples

Parameter	Swan Hills	Control Areas	Statistical difference
Liver			
total PCBs,µg/kg, whole weight	73.63	15.48	P < 0.02*
total PCDD/Fs, pg/g, whole weight	2348.95	153.31	P < 0.02*
PCDD/F TEQ, pg/g, whole weight	495.53	4.40	P < 0.01*
PCDD/F + PCB TEQ, pg/g, whole weight	558.09	5.19	P < 0.01*
total PCBs, µg/kg, lipid weight	2 408.81	457.05	P < 0.01*
PCDD/F + PCB TEQ, pg/g, lipid weight	12 471.58	120.44	P < 0.001*
Fat			
total PCBs, µg/kg, whole weight	253.10	33.24	P < 0.05*
total PCDD/Fs, pg/g, whole weight	131.50	47.14	P < 0.10
PCDD/F TEQ, pg/g, whole weight	45.19	0.55	P < 0.05*
PCDD/F + PCB TEQ, pg/g, whole weight	66.08	1.42	P < 0.05*
total PCBs, µg/kg, lipid weight	286.00	38.76	P < 0.10
PCDD/F + PCB TEQ, pg/g, lipid weight	75.40	1.71	P < 0.05*
Muscle			
total PCBs, µg/kg, whole weight	21.53	3.48	P < 0.15
total PCDD/Fs, pg/g, whole weight	4.85	17.76	P > 0.50
PCDD/F TEQ, pg/g, whole weight	1.27	0.14	P < 0.05*
PCDD/F + PCB TEQ, pg/g, whole weight	17.98	0.15	P < 0.05*
total PCBs, µg/kg, lipid weight	890.15	475.93	P > 0.25
PCDD/F + PCB TEQ, pg/g, lipid weight	766.01	13.27	P < 0.05*

* statistically significant differences

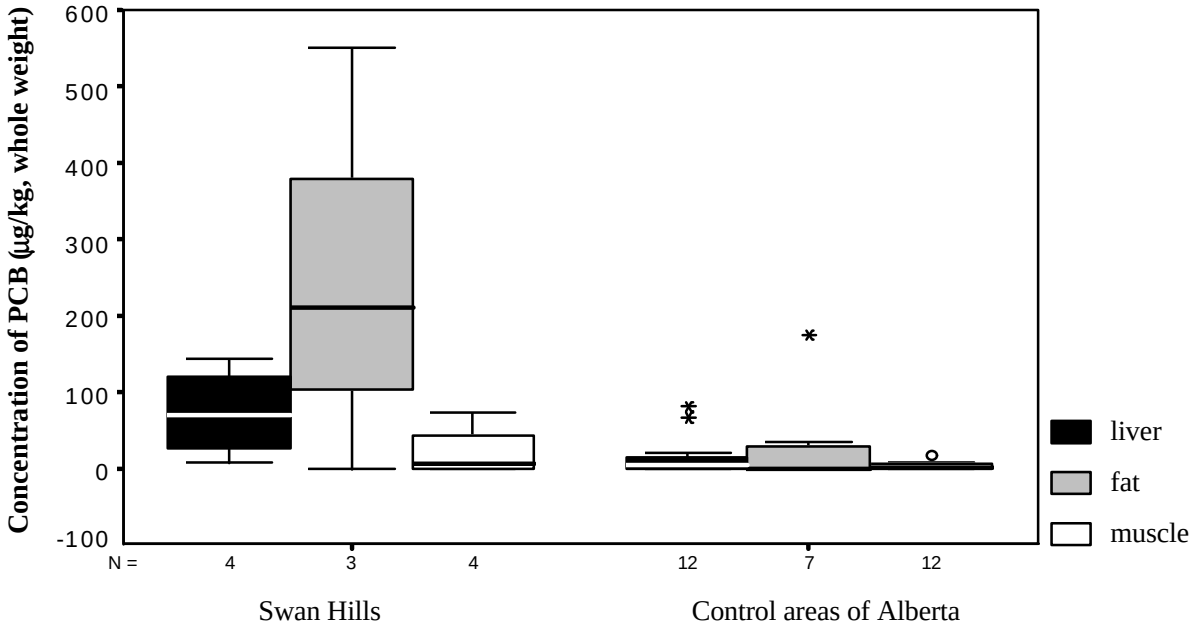

Figure 3-4 Concentrations of Total PCBs in Fresh Deer Samples

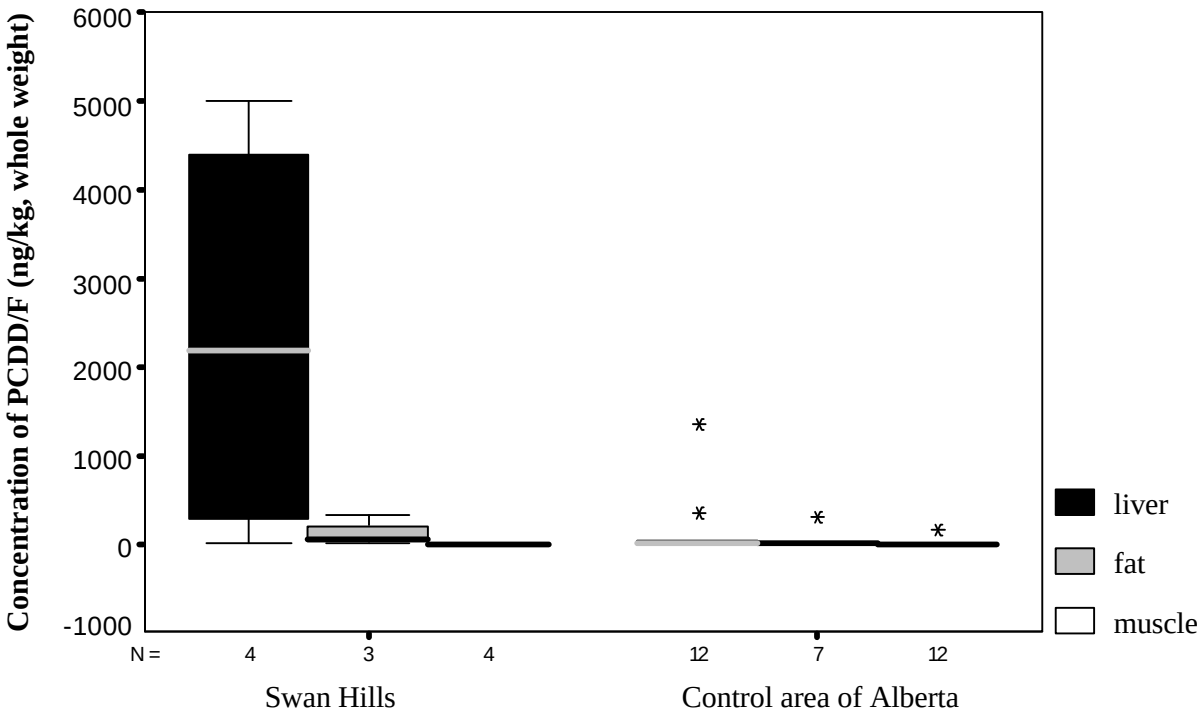

Figure 3-5 Concentrations of Total PCDD/Fs in Fresh Deer Samples

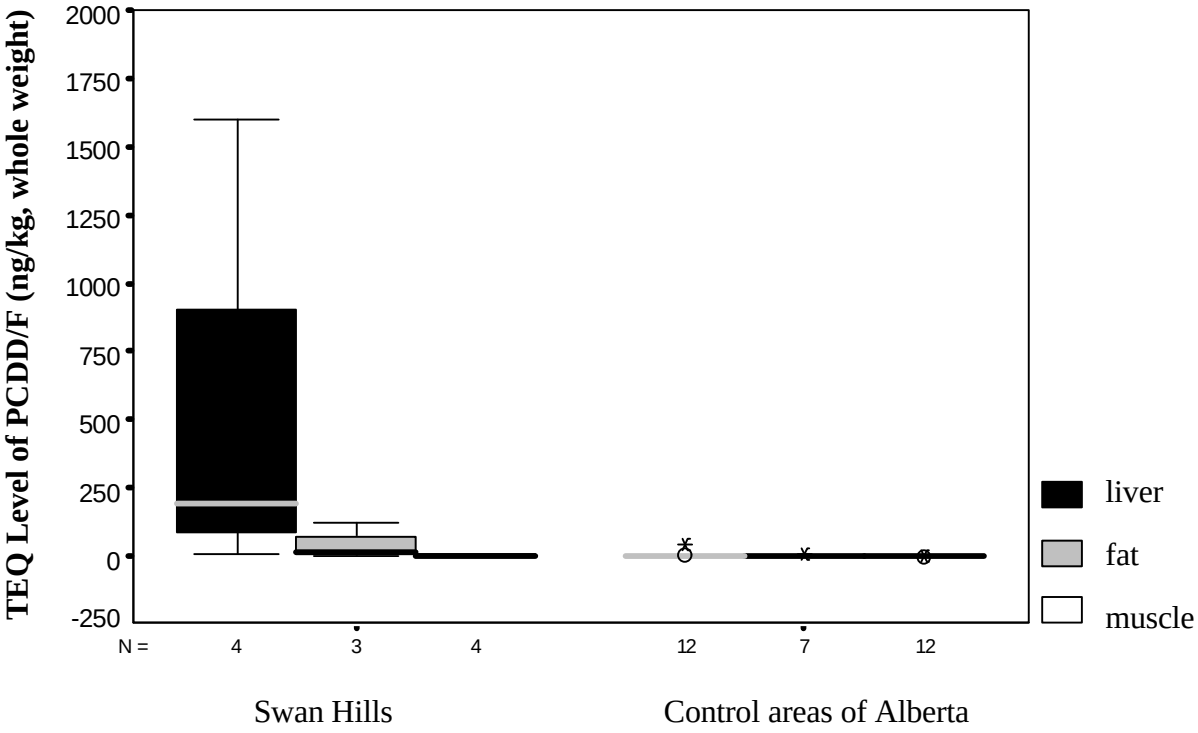

Figure 3-6 TEQ Levels of PCDD/F in Fresh Deer Samples

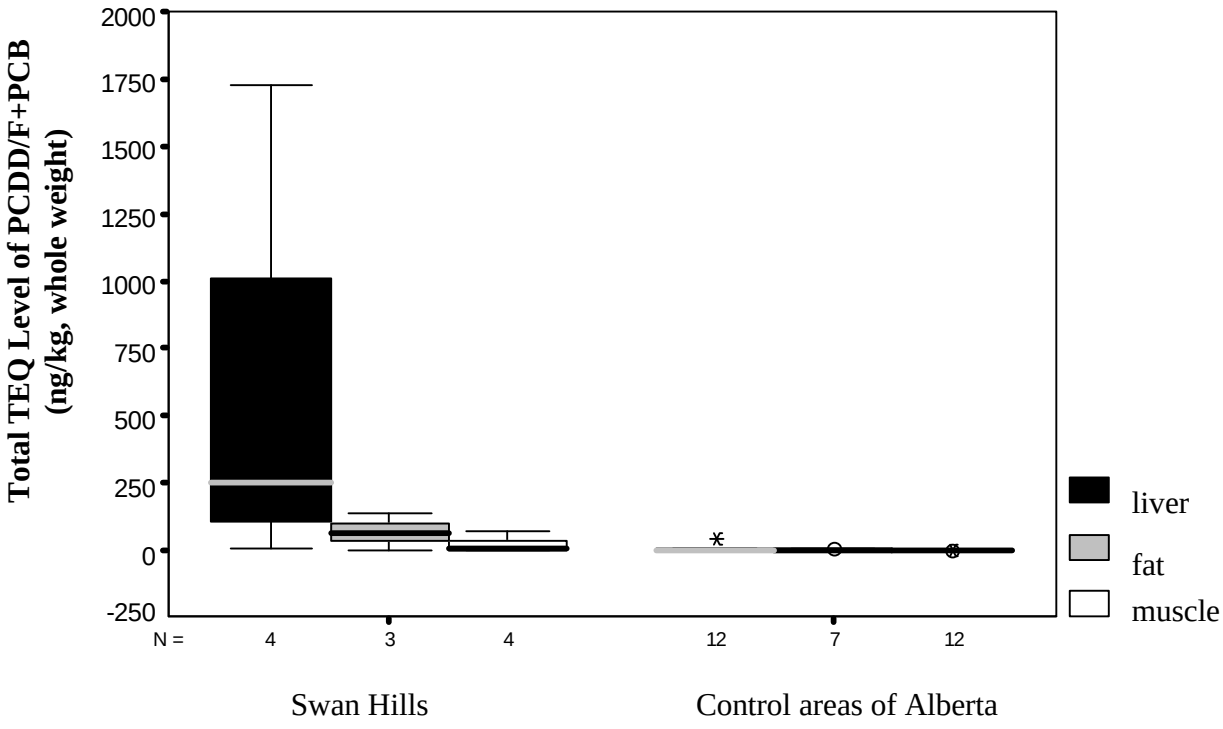

Figure 3-7 Total TEQ Levels of PCDD/F+PCB in Fresh Deer Samples

Figure 3-8 shows the PCDD/F whole weight TEQ measures for the four deer from the Swan Hills area as a function of the distance from the SHWTC at which they were captured. When the samples are standardized within tissue type and then correlated with distance across all samples, a statistically significant correlation emerges (r= -0.849, P <0.005) indicating that PCDD/F whole weight TEQ increases as distance from the SHWTC decreases.

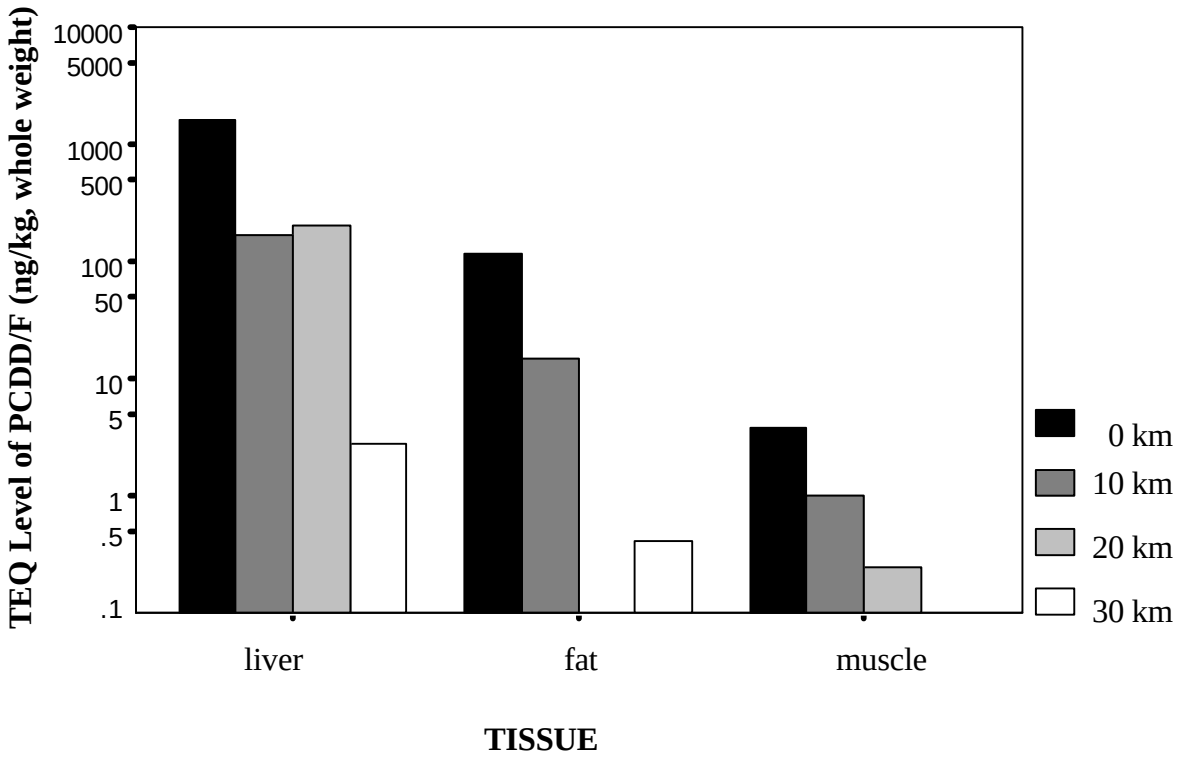

Figure 3-8 TEQ, PCDD/F levels for the Four Deer from Swan Hills

No other correlation emerged as significant. In particular there was no apparent relationship between PCB or PCDD/F levels and age of the animals.

3.2.2 Freezer Meat Samples

Two sample categories for freezer meat samples were established based on the distance from the SHWTC. Samples obtained with a 20 km radius were compared with samples taken outside the 20 km radius. Exploratory analysis showed no significant differences between samples from deer and moose, and the two species were combined for analysis. Given the small number of liver samples, the analysis focused on muscle samples.

Table 3-6 presents the proportion of samples in which no measurable levels of PCBs and PCDD/Fs were detected.

Table 3-6 Proportion of Non-detect in Freezer Meat Samples

Parameter	within 20 km	outside 20 km
total PCBs	11/22	21/28
total PCDD/Fs	15/22	19/28
both PCBs and PCDD/Fs	10/22	18/28

The mean concentrations of whole weight PCBs and PCDD/F; whole weight PCDD/F TEQ and PCDD/F + PCB TEQ; lipid adjusted PCB concentration levels; and lipid adjusted PCDD/F + PCB TEQ are presented in Table 3-7. The mean level of PCBs is significantly higher in samples taken within the 20 km radius for both whole weight ($p<0.02$) and lipid adjusted ($p<0.02$) measures. The mean PCDD/F level is significantly higher in samples taken within the 20 km radius ($p<0.05$) and while the PCDD/F whole weight TEQ does not differ, the PCDD/F+PCB TEQ is significantly higher for both whole weight ($p<0.05$) and lipid adjusted ($p<0.05$) measures.

Table 3-7 Mean Levels of PCBs and PCDD/Fs in Freezer Meat Samples

Parameter	within 20 km Mean	Outside 20 km Mean	Statistical difference
total PCBs, µg/kg, whole weight	18.16	0.65	P < 0.02*
total PCDD/Fs, pg/g, whole weight	4.22	1.03	P < 0.05*
PCDD/F TEQ, pg/g, whole weight	0.07	0.11	P > 0.50
PCDD/F + PCB TEQ, pg/g, whole weight	9.89	0.11	P < 0.05*
total PCBs, µg/kg, lipid weight	3394.35	60.45	P < 0.02*
PCDD/F + PCB TEQ, pg/g, lipid weight	2077.27	7.17	P < 0.05*

* statistically significant differences

Because the distributions of the summary measures were skewed, selected graphical comparisons are presented in Figures 3-9 to 3-12. The distribution of PCB whole weight concentrations for muscle samples is illustrated in Figure 3-9. Within the 20 km radius, 11 samples (50.0%) showed detectable levels of PCBs and 11 samples (50.0%) were non-detects. Outside the 20 km radius, 7 samples (25%) showed detectable PCB level and 21 samples (75%) were non-detects. The distribution of PCDD/Fs is presented based on whole weight in Figure 3-10.

Within the 20 km radius, 7 samples (31.8%) showed detectable levels of PCDD/Fs and 15 samples were non-detects (68.2%). Outside the 20 km radius 9 samples (32.1%) showed detectable levels and 19 samples (67.9%) were non-detects. Figure 3-11 and 3-12 present the distribution of PCDD/f TEQ and PCDD/F plus coplanar PCB TEQ in freezer meat muscle samples.

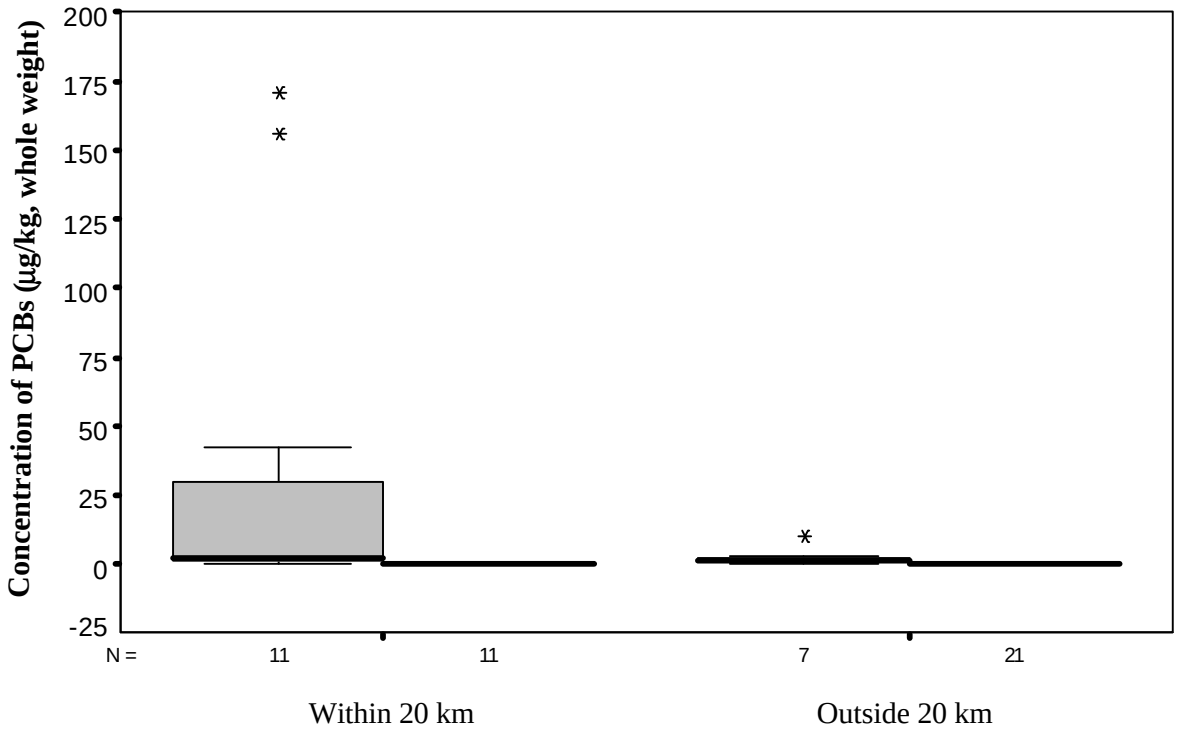

Figure 3-9 **Concentrations of Total PCBs in Freezer Muscle Samples**

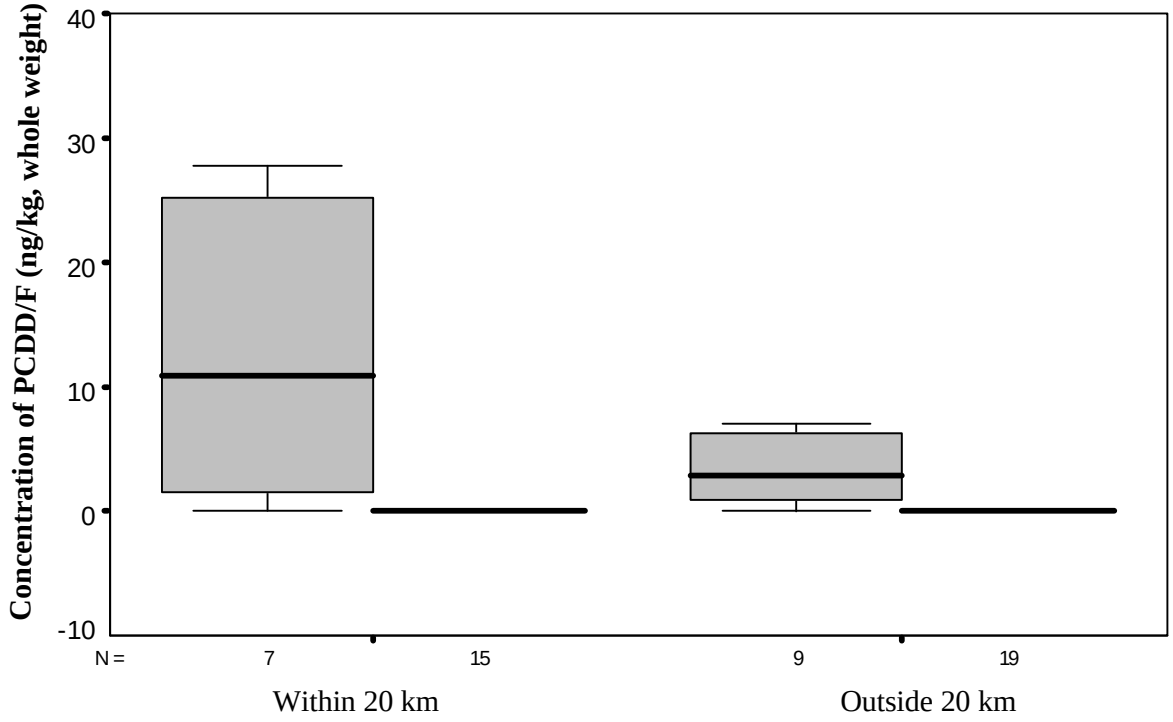

Figure 3-10 Concentrations of Total PCDD/F in Freezer Muscle Samples

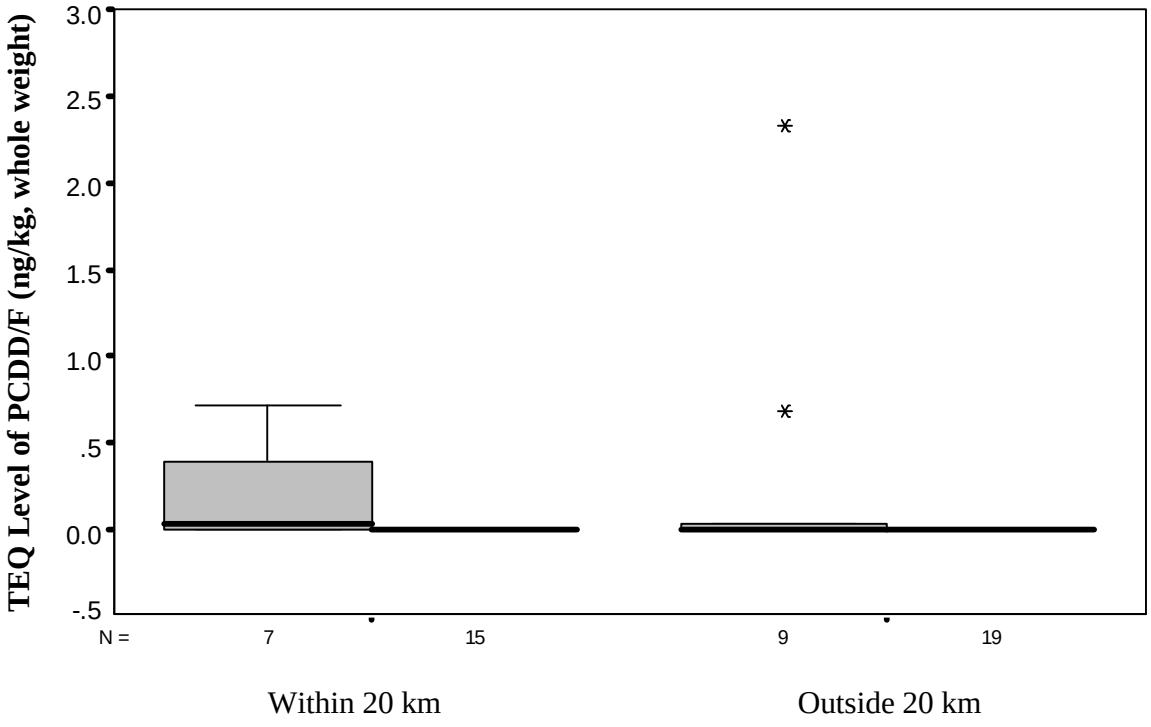

Figure 3-11 TEQ Levels of PCDD/Fs in Freezer Muscle Samples

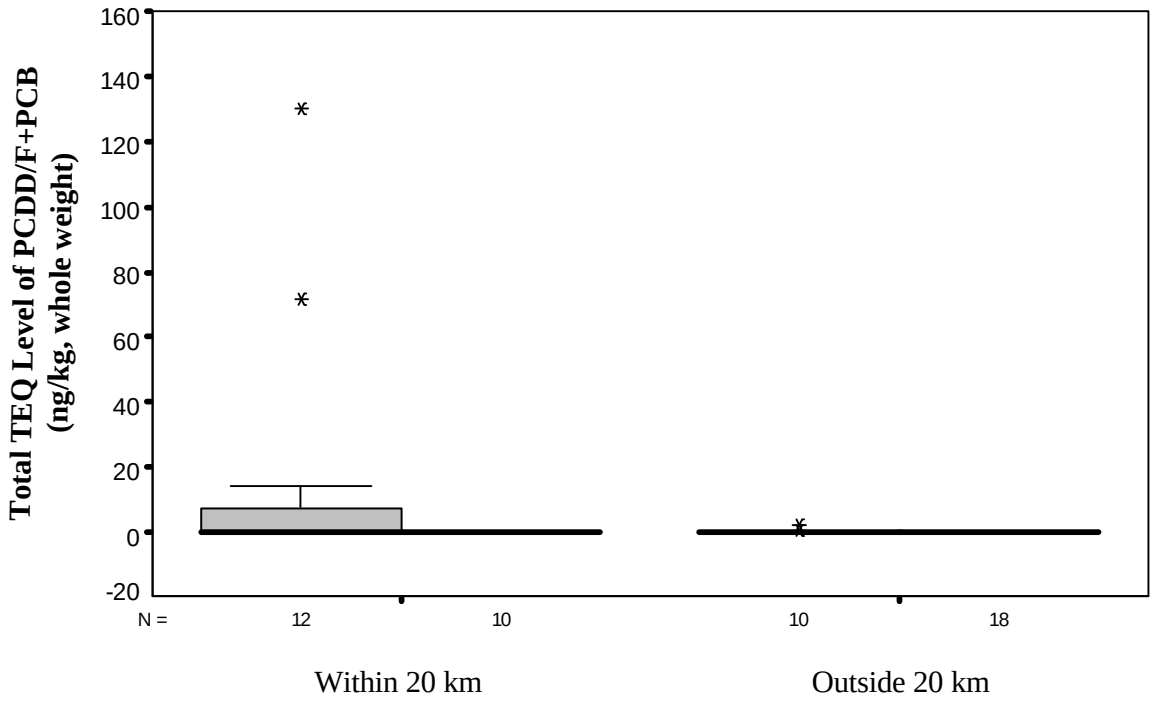

Figure 3-12 Total TEQ Levels of PCDD/F +PCB in Freezer Muscle Samples

Five out of 6 liver samples from within the 20 km radius (83.3%) showed detectable levels of PCBs and PCDD/Fs. The mean PCB levels were 4.07 µg/kg in whole weight and 158.42 after lipid adjustment. The mean PCDD/F levels were 170.18 pg/g in whole weight, 7.38 whole weight PCDD/F TEQ, 7.39 whole weight PCDD/F + PCB TEQ, and 439.64 lipid adjusted PCDD/F PCB TEQ. No statistical analysis could be performed because of the small number of liver samples.

3.2.3 Fish

Levels of PCBs and PCDD/Fs for fish samples taken from the three lakes are shown for muscle in Table 3-8 and for liver in Table 3-9. For all measures, levels in Chrystina Lake were higher than levels in Roche and Chip lakes which did not differ from each other (One-way ANOVAs, Scheffe tests, $p<0.01$). Because analysis was performed on composite samples, the distribution of contaminants across particular fish is not known; in particular, if this distribution is skewed, statistical tests may be liberal. This is likely to be more than offset by the use of composite samples which substantially underestimate the variability of contamination across individual fish.

Table 3-8 Mean Levels of PCBs and PCDD/Fs in Fish Muscle

Parameter	Chrystina Lake	Roche Lake	Chip Lake
total PCBs, µg/kg, whole weight	17.85 *	1.01	0.25
total PCDD/Fs, pg/g, whole weight	21.83 *	0.93	0.68
PCDD/F TEQ, pg/g, whole weight	2.74 *	0.003	0.002
PCB TEQ, pg/g, whole weight	9.67 *	0.24	0.002
PCDD/F + PCB TEQ, pg/g, whole weight	12.41 *	0.24	0.004

* difference statistically significant at $p<0.01$

Table 3-9 Mean Levels of PCBs and PCDD/Fs in Fish Liver

Parameter	Chrystina Lake	Roche Lake	Chip Lake
total PCBs, µg/kg, whole weight	70.03 *	7.76	6.39
total PCDD/Fs, pg/g, whole weight	226.48 *	1.15	7.46
PCDD/F TEQ, pg/g, whole weight	16.63 *	0.24	0.12
PCB TEQ, pg/g, whole weight	44.98 *	3.03	2.36
PCDD/F + PCB TEQ, pg/g, whole weight	61.61 *	3.27	2.48

* difference statistically significant at $p<0.01$

Caution should be exercised in the interpretation of contaminant levels since the fish in Chrystina lake are of a different species than the fish taken from Roche and Chip lakes.

3.3 Discussion

Wild Game

Limited information is available on PCBs and dioxins/furans in large terrestrial herbivores (Table 3-10). Direct comparisons among these data can be misleading due to differences in analytical techniques, quantitative methods and species of herbivores examined. In the Canadian North studies, the means of total PCBs was derived from the sum of individual congeners (Muir et al., 1988; Thomas and Hamilton, 1988; Elkin and Bethke, 1995).

The mean level of PCBs in deer from control areas of Alberta (with one exception as noted below) are close to those found in caribou from the Canadian North. These levels may be related to the presence of local industrial effluence and/or to global atmospheric transport. For unknown reasons, a very high level of dioxins and furans was presented in a single road-kill deer taken from a highway to the east of Edmonton.

Table 3-10 Concentrations of Total PCBs (mean, μg/kg) in Large Terrestrial Herbivores

Species	Muscle		Liver		Fat		Quantit-ative method	Location	Reference
	WW	LW	WW	LW	WW	LW			
Caribou	-	-	-	-	-	6-32	SIC	Canadian North	Elkin & Bethke 1995
Caribou	2	-	8	-	11 -52	-	SIC	Canadian North	Thomas & Hamilton 1988
Caribou	10	-	-	-	33	-	SIC	Canadian North	Muir *et al* 1988
Roe deer	-	-	-	-	-	18	Aroclor 1260/54	Poland	Przybycin & Juszkiewicz 1993
Roe deer	-	-	-	-	-	32	Kane-chlor	Poland	Falandysz & Kannan 1992
Red deer	-	-	-	-	-	21	Aroclor 1260/54	Poland	Przybycin & Juszkiewicz 1993
Stage	-	-	-	-	-	23	Kane-chlor	Poland	Falandysz & Kannan 1992
White-tail/ mule deer (fresh)	22	890	74	2408	253	286	SHG	Swan Hills, Canada	this study
Moose/ deer (freezer)	18	3394	3.9	150	-	-	SHG	Swan Hills, Canada	this study
White-tail/ mule deer (fresh)	3.5	476	16	457	33	39	SHG	Alberta, Canada (control)	this study

WW= Wet Weight; LW= Lipid-adjusted Weight; SIC= sum of individual congeners; SHG= sum of homologous groups

Levels of PCBs and PCDD/Fs were significantly higher in deer from the Swan Hills area than other areas of Alberta indicating that contamination has occurred in the ecosystems near the SHWTC. Specifically, an air-plant-

herbivore pathway of contamination is implicated. First, recent studies have shown that an increased atmospheric deposition of PCBs contributes to an increased PCB burden in plant and herbivores (Larsson et al, 1990; Eisler and Belisle, 1995). Contaminants from the atmosphere are known to accumulate on the surface of lichens (Thomas et al, 1992). Lichens and moss are abundant in the vicinity of the plant and are used to monitor airborne pollutants. The data in the 1996 fall monitoring program of the company showed elevated levels of PCBs in live moss and Labrador tea leaves. In these analyses, the predominant congeners were 28, 101, 105, 118, 138, 153 and 183 (based on analyses for 12 congeners). Three coplanar PCBs (77, 126 and 169) were detected, with relatively higher levels for 77 and 126. Second, the current study shows similar patterns of PCB bioaccumulation for deer and moose. Lower-chlorinated congeners were frequently detected in deer and moose in the current study and lower-chlorinated congeners are known to persist in vegetation (Larsson et al. 1990; Muir 1997). Third, research has shown that in harsh winters the primary food source for white-tail and mule deer is browse. The average temperature in January and February in the Swan Hills is about - 18^{o}C. While moose may range farther, the mobility of white-tail and mule deer is likely to be restricted to a radius of 4 to 5 km in the winter. These findings offer a strong indication of an air-plant-herbivore pathway of PCB contamination in the immediate area of the SHWTC.

Fish

Variability in lipid content, feeding habits, tropic structure of the food chains, biomagnification rate, and fish age can attribute to variations of accumulations of PCB and dioxins/furans in different fish species (de Wit et al. 1992; Whittle et al. 1993; Eisler and Belisle 1995).

Northern pike is a predator and can bioaccumulate PCBs and dioxins/furans to a relatively high degree. The fish caught for chemical analysis were moderately large (ranging from 906 to 1615 gm for fish 3-6 years old for Roche Lake and from 636 to 1156 gm for fish 4-7 years old for Chip Lake) and had low lipid content (ranging from between 0.1% and 0.77% in fillets). Comparable chemical analyses from the Northern River Basin study showed average levels of dioxins/furans ranging from non-detectable levels to 28.9 pg/g in northern pike fillets collected from 30 fishing locations across Alberta (NRBS 1996). The levels of contaminants reported in the current study are lower, though it is important to note that some rivers and lakes selected for monitoring in the NRBS are contaminated, to a certain extent, with dioxins/furans.

In contrast, brook trout in Alberta eat benthic and plantonic invertebrate. Brook trout in Chrystina Lake which is located near by the waste treatment plant is a stocked, non-productive population, ranging in age between 1 and 3 years. Brook trout caught for chemical analysis were small (ranging from 71 to 187 gram) and had low lipid content (between 0.15% to 0.66% in fillets). Data on levels of PCBs and dioxins/furans in brook trout from other areas of the province are not available.

Similar PCB congener patterns were observed in fillet samples of brook trout from Chrystina Lake and northern pike from Roche Lake. In liver samples, the PCB congener patterns were similar across all species and locations. Concentrations of individual PCB congeners were generally one order of magnitude higher in brook trout compared to northern pike. The levels of TCDD in fillets and livers were under detection limits in all species across all locations. The most prominent isomer in fish from Chrystina Lake was 2,3,7,8-TCDF. This is consistent with the results from the Canadian National Dioxins program (Whittle et al 1993) and the BOVAR monitoring program (BOVAR, 1997).

PCB TEQ values in fillets and liver samples from Chrystina Lake were greater than PCDD/F TEQ values. This supports results from fresh and frozen deer/moose monitoring. High levels of congeners 126 and 169 contribute to the higher levels of PCB TEQs. This finding is consistent with the results of the BOVAR monitoring program in which elevated levels of coplanar PCBs were found in Labrador tea leaves, living moss and soils (BOVAR 1997). Combustion processes could be the source of the increased environmental levels of congeners 169 and 126 (Brown et al 1995).

3.4 Conclusion

The results of wild game monitoring indicate elevated levels of PCBs and PCDD/Fs in deer and moose from the area immediately surrounding the Swan Hills Waste Treatment Center. The results of fish monitoring indicate elevated levels of PCBs and PCDD/Fs in the liver and muscle tissues of brook trout sampled from Chrystina Lake compared to northern pike sampled from Roche Lake and Chip Lake. Air emissions from the waste treatment facility are probably a significant source of contaminants. The pathway from air to plant to herbivore is probably the source of deer and moose exposure to contaminants.

4. HUMAN TISSUE MONITORING: BLOOD

The purpose of blood sampling was to estimate the concentration of contaminants in human blood in residents of the Swan Hills and the surrounding areas. This study provides information on the absorption of PCBs and PCDD/Fs into the human body which indicates exposure from all sources and long-term exposure in addition to current exposure. Special efforts were made to determine the effects of regular consumption of wild game and fish, and the effects of ethnic group (aboriginal vs. non-aboriginal) were examined. In addition, pooled blood samples were obtained from blood donors at clinics in a large metropolitan area to serve as control samples.

4.1 Materials and Methods

4.1.1 Sampling Strategy

Strategies for human serum sampling were developed by Health Surveillance, Alberta Health. A sufficient number of samples for a study group must be collected to determine the mean level of PCBs precisely enough to evaluate whether that observed level might simply be a chance fluctuation from levels found in the general population of Alberta. To determine this number, an estimate of the variability of the PCB levels within humans is required. Published reports provide estimates of the standard deviation of PCB levels ranging between 3.6 and 4.7 ppb in exposed individuals. Using this figure, an estimate of the number of samples required for a confidence interval of a particular width can be developed. Thus, in order to have a 95% confidence interval of about +/- 1 ppb on the mean PCB level, a sample of about 100 is required. This also means that if the average PCB level in Swan Hills in 100 samples is 1.0 ppb higher than the level discovered in a pooled control sample, there would be reasonable confidence that this difference did not occur by chance.

In order to provide information about laboratory analysis variability and further information about risk factors, a control sample was formed for PCB levels from analyses of blood samples pooled across a number of individuals. The following sampling protocol was employed (1) one sampling site (Edmonton) was chosen; (2) individual pooled samples were collected by gender and by age group as follows: male 17-35, male 35-55, male 55+, female 17-35, female 35-55, and female 55+; (3) each pooled sample was composed of 25 samples; and (4) each pooled sample was mixed and then split in two for purpose of analysis. This protocol resulted in 12 samples.

4.1.2 Selection of Target Population

Target Population

The target population consisted of individuals over the age of 18 years who resided in communities in the Swan Hills area.

Criteria of selection

The Town of Swan Hills and all communities within a 100 km radius were chosen for study. These included Fox Creek, Little Smoky, Sunset House, High Prairie, Enilda, Joussard, Driftpile, Faust, Kinuso, Canyon Creek, Widewater, Slave Lake, Fort Assiniboine, and Swan Hills (Figure 4-1).

The source of the sampling frame was the Alberta Health Care Insurance Plan registration files. Individuals were included in the frame if their recorded mailing address included a postal code associated with one of the chosen communities and if their recorded age exceeded 18 years as of January 1, 1997. All individuals whose postal code or age was missing from the registration file were excluded. Because initial contact was to be made by telephone, individuals without a recorded telephone number were also excluded from the frame. Since individuals rather than households were placed in the frame, the possibility existed that two individuals living in one household might have been included in the sample.

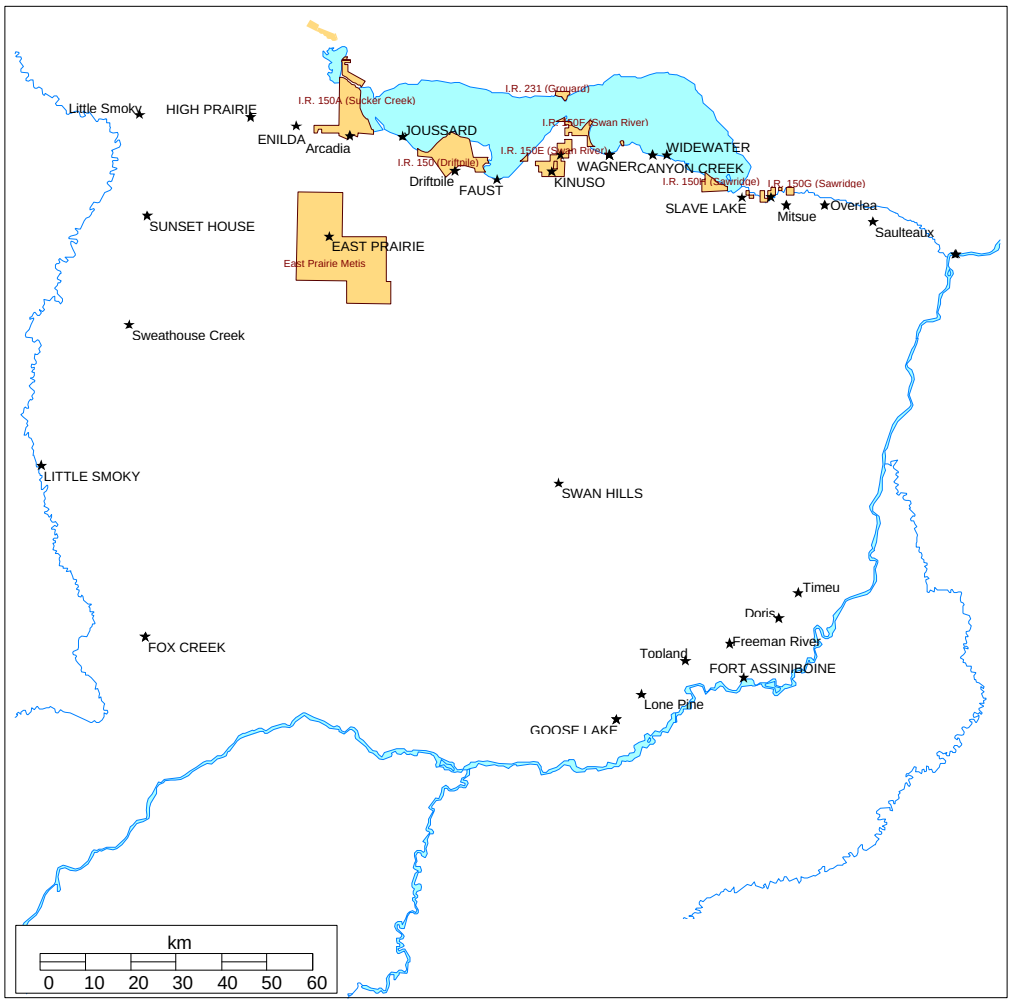

Figure 4-1 Communities in the Swan Hills and its Surrounding Areas

The sampling frame was divided into two: Frame A included those living in the town of Swan Hills (a total of 2,440 individuals), and Frame B included those living in surrounding communities (a total of 10,361 individuals).

4.1.3 Recruitment Procedures

Recruitment for the study group was undertaken by Health Surveillance and Environmental Health Service, Alberta Health in cooperation with Regional Health Authority (RHA) under a protocol (Appendix I). The procedures included selection of a random sample, identification of potential participants, identification of eligible participants and identification of study participants.

Random Sample

A random sample of 500 individuals from each sampling frame was selected.. The distribution of the population of the target communities and of the randomly drawn samples by ethnic group is presented in Table 4-1.

Table 4-1 Distribution of the Population and Sampling Frame for Phase I Study

Community	Group	Population	Random sample
Town of Swan Hills	unknown	249	33
	aboriginal	42	6
	non-aboriginal	2 149	461
	Total	2 440	500
Surrounding Areas	unknown	993	52
	aboriginal	1 326	66
	non-aboriginal	8 042	382
	Total	10 361	500

Potential participants

A telephone interview (Phase I of the study) was conducted with individuals drawn randomly from the sampling frame. During March and April 1997, two trained interviewers conducted telephone interviews to identify individuals willing to provide a blood sample (Phase II of the study). All selected subjects were dialled at least once. A total of 370 subjects were contacted in the Town of Swan Hills and its surrounding areas. Of the remainder, 197 phone numbers were out of service, 154 numbers were wrong numbers, and 279 individuals could not be reached. Of the 370 subjects, 88% individuals (327) agreed to participate in Phase I of the study. Of these, 91% (296) completed Phase I of the study and also agreed to participate in Phase II of the study. These 296 individuals were considered potential participants.

Eligible participants

The Phase I interview included detailed questions about residence history, and wild game and fish consumption. A total of 123 (38%) respondents had consumed wild game taken from the Swan Hills, and 127 (39%) respondents had consumed wild fish. Of these, 90% had consumed wild game and fish for two years and more. Based on the reported consumption rates, four consumption categories were identified as showed in Table 5-4 and 5-6 in Section 5.2.2. Potential participants were divided into two groups. The consumption group consisted of all individuals who reported high, medium, or low intake of wild game; or high, medium, or low intake of wild fish. The non-consumption group consisted of individuals who reported that they did not eat wild game or fish. From these groups, 30 individuals who ate wild game or fish and 20 individuals who did not eat wild game or fish were randomly selected from each of the sample populations (Table 4-2).

Table 4-2 Sampling Frame for Phase II study

Community	Consumption Group		Non-consumption Group		Total	
	potential participants	eligible participants	potential participants	eligible participants	potential participants	eligible participants
Town of Swan Hills	58	30	106	20	164	50
Surrounding areas	41	30	91	20	132	50
Total	99	60	191	40	296	100

A trained interviewer conducted a second telephone interview of these individuals during April, 1997. Verbal consent for participation in Phase II was obtained. Consenting individuals were considered eligible participants and were informed about the sampling process, the volume of blood required for chemical analysis and the specimen banking procedure.

Study Participants

Consent forms and a list of locations for providing a sample of blood were mailed out to eligible participants. A total of 65 study participants contacted managers in the designated health care centers during April and May of 1997. After the manager had discussed consent forms with them, participants signed these forms under the manager's witness, and blood samples were collected. Sample collection took place at the following hospitals: Swan Hills General Hospital, Slave Lake General Hospital, High Prairie Complex, Barrhead Hospital and Fox Creek Hospital. Demographic characteristics of the participants are presented Table 4-3.

Table 4-3 Demographic Characteristics of Blood Donors

Parameter	Consumption Group		Non-consumption Group		Total	
Number of blood donors						
Town of Swan Hills	24	(56%)	12	(55%)	36	(55%)
Surrounding areas	19	(44%)	10	(45%)	29	(45%)
Gender						
Male	22	(51%)	6	(27%)	28	(43%)
Female	21	(49%)	16	(73%)	37	(57%)
Age (year)	39		41.5			
Ethnic group						
First nations and Métis	6	(12%)	0		6	(9%)
Non-aboriginal groups	37	(88%)	22	(100%)	59	(91%)

Of the 65 blood donors, 43 reported consuming wild game or fish taken from the Swan Hills in 1996. Of these, 27 participants eat both wild game and fish. All but one of these participants reported having eaten wild game and fish for two years or more. Table 4-4 presents the consumption rates for these individuals.

Table 4-4 Consumption Rates of Wild Game and Fish

Group	Wild Game			Wild Fish		
	No. of Consumers	Mean	Range	No. of Consumers	Mean	Range
High intake (>100 g/d)	6	178	130 - 227	0	-	-
Medium intake (30-99 g/d)	14	60	32 - 97	7	37	32-49
Low intake (5-29 g/d)	12	13	7.5 - 23	10	13	7.6 - 23
Very low intake (<4 g/d)	6	2.8	1.5 - 3.8	15	2.7	0.8 - 3.8

4.1.4 Specimen Collection Procedures

Study Group

Serum specimens were collected according to a standard protocol (Appendix J). Fifty ml of venous blood was collected from each participant via venipuncture into five 10 ml-Red Top Vacutainers. The specimens were allowed to clot for 30 minutes and then centrifuged for 15 to 20 minutes. Sera were transferred with a glass pipette to an acetone-washed glass vial with a Teflon cap liner. All serum specimens were packed with dry-ice and shipped to the MAXXAM Laboratory via next-day courier on May 7-20, 1997. The completed consent forms and a copy of the shipping list were mailed to Health Surveillance, Alberta Health.

Serum acidification was completed at the MAXXAM Laboratory. Five ml of serum without acidification from each sample was transferred to a glass vial and shipped to the Toxicology Laboratory in Calgary for specimen banking.

Control Group (Composite Samples)

The Canadian Red Cross Society undertook the pooled serum sample collection under a separate protocol (Appendix K). Six composite samples were collected in Edmonton, Alberta. These samples were formed from six age and gender specific groups: males aged 17-35, males aged 35-55, males older than 55, females aged 17-35, females aged 35-55, and females older than 55. Each composite sample contained 25 individual samples from individuals in the same age and gender group for a total of 150 individual samples.

For each composite sample, 1 ml serum from each individual's serum sample was transferred into a clean vial, and an additional 1 ml serum was transferred into another vial labeled for the same group. Each composite sample consisted of 2 vials containing 25 ml of serum. All specimens were kept frozen prior to shipping to the laboratory. All specimens were packed with dry-ice and shipped to MAXXAM Laboratory via next-day courier on May 23, 1997. The completed shipping list was mailed to Alberta Health.

4.1.5 Laboratory Methods

The analytical methods were the same as those described in Section 3.1.5 with the exception of

lipid determination. Method detection limits were 0.03 μg/L for PCB congeners and 0.5 to 0.7 for PCDD/Fs. Recovery rates of 44 PCB congeners for spiked blanks ranged from 77% to 122%. Lipid content was determined by enzymatic methods in a clinical laboratory at the Alberta University Hospital. The measured lipids included triglycerides and total cholesterol (expressed as mmol/l). Total lipid concentration was calculated by summation of the amount of triglycerides and total cholesterol. In these calculations, the average molecular weights of triglycerides and total cholesterol were assumed to be 807 and 571 (Grimvall et al 1997). For instance, 1 mmol triglycerides/liter serum equals 807×10^{-6} kg triglycerides/liter serum.

4.1.6 Data Analysis

Prior to analysis, summary measures for PCBs and PCDD/Fs were calculated. International TEFs (WHO-IPCS for PCBs and NATO-CCMS for dioxins/furans) were used for calculating TEQ values. The concentration of a congener below detection limits was assigned a value of 0 in calculations. The summary measures included total PCB (summation of 44 congeners) and total PCDD/F (summation of 17 congeners) across residence groups and wild game consumption groups. The concentrations were reported in whole weight, lipid adjusted, and lipid adjusted TEQ (PCBs plus PCDD/Fs).

Both non-parametric and parametric significance tests were performed to explore the relationships between summary concentration measures, community of residence and wild game consumption. Multiple linear regression analysis of summary measures in relation to age and sex were conducted for the community samples and for the pooled blood samples. Exploratory analysis of the pattern of congeners for PCB and PCDD/F was also undertaken.

4.2 Results

Means, medians and 90^{th} percentiles for PCB and PCDD/F summary measures for the Swan Hills and surrounding communities and the mean levels of PCBs and PCDD/Fs for the pooled blood samples are shown in Table 4-5.

Table 4-5 Total PCB and PCDD/F Levels in Communities and Pooled Samples

Parameter	Communities			Pooled Samples
	Mean	Median	90th Percentile	Mean
Total PCB[a] (µg/kg, whole weight)	0.14	0.06	0.29	0.16
Total PCB[b] (µg/kg, lipid weight)	31.07	10.01	55.99	32.90
Total PCDD/F[c] (ng/kg, whole weight)	21.47	14.10	50.50	21.24
Total PCDD/F (ng/kg, lipid weight)	5112	2900	9668	4984
TEQ, PCB (ng/kg, lipid weight)	0.43	0.00	0.64	0.34
TEQ, PCDD/F (ng/kg, lipid weight)	18.30	8.96	38.65	14.36
Total TEQ (ng/kg, lipid weight)	18.73	8.96	39.29	14.70

a: total PCB is summation of 44 congener concentrations; b: average serum lipid content is 0.48%; c: total PCDD/F is summation of 17 congener concentrations.

Statistical analysis revealed no statistically significant differences attributable to community of residence or wild game consumption status on any of the summary variables. Similarly, there were no significant differences between the target sample and the pooled blood samples levels on any summary measures. Although the number of aboriginal participants was small, there is no evidence to suggest that serum levels differ for this subgroup.

Regression analysis of the relationship between age and sex for summary measures were conducted for the community samples and for the pooled samples separately. The pattern of results is illustrated in Figure 4-2 and 4-3. In general, both PCB and PCDD/F measures showed statistically significant increases with age. Sex differences were less stable but tended to show relative elevations for males relative to females, most consistently for PCB measures.

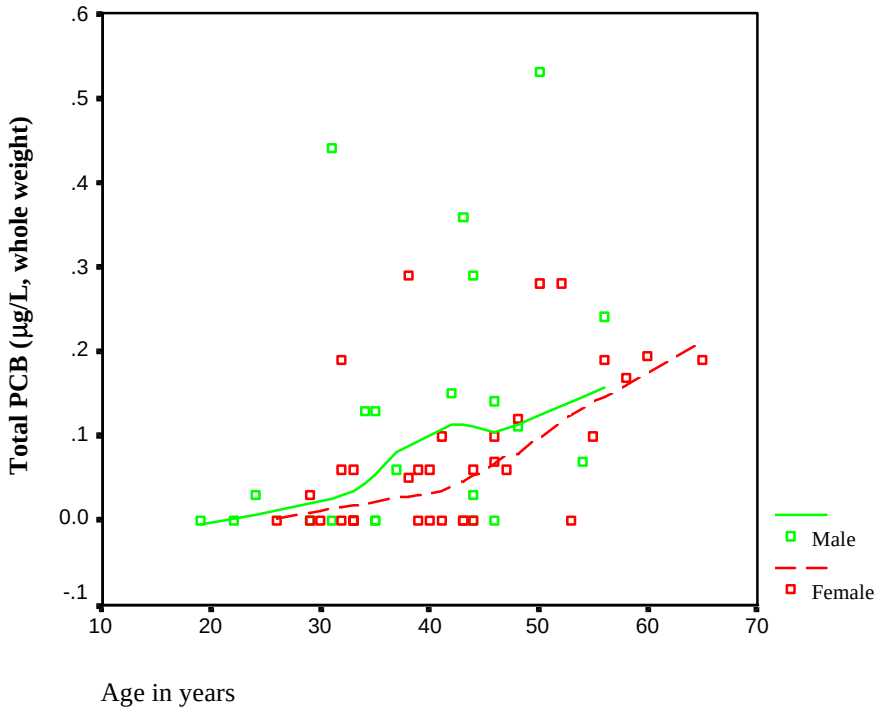

Figure 4-2 Relationship between PCB levels & Age-gender for Community Sample

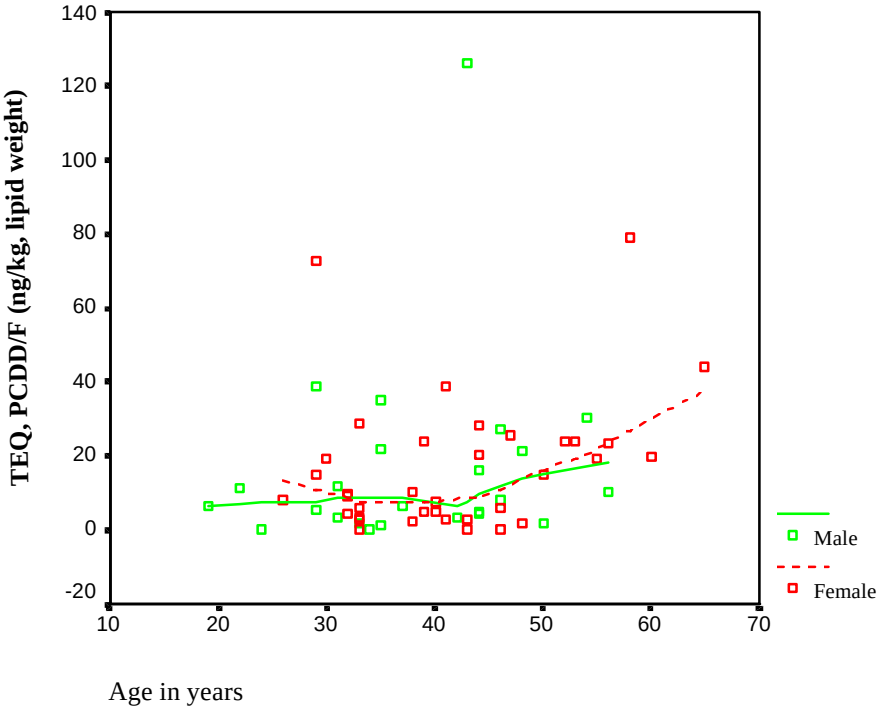

Figure 4-3 Relationship between PCDD/F levels & Age-gender for Community Samples

Appendix L presents the PCB and PCDD/F congener patterns for selected samples and sample types in graphical form. An exploratory cluster analysis of these patterns isolated a small set of profiles with a substantially different pattern, both in terms of the individual congeners isolated and the levels of PCBs. Further examination of the phase II questionnaire data revealed that those individuals were employees of the SHWTC.

4.3 Discussion

The average background blood levels of PCBs in the general population of Canada and U.S. in the 1980s and 1990s ranged from non-detect to 7 μg/L (ppb) on a whole weight basis and from non-detect to 330 μg/kg serum lipid (Table 4-6). In the scientific literature, the levels of dioxins and furans in the blood are also reported as TCDD equivalents (TEQs) on a lipid basis. The average background blood levels of dioxins/furans in the general population of Canada and U.S. ranges between 20 and 40 pg TEQ/g serum lipid (ppt) (Table 4-7). An estimate of the total TEQ value of dioxin-like compounds (PCBs, PCDDs and PCDFs) in the general population was determined by the EPA to be between 40 and 60 pg/g serum lipid (EPA 1994). The EPA also estimated that 10% of individuals may have three-fold higher levels compared to the average level (EPA 1994). In Germany, the mean TEQ values in human blood decreased to 16.5 pg/g blood lipid in 1996 from 43 pg/g reported for 1989. Although these estimates should be compared with caution because of the different background exposures, laboratory analytical methods, and quantitative methods, they can provide a context of background levels against which the estimates derived from the Swan Hills samples can be considered.

Table 4-6 Average Levels of PCBs (μg/kg or ppb) in Human Blood for Selected Nations

Location	Year of Study	Type of subjects	Type of Specimen	No. of Measured Congener	Concentration of Total PCBs (whole weight)	Concentration of Total PCBs (lipid weight)	Reference
East Canada	1994	general population	pooled plasma	30	-	300	Ryan *et al* 1997
Quebec, CA	1989	general population	plasma (n = 59)	7	-	239	Dewailly *et al* 1994
Arctic circum-polar countries	1994-1996	indigenous people	maternal plasma	16-196	1.6 -14.8 Aroclor 1260	-	Muir 1997
Atlanta, U.S.	1988	general population	pooled serum	9	3.0	330	Patterson *et al* 1994
U.S.		general population	pooled whole blood	17	-	123	Schecter *et al* 1994a
California U.S.	1982-1984	general population	plasma (n = 738)	Aroclor 1260	5.0	-	Sahl 1985
Michigan, U.S.	1982-1989	general population	Serum (n = 127)	Aroclor 1260	6.8	-	Hovinga *et al* 1993
Germany		general population	blood (n = 15)	12	-	740	Wuthe *et al* 1996
Sweden		general population	plasma (n = 123)	16	-	900 - 1 340	Svensson et al 1995
Norway		general population	whole blood (n = 10)	20	-	1340	Johansen *et al* 1996
Canada & US	1980s	people/ workers (incidents)	serum	Aroclor 1254/1260	2 - 13	-	Wolff & Schecter 1992
Alberta, Canada (medical guideline)	1994	workers in Alberta	blood	-	< 10 (no action) 10-30 (action)	-	Alberta Labour 1994

Table 4-7 Average Levels of PCDD/Fs (ng/kg or ppt) in Human Blood for Selected Nations

Location	Type of subjects	Type of Specimen (number)	Concentration of TEQ, PCDD/Fs (lipid weight)	Reference
East Canada	general population	pooled plasma	18 - 21	Ryan *et al* 1997
Ontario, CA	general population	pooled plasma	25 - 37	Cole *et al* 1995
Ontario, CA	sport fish consumers	pooled plasma	21 - 41	Cole *et al* 1995
U.S.	general population	pooled whole blood	23	Schecter *et al* 1994a
U.S.	general population	pooled plasma	41	Schecter *et al* 1994b
U.S.	general population	serum	28	EPA 1991
Germany	general population	blood (n = 15)	18	Wuthe *et al* 1996
Germany	general population	whole blood (n = 100)	41	Päpke *et al* 1992
Germany	general population	whole blood (n = 180)	16.5	Päpke *et al* 1997 Schecter *et al* 1997
Sweden	general population	plasma (n = 123)	37 - 54	Svensson et al 1995
Norway	general population	whole blood (n = 10)	21	Johansen *et al* 1996
Vietnam	general population	pooled whole blood	12 - 49	Schecter *et al* 1994b

The results of the current study indicate that residents in Swan Hills and its surrounding areas and residents in Edmonton have substantially lower PCB serum levels than do residents of other jurisdictions, and have PCDD/F levels at the lower end of PCDD/F levels reported from other jurisdictions. However, PCB and PCDD/F levels were positively correlated with age, as was found by other studies. There was no significant association between wild game consumption and blood levels of PCBs and PCDD/Fs in the sample population. It should be noted that the total PCB levels reported for this study are based on a summation of 44 PCB congener values and thus may underestimate levels obtained by different methods. Similarly, the current study used 0 (‘zero’) as the value for non-detect samples rather than an estimate of

half of the method detection level. Because the detection limits were very low, using a value equal to half the detection limit for samples where no contaminant was found would not substantially change the current levels. However, if that method was used in studies with larger detection limits, the reported levels would be higher than expected and the results would not be comparable. In many Canadian studies (Derek Muir, personal communication), the average PCB levels are about 1 to 1.5 μg/L whole weight when a total PCB level is calculated based on comparison of peaks with Aroclor 1260. The correction factor between this method and the current method is not known. As one component of the QA/QC protocol, it is planned that an independent laboratory will reanalyze selected samples.

Blood levels of PCBs and PCDD/Fs frequently serve as surrogate measures for the individual's current level of exposure. The blood profile alone cannot be used to fully explain historical exposures unless initial exposure and half-life elimination rates of contaminants are known. The blood levels can be influenced by serum lipid content because these lipophilic contaminants partition into serum lipid and adipose tissue.

A steady-state body burden in the general population represents the average background exposures from all the environmental media at a given time. Background exposures in industrialized nations mainly result from the food supply. In addition to the background exposures, some individuals may be exposed to these contaminants from discrete sources locally. Wild game consumers may not have eaten wild game meat contaminated with a high level of chemicals because the contamination was unevenly distributed in deer and moose in the vicinity of the facility. Furthermore, the blood levels might not reflect such a short-term exposure to PCBs and PCDD/Fs.

Relatively high levels of PCB congeners 153 and 138 and of Octa-CDD were observed in this study. This observation was also reported for the general populations in other studies (Feeley 1995). Serum levels reported in this study most likely reflect typical exposures, without distinguishing discrete sources and pathways. In order to track down the specific exposures for other individuals having unusual patterns of specific congeners, more detailed information such as dietary habits and occupational histories would need to be collected.

Two comprehensive reviews of the scientific literature related to human exposure to PCBs revealed that no well-established overt adverse health effects were observed from lower levels of exposure [Kimbrough 1995; Swanson et al 1995]. However, in recent years, scientists have begun investigating subtle effects which may arise in response to low levels of PCB exposure. For PCDD/Fs, there is evidence that high-level exposure is associated with a variety of adverse human health effects [DeVito et al 1995]. However, whether the background exposure is associated with adverse effects remains to be determined.

In an occupational setting, the maximum allowable concentration of PCBs blood level is higher than typical background levels. The medical guideline for PCBs required by Alberta Labour is less than 10 μg/kg (ppb) in blood for occupational exposures, a level met by BOVAR employees tested in this study.

4.4 Conclusion

Overall, the assessment of human blood serum from residents of Swan Hills and the surrounding communities found that: a) Human blood serum levels of PCBs and PCDD/Fs for study participants were below the levels reported in other jurisdictions, but follow similar age and gender patterns; b) Human blood serum levels of PCBs and PCDD/Fs for residents of Swan Hills and its surrounding communities did not exceed the levels found in Edmonton residents; and c) No differences were observed between individuals who consumed wild game and fish from the Swan Hills area and those who did not. This does not mean that individuals should feel free to consume wild game captured in the Swan Hills area; rather, individuals should still observe the Public Health Advisory regarding wild game consumption which suggests limits for rates of consumption and advises against consumption for particular groups.

5. DIET AND ACTIVITY SURVEY

The purpose of the diet and activity survey was to obtain accurate information on the dietary habits and activities of individuals living in the Swan Hills and surrounding areas.

5.1 Materials and Methods

As part of the human blood sampling study, a diet and activity survey was conducted through telephone interviews during March and April 1997. The survey was divided into two phases. Questionnaires are presented in Appendices M, N, and O. Eighty-eight percent (327) of 370 respondents participated in the first telephone interview. A second telephone interview was then conducted with 100 participants selected from those who had participated in the first telephone interview as described in the Human Blood Monitoring section.

Participants were asked to recall their consumption of wild game and fish and their outdoor recreational activities for the previous 12 months. Specifically, the initial survey was used to determine types of outdoor activities within the Swan Hills area; frequency, duration and amount of wild game and fish consumption; and the respondents' awareness of and adherence to the existing health advisory.

The second survey requested demographic characteristics (age, gender, ethnic group, weight and height, occupation, duration of residency, number of persons in the household); proportion of activity time spent indoors and outdoors and detailed information about outdoor activities; detailed information about daily food consumption including consumption of wild game, fish and wild fruit, vegetables and herbs, and cooking and preparation techniques for wild game and fish; and more detailed information about lifestyle (use of alcohol and cigarettes, health conditions and perception of the current health advisory).

For wild game and fish consumers, the typical meal size was obtained by comparison to a 4 oz portion of meat. When participants estimated their meal size as less than 4 oz, a 2 oz size was assumed. When participants estimated their meal size as greater than 4 oz, an 8 oz size was assumed.

In order to control the quality of the survey, similar questions on wild game consumption rate were presented in the initial and second questionnaires. In the second questionnaire, different species such as deer, moose, elk and bear were separately listed (rather than giving a general term "wild game"). The recall bias can be examined by comparison of reported consumption rates in these two questionnaires. When the reported rates were not consistent, the rates from the second questionnaires were used in analysis.

5.2 Results

5.2.1 Outdoor Activities and Diet

5.2.1.1 Outdoor Activities

The proportion of individuals who participated in outdoor activities in the Swan Hills area is summarized in Table 5-1. Twenty to forty percent of the respondents engaged in various recreational activities in the Swan Hills area during 1996. Fishing, hiking and camping were the most popular activities.

Most participants brought drinking water from home or from taps/pumps to the activity sites. A few participants took drinking water directly from lakes or rivers without filtering or boiling it. Some individuals ate wild berries (blueberry, huckleberries and raspberries) picked from the Swan Hills area.

Table 5-1 Summary of Outdoor Activities in the Swan Hills Area

Parameters	Town of Swan Hills (n=172)	Surrounding areas (n=155)	Total (n=327)
Hunting	34 (20%)	24 (15%)	58 (18%)
Trapping	2 (1%)	0	2 (0.6%)
Fishing	65 (38%)	48 (31%)	113 (35%)
Swimming	53 (31%)	41 (26%)	94 (29%)
Hiking	89 (52%)	41 (26%)	130 (40%)
Camping	88 (51%)	55 (35%)	143 (44%)
Canoeing	48 (28%)	26 (17%)	76 (23%)
Snowmobiling	56 (33%)	27 (17%)	83 (25%)

5.2.1.2 Wild Game Consumption

A total of 123 (38%) respondents had consumed wild game taken from the Swan Hills area (Table 5-2). Of these, 90% indicated they have consumed wild game meat for two years or more. Based on the reported consumption rates, four consumption categories were identified: high intake (>100 grams per day [g/d]), medium intake (30-99 g/d), low intake (5-29 g/d) and very low intake (<4 g/d) (Table 5-3). The results correspond well to those based on daily, weekly, monthly and yearly categories presented in the interim report (Alberta Health May, 1997). The distribution of participants across the four categories is illustrated in Figure 5-1. Moose, deer and grouse are the most common wild game for consumption. Some participants indicated they also eat elk, bear, duck, and rabbit.

Table 5-2 Proportion of Individuals Consuming Wild Game From the Swan Hills Area

Parameters	Town of Swan Hills (n=172)	Surrounding areas (n=155)	Total (n=327)
Individuals ever consumed wild game	75 (44%)	48 (31%)	123 (38%)
Individuals consumed both wild game/ fish	46 (27%)	34 (22%)	80 (24%)
Individuals only consumed wild game	29 (17%)	14 (9%)	43 (13%)
Duration of wild game consumption			
less than 1 year	-	-	11 (9%)
2 to 5 years	-	-	26 (21%)
more than 5 years	-	-	86 (70%)

Table 5-3 Wild Game Consumption Rate (g/d)

Group	Mean	SD	95% CI	Median	Range	Mean [a]
High Intake-muscle (>100)	191	47	162-220	227	130-227	210 (daily)
Medium Intake-muscle (30-99)	58	26	48-67	49	30-97	60 (weekly)
Low Intake-muscle (5-29)	13	6	1.87-12	13	7.5-23	12 (monthly)
Very Low Intake-muscle (<4)	2	0.98	1.95-2.54	1.71	0.3-3.8	2 (yearly)
Average Intake-liver	2	0.8	1.26-2.66	1.83	1.83-3.06	2 (yearly)

[a:] mean reported in the interim report May, 1997 by Alberta Health based on daily, weekly, monthly and yearly categories.

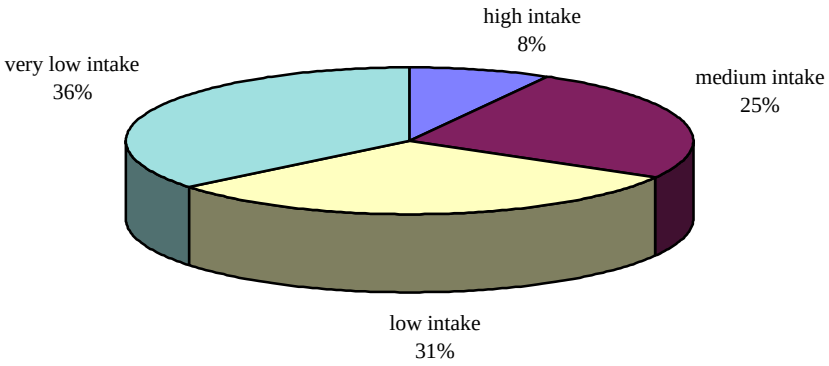

Figure 5-1 Proportion of Four Wild Game Consumption Groups

5.2.1.3 Fish Consumption

A total of 127 (39%) respondents indicated that they ate wild fish taken from the lakes surrounding the Swan Hills area (Table 5-4). Of these, 98% have eaten wild fish for two years or more. Four fish consumption groups (high, medium, low and very low) were identified (Table 5-5). The distribution of participants across the four consumption groups is illustrated in Figure 5-2. The most commonly consumed species were walleye, northern pike, perch, brook trout, lake whitefish and arctic grayling. The most popular fishing sites were Chrystina Lake, Roche Lake, Edith Lake, Freeman Lake and Lesser Slave Lake. The most common cooking methods were frying and baking.

Table 5-4 Proportion of Individuals Consumed Wild Fish From the Swan Hills Area

Parameters	Town of Swan Hills (n=172)	Surrounding areas (n=155)	Total (n=327)
Any consumption of wild fish	69 (40%)	58 (37%)	127 (39%)
Consumption of both wild game/fish	46 (27%)	34 (22%)	80 (24%)
Consumption of wild fish only	23 (13%)	24 (15%)	47 (14%)
Duration of consumption			
less than 1 year	-	-	4 (3%)
2 to 5 years	-	-	35 (28%)
more than 5 years	-	-	88 (69%)

Table 5-5 Fish Consumption Rate (g/d)

Group	Mean	SD	95% CI	Median	Range
High consumption (>100)	167	57	103-232	162	113-227
Medium consumption (30-99)	47	20	37-56	32	32-97
Low consumption (5-29)	13	5.4	11-15	11	7.6-23
Very Low consumption (<4)	2	0.94	1.9-2.3	1.53	0.77-3.8

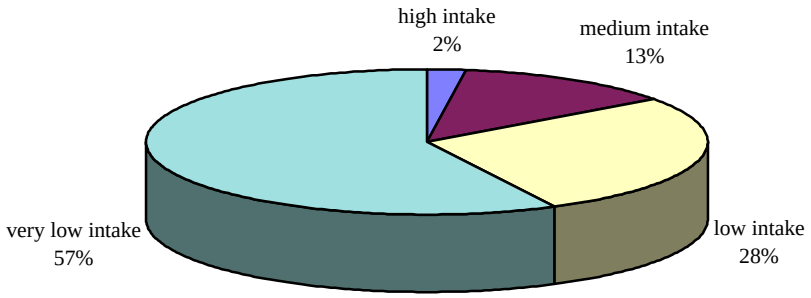

Figure 5-2 Proportion of Four Fish Consumption Group

5.2.2 Additional Information from Questionnaire 2

5.2.2.1 Demographic Information

The demographic characteristics of the 100 individuals who participated in the second telephone interview are summarized in Table 5-6. Participants were grouped into a wild game/fish consumption group if they had consumed any wild game or fish during 1996; otherwise they were classified into the non-consumption group. About 55% of the wild game/fish consumption group were male while about 77% of the non-consumption group were female. The average duration of residence was 12.5 years for participants in the Swan Hills area and 15.5 years for participants in the surrounding areas. Five First Nations and six métis individuals were included in the consumption group. In the consumption group, 47% of participants in the Swan Hills and 20% in the surrounding areas work outdoors in occupations such as oil and gas operator and truck driver. In the non-consumption group, over 85% participants work in indoor occupations such as clerk in a grocery store, teacher and secretary. In the consumption group, 60% of respondents in the Swan Hills area and 23% of respondents in the surrounding areas had smoked cigarettes.

Respondents reported a variety of illnesses, but there was no consistently reported diagnosis or group of diagnostic categories. Overall, 20% of the respondents in the consumption group reported a diagnosis of a chronic illness, while 25% of the non-consumption group reported having a diagnosis of a chronic illness. In the consumption group, two participants had ovarian cancer, two participants had heart conditions and one participant had high cholesterol. Other chronic diseases mentioned included: bronchitis, diabetes, gout, stroke, anaemia, hiatus hernia, and rheumatoid arthritis. In the non-consumption group, participants reported various health problems such as thyroid, skin and cervical cancer, over-stimulated thyroids, under-stimulated thyroid, high blood pressure, ulcerative colitis, adrenal gland disorders, asthma, allergies and liver problems (high gamma - glutamyl transpeptidase (GGTP)).

Table 5-6 Demographic Characteristics of Participants

Parameter	Consumption Group		Non-Consumption Group	
	Swan Hills (n=30)	Surrounding areas (n=30)	Swan Hills (n=20)	Surrounding areas (n=20)
Gender (number)				
male	17 (57%)	16 (53%)	4 (20%)	5 (25%)
female	13 (43%)	14 (47%)	16 (80%)	15 (75%)
Age (year)	37	39	40	41
Duration of Residence (year)	13	17	12	14
Body weight (kg)	79	81	71	73
Ethnic group (number)				
Caucasian	25	23	20	18
First Nations	1	4	-	1
Métis	3	3	-	-
East Indian	-	-	-	1
Unknown	1	-	-	-
Family size (number)				
persons in one household (range)	4 (1-7)	3 (1-7)	4 (1-6)	3 (1-6)
children in one household (range)	1 (0-5)	1 (0-5)	1 (0-4)	1 (0-4)
Occupation (number)				
indoor worker [>75% time]	16 (53%)	24 (80%)	17 (85%)	19 (95%)
outdoor worker [>35% time]	14 (47%)	6 (20%)	3 (15%)	1 (5%)
Use of alcohol (number)				
ever	21 (70%)	21 (70%)	15 (75%)	14 (70%)
never	9 (30%)	9 (30%)	5 (25%)	6 (30%)
Cigarette smoking (number)				
ever	18 (60%)	7 (23%)	8 (40%)	7 (35%)
never	12 (40%)	23 (77%)	12 (60%)	13 (65%)

5.2.2.2 Consumption of Food from Markets

The rate of consumption of various food items obtained from commercial sources reported by participants in the second telephone interview are presented in Table 5-7.

Table 5-7 Consumption Rates for Commercially Available Food Items

Food item	**Wild game consumption group (n = 60)** (g/person/day)	**Non-wild game consumption group (n = 40)** (g/person/day)	**Food item**	**Wild game consumption group** (g/person/day)	**Non-wild game consumption group** (g/person/day)
Ground beef	38	46	Margarine	20	19
Roast beef	10	14	Cheese	33	25
Beef steak	20	21	Cheese spread	6.9	3.3
Fresh pork	11	23	Cottage cheese	2.9	2.8
Poultry	20	39	Ice cream	32	29
Canned fish	15	10	Cream	14	7.8
Eggs	46	34	Shellfish	1.5	5.4
Butter	4.4	6.8	Fresh water fish	3.0	5.2

5.3 Discussion

Because wild game meat and local fish are not a regular part of the diet for most residents in the Swan Hills and surrounding areas, a 12-month recall questionnaire was used. Only five out of 100 respondents provided different wild game consumption rates in the second questionnaire than they reported in the initial questionnaire. The reported consumption rates are therefore considered to be reliable.

The estimated daily intake varies with the consumption rate and body weight across individuals. The average consumption rate was 35 grams/day of wild game and 15 grams/day of fish. A small proportion of consumers eat a relatively large quantity of local wild game and fish. Aboriginal people may have higher rates of consumption of food from local sources, though specific data for aboriginal people living in Swan Hills and surrounding areas are not available. The results from a study conducted for the NRBS Study indicated that people who eat fish in the Northern River Basin area consume an average of 13.6 kg of fish per year (37 g/d) (MacLock and Thompson 1996). About two-thirds of people who fish in Northern Alberta consume less than 10 kg of fish per year and 3% eat more than 100 kg of fish per year. Another study reported that consumption rates for Native Canadians near Wood Buffalo National Park were 55 g/d for wild meat and bird and 14 g/d for locally caught fish (Wein *et al*. 1991). The 95th percentile of consumption rates were 175 g/d for meat and birds and 39 g/d for fish. These respondents indicated that they ate locally caught or killed food more than 6 times per week. The average and high-end consumption rates are close to the survey data reported by the participants from Swan Hills and the surrounding areas.

The current survey data indicated that meat from commercial markets is the primary food for local residents. This observation is consistent with findings from the National Total Diet survey (Conacher et al. 1989). In Canada, fresh meat products from commercial markets contribute 90% of the total intake of PCBs and dioxins/furans (Birmingham *et al*. 1989; Davies 1989; Mes *et al*. 1989; Gilman *et al*. 1991; Conacher and Mes 1993; Ryan et al. 1997). Thus, the primary dietary source of these contaminants for local residents may be daily consumption of meat from commercial markets.

5.4 Conclusion

About forty percent of local residents consume local wild game and fish although the amount varies considerably. Only a small portion of the residents consume large quantities of local wild game and fish.

6. ESTIMATION OF DAILY INTAKE AND EXPOSURE RATIO

The purpose of estimating daily intake is to assess exposure levels resulting from consuming contaminated wild game and fish. The resulting estimates can be compared to existing guidelines.

6.1 Estimation of Average Daily Intake

Assessment of human exposure to PCBs, PCDDs and PCDFs by consumption of wild game and fish requires translating concentrations of the contaminants into quantities of the contaminants that come in contact with an individual within the exposed population. Average daily intake (ADI) from wild game and fish consumption represents the amount of a contaminant per unit of body weight per day that crosses the mouth of an exposed individual and reaches the surface of the gastrointestinal tract.

6.1.1 Development of Exposure Scenario

According to their consumption frequency, people who eat locally caught wild game and fish were divided into four groups: high, medium, low and very low intake (see Section 5.2.1). The concentrations of total PCB and total TEQ, PCDD/Fs and coplanar PCBs at the 50^{th} and 90^{th} percentile in different types of meat samples were calculated, using AEMPIRICAL methods (Table 6-1). For fish samples, the 90^{th} percentile concentrations and means for contaminants for fish in Roche and Chrystina Lake were estimated (Table 6-2). Because all analyses were performed on composite samples, the distribution of contaminants in individual fish is not known. For the current purposes, this distribution was assumed to be normal. The variability of the contamination distribution was estimated from the variability between the composite samples using assumptions derived from the central limit theorem.

Exposure scenarios were developed as follows:

- Exposure Scenario 1A (ES 1A): exposure to 90^{th} percentile concentration of total PCB in fresh deer muscle;
- Exposure Scenario 1B (ES 1B): exposure to 50^{th} percentile concentration of total PCB in fresh deer muscle;
- Exposure Scenario 1C (ES 1C): exposure to 90^{th} percentile concentration of total TEQ, PCDD/F + coplanar PCB in fresh deer muscle;

- Exposure Scenario 1D (ES 1D): exposure to 50th percentile concentration of total TEQ, PCDD/F + coplanar PCB in fresh deer muscle.
- Exposure Scenario 2A (ES 2A): exposure to 90th percentile concentration of total PCB in fresh deer liver;
- Exposure Scenario 2B (ES 2B): exposure to 50th percentile concentration of total PCB in fresh deer liver;
- Exposure Scenario 2C (ES 2C): exposure to 90th percentile concentration of total TEQ, PCDD/F + coplanar PCB in fresh deer liver;
- Exposure Scenario 2D (ES 2D): exposure to 50th percentile concentration of total TEQ, PCDD/F + coplanar PCB in fresh deer liver.

- Exposure Scenario 3A (ES 3A): exposure to 90th percentile concentration of total PCB in freezer muscle;
- Exposure Scenario 3B (ES 3B): exposure to 50th percentile concentration of total PCB in freezer muscle;
- Exposure Scenario 3C (ES 3C): exposure to 90th percentile concentration of total TEQ, PCDD/F + coplanar PCB in freezer muscle;
- Exposure Scenario 3D (ES 3D): exposure to 50th percentile concentration of total TEQ, PCDD/F + coplanar PCB in freezer muscle.

- Exposure Scenario 4A (ES 4A): exposure to 90th percentile concentration of total PCB in fish muscle from Chrystina Lake and Roche Lake;
- Exposure Scenario 4B (ES 4B): exposure to mean concentration of total PCB in fish muscle from Christina Lake;
- Exposure Scenario 4C (ES 4C): exposure to 90th percentile concentration of total TEQ, PCDD/F + PCB in fish muscle from Chrystina Lake and Roche Lake;
- Exposure Scenario 4D (ES 4D): exposure to mean concentration of total TEQ, PCDD/F + PCB in fish muscle from Chrystina Lake.

Table 6-1 Levels of PCBs and PCDD/Fs in Fresh and Freezer Meat from Swan Hills

Parameter	Muscle		Liver	
	50th percentile	90th percentile	50th percentile	90th percentile
Fresh Meat				
Total PCB (µg/kg or ppb)	6.5	73	71	144
Coplanar PCB, TEQ (pg/g or ppt)	1.76	63.2	60	130
PCDD/Fs, TEQ (pg/g or ppt)	0.64	3.8	190	1600
Total TEQ (pg/g or ppt) [a]	2.4	67	250	1730
Freezer meat				
Total PCB (µg/kg or ppb)	-	42.2	-	-
Coplanar PCB, TEQ (pg/g or ppt)	-	13.93	-	-
PCDD/Fs, TEQ (pg/g or ppt)	-	0.07	-	-
Total TEQ (pg/g or ppt) [a]	-	14.0	-	-

a: Total TEQ = PCDD/Fs, TEQ + coplanar PCB TEQ (No.77 and No.126 congeners)

Table 6-2 Concentrations of PCBs and PCDD/Fs in Fish Muscle from Swan Hills

Parameter	Chrystina Lake		Roche Lake	
	90th percentile	mean	90th percentile	mean
Total PCB whole weight µg/kg	36.2	17.85	4.1	-
Total TEQ whole weight pg/g	28.7	12.41	1.5	-

6.1.2 Definition and Documentation of Parameters

Average daily intake was calculated as follows:

$$ADI = C * IR * CF * ED * BF/BW * AT \quad (6\text{-}1)$$

Body weight is an important parameter in estimating daily intake. A default value of 60 kg body weight was used by Health Canada to establish guidelines for levels of PCBs and dioxins/furans in food. However, the average body weight for adults in Alberta is about 73 kg based on 1994 National Population Health survey. The average body weight in the current survey ranges from 72 kg for non-consumption group to 80 kg for the consumption group. The Alberta average body weight was adopted for risk assessment in the current study. The definitions for each parameter in this equation are summarized in Table 6-3.

Table 6-3 Definition of Parameters in the Daily Intake Equation

Parameter	Specific Definition	Unit
ADI = daily intake LADI = lifetime average daily intake	average potential dose of PCBs and total TEQ, PCDD/Fs + PCBs received by an individual through wild game consumption at units of microgram of the chemicals per day, normalized over body weight (bw) and averaged exposure time (or lifetime for PCDD/Fs)	µg PCB/kg bw/day pg TEQ/kg bw/day
C = concentration of a contaminant	concentrations of total PCB, or total TEQ, PCDD/F + PCB directly measured in tissues (wet weight, ww)	µg PCB/kg ww pg TEQ/kg ww
IR = ingestion rate	average amount of each food item consumed by an individual per day.	kg/day
CF = contact fraction	the distribution of total contact rate between contaminated and uncontaminated tissue. For the worst case scenario, all tissues are assumed to be contaminated with PCBs and PCDD/F.	1.0
ED = exposure duration	the overall time period of exposure (length of time for consuming contaminated meat).	Year
BF = bioavailability factor	absorption fraction. Both PCBs and PCDD/Fs were observed to be efficiently absorbed through oral exposure in infants and experimental animals.	1.0
BW = body weight	average body weight for Albertans at age of 20^{+} (source: NPHS 94-95, Statistic Canada)	73 kg (SD = 12)
AT = average of exposure time period	average days of the overall time period of exposure.	year
	average lifetime exposure days are derived from life expectancy in Alberta (source: Alberta Health, Health Surveillance)	78 years

6.1.3 Estimated Daily Intake

The estimated daily intakes (EDI) of total PCBs and total TEQ, PCDD/Fs + PCBs were calculated, using equation 6-1, for fresh deer muscle (Table 6-4), fresh deer liver (Table 6-5), freezer meat (Table 6-6) and fish muscle (Table 6-7).

Table 6-4 Estimated Daily Intake of PCBs, PCDD/Fs in Fresh Deer Muscle

Consumption Group	High		Medium		Low		Very Low	
Concentration	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}
Total PCB (µg/Kg/d)	.02	.2	.005	.06	.001	.01	.0002	.002
Planar PCB TEQ (pg/Kg/d)	4.5	165	1.5	50	.3	11	.05	1.7
PCDD/F TEQ (pg/Kg/d)	1.7	10	.5	3	.1	.7	.02	.1
Total TEQ (pg/Kg/d)	6.2	175	2.0	53	.4	12	.07	1.8

Table 6-5 Estimated Daily Intake of PCBs, PCDD/Fs In Fresh Deer Liver

Parameter	50^{th} percentile concentration	90^{th} percentile concentration
Total PCB (µg/Kg/d)	.002	.004
Planar PCB TEQ (pg/Kg/d)	1.6	3
PCDD/F TEQ (pg/Kg/d)	5.2	44
Total TEQ (pg/Kg/d)	6.8	47

Table 6-6 Estimated Daily Intake of PCBs, PCDD/Fs in Freezer Muscle

Consumption Group	High		Medium		Low		Very Low	
Concentration	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}	50^{th}	90^{th}
Total PCB (µg/Kg/d)	7^{-4}	.12	2^{-4}	0.03	4^{-5}	.007	7^{-6}	.001
Planar PCB TEQ (pg/Kg/d)	-	40	-	11.4	-	2.3	-	.38
PCDD/F TEQ (pg/Kg/d)	-	.2	-	.1	-	.02	-	.002
Total TEQ (pg/Kg/d)[a]	-	40.2	-	11.5	-	2.3	-	.38

Table 6-7 Estimated Daily Intake of PCBs, PCDD/Fs in Fish Muscle

Consumption Group	High		Medium		Low		Very Low	
Concentration	mean	90th	mean	90th	mean	90th	mean	90th
Chrystina Lake								
Total PCB (µg/Kg/d)	.04	.08	.01	.02	.003	.007	.0005	.001
Total TEQ (pg/Kg/d)	28	66	8	18	2.2	5.1	.3	.8
Roche Lake								
Total PCB (µg/Kg/d)	-	.01	-	.003	-	.001	-	.0001
Total TEQ (pg/Kg/d)	-	3.4	-	.96	-	.27	-	.04

6.2 Quantitative Estimates of Risk - Exposure Ratio

The process for quantitative estimates of risk arising from consumption of contaminated wild game and fish requires the combination of the information on estimated exposure (i.e. estimated daily intake, EDI) with the information on dose-response (i.e. tolerable daily intake, TDI) to set safety margins for exposure to PCBs, PCDDs and PCDFs. Estimates of risk are expressed as an exposure ratio (ER).

6.2.1 Selection of the Existing Guidelines

The Health Canada Guidelines for PCBs and TCDD in food were established in the 1970s based not only on toxicity data but also on food distribution in Canadian markets and national consumption patterns at that time (Table 6-8). The guidelines are appropriate to commercial food such as beef, dairy products, eggs, poultry and fish. Administrative guidelines for PCB mixtures are under review by Health Canada.

Table 6-8 Health Canada Guidelines/Tolerances for PCBs and TCDD in Foods

Chemicals	Food Item	Value
PCB	Meat/Beef/Dairy products (fat basis)	200 ppb [a]
	Egg (whole egg less shell basis)	100 ppb [a]
	Poultry (fat basis)	500 ppb [a]
	Fish (edible portion)	2 000 ppb [a]
TCDD	Fish (edible portion)	20 ppt [a]
TEQ, PCDD/F	Fish (edible portion, muscle)	15 ppt (40 g/d, 60 kg body weight)
	Fish (viscera)	30 ppt (20 g/d, 60 kg body weight)

a: under review

In order to estimate risk arising from consuming local wild game containing PCBs and PCDD/Fs, relevant guidelines that were established based on different health outcomes by a variety of regulatory agencies were examined (Table 6-9). The guideline values range from 0.01 pg/kg/ to 10 pg/kg/d for TCDD and from 0.02 µg/kg/d to 1 µg/kg/d for PCBs. For TCDD, the Health Canada Tolerable Daily Intake (TDI) refers to a lifetime dose through all exposure routes. Exposure to PCBs and PCDD/Fs in food accounts for 90% of total human exposure in Canada [Birmingham et al 1989; Davies 1990; Gilman et al 1991]. The TDI for PCBs proposed by Health Canada was established based on overt human effects and is currently under review. A reference dose (RfD) proposed by USEPA and a minimal risk level (MRL) proposed by USATSDR for PCBs were established on the basis of reproductive and immune effects. To provide insight into the potential health risk posed from exposure to PCB mixtures, three PCB guidelines (as proposed by Health Canada, USEPA and USATSDR) were used to calculate exposure ratios. For estimating exposure ratio for PCDD/Fs, the Health Canada TDI for TCDD was adopted.

Table 6-9 Summary of TDI and RfD/RSD for PCB and TCDD

Agency	Chemical	Method	Species	End-point	NOAEL or CPF	UF or CA	Dose
Health Canada	TCDD[a]	NOAEL-UF	female rat[b]	malignant tumor in liver, lung, nasopharynx	1 ng/kg/d	100	10 pg/kg/d (TDI)[c]
USEPA	TCDD	LMS	same as above	same as above		$1x\ 10^{-4}$	0.01 pg/kg/d (RSD)
USFDA	TCDD	LMS	same as above	same as above	1.75E4 mg/kg/d	$1x\ 10^{-6}$	0.57 pg/kg/d (TDI)
Netherlands	TCDD	NOAEL-UF	rhesus monkey[d]	cognitive development	100 pg/g	100	1 pg/kg/d (TDI)
Health Canada and USFDA	PCB (Kane-chlor 400)	NOAEL-UF	human[e]	chloracne, other signs/ symptoms	10 µg/kg/d[f]	10	1 µg/kg/d (TDI)
USEPA	PCB (Aroclor 1016 / 1248)	NOAEL-UF	rhesus monkey[g]	reduced birth weight	0.007 mg/kg/d	100	0.07 µg/kg/d (RfD_{oral})
ATSDR	PCB (Aroclor 1254)	NOAEL-UF	female rhesus monkey[h]	reduction in serum IgM and IgG	0.005 mg/kg/d LOAEL	300	0.02 µg/kg/d (MRL_{oral})[i]

a: TDI of TCDD can apply to PCDD/PCDF and coplanar PCB;
b: Kociba et al. 1978;
c: lifetime exposure such as 70 years;
d: Bowmen et al. 1989;
e: Karatsune and Fukoka, 1971; Federal Register 38(129), July 6, 1973;
f: NOAEL 10 µg/kg/d is based on Yusho data (200 µg/kg/d actual 50 day exposure) assuming 1000 day exposure;
g: Barsotti and van Miller, 1984; Levin et al., 1988; Schantz et al. 1989;
h: Tryphonas et al. 1989, 199;
i: minimal risk level for chronic-duration oral exposure (365 days or more)
NOAEL = no-observed-adverse-effect-level;
LOAEL = low-observed-adverse-effect-level;
UF = uncertainty factor;
CPF = cancer potency factor; CA = cancer risk;
LMS = linearized multistage model;
RfD = reference dose,
TDI = tolerable daily intake;
RSD = risk specific dose;
MRL = minimal risk level

6.2.2 Point Estimates

The exposure ratio reflects the ratio between the actual level of exposure (external dose) in a particular circumstance and a reference standard associated with observed toxicity in humans or animals.

Point estimates are most commonly used in risk assessment for reasons of simplicity, accessibility and acceptance by most regulatory agencies. Point estimates are determined by assigning a single default value that would represent an average value or a high-end (worst-case) value to each exposure model parameter in each exposure scenario In the past decades, regulation and decision making in environmental health has relied on the simple point estimates, including fractile-based summary (50^{th} or 95^{th} percentile) and the mean and variance of the distribution with a statement of the potential for bias in these estimates. In order to be conservative, the "worst case" or upper bound estimates are generated when the input parameters are set at worst values. In many cases, uncertainty assessment is only a qualitative statement of confidence in the results. When many conservative factors are involved in the analysis, the risk estimates can be higher than those that are intended for risk management. The limitations of this approach include: (1) bias in the estimates away from mean values; (2) limited information about the degree of conservatism in risk assessment; (3) major sources of uncertainty remain unidentified; (4) results of sensitivity analyses are less meaningful; and (5) explicit indications are not provided for decision makers and the public.

Exposure ratios based on regulatory guidelines (TDI) were calculated by using the following equation:

$$ER = EDI/TDI \qquad (6\text{-}2)$$

The TDI for PCBs is 1 μg/kg/d. From a public health perspective, an oral reference dose proposed by USEPA (0.07 μg/kg/d) and a minimal risk level proposed by USATSDR (μg/kg/d) were selected for comparison. The TDI for TCDD proposed by Health Canada is 10 pg/kg/d.

6.2.1.1 Fresh and Freezer Meat

The resulting estimates of exposure ratios were tabulated for fresh deer muscle (Table 6-10), fresh deer liver (Table 6-11), and freezer muscle (Table 6-12).

The exposure ratios for all consumption groups are less than 1.0 as compared to all the guidelines at the 50th concentration percentile of total PCBs. At the 90th concentration percentile, in both fresh and freezer muscle, the estimated daily intakes for the high consumption group exceed the USEPA and USATSDR standards. At the 90th percentile, the estimated daily intake for the medium consumption group exceeds the USATSDR standard. At the 90th concentration percentile of total TEQ, PCDD/F + PCBs, the estimated daily intake for high and medium muscle consumption groups and the liver consumption group exceeds the Health Canada TDI value.

Table 6-10 Exposure Ratios for Consuming Fresh Deer Muscle

Consumption Group	High		Medium		Low		Very Low	
Concentration	50th	90th	50th	90th	50th	90th	50th	90th
Guideline								
HC and FDA - PCB	.02	.2	.005	.06	.001	.01	.0002	.002
EPA - PCB	.2	**3**	.07	.8	.01	.2	.003	.03
ATSDR - PCB	0.9	**10**	.25	**3**	.05	.7	.01	.1
HC - TCDD	.6	**18**	.2	**5**	.04	**1**	.007	.2

Table 6-11 Exposure Ratios of PCBs, PCDD/Fs for Consuming Fresh Deer Liver

Guidelines	50^{th} Percentile concentration	90^{th} Percentile concentration
HC and FDA - PCB	.002	.004
USEPA - PCB	.03	.06
USATSDR - PCB	.1	.2
HC - TCDD	.7	4.7

Table 6-12 Exposure Ratios for Consuming Freezer Muscle

Consumption group	High		Medium		Low		Very Low	
Concentration	50^{c}	90^{c}	50^{c}	90^{c}	50^{c}	90^{c}	50^{c}	90^{c}
HC and FDA - PCB	7^{-4}	.1	2^{-4}	.03	4^{-5}	.007	7^{-6}	.001
USEPA - PCB	.01	1.6	.003	.5	6^{-4}	.1	1^{-4}	.02
USATSDR - PCB	.03	**6**	.01	1.7	.002	.4	3^{-4}	.06
HC - TCDD	-	**4**	-	1.2	-	.2	-	.04

6.2.1.2 Fish

Estimates of exposure ratios were tabulated for fish muscle from Chrystina lake (Table 6-13). Exposure ratios for the high consumption group exceed 1.0 at the mean concentration in fish muscle, as compared to the Health Canada TDI for TCDD and USATSDR MRL for PCBs. At the 90^{th} concentration percentile, the estimated daily intake for high and medium intake groups exceed the Health Canada, USEPA and USATSDR guidelines. At the 90^{th} concentration percentile in fish liver, the estimated daily intake for high, medium and low intake groups exceeds the Health Canada TDI value for TCDD.

Table 6-13 Exposure Ratios for Consuming Fish Muscle from Chrystina Lake

Consumption group	High		Medium		Low		Very Low	
Concentration	mean	90th	mean	90th	mean	90th	mean	90th
Chrystina Lake								
HC and FDA - PCB	.04	.08	.01	.02	.003	.007	.0005	.001
USEPA - PCB	.6	**1.2**	.2	.3	.05	.09	.007	.01
USATSDR - PCB	**2**	**4**	.6	**1.2**	.2	.3	.02	.05
HC - TCDD	**2.8**	**6.6**	.8	**1.8**	.2	.5	.03	.08
Roche Lake								
HC and FDA - PCB	-	.01	-	.003	-	.001	-	.0001
USEPA - PCB	-	.1	-	.04	-	.01	-	.002
USATSDR - PCB	-	.5	-	.1	-	.04	-	.006
HC - TCDD	-	.3	-	.1	-	.03	-	.004

6.3 Development of Consumption Limit

The calculation of the consumption limit (CR) is based on the following equation:

$$CR = TDI * BW / C \quad (6\text{-}3)$$

where: TDI is tolerable daily intake (which may, in some cases, be substituted by reference dose or minimal risk level dose),

BW is human body weight and

C is measured concentrations of PCBs and PCDD/Fs.

The average adult body weight for Albertans is 73 kg (SD = 12) derived from National Population Health survey, 1994. The 90th percentile concentrations of total PCB (whole weight) and total TEQ (whole weight) were used for calculating consumption limits. Health Canada TDI for TCDD (10 pg/kg/d) was adopted for estimating consumption limits.

The recommended consumption limits are presented in Table 6-14. These consumption limits provide guidance on the evaluation of the potential risk associated with exposure to PCBs and dioxins/furans for individuals who consume deer or moose meat taken within 30 km radius of the plant and/or brook trout from Chrystina lake. The estimated values represent the amount of meat from deer or moose and from edible portions of brook trout expected to generate a risk no greater than the tolerable daily intake proposed by Health Canada, based on a lifetime of daily consumption at that consumption limit. Because the contaminants tend to accumulate in the internal organs in various animals and the measured levels of the contaminants were very high in the liver samples, people should avoid consumption of viscera from wild game and fish.

Table 6-14 Species-Specific Consumption Limit

Parameter	Wild Game Meat	Fish
Species	deer and moose	brook trout
Location	within 30 km radius of the SHWTC	Chrystina lake
Type of tissue	muscle	muscle
Health Canada TDI for TCDD(pg/kg bw/day)	10	10
Body weight (kg) based on Alberta average	73	73
Consumption limit (g /day)	12	25
Consumption limit (g /week)	84	178
Consumption limit (oz /week)	3	6
Consumption limit (oz/month)	13	26

6.4 Discussion

The daily intake of PCBs and PCDD/Fs comes mainly from the diet through commercial food sources, and to a lesser extent, from breathing air and drinking water. The daily intake from background exposure for adult Canadians is estimated to be 2-4 pg PCDD/F/kg/d (Gilman *et al*. 1991). The exposure ratio reflects the ratio between the actual level of exposure (external dose) in a particular circumstance and a reference standard associated with observed toxicity in humans or animals. In the current assessment, the estimated daily intake and exposure ratios provide insight into additional exposure that might be expected from consuming local wild game and fish.

Around the world, various regulatory guidelines have been developed for TCDD, the most toxic dioxin in the group of dioxins/furans. The guidelines are expressed as a reference dose (RfD) or a tolerable daily intake (TDI), that is, a lifetime daily dose for TCDD which is believed to be without potential health effects to humans. In the past TCDD has been treated as a threshold carcinogen by some regulatory agencies. Based on this assumption, a value of 10 pg/kg body weight/day has been adopted by Health Canada (Canada 1990). Some PCB and dioxin/furan congeners produce similar toxic effects to humans and animals as TCDD. The similarity of toxicity between these congeners and TCDD was assessed using toxic equivalency factors (TEFs). The daily intake calculations in this study are based on the international dioxin toxic equivalency factors (I-TEFs which assumes the additive toxicity of the congeners and TCDD present in a sample.

Based on 90th concentration percentile of total TEQ values, individuals who consume over 13 ounces of deer or moose muscle per month or who consume over 26 ounces of brook trout fillet per month will exceeded the Health Canada TDI. Limiting daily intake for local wild game and fish should be considered as a precaution. The levels of PCBs and PCDD/Fs in the livers of deer and brook trout were high. The consumption of the livers and other internal organs should be avoided altogether.

The current Health Canada TDI for TCDD is based on the potential for cancer. The toxicity of TCDD and related congeners also includes reproductive, developmental and immunotoxic effects (DeVito *et al*. 1995). Humans are sensitive to the toxic effects of dioxin-like compounds. Children and pregnant women or women who are breast-feeding are susceptible groups and should avoid consuming wild game and fish.

6.5 Conclusion

Based on estimated daily intake and exposure ratio calculations, daily and weekly consumption of wild game meat and fish taken near the SHWTC may result in increased exposure and potential health risk over a person's lifetime. Thus, restrictions on the consumption of wild game and fish contaminated with PCBs and dioxins/furans are warranted.

7. RISK MANAGEMENT AND COMMUNICATION

Risk management is a cyclic process designed to identify problems in a broad context, integrate scientific, social, cultural, economic and legal considerations in the evaluation and selection of options, and implement actions to minimize public risk. The framework for risk management is presented in Figure 7-1.

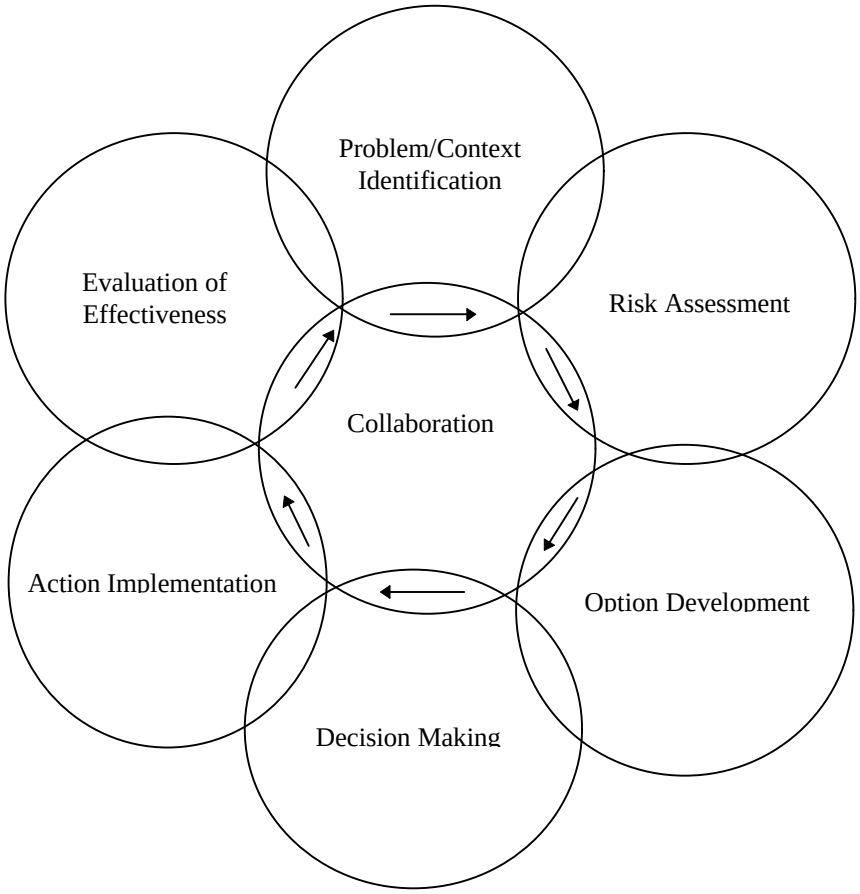

Figure 7-1 Risk Management Framework
(after Commission's final report, 1997)

7.1 Initial Identification

The potential of a health risk was identified after the October 1996 incident in which a large quantity of PCBs and dioxins/furans were emitted into the air. The impacts on the ecosystem and on public health due to this incident were of immediate concern to local residents, the SHWTC, and the provincial government.

7.2 Initial Response

After the accident, the SHWTC transformer furnace was shut down. BOVAR conducted an immediate monitoring of air, vegetation, soil, water, fish and wild game. Initial findings indicated elevated concentrations of contaminants in air, vegetation, soil, voles and deer. BOVAR informed Alberta Environmental Protection who in turn informed Alberta Health of the incident and preliminary findings.

Under the Public Health Act, provincial health officials are responsible for protecting the public from any harm resulting from hazardous substance release. A preliminary risk assessment suggested a potential health risk from exposure for local residents and traditional/recreational wilderness users in the Swan Hills area. The provincial health officer issued a public health advisory on December 13, 1996. In accordance with the precautionary principle, this advisory cautioned against consumption of any wild game and fish taken from within a 30 km radius of the SHWTC.

7.3 Development of a Risk Management Plan

In order to obtain additional information for evaluating and refining the public health advisory, a detailed health risk assessment was initiated in January, 1997 to provide the best available scientific information about the degree and scope of contamination. The current report presents the results of this assessment.

Alberta Health established a process to facilitate an exchange of information and ideas among all affected parties during the health risk assessment (Figure 7-2). Stakeholders included various groups that were potentially affected by the risks arising from the incident and by risk management decisions, including the Swan Hills community, the Lesser Slave Lake Indian Regional Council, BOVAR Waste Management, experts in various scientific fields, the Edmonton Friends of the North, Alberta Environmental Protection, Alberta Health, Alberta Labour, Alberta Agriculture, Alberta Justice, Environment Canada, and Health Canada.

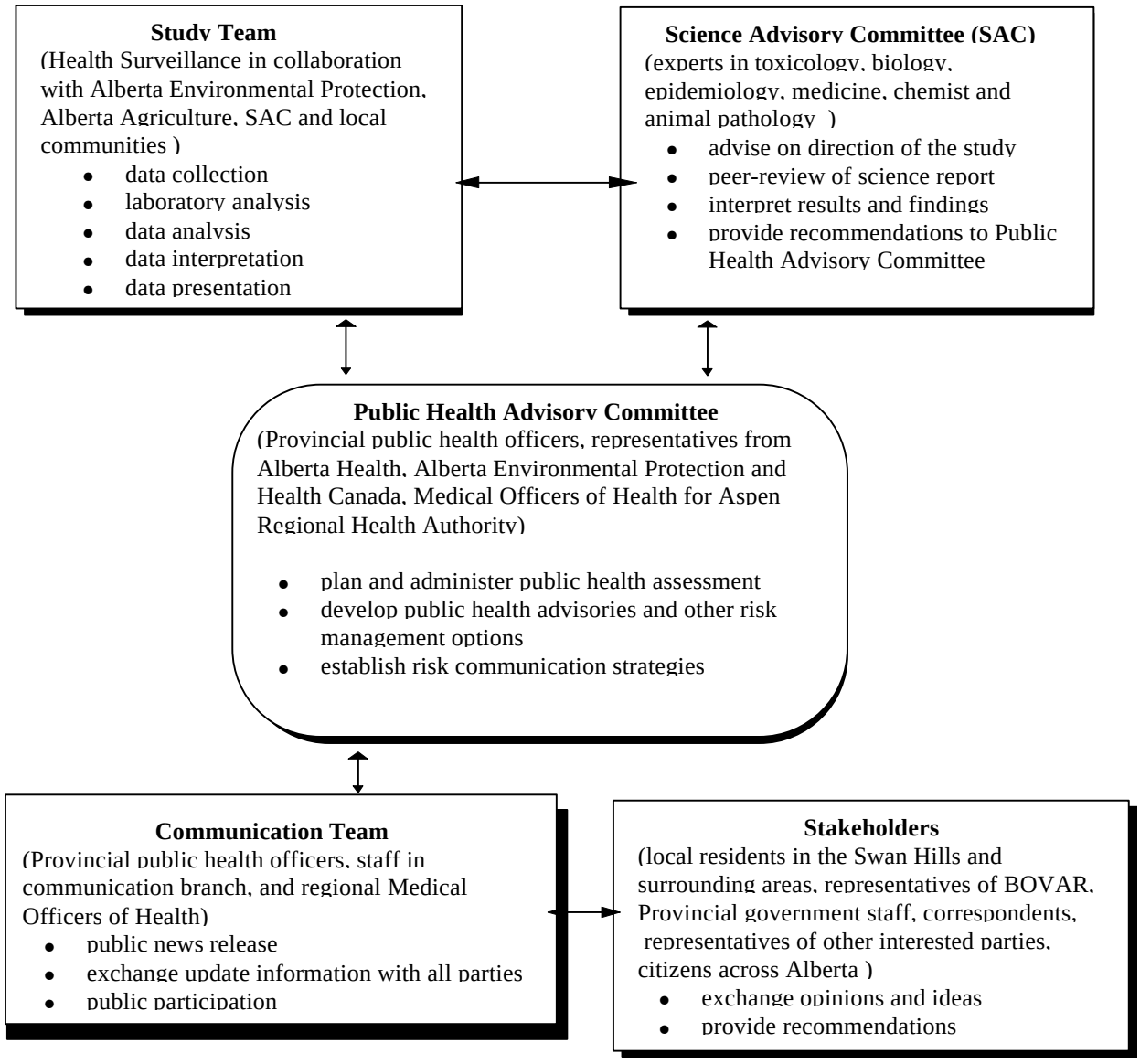

Figure 7-2 Stakeholder Involvement in the Swan Hills Health Assessment

Additional related activities included BOVAR's submission of an assessment plan for continued environmental monitoring to Alberta Environmental Protection, and the continuation of a blood sampling program for BOVAR workers by Alberta Labour.

7.4 Public Health Advisories

A public health advisory is a non-regulatory risk management option intended to assist individuals in making informed decisions although the guidelines presented in advisories cannot ensure compliance. Considerations for evaluating the need for a public health advisory are presented in Table 7-1.

Three public health advisories were issued by provincial public health officials between December 1996 and October 1997 as information became progressively available (Table 7-2). The Health Canada guidelines for PCBs and dioxins/furans were adopted in constructing these advisories.

Table 7-1 Evaluating the Need for a Public Health Advisory

Criterion	Issue	Rescind	Resource
Source environmental quality			
indicator: compliance with regulations, guidelines and standards	above	below	Health Canada Documents
indicator: magnitude and duration of contaminants in environmental media	upward trend	downward trend	BOVAR environmental monitoring program Swan Hills health assessment (Alberta Health)
Manufacturing performance			
indicator: manufacturing deficiency	failure of industrial operations	corrected or reduced technological changes	BOVAR reports
Insurance of field collection and laboratory analysis			
indicator: basic QA/QC criteria	good	good	Standard protocols
Local resource			
indicator: human consumption patterns	heavy consumption of local food	average consumption of local food	Dietary and activity survey (Alberta Health)
indicator: traditional or recreational values	heavy land use in recreational and traditional lifestyles	average or less than average level	Dietary and activity survey (Alberta Health)
indicator: commonly consumed fish and wild game species	very common	average or less common	Dietary and activity survey (Alberta Health
Health Risk Assessment			
indicator: estimated daily intake and exposure ratio	above tolerable daily intake proposed by Health Canada	below tolerable daily intake proposed by Health Canada	risk-based consumption model (Alberta Health)
Human health study			
indicator: various health endpoints	positive association	negative association	not available
Public value	public anxiety	public understanding	media, community meeting
Scientific review	consensus	consensus	Science advisory committee

Table 7-2 Public Health Advisories

Advisory	Consideration	Content
Public Health Advisory I: Wild Game and Fish (December 13, 1996)	• accidental emissions in October, 1996 • failure of industrial process • large quantities of PCBs and dioxins/furans released • elevated level of PCB in one deer taken near the SHWTC	• avoid eating wild game and fish taken from a 30 km radius of the SHWTC • avoiding eating any more of the meat if wild game from the area has already been eaten • no need to dispose of any wild meat until further information is available
Public Health Advisory II: Wild Game (May 15, 1997)	• elevated levels of PCBs and dioxins/furan in fresh deer muscle and liver taken from a 30 km radius of the SHWTC • estimated daily intake exceeded the Health Canada TDI in heavy consumption groups • PCBs and dioxins/furans persist in the environmental media • PCBs and dioxins/furans are slowly removed from wildlife bodies	• limit consumption of wild game taken from a 30 km radius of the SHWTC to 13 ounces (370 grams) per month • avoid eating organ meat or using fat harvested from within a 30 km radius of the SHWTC • pregnant or breast feeding women should avoid eating wild game taken from within a 30 km radius of the SHWTC • young children should avoid eating wild game taken from within a 30 km radius of the SHWTC • continue to avoid eating fish from within a 30 km radius of the SHWTC until fish sample testing is complete
Public Health Advisory III: Fish (October 30, 1997)	• elevated levels of PCBs and dioxins/furan in brook trout muscle and liver taken from Chrystina Lake • estimated daily intake exceeded the Health Canada TDI in heavy consumption groups • PCBs and dioxins/furans persist in the environmental media • PCBs and dioxins/furans are slowly removed from fish	• limit consumption of fish taken from within a 20 km radius of the SHWTC to 6 ounces (170 grams) per week. • avoid eating fish organs or using fat. • pregnant or breast feeding women should avoid eating fish taken from within a 20 km radius of the SHWTC. • young children should avoid eating fish taken from within a 20 km radius of the SHWTC

7.5 Communication

The public health advisories were delivered to target audiences through various channels including public media, local town hall meetings, and direct mail.

The public media was a major vehicle for information dissemination. The provincial health officer held press conferences at each stage. Media packages included public news releases, interim reports, detailed public health advisories, briefing background information and a brochure outlining the potential health effects of PCBs and dioxins/furans (Appendices P- S). In addition, a single large ad was placed in local paper, the *Swan Hills Grizzly Gazette*.

A fact sheet was provided to anyone purchasing a hunting license for the Swan Hills area for the upcoming hunting season. Fish and Wildlife Officers received written information to assist them in dealing with public inquiries. The news release, background information, and fact sheet were also sent to Alberta Native Bands, the Medical Services Branch of Health Canada, and to the Regional Health Authorities for distribution.

As well, briefing meetings were held with local residents to provide them with an opportunity to ask questions and get all of the facts, and with regulators in other provincial government departments.

The results of freezer meat and blood sampling were sent by direct mail to all individuals who had supplied meat or blood samples. The letter and accompanying fact sheet included the levels of PCBs, dioxins and furans in each type of sample, an explanation of regulatory guidelines and background data, current public health advisories, and the names of individuals to contact for further information (Appendix T and U). The regional Medical Officers of Health played a major role in communicating with individuals.

7.6 Public Response and Perception

As part of the dietary and activity survey during February to May 1997, participants were provided an opportunity to express their concerns about the situation and the processes for risk management.

In the first telephone interview, participants were informed of the occurrence of the incident in SHWTC, the public health advisory of December 1996, and the objectives of the risk assessment. Most respondents understood the purpose of the study and recognized the need to conduct a detailed assessment. Participants also appreciated that the Alberta Health assessment was being conducted independently of the SHWTC. Many suggestions about the study structure were provided including the importance of appropriate control groups, the importance of placing a special emphasis on people who ate a large amount of wild game and fish, and proposals for investigations of air quality, water quality, and livestock in the surrounding area.

Participants were asked how they had learned about the public health advisory (Table 7-3) and whether they felt the advisory was effective. Fifty seven percent of respondents who were wild game and fish consumers stated that the advisory was effective. A major reason for considering the advisory ineffective was that the initial advisory was not based on clear evidence.

Table 7-3 Sources of Public Awareness of Public Health Advisory

Source	Wild Game and Fish Consumers	Non-Consumers
Media (newspaper, TV, radio)	47%	63%
Media + word of mouth	22%	13%
word of mouth	15%	8%
BOVAR company	3%	3%
current study (initial questionnaire)	7%	8%
community meetings or mail notice	6%	5%

Although the majority of people in the sample were aware of the public health advisory, only 12% quit eating wild game and fish after the first public health advisory was issued. Participants who chose to continue consuming wild game and fish were asked to provide the most important reason that influenced this decision. One third indicated that the wild game and fish that they were consuming were taken from outside a 30 km radius of SHWTC which reflects an understanding of the advisory. An additional third of consumers believed that the contamination in the Swan Hills area was less severe than had been estimated. Some of the responses suggested that the method of communication used at the Town Hall meeting significantly impaired the effectiveness of the public health advisory. Additional reasons provided for continuing to consume meat included:

- lack of evidence for contamination
- it is safe to eat small amount of local meat and fish
- I feel safe because Alberta Health is investigating
- local food is main food source for me

Participants were given the option to express their opinions about the incident and the current study. Some participants noted the economic benefits of the SHWTC; some were disappointed by the media's portrayal of Swan Hills; many felt that the situation at the SHWTC had been exaggerated. Some participants did not believe that they had been exposed to PCBs, dioxins and furans, and some were concerned about contamination from other sources. However, the majority of participants were strongly concerned about children and pregnant women being exposed to PCBs, dioxins and furans. The local residents also seemed to have diverse attitudes towards the

Swan Hills Treatment Center itself. Overall, the mixed opinions of local residents likely reflect a felt tension between economic stability and environmental health concerns.

7.7 Implications of Cultural Values

Wild game and fish may supplement the diet of a number of people living in the area surrounding the SHWTC. Concern has been raised by both recreational users and traditional users because these two groups consume more wild game and fish than the general population. The balance between nutritional benefits and health risks arising from the consumption of contaminated food is an important consideration in issuing public health advisories (Kimbrough, 1991; Burger and Gochfeld, 1996).

The current advisories address this issue in three ways. First, the dietary survey attempted to determine the extent of wild game and fish consumption by residents of the Swan Hills area. Survey results indicate that only a small proportion of people ate fish caught in Chrystina Lake. Second, the advisories provided consumption limits developed from risk estimates rather than an outright ban on consumption. These limits do indicate that wild game and fish may still be safely consumed in moderation. Third, the advisories are restricted to a 30 km radius of the SHWTC in accordance with evidence that contamination with PCBs, dioxins and furans is restricted to areas near the SHWTC. Therefore, traditional and recreational users can still safely consume wild game and fish obtained from outside the affected area.

Finally, it should be noted that the consumption limits provided in the advisories were calculated in reference to uncooked food. Many studies have shown that appropriate food preparation and cooking techniques can reduce the concentrations of PCBs, dioxins and furans in fish and meat (Zabik, 1995; USEPA 1996; Schecter *et al* 1997; Petroske et al. 1997). Thus, techniques such as removing the skin prior to cooking, broiling and baking are recommended for individuals who continue to consume wild game and fish taken from the areas immediately surrounding the SHWTC.

8. LONG TERM MONITORING PLAN

The next phase of the Swan Hills health assessment is the implementation of a longer term human health monitoring plan. This includes (a) continued environmental monitoring, (b) on-going human health surveillance, and (c) research activities. A comprehensive environmental monitoring program has already been developed by BOVAR Waste Management as a response to the Alberta Environmental Protection Enforcement Order-97-01. This part of the program is focused on ecosystems such as air, surface and ground water, soil, sediment, vegetation, aquatic life, and wildlife in the area surrounding the Swan Hills Waste Treatment Center (BOVAR 1997). The recommendations in this section emphasize the monitoring needs from a human health perspective. In order to ensure the continued protection of the residents in the town of Swan Hills and surrounding areas Alberta Health, Aspen and Keeweetinook Regional Health Authorities, Alberta Environmental Protection and Alberta Labor, in collaboration with BOVAR Waste Management, will ensure the implementation of the following activities:

1. *Fish monitoring*. PCBs and PCDD/Fs levels in brook trout fillet and liver from Chrystina Lake will be analyzed each fall. The minimum sample size will consist of at least four composite samples containing 16 to 20 large and older fish. Other fish species in other lakes within the Swan Hills area will also be monitored.

2. *Wildlife monitoring*. PCBs and PCDD/Fs levels in wild game used for human consumption will be analyzed each year. Samples will include deer muscle and liver, and moose muscle and liver. Based upon the dietary survey conducted in the Swan Hills area, wildlife monitoring will be extended to include the analysis of wild grouse. Although not directly related to human health, predators should also be monitored to gain a better understanding of the biomagnification of the contaminants in the food chain.

3. *Human blood monitoring*. If warranted by the results of fish and wild game monitoring, or any other unforeseen events, PCBs and PCDD/F levels in human serum

of the residents in the town of Swan Hills and the surrounding areas will be assessed on as needed basis.

4. *Workers health monitoring*. Biological monitoring data from workers at the SWTC will be analyzed and reviewed on a regular basis to detect any changes or trends in blood levels of PCBs and PCDD/Fs.

5. *Specific risk groups.* If warranted by the on-going monitoring results, targeted studies of specific risk groups (e.g., First Nations, children, women) should be conducted.

6. *Research.* Additional studies may be conducted to further understand the relationships between PCBs and PCDD/F exposure and human health effects. Priorities should include the assessment of total dietary exposure to PCBs and PCDD/Fs, the development and assessment of biomarkers of effect, and the effect of freezer temperatures and storage on wild game meet contaminant levels.

7. *Common database.* A computerized data repository for monitoring data will be jointly established by Alberta Health, Alberta Environmental Protection, Alberta Labor, BOVAR Waste Management, and other stakeholders to ensure the availability of high quality data for the purpose of analysis, monitoring and research (Appendix V).

8. *Review and interpretation of information*. An independent Science Advisory Committee will be used to provide scientific direction and to advise on the interpretation of the monitoring results. The Provincial Health Officer and Medical Officers of Health will review the findings from a human health perspective and make health risk management decisions.

9. *Dissemination of information* All relevant monitoring information will be made public in a timely fashion, in the form of periodic reports, or other means of communication.

10. *Review of the fish and game consumption advisory*. Alberta Health and Alberta Environmental Protection establish a process for the on-going review of fish and game consumption advisories. Changes to the advisory (e.g., lifting) will be made based on the available scientific information.

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