POLLUTION PROBE

CLEAN AIR. CLEAN WATER.

Sulphur Dioxide and Toxic Metal Emissions from Smelters in Ontario

February 2003

February 2003

Pollution Probe is pleased to release this report on sulphur dioxide (SO_2) and toxic metal emissions from smelters in Ontario. The results of this report demonstrate a significant opportunity to reduce acid-causing emissions of sulphur dioxide (SO_2) and a range of toxic substances, especially from Inco's facilities in Sudbury. The conclusions reached are based, in part, on comparisons of emissions from Ontario nickel-copper smelters to reduction levels achieved by copper and lead smelters in the United States, as well as on information obtained from discussions with technical staff of both Inco and Falconbridge.

Some uncertainties remain over the precise details of pollution control technologies and related emission removal efficiencies at the smelters. Pollution Probe believes these uncertainties can be overcome by studies conducted by the companies themselves.

There is reason to believe that both Inco and Falconbridge can reduce their SO_2 emissions by a further 75% below their existing regulated limits. Falconbridge has almost achieved a 75% reduction in SO_2 emissions using a continuous improvement philosophy, including certification of all of its sites and facilities worldwide to the ISO 14001 Environmental Management System standard. Inco should be able to achieve comparable environmental performance at Sudbury.

If the goal of 75% reduction in SO_2 emissions is achieved by Inco, there will also be significant reductions in emissions of toxic metals, such as arsenic and nickel compounds, with ecological and health benefits to Ontario, Quebec and US states downwind of the smelters.

To ensure achievement of the SO_2 and toxic substances reductions that Pollution Probe believes are possible at Inco and Falconbridge, we recommend that both companies negotiate and sign Environmental Performance Agreements committing to 75% reductions of SO_2 below their existing regulated limits in timeframes linked to the completion of studies on technological opportunities for achieving these reductions. The target date for achieving the 75% reductions should be no later then 2015. An open and transparent public process should be used to develop the Environmental Performance Agreements and to ensure routine public reporting on progress.

Pollution Probe offers to work cooperatively with Inco and Falconbridge, as well as the provincial and federal governments and other stakeholders, to develop the appropriate regulatory measures and performance requirements to achieve the recommended goal.

K.B. Ogilvie

K.B.Ogilvie
Executive Director, Pollution Probe

Acknowledgement: *Pollution Probe thanks Dr. T. Burnett for his invaluable contribution to the preparation of this report. Dr. Burnett's advice was instrumental in enabling Pollution Probe to reach the conclusions made in this report.*

Table of Contents

1. Summary

This paper analyzes and summarizes the results of reports prepared by Environment Canada and Hatch Engineering that studied ways to reduce sulphur dioxide (SO_2) and toxic metal emissions from base metal smelters. There are 15 base metal smelters in Canada. However, due to resource constraints and to the fact that the Ontario Ministry of the Environment is currently proposing new emissions regulations for SO_2 for Inco and Falconbridge, this report is directed towards these facilities. The analysis of Ontario operations was done principally for the operations in Sudbury by Inco and Falconbridge nickel and copper smelters.

In the report entitled Strategic Options for the Management of Toxic Substances from the Base Metals Smelting Sector — Report of Stakeholder Consultations — June, 1997 (reference 1) — Recommendation #1 — Release Reduction Targets and Schedules states: “It is recommended that total releases of the CEPA [Canadian Environmental Protection Act] Substances from the Base Metal Smelting Sector should be reduced from 1988 levels by 80% by the year 2008 and by 90% beyond 2008 through the application of technically and economically feasible methods.”

A further Hatch report makes specific technical recommendations that could reduce emissions of toxic substances in Sudbury by 88% at Falconbridge and 85% at Inco, while at the same time reducing sulphur dioxide by 90% and 95%, respectively (reference 2) from emission levels that prevailed before the currently regulated SO_2 limits were put in place in 1985. In this report, Pollution Probe identifies five additional actions that could be taken to exceed these targets and approach the reduction levels achieved in the United States for copper and lead smelters. While the Hatch suggestions would yield impressive cuts in emissions, these emissions would still be significantly higher than the emissions permitted for base metal smelters in the United States. Canadian nickel-copper smelters may not be directly comparable to US copper and lead smelters, but Pollution Probe believes that a discussion of US achievements is relevant and provides valuable information on what might be achieved in Canada.

The smelters in Ontario should examine means of reducing SO_2 and toxic metal emissions beyond the levels that are indicated to be technically feasible by Hatch in 2008. The toxic metals deserve more attention because of known human health effects.

2. Background

The Canadian Environmental Protection Act (CEPA) has scheduled lead and mercury as toxic substances, and further to this, using the Priority Substances List (PSL-1), subsequent assessments have deemed inorganic arsenic compounds, inorganic cadmium compounds and oxidic, sulphidic and soluble inorganic nickel compounds, plus a number of other substances, to be toxic substances. Collectively, these are referred to as the "CEPA Substances." The basis for the designation of CEPA priority substances is provided in the report entitled "Canadian Environmental Protection Act: Human Health Risk Assessment for Priority Substances" (reference 7). Some of these substances are carcinogenic to humans and may also be endocrine disrupters, as well as strong chemical poisons. A discussion of the health effects of the CEPA Priority Substances described above is given in reference 1 (and is summarized in Appendix 1 of this report).

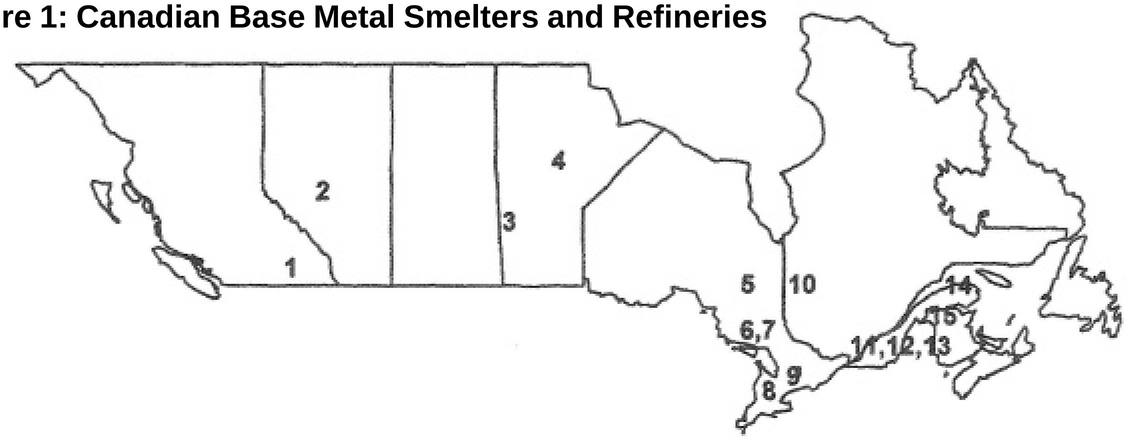
The base metal smelters in Canada emit CEPA substances at various levels. Under CEPA, a strategic options report was prepared in 1996/97 to quantify the releases and develop a plan to decrease and/or virtually eliminate these releases, as required by the Act (reference 1). The strategic options report was reviewed and updated in November 2000 (reference 2). The data used herein are obtained from these reports, to a large extent, supplemented by updated information provided by Inco and Falconbridge. Emphasis in this report has been focused on emissions to air, since emissions to water have been well controlled for many years. Also, during the smelting process, most of the emissions are directed to the atmospheric environment

As well as CEPA designated substances, this Report describes sulphur dioxide (SO_2) and Particulate Matter (PM) releases from Canadian smelters and describes alternative mitigation options that could be installed to control and reduce SO_2 and PM emissions. Addressing SO_2 and PM emissions is also expected to result in lowering metal emissions.

3. Sector Description

There are 15 base metal smelters in Canada, as shown in Figure 1. Of these, five are in Ontario, with the major concentration of activity being in the Sudbury district where Inco and Falconbridge have operated for many years. Throughout Canada, these smelters represent important economic activity, often in remote areas. The products of the Canadian mining and smelting industry are sold largely into international markets, with the sector employing some 100,000 people throughout Canada. Many new facilities have been built outside of Canada and these compete on the world market with Canadian producers. The more modern facilities built outside of Canada are generally done with international financing, which now requires that the facilities be built using the Best Available Technology (BAT) in order to secure international financing.

Figure 1: Canadian Base Metal Smelters and Refineries



Province	Company	Site	Map	Facility
British Columbia	Cominco	Trail	1	Lead & Zinc Smelter/Refinery
Alberta	Sherritt	Fort Saskatchewan	2	Nickel & Cobalt Refinery
Manitoba	Hudson Bay	Flin Flon	3	Copper Smelter
				Zinc Refinery
	Inco	Thompson	4	Nickel Smelter
				Nickel Refinery
Ontario	Falconbridge*	Kidd/Timmins	5	Copper Smelter
				Copper Refinery
				Zinc Refinery
		Sudbury	6	Nickel & Copper Smelter
	Inco	Copper Cliff/Sudbury	7	Nickel & Copper Smelter
				Copper Refinery
				Nickel Refinery
		Port Colborne	8	Cobalt Refinery
	Tonolli	Mississauga	9	Secondary Lead Smelter
Quebec	Noranda	Horne/Rouyn-Noranda	10	Copper Smelter
		CEZ/Valleyfield	11	Zinc Refinery
		CCR/Montreal	12	Copper Refinery
	Nova Pb	Ville St. Catherine	13	Secondary Lead Smelter
	Noranda	Gaspe/Murdochville	14	Copper Smelter
New Brunswick	Noranda	Brunswick Smelting Belledune	15	Lead Smelter

** Noranda owns 55% of Falconbridge*
Source: reference 1

4. Focus on Ontario Operations

There are five operations in Ontario (Figure 1). The secondary lead smelter in Mississauga and the cobalt refinery in Port Colborne are not be discussed in detail in this report since their air emissions are small compared to the operations in Sudbury.

4.1 Falconbridge — Timmins

The Falconbridge, Timmins, site has a zinc plant, started in 1972, and a copper plant, started in 1981. In 1982, the Canadian Development Corporation (CDC), which already owned about 25% of Texas Gulf, acquired 100% of its Canadian holdings and for several years operated this subsidiary as Kidd Creek Mines Limited. In 1986, Falconbridge purchased Kidd Creek from the CDC.

When the Kidd Creek smelter was built, it was one of the cleanest smelters in the world. It had only minor environmental incidents when it first opened and sulphur dioxide dispersion problems occurred due to irregular operating conditions in the start-up phase. Some high ground level concentrations of sulphur dioxide were recorded. These problems were corrected long ago.

At this site, there is an integrated multi-plant facility producing copper, zinc, cadmium, indium, and sulphuric acid and liquid sulphur dioxide by-products. Emissions of CEPA substances are summarized in Table 1.

Zinc concentrate is processed in a standard electrolytic zinc process, with the sulphur dioxide from the zinc roasters being cleaned and converted in a single contact sulphuric acid plant. Copper concentrate is processed in the Mitsubishi continuous smelting system, consisting of three interconnected furnaces, with the sulphur dioxide gases cleaned and converted to sulphuric acid in a double contact acid plant. The converter matte is refined to copper at the site. Indium is recovered from the smelter's electrostatic precipitator dust, whereas cadmium is largely concentrated in the zinc feed and is recovered from the calcine in the Zinc Leach Plant.

Table 1: Falconbridge Kidd Creek Release Data (tonnes)
(Note: Table 1 represents total emissions from the site, not just the smelting operations, although the copper smelter accounts for the bulk of air emissions.)

	1988	1993	1995	1996	1997	1998	1999	2000
Arsenic								
Air	6.52	6.52	5.77	5.66	5.12	1.451	1.418	1.29
Water	0.81	0.81	0.03	0.06	0.08	0.081	0.097	0.08
Total	7.33	7.33	5.8	5.72	5.2	1.531	1.515	1.37
Cadmium								
Air	1.61	1.09	0.76	0.64	0.61	0.581	0.484	0.54
Water	0.16	0.16	0.14	0.15	0.14	0.05	0.119	0.21
Total	1.77	1.25	0.9	0.79	0.75	0.631	0.603	0.75
Lead								
Air	34.2	32.1	75.16	74.2	63.08	75.591	28.694	29.56
Water	0.8	0.8	0.03	0.04	0.06	0.09	0.147	0.15
Total	35	32.9	75.19	74.24	63.14	75.681	28.841	29.71
Mercury								
Air	0.01	0.01	<LMDL	<LMDL	<LMDL	n.m/e	<LMDL	<LMDL
Water	0.01	0.01	0.01	0.015	0.02	<LMDL	<LMDL	<LMDL
Total	0.02	0.02	0.01	0.015	0.02	<LMDL	<LMDL	<LMDL
Nickel								
Air	0.3	0.3	0.31	0.31	0.29	0.28	0.224	0.24
Water	0.2	0.2	0.2	0.38	0.37	0.1	0.155	0.12
Total	0.5	0.5	0.51	0.69	0.66	0.38	0.379	0.36
Particulate Matter								
Total	940	940	423	357	304	367	358	386
Sulphur Dioxide								
Total	5980	5947	6180	6510	5240	4090	5110	3817

** All metals data as reported in the 2001 MAC Environmental Progress Report — data in parentheses, and 1999 and 2000 data.*
** All particulate matter and sulphur dioxide data originate from the 2000 Kidd Metallurgical EHS Performance Progress Report, and from the division.*
<LMDL — All laboratory analyses (over the year) are low-level qualified data
n.m/e — not measured or estimated
Source: reference 2

4.2 Inco — Sudbury

The Inco facility at Sudbury is an integrated complex of mines, mill, smelter and refineries, producing finished nickel, copper, gold, silver, sulphuric acid and intermediates that are refined in other Inco facilities. The total emissions of CEPA and other substances from the Inco operations at Sudbury are summarized in Table 2. In addition, Inco emits less than 265,000 tonnes per year (MTPY) of sulphur dioxide from its combined operations in Sudbury under the terms of Ontario Regulation 660/85.

Table 2: Inco Copper Cliff Release Data (tonnes)

	1988	1993	1995	1996	1997	1998
Arsenic						
Air	35	10.62	9.4	40.8	55.13	52.87
Water	Data not provided	0.13	0.12	0.14	0.008	0.0003
Total	35	10.75	9.52	40.94	55.13	52.87
Cadmium						
Air		2.76	n.m/e	0.95	n.m/e	7.009
Water		n.m/e	n.m/e	n.m/e	n.m/e	Data not provided
Total	Data not provided	2.76	n.m/e	n.m/e	n.m/e	7.009
Lead						
Air	133	111.6	83.78	68.95	67.29	146.7
Water	Data not provided	0.13	12	13	0.124	0.0005
Total	133	111.7	95.78	81.95	67.42	146.7
Mercury — Not significant						
Nickel						
Air	1019	334.3	509.4	221.5	238.4	189.6
Water	0.3	0.63	0.6	0.65	0.5	0.132
Total	1019	335	510	222.1	238.9	189.7
Particulate Matter						
Total	6410	2381	2053	2473	2345	1981
Sulphur Dioxide						
Total	658515	357751	236033	236041	200003	235000

Source: reference 2

4.2.1 Smelter and Matte Processing

In the smelter, Inco operates two oxygen flash furnaces at Sudbury, together with a group of horizontal side-blown (Pierce-Smith) converters, producing some 238,500 tonnes of nickel-copper matte in 1998. The molten matte is transferred on-site to the matte processing plant where nickel and copper are separated as feed to the refineries and as reverts to the smelter. Matte processing involves roasting of the matte in fluid bed roasters, with substantial releases of sulphur dioxide and CEPA substances. High strength sulphur dioxide from the flash furnaces is diluted with air to produce sulphuric acid at the smelter in a double contact acid plant. Approximately 86% of the sulphur from the ore, or 70% of the sulphur in the feed to the smelter, is captured. The balance of the sulphur is emitted from the converters and matte roasters as sulphur dioxide in the 381 metre stack. There are also fugitive emissions from the converters and from the transfers of molten material within the smelter. At present, the principle sources of sulphur dioxide emissions are: flash furnaces 3%, converters 59%, fluid bed roasters 28%, refineries 3%, and copper smelter/refinery 7%.

The flash furnaces were commissioned in 1994 as part of the 1985 Ontario Regulation 660/85, decreasing the sulphur dioxide emissions from 685,000 tonnes per year to a maximum permissible level of 265,000 tonnes per year. This abatement program also provided a decrease of 96% in emissions of oxides of nitrogen from the pre-1994 emission level of 47,000 MTPY. This abatement program required an investment in excess of $650 million, which is the largest single investment by a Canadian company to control air emissions. Inco has also reduced the occurrences of ground level sulphur dioxide concentrations. During 2001, there were three exceedences of the ground level concentration limit of the Control Order. This was down from 11 exceedences in 2000, 14 in 1999, and 78 in 1998.

Efforts are underway to achieve further reductions by scrubbing of fluid bed roaster gases to bring the sulphur dioxide emission level to 175,000 MTPY. To go below this level, changes are required in the converting operation. Inco claims that it will be continuing to explore technologies that will allow the capture of sulphur dioxide from the converters without the dilution air that renders sulphur dioxide fixation in an acid plant impractical. Inco has already spent more than $5 million on converter research and there are interesting prospects, but more work is needed before all the issues can be solved to allow a new converting system with sulphur dioxide fixing to be considered. On February 12, 2002, the Ontario Ministry of the Environment issued a new Director's Order requiring Inco to investigate measures to further reduce SO_2 emission levels beyond the 175,000 MTPY level. The Director's Order would require Inco to report annually on its progress toward identifying future SO_2 reduction strategies. A final Report is due no later than December 31, 2010 and will include an implementation plan.

The fundamental problem with the existing converters is that they are batch operations, involving many transfers of molten, fuming material within the smelter. The off-gas from the converters starts at a reasonable strength of sulphur dioxide, but it tapers off towards the end of the cycle. No acid plant can cope with an input feed of variable sulphur dioxide strength and variable total flow. Inco did try to make sulphuric acid from converter gas in 1925, but the process was abandoned long ago.

The release of the CEPA substances and other dust pollutants has been largely influenced by a voluntary program since 1988 know as ARET (Accelerated Reduction and Elimination of Toxics) in which all of the mining and smelting industry participated. In 1998, Inco met its target of a 50% reduction in toxic metal releases, reducing its combined metal emissions of arsenic, copper lead and nickel by 67%.

4.2.2 Nickel Refinery

Feed for the nickel refinery is obtained from the matte processing section of the smelter. The first step involves the removal of sulphur in two top blown rotary converters (TBRC), with subsequent emissions of sulphur dioxide to a five hundred foot stack. The balance of the process is a modified high pressure version of the Mond process, using carbon monoxide to separate nickel and iron, and leaving a copper-cobalt-precious metal residue that is refined in the copper electrowinning plant and the Port Colborne cobalt refinery, with the precious metal residue ultimately being refined in England. Since the carbonyl process is virtually a closed process, the emissions of CEPA substances are minor.

4.2.3 Copper Refinery

This is an old facility that Inco acquired in the 1940s from the Ontario Refining Company, which built the facility in 1930. There were emissions of CEPA substances, principally arsenic and lead, from the anode furnaces, which vented directly to the atmosphere through very short metal chimneys. In 2000, Inco constructed a new anode casting facility in the smelter building. This was successfully commissioned in 2001, resulting in substantial reductions in these metal emissions and eliminating the opacity problem that was experienced with the old anode furnaces.

4.3 Falconbridge — Sudbury

Falconbridge operates an integrated complex of mines, mill and smelter in Sudbury, with the smelter product being shipped to Norway for nickel-copper separation and refining. The Sudbury smelter also processes concentrate from the Falconbridge Raglan operations in Ungava and other purchased nickel-containing materials. Nickel-copper concentrate is received from the mill as a slurry that is processed in fluid bed roasters for removal of more than 60 percent of the sulphur, as well as oxidation of some of the iron. The sulphur dioxide from the roasters is cleaned and processed to sulphuric acid on-site in a single contact acid plant. The hot roaster calcine is mixed with flux and coke and charged to an electric furnace where it is reduction-smelted to a nickel-copper-cobalt-iron sulphide matte phase. Off-gas from the electric furnace is cleaned and the dust that is collected is reverted to the electric furnace. Electric furnace slag is granulated and impounded.

In the last operation, molten electric furnace matte is transferred to horizontal side-blown converters where flux is added. Iron and sulphide sulphur are further oxidized, but because the matte is sulphur-deficient, not much additional sulphur dioxide is produced. The matte is granulated and shipped to Norway for further processing, while the converter slags are processed on-site for removal of contained metals. Off-gas from the converters is cleaned with electrostatic precipitators before being emitted to the atmosphere, while the dust that is collected is reverted to the electric furnace.

The emissions of CEPA substances are summarized in Table 3.

Table 3: Falconbridge Sudbury Release Data (tonnes)

	1988	1993	1995	1996	1997	1998	1999	2000
Arsenic								
Air	11.73	0.208	0.277	0.083	0.115	0.081	0.342	0.165
Water	(<LMDL)	(<LMDL)	0.026	0.03	0.054	0.082	0.02	0.013
Total	11.73	0.208	0.303	0.113	0.169	0.16	0.362	0.178
Cadmium								
Air	2.66	3.98	3.53	2.76	3.79	2.74	2.597	1.515
Water	0.039	0.005	0.001	0.003	0.001	0.004	0.001	0.028
Total	2.699	3.985	3.531	2.763	3.791	2.74	2.598	1.543
Lead								
Air	17.236	18.006	10.199	8.029	11.965	9.1481	7.002	5.263
Water	0.868	0.044	0.028	0.04	0.016	0.006	0.006	0.002
Total	18.107	18.05	10.227	8.069	11.981	9.151	7.008	5.265
Mercury								
Air	0.6	<LMDL	<LMDL	<LMDL	<LMDL	<LMDL	0.004	0.002
Water	<LMDL	<LMDL	<LMDL	<LMDL	<LMDL	<LMDL		n.m/e
Total	0.6	<LMDL	<LMDL	<LMDL	<LMDL	<LMDL	0.004	0.002
Nickel								
Air	20.42	7.076	8.459	8.959	11.64	11.431	7.042	5.3
Water	47.89	2.906	2.64	2.921	2.516	3.106	1.011	0.978
Total	68.32	9.982	11.1	11.88	14.16	14.541	8.053	6.278
Particulate Matter								
Total	1066	681	617	431	506	471	?	?
Sulphur Dioxide								
Total	59600	57300	45200	53200	53600	57200	35820	27654

** All metals data as reported in the 2001 MAC Environmental Progress Report — data in parentheses, and 1999 and 2000 data.*
** All particulate matter and sulphur dioxide data originate from the 2000 Sudbury Smelter EHS Performance Progress Report.*
<LMDL — All laboratory analyses (over the year) are low-level qualified data
n.m/e – not measured or estimated
Source: reference 2

The Sudbury Smelter Business Unit will develop targets by the end of 2002 for metals and SO_2 to be emitted over the 2003 to 2010 period. The levels beyond 2008 may be higher or they may be lower than the levels indicated in Table 3. It is Falconbridge's opinion that the levels in Table 3 may not be economically achievable. The reasons for stating this position are that the study was preliminary. It did not investigate in detail the implications of a number of issues, including:

1. Lack of plume rise from heavy, low temperature scrubber exhaust. Stack reheat would probably be required.
2. High maintenance due to scaling of SO_2 scrubber units.
3. Disposition and recycling of scrubber filter cake.
4. Extra manpower required to operate scrubber units.
5. Particulate collection efficiencies are too optimistic, as much of the fume is condensed vapours that are too fine for high collection efficiencies in scrubber units. Low to medium energy pressure drop scrubbers do not attain high particulate collection efficiencies required for the fine metal fume to be collected. High energy scrubbers would not be feasible due to the high energy consumption.

In conclusion, in Falconbridge's opinion, the capital and operating cost, as well as the performance, of scrubbers may preclude their feasibility at the Sudbury Smelter Business Unit. Falconbridge will re-evaluate metal and SO_2 emission control technologies and will establish, by the end of 2002, annual emission targets up to and including 2010. Falconbridge has stated to Pollution Probe that those targets could be made available to the public.

5. Opportunities for Further Emission Reductions

The Hatch report (reference 2) makes specific recommendations for the smelter operations in Sudbury, but not for the other base metal operations in Ontario. Copper and lead smelters use the same types of furnaces that are used in the smelting of nickel, such as reverberatory, horizontal side-blown converters and flash furnaces.

5.1 Falconbridge — Timmins

Compared to the other smelters in Canada, this is a clean, modern operation and there are limited opportunities for further reductions of emissions. The cadmium emission is within the current standards set by the United States Environmental Protection Agency (EPA). However, the lead emission for the site exceeds the Best Available Technology (BAT) limitation for primary zinc producers by approximately a factor of ten. When questioned about this, Falconbridge divided the total lead emission into an emission of 75.2 MTPY at the copper plant and 0.16 MTPY at the zinc plant. Thus, both plants comply with current EPA rules, although it is worth noting that there currently are no specific emission factors for lead from copper smelters in the United States (reference 2). The company has promised a 50% reduction in lead emissions from the 1998 levels by 2001. However, the company could be asked to investigate potential technologies for removing more lead. By way of comparison, Cominco in Trail, British Columbia, a major lead producer, emits only 30% of the amount of lead that Falconbridge Timmins emits, whereas Cominco produces 30% more smelter product.

The Mitsubishi process used by Falconbridge has a good record of high fixation of sulphur, with upwards of 98% of the sulphur in ore feed being captured and converted to sulphuric acid. When it was built in the late 1970s, it exceeded the then-applicable EPA requirement of 90% sulphur fixation, and it now ranks between the 95% fixation required by the EPA and the BAT level of over 99% achieved in Utah at the Kennecott operation. The Timmins operation is probably the only smelter in Canada that meets current EPA regulations for SO_2.

5.2 Inco — Sudbury

5.2.1 Smelter and Matte Processing

The Hatch report (reference 2) made three suggestions for reducing emissions before 2008, as follows:

1. Wet scrubbing of fluid bed roaster gases to recover dust and produce sulphuric acid.

2. Replacement of the converter electrostatic precipitator.

3. Implementation of continuous converting of flash furnace matte.

Table 4 compares the Inco operations in Sudbury with Falconbridge operations in Sudbury. In studying the table, it is important to remember that Falconbridge does its further processing and refining at another site, outside Canada, which may account for the relatively lower sulphur dioxide emissions per tonne of smelter product and may also contribute to the lower releases of metals to the environment. It is noted that care must be exercised in comparing emissions from sources using differing processes.

Inco Copper Cliff stands out in North America in its arsenic, nickel and lead emissions to the atmosphere. Using data compiled by the Commission for Environmental Cooperation (reference 4), Inco alone accounts for 20% of all of the arsenic emitted in North America, 13% of the lead and 30% of the nickel. In 1998, the Inco emissions of lead and arsenic were only exceeded by those of Noranda at the Horne smelter in Noranda, Quebec. Together, Inco and Noranda account for 55% of the arsenic and 27% of the lead released into the atmosphere of North America. Noranda has indicated that arsenic emissions will be significantly reduced by 2002.

In the Strategic Options Process (reference 1) Inco indicated that it could achieve an 80% reduction in total CEPA substances by 2008 by scrubbing the off-gases from the fluid bed roasters. This is reiterated in the Hatch Report (reference 2). Incorporated in the fluid bed roaster project is an arsenic removal circuit. The arsenic circuit will prevent the build-up of arsenic, as a circulating load in the smelter. In addition, Inco is exploring other measures to remove metals, such as lead, from the fluid bed roaster off-gas system.

Using data from the National Pollutant Release Inventory (NPRI) for 1998, 94% of the arsenic emissions of Inco and 69% of the lead emissions originate in the smelter. Removing these metals and stabilizing them is a key to reducing the releases to the environment.

Although it is not strictly fair to compare a nickel-copper smelter to a lead smelter, by so doing one can get an idea of how poor the containment of lead is at Copper Cliff. In 1998, Inco emitted 146.7 MT of lead at Copper Cliff with a smelter production of 238,500 MT of nickel-copper matte. The EPA regulations in the United States require a primary lead smelter to limit emissions of lead to 3.0 gm per MT of product. With this emission factor, Copper Cliff would be required to limit emissions of lead to approximately 1.0 MT per year, demonstrating that the actual emission is about 150 times greater than allowed by US regulations for a lead smelter. Even with the 85% reduction postulated by Hatch, Inco would still emit 10 tonnes per year of lead, or four times the amount allowed by the EPA for a lead smelter. As a further comparison, the Cominco lead smelter in BC under US regulations would be limited to about 3 MT per year, whereas the actual lead emission is about 7 times higher.

Inco has undertaken a number of research activities to investigate process changes or mitigative options to reduce the emissions of SO_2 and metals. One alternative is to investigate the horizontal side-blown converters. Employing a continuous process would enable the company to control dust and sulphur dioxide emissions more carefully. Sulphur dioxide, which is currently discharged during a short period of time at high concentrations, would be discharged at a more stable flow rate. This would provide the opportunity to capture, treat and process the gas through the sulphuric acid plant. Inco has spent in excess of $5 million on research into continuous and batch converting in order to be in a position to better capture and fix the sulphur dioxide emissions from the converters. While this research has shown promise, there are still significant problems, associated with the metallurgy, that have to be overcome before this technology can be applied at a production scale. Pollution Probe notes, however, that copper smelters have been able to recover SO_2 from horizontal side-blown converters for many years. Hatch has recommended that Inco continue with this research as Hatch feels that more technical development is required before a commercial process can be implemented.

Currently, the Inco smelter fixes approximately 70% of the sulphur contained in the feed to the smelter, or 86% of the sulphur that is contained in the ore. This is lower than the fixation required for smelters in the United States for the past 20 years. However, as the US smelters are smelting either copper or lead, it may be an easier task to capture sulphur dioxide than it is for a nickel smelter. With the changes suggested by Hatch, sulphur fixation may approach 95%, which is comparable to base metal smelters in the United States. Pollution Probe notes that one copper smelter in the United States has operated with a containment of more than 99% for at least the past ten years.

5.2.2 Nickel Refinery

The carbonyl part is a closed process and presents essentially no opportunities for additional reductions in emissions. In the feed preparation area, however, there are emissions of dust and sulphur dioxide from the TBRCs. Until recently, the dusts were not well controlled, with about 135 MTPY of nickel being emitted to the atmosphere. With recent improvements to the dust collection system, emissions from the nickel refinery are expected to be significantly reduced by the next reporting period.

5.2.3 Copper Refinery

Inco has addressed the main problem with this facility by building new anode casting facilities within the smelter. This has solved the plume opacity problem at the old anode furnaces and has allowed for better capture of the dusts.

5.2.4 Overview of Inco Operations in Sudbury

Before reviewing Inco's operation in Sudbury, some discussion of smelter regulations is needed. There are no specific EPA regulations for copper and nickel smelters pertaining to the emission of toxic metals. However, the EPA set strict sulphur containment regulations for smelters, beginning in the 1970s, with a target of 90% sulphur containment to be attained by the mid-1980s, rising to 95% by the end of the 1980s. In order to achieve these targets, all of the smelters in the USA had to be either modernized or closed. Small operators using the older reverberatory furnaces had to close and consolidate their processing with other larger operators using either flash furnaces or the Noranda reactor. In order to fix the sulphur, acid plants were installed, and in order to make a marketable sulphuric acid, it was necessary to install efficient gas cleaning plants to prevent the toxic metals from entering the sulphuric acid product. Since much of the sulphuric acid is used to make fertilizer, there are strict regulations on trace metal contamination. Therefore, the sulphur containment regulations had the added beneficial effect of leading to containment of the toxic metals.

In 1998, the NPRI seems to indicate that about 6% of the total arsenic at Inco was emitted at the copper refinery, or about 3 MT, which is still about 50 times greater than that calculated using the EPA standard for copper refining. With the new anode casting facilities, the picture will change, hopefully for the better, but the total arsenic emission is not likely to fall until the gas cleaning facilities are built for the matte processing section, and then likely only if the dust catch is impounded or processed for tramp metal removal. In order for the off-gas from the fluid bed roasters to be sent to the acid plant for SO_2 fixation, the metals have to be removed. Inco is currently designing and testing technology to remove the metals from this gas stream, which contains the major source of arsenic emissions in the smelter, and technology to stabilize it for permanent, safe disposal.

In Canada, there are no sulphur containment regulations at the federal level, but targets for acidifying emissions have been set for each region of the country. The responsibility for negotiating international agreements addressing trans-boundary issues falls within the domain of the federal government. For example, in 1991, Canada and the United States signed the Canada-United States Air Quality Agreement, which focused on acid rain, and, in 1985, Canada and the eastern provinces developed the Eastern Canada Acid Rain Program. The latter agreement has since been replaced by the Canada-Wide Acid Rain Strategy for Post-2000. Each province allocates its budget for sulphur dioxide emissions to the major point sources, which then operate under control orders. There are also regulations limiting the maximum ground level concentration of sulphur dioxide. In addition, the federal government, under CEPA, has declared various smelter emissions to be toxic, and using the strategic options process as defined under CEPA, the smelting industry and the federal government have agreed to emission reduction targets. One of industry's concerns about the interplay between the federal and provincial governments is the possibility of duplication by these jurisdictions.

In 1998, Inco produced 192,000 MT of copper (reference 5) and emitted 52.87 MT of arsenic. Some of these emissions were from the matte processing and some from the copper refinery. The recommendations identified in the Hatch Report (reference 2) would reduce arsenic emissions by 80%. However, by resolving the technical problems associated with the application of copper smelting technology to nickel smelters, further emission reductions may be viable.

5.3 Falconbridge — Sudbury

The Hatch report recommended wet scrubbing of the smelter gases to achieve a 90% reduction in emissions of sulphur dioxide and a 96% reduction in emissions of particulate matter. In 1998, fixation of sulphur in the feed to the smelter was 91.8 percent, rising to 94.2 percent in 2000, according to data provided by Falconbridge. To bring this up to the American standard for copper smelting, some additional sulphur dioxide could be fixed by scrubbing the acid plant tail gases since only a single contact acid plant is being used. As an alternative to scrubbing, Falconbridge could also consider converting the single contact acid plant to a double contact acid plant to decrease the sulphur dioxide emissions.

Falconbridge reduced its sulphur dioxide levels from the 1998 levels by more than 40% in 1999, and the emissions continue at this level (reference 6). The additional recovery of sulphur dioxide was achieved by increasing the sulphur elimination at the roasters so that more acid can be made, and by adjusting conditions in the electric furnaces. As well, Falconbridge is using an improved semi-batch converting process with counter-current flow of the matte and slag, using the existing Pierce-Smith converters, so that only one converter emits most of the remaining sulphur.

Emissions of copper and cobalt exceed the ARET limits, but plans are being developed to meet the ARET targets in the near future. Emissions of the CEPA substances are reasonable, but the nickel emission of 14 MTPY to air is somewhat high. However, the installation of the scrubbers suggested by Hatch would likely reduce the current emissions.

5.4 Discussion

Tables 4 and 5 compare the emissions of Inco and Falconbridge in Sudbury to illustrate what can be achieved through different processes and different gas cleaning opportunities. Looking at Table 4, the process that Inco uses is clearly less efficient at containing arsenic, lead and nickel since the emissions of these metals per tonne of smelter product range from four times higher in the case of nickel to 100 times higher in the case of arsenic. Both companies process ore from the Sudbury basin.

In order to reach targets close to those that Falconbridge has achieved, Inco will have to adopt a strategy of reducing sulphur dioxide emissions so that more of the toxic metals will be contained within new high efficiency gas cleaning systems. In order for Inco to achieve the targets that have been set in the Hatch report, the current research into new converting processes will have to be successful, taking into account economic factors as well as technological advances.

Table 4: Comparison of Air Emissions at Inco vs. Falconbridge (1998 base year)

	Inco MTPY	Inco T/1000T	Falco MTPY	Falco T/1000T
Matte	238,500		93,481	
SO_2	235,000	980	57,200	611
Arsenic	52.87	0.221	0.08	0.00086
Cadmium	7.009	0.029	2.74	0.029
Lead	146.7	0.615	9.15	0.098
Nickel	189.6	0.794	11.43	0.122
Dust	1981	8.31	135	1.45

Table 5: Comparison of Air Releases by Falconbridge and Inco in Sudbury

	FALCONBRIDGE			INCO		
Parameter	1988	Beyond 2008	Change	1988	Beyond 2008	Change
	Tonnes	Tonnes	Percent	Tonnes	Tonnes	Percent
Particulate	1,066	47	96	6,410	275	96
SO_2	59,600	5,700	90	658,515	31,500	95
Arsenic	11.73	0.02	Over 99	35	10	80
Cadmium	2.66	0.03	89	No data	1	
Lead	17.236	1.0	90	133	23	83
Mercury	0.6	Under LMDL	Over 99	Not significant		
Nickel	20.42	2	88	1,019	146	86

6. Actions That Could be Taken to Reduce Emissions of SO_2 and CEPA Substances

1. Hatch recommended that Inco install wet scrubbing of fluid bed roaster gases to produce sulphuric acid. In addition, Inco could install a treatment process to remove tramp elements, such as arsenic and lead, from the dust.

2. Hatch recommended that Inco upgrade the electrostatic precipitator for converter gases. In addition, Inco could upgrade the electrostatic precipitator in the top blown rotary converters plant and install scrubbers to remove the sulphur dioxide.

3. Hatch recommended that Inco implement a continuous converting process. This process is critical to any plans to further reduce emissions of dusts and sulphur dioxide.

4. Falconbridge has had some success at reducing particulate emissions, such as lead, from its copper-lead furnace offgas system, but it should investigate new options to further reduce lead emissions at its Timmins plant.

5. Falconbridge could investigate further opportunities for sulphur fixation at Sudbury, such as acid plant tail gas scrubbing, with a view to achieving a 95% containment of sulphur. This could also include cooperative work with Inco on the continuous converting process.

7. References

1. Base Metals Smelting Strategic Options Report, Environment Canada, 1997.

2. Review of Environmental Releases for the Base Metals Smelting Sector, Hatch Engineering, November 2000.

3. Review of Environmental Management Practices for the Base Metals Smelting Sector, Hatch Engineering, November 2000.

4. Taking Stock, 1997, North American Pollutant Releases and Transfers, Commission for Environmental Cooperation, 2000.

5. Inco Annual Report to the Shareholders, 1999.

6. Report on Sustainable Development, Falconbridge, 1999.

7. Health Canada, CEPA Human Health Risk Assessment for Priority Substances, Ottawa, Canada, 1994.

Appendix 1 — Health and Environmental Profiles for CEPA Substances

(from: Base Metals Smelting Sector Strategic Options Report, Revision 97-06-23)

Introduction

A number of substances released, produced or used by the Base Metal Smelting Sector have been assessed and declared toxic under paragraphs 11(a) and (c) of the Canadian Environmental Protection Act (CEPA). The Priority Substance List (PSL) assessment reports for arsenic, cadmium and nickel and their compounds, and for polychlorinated dibenzodioxins (PCDDs) and polychlonnated dibenzofurans (PCDFs) assessed whether these substances are present in the environment in quantities or concentrations that have an immediate or long-term harmful effect on the environment and that constitute a danger in Canada to human life or health. It was concluded that some forms of these compounds (see Section 3 for list of actual compounds) meet these conditions. Mercury and lead, also released by this sector, were regulated under the Clean Air Act and were placed on the List of Toxic Substances when the Clean Air Act was incorporated into CEPA.

The purpose of Environment Canada in this undertaking is to consider options to reduce the releases and the environmental impacts of substances considered toxic under CEPA. Similarly, the goal of Health Canada in this exercise is to minimize health risks by examining measures to reduce human exposure to these substances, in accordance with the recommendations contained in the Priority Substances Assessment Reports and "Guiding Principles for the Risk Management of Toxic Substances" (Health Canada, 1995).

The approach used by Health Canada in the assessment of PSL 1 substances is described in the publication "Human Health Risk Assessment for Priority Substances" (Health Canada, 1994). The conclusions of the health assessments are based on critical review of available toxicological and epidemiological studies and assessment of exposure to these substances in environmental media. Human exposure to environmental substances may occur by inhalation, ingestion and/or dermal absorption from air, water, soil and food. To the extent possible, information on concentrations of the Priority Substances acquired in national surveys of ambient air, drinking water, soil and food is used as the basis for the assessment of exposure of the general population. Due to the lack of identified data on the speciation of metals in various environmental media, it was not possible to estimate the exposure of the general population to individual compounds. Standardized reference values for body weights, the volume of air breathed, and quantities of food, water and soil ingested, form an integral part of the estimation of exposure from these sources. Human exposure is estimated for several defined stages of life due to the fact that exposure levels may change substantively over the course of an individual's lifetime. Where possible and appropriate, exposure estimates for "high exposure' subgroups in the general population are considered.

With respect to the assessment of adverse health effects associated with exposure to a particular substance, Health Canada adopts one of two approaches, depending upon whether the critical effect is considered to have or not to have a threshold. For many types of toxic effects (i.e., organ-specific, neurological/behavioral, immunological, reproductive or developmental), the current scientific understanding is that there is a dose or concentration below which effects will not occur (i.e., a threshold). However, for genotoxic carcinogenesis and for mutagenesis it is generally assumed that there is some probability of harm at any level of exposure (i.e., that no threshold exists). For substances for which the critical effect is believed to have no threshold, it is assumed there is some probability of harm to human health at any level of exposure, and consequently it is not appropriate to calculate a dose below which adverse effects are not expected to occur. Therefore, it is the policy of Health Canada that human exposure to substances that have been assessed as carcinogenic to humans, or probably carcinogenic to humans, should be reduced to the greatest extent possible.

In 1992, Environment Canada issued draft "Guidelines for Conducting Environmental Assessments for Priority Substances Under CEPA." The purpose of this document is to describe what information should be included in a PSL environmental assessment, how that information is to be used, and, given the diversity of substances on the Priority Substances List, emphasize the need for scientific judgement to ensure that assessors have the capability and flexibility necessary to conduct scientifically-defensible environmental assessments for each of the listed substances. In general, Environment Canada addresses three major components when conducting an assessment: (i) proving entry to the environment; (ii) proving exposure to biota in the environment; and (iii) proving effects to the environment. If a substance enters the Canadian environment, and biota are exposed to levels high enough to cause harmful effects, the conclusion is that the substance is CEPA toxic. Conversely, if a substance does not enter the Canadian environment or biota in Canada are not exposed to the substance at levels high enough to cause harmful effects, then a substance is not declared toxic.

Both Health Canada and Environment Canada recognize that scientific uncertainty is a factor in the risk assessment process. Like traditional science, risk assessment examining human and environmental risk invariably identifies new data needs and generates recommendations for additional research. However, unlike traditional scientific exploration, risk managers must inevitably make decisions in the face of scientific uncertainty. In addition, it is recognized that while zero risk is always an ideal, it is not always an attainable ideal. Zero risk is unattainable for contaminants that, at least partly, are naturally occurring in the environment (Health Canada, 1990). It is also recognized that the incremental risks associated with exposure to low levels of a toxic substance may be small relative to other risks in society. Therefore, in consideration of these factors it may be both impractical and unnecessary to reduce exposure to zero.

Nonetheless, as stated in the "precautionary principle" (Principle 15 of the Rio Declaration on Environment and Development), where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. Health Canada's position is that where significant adverse health effects are known to be associated with exposure to a toxic substance, the lack of full scientific data should not prevent the consideration of control measures (Health Canada, 1995).

Assessment of Health and Environmental Effects

Arsenic and its Compounds

It has been consistently demonstrated in numerous occupational studies that exposure by inhalation of inorganic arsenic compounds causes cancer of the respiratory tract. Ingestion of arsenic in drinking water or medicines has also been linked with skin cancer and cancers of various internal organs including the bladder, kidney, lung and liver. Health Canada has concluded on the basis of available data that the group of inorganic arsenic compounds as a whole are carcinogenic to humans, and therefore toxic under Section 11(c) of CEPA.

Concentrations of dissolved and soluble forms of inorganic arsenic in environmental media in the vicinity of anthropogenic sources are high enough to cause adverse effects in a variety of aquatic and terrestrial organisms. Therefore, Environment Canada has concluded that dissolved and soluble forms of inorganic arsenic are toxic under Section 11(a) of CEPA.

Cadmium and its Compounds

The determination of toxicity was based principally on the observation of an increased incidence of cancer in experimental animals exposed to inorganic cadmium compounds by inhalation. In addition, cadmium has been associated with the development of kidney disease in humans in both occupational and non-occupational situations, and in experimental animals. There is evidence that mild effects on the kidney are associated with levels of cadmium at or near those to which a portion of the Canadian general population is exposed. There is also evidence that some inorganic cadmium compounds are genotoxic in mammalian cells in vivo and in vitro. On the basis of available data, inorganic cadmium compounds have been classified as “probably carcinogenic to humans” by Health Canada, and are therefore classified as toxic under Section 11(c) of CEPA.

Cadmium levels in some Canadian water bodies in the vicinity of known anthropogenic sources have been found to exceed the estimated effects threshold for the most sensitive environmental species. Similarly, cadmium levels in kidney tissue of some Canadian mammalian wildlife and domestic species have exceeded the estimated effects threshold for renal dysfunction determined in laboratory animals. Therefore, Environment Canada has concluded that dissolved and soluble forms of inorganic cadmium are toxic in accordance with Section 11(a) of CEPA.

Dioxins (Polychlorinated Dibenzo-p-Dioxins — PCDDs) and Furans (Polychlorinated Dibenzofurans — PCDFs)

Chlorinated dioxins and furans are highly persistent, fat-soluble compounds which have been found in all compartments of the ecosystem including air, water, soil, sediments, animals and foods, and have a high potential for accumulating in biological tissues. All animals and humans in Canada are exposed to these substances. The compound 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), and to a lesser extent, the other chlorinated dioxins and furans substituted in the 2, 3, 7 and 8 positions are extremely toxic to mammals, with a wide variation in sensitivity among species. Studies of human populations indicate that exposure to several milligrams of mixtures of chlorinated dioxins and furans can lead to a variety of effects on skin, eyes and sensory and behavioral processes. Virtually all of this intake comes from food. Some chlorinated dioxins and furans are very persistent, and continued release of these chemicals into the environment could unnecessarily prolong exposures, with a resultant increase in the risk to the environment and human health. In the PSL assessment, Health Canada concluded that there is no adequate demonstration that human populations exposed to chlorinated dioxins and furans have suffered excess cancer. However, based on the results of studies in animals, it was assumed that chlorinated dioxins and furans are non-genotoxic carcinogens and reproductive toxicants with a threshold, and therefore a tolerable daily intake for human exposure was derived. It was estimated that some fish-eating populations could have intakes that approach or exceed this guideline for intake. Based on these considerations, the Ministers of Environment and Health have concluded that PCDD/PCDF may enter into the environment in quantities which have immediate and long-term harmful effects on the environment, and which constitute a danger in Canada to human health. These substances are therefore considered toxic as defined under Sections 11(a) and (c) of CEPA.

Lead

Studies have indicated that chronic exposure to even small amounts of lead can be harmful. Lead may enter the body through ingestion or inhalation. Certain organic species of lead may also enter the body through dermal contact. Once lead is absorbed, it is distributed to the soft tissues and the skeleton. Lead in the skeleton represents long-term accumulation and its half-life is several decades. Recent research has shown that adverse health effects, particularly neurological, may occur at blood levels previously thought not to result in adverse effects. Evidence is growing that effects may occur at blood lead levels of 10 ug/dl or lower. Chronic exposure to lead is associated with blood and kidney problems, as well as neurological disorders. Childhood neurological disorders such as hyperactivity, learning disabilities and possibly lower lQ scores have been linked to lead. Studies also show that pregnant women with high levels of lead in their blood have a greater risk of miscarriages, stillbirths and premature deliveries. Possible environmental impacts of exposure to lead include mortality and reduced growth in algae, reduced growth of micro-organisms, reduced survival, growth and reproduction of aquatic invertebrates, malformations and reduced survival of fish, mortality and reduced reproduction in amphibia, and reduced survival, growth and/or reproduction in terrestrial plants and invertebrates. Lead was regulated under the Clean Air Act and was placed on the List of Toxic Substances when the Clean Air Act was incorporated into CEPA.

Mercury

It has been shown that long-term exposure to either organic or inorganic mercury can permanently damage the brain, kidneys, and developing fetuses. Mercury may enter the body through ingestion or inhalation. Metallic mercury, inorganic mercury compounds and alkyl mercurials are known to cross the skin barrier. Mercury is of particular concern because of its tendency to methylate, and because methyl mercury bioaccummulates and biomagnifies in the food web, which may contribute to increased exposure. Mercury was regulated under the Clean Air Act and was placed on the List of Toxic Substances when the Clean Air Act was incorporated into CEPA.

Nickel and its Compounds

Based on the results of epidemiological studies of occupationally-exposed workers, there is a clear association between inhalation of each of the groups, oxidic, sulphidic and soluble nickel compounds and the development of respiratory and nasal cancer. Exposure to some nickel compounds has also been associated with non-neoplastic effects including contact dermatitis in humans and experimental animals). Genotoxic effects have also been observed in studies in both humans and animals. Inhalation of some nickel compounds has also been observed to induce cancer in experimental animals. Using a “weight-of-evidence” approach, Health Canada has concluded that each of the groups, oxidic, sulphidic and soluble nickel compounds are carcinogenic to humans, and therefore toxic under Section 11(c) of CEPA.

Comparison of reported effect levels to environmental concentrations indicates that dissolved and soluble forms of inorganic nickel likely cause harmful effects in sensitive pelagic organisms and terrestrial plants in the vicinity of major anthropogenic and natural sources. Therefore, based on the available information, Environment Canada has concluded that dissolved and soluble forms of inorganic nickel are toxic in accordance with Section 11(a) of CEPA.

Considerations Regarding Human Exposure

Arsenic, cadmium, lead, mercury and nickel are present in various environmental media across Canada. Canadians are exposed to these substances in food, drinking water, soil and ambient air, with food generally being the largest source of intake. People residing in the vicinity of point sources may be exposed to higher levels of these substances in all media, and consequently the risk of adverse health effects may be further increased. Nickel and cadmium levels may be elevated in the vicinity of smelting operations. The highest concentrations of inorganic arsenic compounds occur near active and abandoned gold- and base-metal mining and ore processing facilities, and areas affected by the use of arsenical pesticides. It should be also noted that exposure to these substances may be elevated in populations residing in the vicinity of geological sources. Canadian and US studies note that mercury is elevated in air, water, soil and grain crops as a result of industrial and natural sources, and accumulates in certain fish in lakes and oceans, any of which may contribute to increased exposure.

Inorganic arsenic compounds, inorganic cadmium compounds and each of the groups, oxidic, sulphidic and soluble nickel compounds have been classified as substances for which the critical health effect (cancer) is believed not to have a threshold, that is there is some probability of harm at any level of exposure. Therefore, effort should be directed toward reduction of exposure of the Canadian population to the extent practicable. An Exposure/Potency Index (EPI), a measure of risk in which exposure to a substance is compared to its potential to cause cancer, was used in the health assessments to determine the ranking of the toxic substances. Carcinogens with a high EPI are to be given priority in examining measures to control exposure. The EPIs are such that the priority for further action is classified as moderate-to-high for each of the groups, oxidic, sulphidic and soluble nickel compounds and inorganic arsenic compounds, and high for inorganic cadmium compounds. In addition, in view of the fact that mercury and lead have been shown to cause severe non-neoplastic (non-cancerous) health effects and that both have the potential to persist in the body, efforts should also be directed toward minimizing exposure to these substances. Furthermore, with respect to lead, the Canada Gazette (Regulatory Impact Analysis Statement of the Gasoline Regulations, SOR/9O– 247, Part II, Vol. 124, No. 10, May 1990) states, “In order to seek stronger safeguards for the Canadian population and minimize the risk against known and potential harmful effects of lead exposure, the Government of Canada has adopted the policy of reducing blood lead concentration to the lowest possible level...” The latter statement is in accordance with the recommendation of the Royal Society of Canada Commission on Lead in the Environment (1986). There is evidence that the actions taken as a whole in Canada have had a significant health benefit; average blood lead concentrations in Canadian children have shown a steady decline, from about 19 ug/dl in 1972, to 12 ug/dl in 1984, and to 6 ug/dl in 1988 (OECD, 1993).

Appendix 2 — List of Acronyms Used in This Report

ARET	Accelerated Reduction and Elimination of Toxics
BAT	Best Available Technology
CEPA	Canadian Environmental Protection Act
EHS	Environmental health and safety
LMDL	Lowest measurable detection limit
MAC	Mining Association of Canada
MT	Metric tonnes
MTPY	Metric tonnes per year
NPRI	National Pollutant Release Inventory
PM	Particulate matter
PSL	CEPA Priority Substances List
SO_2	Sulphur Dioxide
TBRC	Top blown rotary converters