SARA GROUP

Sudbury Area Risk Assessment
Volume II

Appendix H:

Livestock Survey
Data Report

EXECUTIVE SUMMARY

A Human Health Risk Assessment (HHRA) is currently being undertaken in the Greater Sudbury area as part of the Sudbury Soils Study. The Chemicals of Concern (COC) for the Sudbury Soil Study are arsenic, cobalt, copper, lead, nickel and selenium. One potential exposure route for humans for these COC is via livestock grown and slaughtered in the area, such as cattle, which needs to be considered in the HHRA. The Livestock Survey was intended to obtain site-specific data on the range of metal concentrations found in the tissue of beef cattle raised in the Greater Sudbury area. The majority of these animals are raised and consumed within the local area, possibly comprising a portion of the dietary intake of the residents of the Greater Sudbury area. The results of the survey are intended to provide data specific to the Sudbury community to be used as part of the exposure assessment component of the HHRA. As a result, tissue samples were collected in a manner consistent with how they are normally collected by residents consuming this dietary source, and then analyzed for metal content.

During the fall of 2003 a livestock survey was conducted to fill this data gap. Kidney, liver and muscle samples were collected from 10 cattle, and analyzed for a suite of 20 parameters, including the COC for the Sudbury Soils Study. Metal or metalloid levels varied between tissues, with the concentration of copper being markedly higher in liver followed by kidney, then muscle. In contrast, levels were generally higher in kidney tissue for arsenic, lead, nickel and selenium. The levels of all elements were generally lowest in muscle, which represents the most significant tissue from a human consumption perspective.

The data provided in this report are intended to be specific to the Sudbury community and will be used as part of the exposure assessment component of the on-going HHRA for the area.

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SUDBURY AREA RISK ASSESSMENT
LIVESTOCK SURVEY

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H-1.0 INTRODUCTION

H-1.1 Background

The Sudbury Basin is an area rich in mineral deposits, particularly the nickel and copper ores that have drawn people to the region for the past 125 years. Recent studies have identified areas in Sudbury with elevated metal levels in the soil. These areas are generally close to the historic smelting sites of Coniston, Falconbridge and Copper Cliff. Although these metals do occur naturally in all soils, the studies generally indicate higher levels in surface soil (the top 5 cm) as a result of local mining, smelting and refining operations.

In 2001, the Ontario Ministry of the Environment (MOE) released a report that identified that concentrations of nickel, cobalt, copper and arsenic in the area exceeded the generic MOE soil quality guidelines. Under Ontario legislation, this triggers the need for more detailed study. Therefore, the MOE made two recommendations:

- That a more detailed soil study be undertaken to fill data gaps; and,
- That a human health and ecological risk assessment be undertaken.

Both Vale Into and Xstrata Nickel voluntarily accepted the recommendations and began working together to establish what is commonly referred to as “The Sudbury Soils Study”. The mining companies partnered with four other major stakeholders in Sudbury to oversee this rigorous study. The community partners are Vale Inco, Xstrata Nickel, the MOE, the Sudbury & District Health Unit, the City of Greater Sudbury, and Health Canada First Nations and Inuit Health Branch. These partners formed a Technical Committee to oversee the study. A Public Advisory Committee was also established to help address questions and concerns about the potential impact of elevated metal levels on the local environment and human health.

Later in 2001, a comprehensive soil sampling and analysis program was undertaken by the MOE and the mining companies. Approximately 9,000 soil samples were collected from urban and remote areas and analysed for 20 elements. These data form the basis of the Sudbury Soils Study. Early in 2003, a consortium of consulting firms working together as the SARA (Sudbury Area Risk Assessment) Group was retained to undertake the risk assessment portion of the study.

The human health implications of metal levels in soils and the environment will be examined under the Human Health Risk Assessment (HHRA) of the Sudbury Soils Study. To conduct the HHRA exposure

pathway analysis, detailed information was collected on metal levels in air, soil, water, vegetation and other environmental matrices. The purpose of the livestock sampling program was to collect samples of local livestock consumed by residents of the Greater Sudbury area as part of the overall HHRA.

H-1.2 Objective of the Collection

The Livestock Survey was intended to obtain site-specific data on the range of metal concentrations found in the tissue of beef cattle raised in the Greater Sudbury area. The majority of these animals are raised and consumed within the local area, possibly comprising a portion of the dietary intake of the residents of the Greater Sudbury area. The results of the survey are intended to provide data that are specific to the Sudbury community and can be used as part of the exposure assessment component of the on-going HHRA for the area. As a result, tissue samples were collected in a manner consistent with how they are normally collected by residents consuming this dietary source, and then analyzed for metal content.

H-2.0 METHODOLOGY

H-2.1 Animal Selection

Samples from 10 beef cattle raised in the Greater Sudbury area were collected by Professor Glenn Parker, Laurentian University in 2003. The samples were taken from animals destined for slaughter for private consumption and ranged in age from 9 months to 2 years.

H-2.2 Animal History

To identify the area where the animal originated, a history was collected and GPS co-ordinates obtained for mapping purposes. These locations are shown in Figure H-2-1.

The history of the animal was collected from the person submitting the animal for processing. Information collected included:

- Age
- Sex
- Breed
- Location where animal was raised and pastured
- Location where the winter hay fed to animal was grown
- If the animal had been fed any store purchased supplementary feeds; if yes, what feed was used
- Contact name and address for person responsible for submitting the animal

Details on the background for each animal are provided in Appendix A.

H-2.3 Tissue Sampling Collection

All samples were collected under the direction of Dr. Glenn Parker of Laurentian University. Table H2.1 outlines the samples collected from each animal included in the study. Samples of kidney, liver and muscle were collected where possible:

- Kidney was a composite of both the medulla and the cortex;
- Liver was taken from the left lobe; and,
- Muscle was taken from the left cheek.

A 10 g sample was collected from each animal. Each sample was split equally into two 5 g portions; one portion was submitted for metal analysis at Testmark Laboratories, Sudbury and the other sample was archived. Duplicate samples were collected from three animals that had all tissue types available for collection.

Additionally, a small subsample (1 g) of each tissue was collected from each animal and stored in a Whirl-Pak® bag; this was used for determination of moisture content of the fresh sample at Laurentian University.

Table H2.1 Livestock Tissue Samples Collected

Sample Number	Tissues Collected	Total Amount of Tissue Collected (g)			Amount of Each Tissue Required (g)		
		Kidney	Liver	Muscle	Analysis[(a)]	Fresh Moisture Content[(b)]	Archive[(c)]
1	Liver, Kidney, Muscle	16	16	16	10	1	5
2	Liver, Kidney, Muscle	16	16	16	10	1	5
3	Liver, Kidney, Muscle	16	16	16	10	1	5
4	Liver, Kidney, Muscle	11	11	11	5	1	5
5	Liver, Kidney, Muscle	11	11	11	5	1	5
6	Liver, Kidney, Muscle	11	11	11	5	1	5
7	Liver, Muscle	n/a	11	11	5	1	5
8	Muscle	n/a	n/a	11	5	1	5
9	Muscle	n/a	n/a	11	5	1	5
10	Liver, Muscle	n/a	11	11	5	1	5

(a) Performed at Testmark Laboratories, Sudbury
(b) Determined at Laurentian University, Sudbury
(c) Archived at NAR Environmental, Sudbury

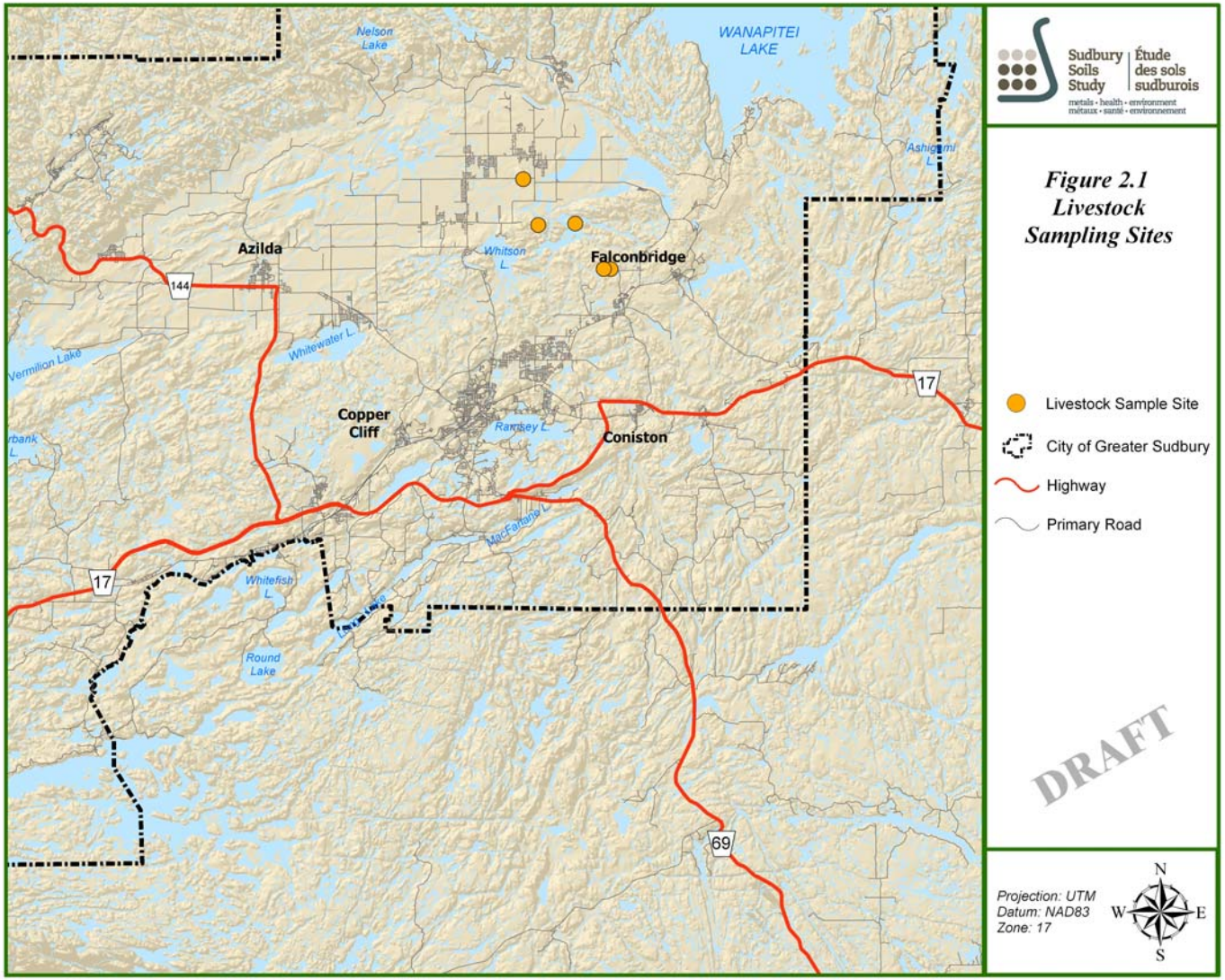

Figure H-2-1. Livestock Sampling Sites

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H-2.4 Sample Handling

H-2.4.1 Shipping

Chain-of-custody forms were sent with each sample shipment. These clearly identified the samples contained within the shipment package, and the analyses to be conducted with each sample. Samples were sent to Testmark Laboratories in a plastic cooler.

H-2.4.2 Storage

Samples were stored in a sealed plastic bag and frozen until submitted for analysis. Care was taken to ensure that all air was removed from the bag to reduce the formation of water crystals during freezing. Archived samples were frozen and stored at NAR Environmental, Sudbury.

H-2.4.3 Labeling

The samples were labelled with the following information:

- Sample number (1-10);
- Tissues type (kidney, liver, muscle);
- Original or duplicate sample; and
- Age of animal.

H-2.5 Sample Treatment

H-2.5.1 Moisture Content

The moisture content of each tissue was determined at Laurentian University (fresh samples after collection) and at Testmark Laboratories (thawed samples prior to analysis). Approximately 1 g of tissue was weighed in a pre-weighed aluminium tray. The wet mass of the sample and the tray was recorded. The sample and the tray were placed into a drying oven until a steady dry weight was achieved. The moisture content was the determined using the following equation:

$$\% \text{ Moisture} = \frac{(\text{wet mass of sample (g)} - \text{dry mass of sample (g)})}{\text{wet mass of sample (g)}} \times 100$$

H-2.5.2 Sample Preparation

At Testmark Laboratories, samples were prepared for metal analysis. Tissue samples were chopped and blended, with 1.0 – 1.7 g of each sample used for analysis.

H-2.5.3 Digestion Method

All samples were prepared by microwave digestion. Each blended tissue sample was mixed with HNO_3 in a lined digestion vessel (CEM Corporation). Sample digestion was performed in a microwave oven (MDS-2000 system, CEM Corporation) with pressure control.

H-2.5.4 Analytical Parameters

All collected samples were analyzed for the following metals and metalloids:

- Aluminum
- Antimony
- Arsenic
- Barium
- Boron
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Molybdenum
- Nickel
- Selenium
- Strontium
- Titanium
- Vanadium
- Zinc

The range of minimum detection limits for the livestock survey provided by Testmark Laboratories is shown in Table H2.2. The instrument detection limit (IDL) is determined experimentally based on the method validation data. The minimum detection limit (MDL) for water is the same as the IDL for undiluted samples. Results for water samples run on the ICP/MS are normally reported in µg/L or parts per billion (ppb). The IDL is used to calculate the real MDL for soil, biota and tissue samples. Therefore, the MDLs are based on the actual mass of sample digested and the final volume. The calculation is as follows:

$$MDL = \frac{IDL \times Vol(digest)}{mass(sample)}$$

Normally, a 1:10 dilution on the final volume is carried out before running on the ICP/MS, to cut down on the amount of acid run through the mass spectrum detector. The ICP/MS can be run at higher acid concentrations but accuracy is sacrificed on the lower molecular weight analytes (Li, B, Be, P, *etc.*); there is little problem with the higher molecular weight metals. For soil and biota samples, it is typical to digest 2 g of sample and dilute up to 100 mL. For tissue samples, about 1 g of sample is digested in the microwave digestion vessel and diluted up to 50 mL.

In practice, every sample digested will have different weights. Therefore, MDLs reported will differ slightly between samples. Furthermore, dilutions resulting from high concentrations of metals or matrix effects may produce MDLs that differ by 1 or 2 orders of magnitude. It is appropriate when presenting large data sets to report the range of MDLs for the samples in the data set.

Table H2.2 Detection Limits for Elements (µg/g)

Element	MDL range	Element	MDL range	Element	MDL range
Al	0.05 - 0.07	Cu	0.05 – 0.5	Sb	0.002 – 0.003
As	0.005 – 0.006	Fe	2 - 3	Se	0.05 – 0.07
B	0.1	Mg	3 - 4	Sr	0.02
Ba	0.008 – 0.01	Mn	0.005 – 0.007	Ti	0.03 – 0.3
Cd	0.004 – 0.005	Mo	0.003 – 0.004	V	0.002 – 0.003
Co	0.002 – 0.003	Ni	0.02	Zn	0.4 – 0.5
Cr	0.03 – 0.04	Pb	0.02		

H-3.0 RESULTS AND DISCUSSION

H-3.1 Moisture Content

Moisture contents measured at Laurentian University for the fresh tissue prior to freezing were compared to that measured at Testmark after freezing the samples. There was a maximum difference of 5.96% between measurements. Therefore, the freezing process did not seem to alter the moisture content of the livestock tissues. The thawed cattle tissue moisture content determined at Testmark is summarized in Table H3.1. Kidney tissue was found to have higher moisture content compared to the other tissues, containing on average approximately 80% water. Muscle tissue contained slightly more moisture than liver tissue - approximately 76% water, compared to 72% for liver tissue.

Table H3.1 Percent Moisture Analyses on Cattle Tissues (Thawed)

Tissue	Percent Moisture (%)		
	Min	Mean	Max
Kidney (n=6)	77.70	79.68	81.50
Liver (n=10)	70.00	72.08	73.40
Muscle (n=10)	70.80	75.94	78.30

H-3.2 QA/QC

The percent differences between the original and duplicate samples for COC concentrations were compared. For each tissue type, duplicates were taken for comparison with the original samples taken from three cattle. Table H3.2 indicates tissues that had at least one case with a percent difference over 20%. Differences over 20% between duplicate samples can primarily be explained by the fact that COC concentrations in tissues were near or below routine detection limits. Therefore, some analytical variability can be expected. The results of duplicate analyses are provided in Appendix B.

Table H3.2 Percent Difference in COC Concentration between Original and Duplicate Samples

Tissue	Percent Difference Over 20%?					
	Arsenic	Cobalt	Copper	Lead	Nickel	Selenium
Kidney (n=3)	Yes	Yes	No	Yes	Yes	No
Liver (n=3)	Yes	Yes	No	No	Yes	Yes
Muscle (n=3)	Yes	Yes	No	No	Yes	Yes

H-3.3 Metal Content of Tissues

Full analytical results for all parameters are provided in Appendix B. Results are provided as both dry weight (Tables B.1-B.3) and wet weight (Tables B.4-B.6). For discussion purposes, only the concentrations of the COC are summarized in the following text. All values are reported as wet weight means concentration. In the cases where concentrations are below detection, one half of the detectable limit has been substituted as the concentration for those samples for statistical purposes. The concentrations of the COC in kidney, liver and muscle tissue samples are summarized in Tables H3.3 to H3.5, respectively. Complete results for all analyzed metals can be found in Appendix B.

Table H3.3 COC Concentrations (µg/g wet wt.) in Kidney Tissue Samples (n=6)

	Arsenic	Cobalt	Copper	Lead	Nickel	Selenium
Max	0.09	0.04	4.20	0.05	0.11	1.94
Min	0.05	0.01	2.94	0.02	0.03	1.15
Mean	0.07	0.02	3.50	0.03	0.07	1.50

Table H3.4 COC Concentrations (µg/g wet wt.) in Liver Tissue Samples (n=8)

	Arsenic	Cobalt	Copper	Lead	Nickel	Selenium
Max	0.06	0.07	58.64	0.04	0.06	0.51
Min	0.00	0.03	24.03	0.00	0.01	0.15
Mean	0.04	0.04	43.94	0.02	0.04	0.29

Table H3.5 COC Concentrations (µg/g wet wt.) in Muscle Tissue Samples (n=10)

	Arsenic	Cobalt	Copper	Lead	Nickel	Selenium
Max	0.12	0.02	2.09	0.01	0.44	0.35
Min	0.00	0.00	0.53	0.00	0.00	0.06
Mean	0.04	0.01	1.42	0.01	0.06	0.17

Metal or metalloid levels varied between tissues. For example, the concentration of copper was markedly higher in liver followed by kidney, then muscle. In contrast, levels were generally higher in kidney tissue for arsenic, lead, nickel and selenium. The levels of all elements were generally lowest in muscle, which represents the most significant tissue from a human consumption perspective.

The data provided in this report are intended to be specific to the Sudbury community and will be used as part of the exposure assessment component of the on-going HHRA for the area.

SUB APPENDIX H-A

LIVESTOCK BACKGROUND

SUB APPENDIX H-B

ANALYTICAL RESULTS

SUB APPENDIX H-C

CHAIN OF CUSTODY SHEETS