SUDBURY AREA RISK ASSESSMENT

CHAPTER 8.0
SELECTION OF CHEMICALS OF CONCERN

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8.0 SELECTION OF CHEMICALS OF CONCERN

8.1 Selection Process

The primary source of Chemicals of Concern (COC) in the Sudbury study area in this assessment is aerial deposition of particulate-associated metals and metalloids from smelter emissions. In addition, fugitive dust from tailings areas and roasting beds may have contributed to metal levels in soils. This step in the process identifies those chemicals present in the study area that pose the greatest potential for exposure and risk to people and the terrestrial ecosystem.

It is common practice in risk assessment to focus detailed evaluation on those substances or chemicals that represent the greatest potential concern in the area under consideration. As part of this screening process, the chemical results from the study area are generally compared with regulatory guidelines or standards for the particular matrix. In this situation, metals data measured in the 2001 soil survey were compared with soil quality guidelines established by the Ontario Ministry of the Environment (MOE). Therefore, those chemicals present on site at concentrations in excess of the criteria are considered to be of most concern and were selected for further study in the form of a risk assessment. In the case of the Sudbury Area Risk Assessment, the screening process was further limited to soil parameters resulting from local smelter operations.

As described in Chapter 1, the terms of reference (TOR) for both the ERA and HHRA for the Sudbury Soils Study initially identified four COC for the study: arsenic, cobalt, copper, and nickel. These were recommended by the MOE following a review of existing soil quality data for the Sudbury area collected up to the year 2000, and subsequently approved by the Technical Committee (TC) for the Sudbury Soils Study.

In addition, the TOR stated that the consultant (SARA Group) would review any new sampling results for 2001 and historical data on soils, air and water, to determine if other substances should be added to the list of COC.

Thus, some of the initial steps of the study were determined by the TC before the SARA Group was retained as the consultant to conduct the risk assessment. Critical decisions concerning the primary COC selection criteria, list of analytes to be reviewed, sampling area (study area) and sampling methods were established based on a combination of regulatory, policy and scientific objectives as determined by the TC. This is considered reasonable practice to help scope the magnitude of the Sudbury ERA and HHRA. As Suter (1993) points out, risk assessments performed for different assessment purposes will use different methods.

In 2001, Inco Ltd., Falconbridge Ltd., and the Ministry of the Environment undertook the Sudbury urban and regional soil surveys. The purpose of these two surveys was to collect and analyze soil samples from a broad geographic area to characterize the concentration of metals and metalloids in soils of the Sudbury area (see also Chapter 7 of this Volume). Approximately 8,400 soil samples from about 1,150 sites were analyzed for the following parameters:

– aluminium (Al)	– antimony (Sb)	– arsenic (As)	– barium (Ba)	– beryllium (Be)
– calcium (Ca)	– cadmium (Cd)	– cobalt (Co)	– copper (Cu)	– chromium (Cr)
– iron (Fe)	– magnesium (Mg)	– manganese (Mn)	– molybdenum (Mo)	– nickel (Ni)
– lead (Pb)	– selenium (Se)	– strontium (Sr)	– vanadium (V)	– zinc (Zn)

The study TOR provided three criteria for the selection of COC;

- Parameter must be above the Table A (potable groundwater) or Table B criteria (non-potable groundwater) published in MOEE's *Guideline for Use at Contaminated Sites in Ontario* (the "Guideline"; MOE, 1997), depending on whether the specific area under study has surface or well water sources for potable water. In general, these criteria were developed "to protect against adverse effects to human health, ecological health and the natural environment" (MOE 1997);
- Parameter must be present across the study area; and,
- Parameter must scientifically show origin from the companies' operations.

The results of the 2001 soils survey were provided to the SARA Group during the winter of 2003. After merging all the soil information into a comprehensive database, the soils data were screened against the three criteria above.

The use of the first criterion for COC screening requires a brief discussion of the MOE soil quality criteria and their purpose. Most of the MOE criteria were established to be protective of human and ecological health and the natural environment (MOE, 1997). Plant toxicity values are typically lower than those reported for animals or the protection of human health. Therefore, many of the generic metals criteria in the MOE *Guideline for Contminated Sites in Ontario* (MOE, 1997) are based primarily on effects of these metals to sensitive plant species, such as wheat. Plant or animal based criteria have been developed for As, Ba, Cr, Co, Cu, Mo, Ni, Se, Sb, Zn and V. Soil criteria exist for different land uses (*i.e.*, agricultural, residential/parkland, industrial/commercial), soil textures (*i.e.*, fine, medium, coarse), and soil depths (*i.e.*, surface, subsurface). Furthermore, the criteria are only applicable to surface soils with a pH range of 5.0 to 9.0 and to subsurface soils with a pH range of 5.0 to 11.0.

The MOE criteria were developed to provide guidance for cleaning up contaminated sites and, at the time the Sudbury Soils Study was initiated, were not legislated regulations. Furthermore, the criteria are not action levels, where exceeding a particular criterion value would indicate immediate risk or that remediation or clean-up is required. The significance of the criteria to the Sudbury area is to provide triggers to identify the need for additional investigations (MOE, 2001). In fact, metal concentrations higher than the generic criteria in soil samples collected up to the year 2000 were the impetus for the Sudbury Soils Study.

The first criterion for COC screening (exceeding MOE Table A citeria) was met by As, Be, Co, Cu, Ni, Pb and Se as summarized in Table 8.1. However, the number of samples with Be levels exceeding the MOE criterion (n = 2 out of 8,148 near-surface samples) was considered exceptionally small (0.03%) relative to the total number of samples, and Be was not considered further.

This initial screening process confirmed that the four original elements (As, Co, Cu and Ni) met the first criterion for being considered a COC for the risk assessments.

In addition to the four elements identified in the TOR, the screening exercise determined that Pb and Se met the first criterion for consideration as COC. Since the distribution of Se and Pb was uneven across the study area, further evaluation of the soils data for these two elements was undertaken. The results of the further detailed evaluation of Pb and Se in the study area are provided in Appendices D and E, respectively, of this Volume (on CD in back cover).

Both Pb and Se are present in soils across the study area (Criterion 2). Soils with concentrations of Pb and Se exceeding the Table A criterion occurred primarily in an area surrounding the Vale Inco smelter at Copper Cliff.

Detailed statistical analysis provided further evidence that the distributions of elevated Pb and Se concentrations were linked to the smelter operations (Criterion 3):

- The concentrations of both Pb and Se in soil are inversely related to distance from the smelters; and,
- There was a high positive correlation between the concentrations of Pb and Se in soil with the levels of Cu and Ni, two elements known to be emitted from the smelter.

Based on this analysis, both Pb and Se were selected as additional COC for the detailed risk assessments.

Table 8.1 Initial data screening and comparison with MOE Table A criteria[1] (n = 8148)[2]

Metal	Concentration in Soil (mg/kg)			MOE Generic Criteria (mg/kg)		
	Minimum	Average	Maximum	Table A Criterion	# Samples above Table A	# Samples equal to or above Table A
Al	2100	10434	39000	NC[3]	-	-
As	< 5	16	620	20	1431	1493
Ba	9.8	56	720	750	0	0
Be	< 0.5	0.61	2	1.2	2	2
Ca	470	5165	250000	NC	-	-
Cd	< 0.8	1	6.7	12	0	0
Co	1	14	190	40	460	483
Cr	9	34	1100	750	1	1
Cu	2.7	260	5600	150	2839	2948
Fe	4400	16327	110000	NC	-	-
Mg	350	3065	26000	NC	-	-
Mn	33	211	3300	NC	-	-
Mo	< 1.5	1	21	40	0	0
Ni	7	264	3700	150	3105	3187
Pb	1	35	790	200	108	129
Sb	< 0.8	0.48	8.1	13	0	0
Se	< 1.0	2	49	10	91	113
Sr	5	35	340	NC	-	-
V	8	31	130	200	0	0
Zn	1.25	44	340	600	0	0

[1] Table A criteria for coarse textured soil (potable groundwater condition); with pH 5.0 > 9.0 for surface soil and pH 5.0 > 11.0 for subsurface soil; and, intended for residential/parkland uses

[2] Sample size is from combined soils database, with soil depths of 0-5, 5-10, 10-20 cm

[3] NC = No Criterion

Soil quality criteria for the protection of human and ecological health have not been established in Ontario, Canada, or the U.S. for several of the inorganic parameters analyzed. These include Al, Ca, Fe, Mg, Mn, and Sr (Table 8.1). These elements are common components of the earth's crust, with Al, Ca, Fe, and Mg comprising approximately 8, 3, 5, and 2%, respectively (McQuarrie and Rock, 1991). The SARA group was not responsible for setting new soil quality criteria, and was not directed to use guidelines from other jurisdictions where no Ontario guideline existed.

Limitations to Table A Criteria for Selection of Additional Chemicals of Concern

Use of the Table A and B soil quality criteria in the *Guideline for Use at Contaminated Sites in Ontario*, (MOE, 1997) (Criterion 1 for evaluating a COC) only applies to soils with a pH range of 5.0 to 9.0. For soils with a pH outside this range, Table F criteria, or background levels, should be used as alternate screening values (MOE 1997).

Soil pH in northern Ontario is known to be naturally low (pH < 5.0) with soil pH further reduced in the study area due to the smelter emissions.

During the original 2001 survey, soil pH was measured in only one in every 10 samples, or 10%. There were 229 soil samples from the urban soil survey for which pH results existed. Of these, 224 (98%) had a pH >5.0. This higher pH range can likely be attributed to homeowners amending residential soils with lime, organic matter and fertilizers. Therefore, it was appropriate to screen the urban soils data against the Table A criteria. Low soil pH relative to the MOE generic criteria was considered to be an issue primarily in samples from rural, un-amended sites, and not urban residential properties.

As part of the Sudbury Soils Study, Laurentian University was contracted to measure soil pH in all of the regional surface soil samples collected in 2001. Of 365 surface (0 to 5 cm) samples analyzed, soil pH was <5.0 for 347 (95%) of the samples. Therefore, the regional soils database was re-screened using Table F as a criterion, for those samples with soil pH <5.0. The results of this secondary screening exercise are summarized in Table 8.2.

Table 8.2 Summary of secondary data screening and evaluation

Parameter	Table A criterion	Table F criterion	Values > Table F # of samples	Values with pH < 5 and > Table F # of samples**	Max Value	95th percentile
Al	NC	NC		-	38000	20000
As	20	17	388	161	410	80
Ba	750	210	2	1	720	130
Be	1.2	1.2	0	0	1	0.25
Ca	NC	NC	-	-	24000	9500
Cd	12	1	152	29	4.1	1.7
Co	40	21	238	58	150	45
Cr	750	71	42	7	1100	67
Cu	225	85	699	241	5000	1100
Fe	NC	NC	-	-	74000	28000
Mg	NC	NC	-	-	10000	5400
Mn	NC	NC	-	-	3300	480
Mo	40	2.5	53	9	17	2.3
Ni	150	43	954	286	3649	1100
Pb*	200	120	57	3	790	120
Sb*	13	1	40	6	4.4	0.9
Se	10	1.9	468	183	27	6
Sr	NC	NC	-	-	110	52
V	200	91	0	0	74	50
Zn	600	160	10	0	310	97

Samples with pH values = 1201 (Values are from original and duplicate samples taken from 0-5, 5-10, 10-20 cm soil depths)
Samples with pH < 5 = 401
NC – No Criterion
*no value reported for some samples
** only values that have an associated pH value
All values are presented in mg/kg

This secondary screening step identified five additional elements that exceeded Table F in samples with pH <5.0 (sample size exceeding Table F in brackets): Ba (1), Cd (29), Cr (7), Mo (9) and Sb (6). Of these, four of the elements (Ba, Cr, Mo and Sb) exceeded Table F in a very small number of samples. In addition, the 95th percentile concentration of these elements was less than Table F. Therefore, these elements were excluded from further consideration as candidate COC.

Cadmium exceeded Table F in 29 soil samples with pH <5.0, and the 95th percentile concentration (1.7 mg/kg) was greater than the Table F value (1.0 mg/kg). Therefore, additional evaluation of the distribution of Cd in Sudbury soils was undertaken.

Consensus was reached within the TC that Cd not be included as a COC for the Human Health Risk Assessment (HHRA) for two main reasons:

1. Low soil pH was associated almost exclusively with samples collected from rural and remote sites; and,
2. The maximum Cd concentration was less than half of the Table A criteria which are protective of human health (*i.e.*, 12 mg/kg for residential/parkland, and 3 mg/kg for agricultural land, based on exposure to grazing animals).

However, Cd was included as a COC for the Ecological Risk Assessment (ERA) at the request of the MOE. Further discussion of Cd as a COC is provided in Appendix F of this volume. Information regarding the evaluation of Cd as a COC in the ERA is provided in Volume III.

The overall selection process for COC for the HHRA and ERA is outlined in Figure 8.1.

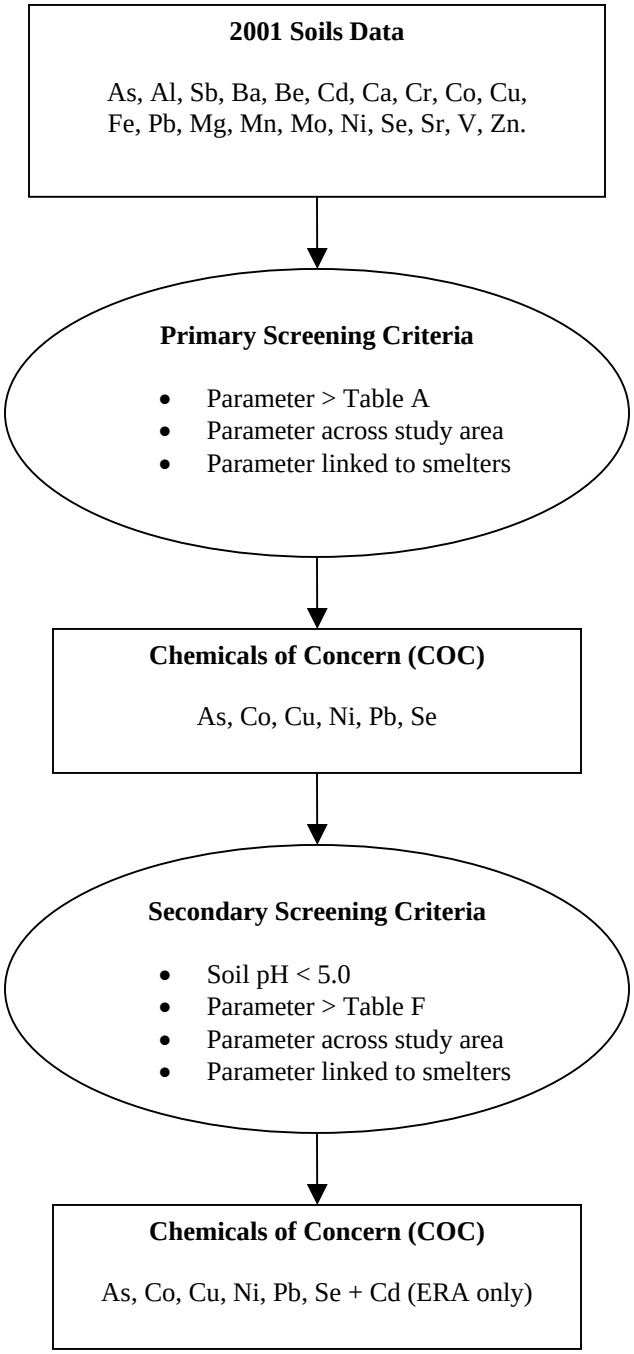

Figure 8-1 Soil Data Screening Process for selection of COC

8.2 References

McQuarry, D. and Rock, A., 1991. Chapter 2 - Atoms and molecules. *In:* General Chemistry, Third Edition. W.H. Freeman and Company. New York.

MOE (Ontario Ministry of the Environment). 1997. Guidelines for Use at Contaminated Sites in Ontario. Toronto: Ontario Ministry of the Environment.

MOE (Ontario Ministry of the Environment). 2001. Metals in Soil and Vegetation in the Sudbury Area (Survey 2000 and Additional Historic Data). Toronto: Ontario Ministry of the Environment.

Suter, G.W., 1993. Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL. 550pp.