

**NATIONAL INVENTORY OF SOURCES AND EMISSIONS OF ZINC (1972)\***

Pollution Data Analysis Division  
Air Pollution Programs Branch  
Air Pollution Control Directorate

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## ABSTRACT

Atmospheric emissions of zinc from various Canadian sources have been estimated for the year 1972. The data presented in this report are summarized in Table 1 and Figures 1 and 2. Total zinc emissions to the atmosphere in 1972 are estimated at 8153 tons. The largest contributor is the primary iron and steel industry which accounts for 36.4% of the total. Emissions from the primary copper and nickel industry account for a further 31%, rubber tire wear for 10.7% and the primary zinc industry for 10.2%. On a geographic basis the Province of Quebec accounts for 39.6% of total zinc emissions followed by Ontario with 19.8%.

Results are first approximations of the actual quantities emitted due to paucity of data. The inventory serves to place the various emission sources in perspective and the reader is cautioned not to use emission estimates out of context of this inventory.

## **RÉSUMÉ**

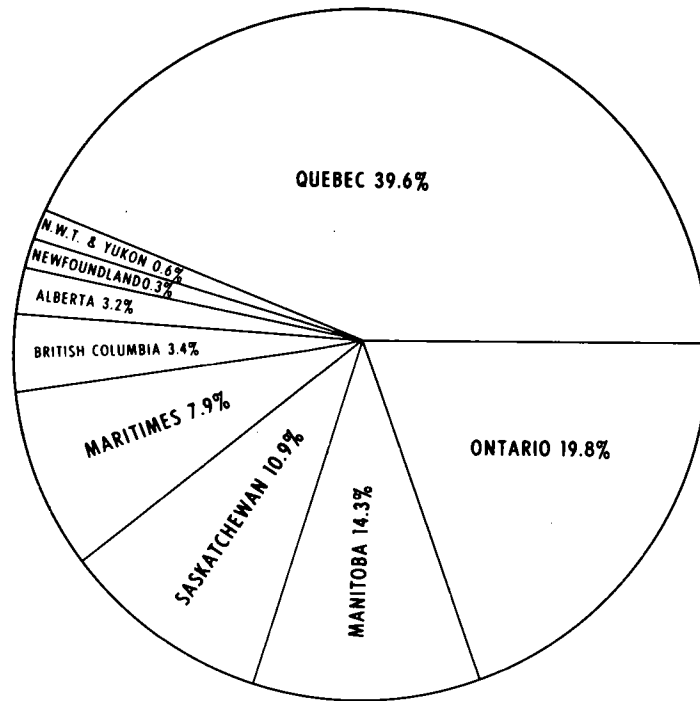
On a fait l'estimation des émissions de zinc dans l'atmosphère en 1972 par les différentes sources canadiennes. Le tableau 1 et les figures 1 et 2 résument les données contenues dans le présent rapport. Les émissions ont été estimées à 8153 tonnes; 36.4% de ces émissions sont attribuables à l'industrie du fer et de l'acier de première fusion, 31% de l'industrie du cuivre et du nickel de première fusion, 10.7% de l'usure des pneus et 10.2%, de l'industrie du zinc de première fusion. Du point de vue géographique, la province de Québec fournit 39.6% du total canadien et l'Ontario, 19.8%.

En raison du peu de données disponibles les résultats sont des premières approximations. Le présent rapport est un inventaire permettant de mettre en évidence les différentes sources d'émissions et le lecteur est mis en garde contre l'utilisation hors contexte des données estimatives.

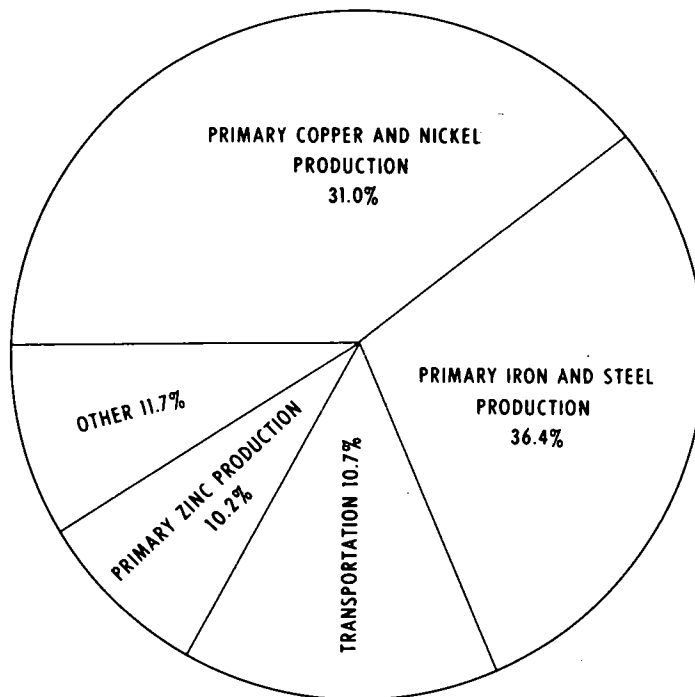
TABLE 1 ZINC EMISSIONS BY PROVINCE AND SECTOR, 1972 (tons)

Sector	Province									N. W. T. Yukon	Total Canada	% Total
	B. C.	Alta.	Sask.	Man.	Ont.	Que.	Nfld.	Maritimes				
INDUSTRY												
Primary copper and nickel production	-	N°	-	181	174	2170	-	-	-	-	2525	31.0
Primary lead production	62	-	-	-	-	-	-	23	-	-	85	1.0
Primary zinc production	42	-	-	685	5	99	-	-	-	-	831	10.2
Primary iron and steel production	30	152	825	210	725	540	-	485	-	-	2967	36.4
Brass and bronze foundries	2	1	-	13	68	18	<1	5	-	-	107	1.3
Die-casting	3	1	-	1	58	31	-	<1	-	-	94	1.2
Iron and steel foundries	6	1	<1	2	81	29	1	4	-	-	124	1.5
Coke manufacture	← Less than 1 ton →						→				<1	<0.1
Galvanizing	11	4	-	5	59	31	1	3	-	-	114	1.4
Battery manufacture	← Less than 1 ton →						→				<1	<0.1
Rubber manufacture	← Approximately 1 ton →						→				1	<0.1
Zinc oxide production	-	-	-	-	<1	2	-	-	-	-	2	<0.1
Mining operations	14	-	1	2	46	17	3	21	36	-	140	1.7
Petroleum refining	← Negligible →											
Miscellaneous sources	← Less than 1 ton →						→				<1	<0.1
FUEL COMBUSTION/ STATIONARY SOURCES												
Power generation	N	24	25	5	3	N	N	21	N	-	78	1.0
Industrial and commercial	2	2	2	3	21	22	<1	13	3	-	68	0.8
Domestic	N	N	N	N	1	1	N	N	N	-	2	<0.1
TRANSPORTATION												
Motor vehicles	← None →				→							
Rail transport	← None →				→							
Shipping	-	N	N	N	<1	<1	-	-	N	-	1	<0.1
Aviation	← None →				→							
Tire wear	104	78	35	43	303	234	16	53	9	-	875	10.7
SOLID WASTE INCINERATION												
	-	-	5	12	73	30	-	17	-	-	137	1.7
PESTICIDE APPLICATION												
	N	N	<1	<1	1	1	N	N	N	-	2	<0.1
TOTAL	276	263	893	1162	1618	3225	21	645	48	-	8153	
% TOTAL	3.4	3.2	10.9	14.3	19.8	39.6	0.3	7.9	0.6	-		100.0

\*N - negligible



**FIGURE 1 PERCENT ZINC EMITTED BY PROVINCE, 1972**



**FIGURE 2 PERCENT ZINC EMITTED BY SOURCE, 1972**

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## 1 INTRODUCTION

### 1.1 Scope

The purpose of this report is to identify and quantify sources of atmospheric emissions of zinc in Canada for the year 1972. The information contained in this report was obtained from a literature survey, a computer search conducted at the National Science Library, and from previous inventory studies. The major information source, however, was a specifically designed questionnaire sent to approximately 1050 plants in Canada, which received an overall response of 51%. Details on response rate and quality of returns are given in the Appendix. As far as possible emission estimates are based on source testing data applicable to Canadian conditions. Emission sources showing seasonal variations are indicated in the text.

### 1.2 Sources and Uses of Zinc

Zinc occurs in nature predominantly as a sulphide ore although other forms, such as zinc oxide, are not uncommon. In Canada, the most abundant zinc sulphide ore is marmatite, followed by sphalerite.

Zinc minerals are seldom found alone, but are usually in varying combinations of two or more sulphides. The most frequent combinations are copper-zinc and lead-zinc ores. The elements cadmium and mercury are closely associated with zinc and are always present to some extent in zinc ores. Pyrrhotite, a readily oxidized iron sulphide, is usually present in zinc ores and must be removed during metallurgical processing.

In Canada, all the primary zinc produced is extracted from its ore by the electrolytic process. The ore is first concentrated followed by roasting and leaching and the leaching solution is purified prior to electrolysis.

Some of the main uses of zinc are outlined below:

*Galvanizing of iron and steel.* A thin coating of zinc, usually applied by the hot dip process, forms a barrier which protects the iron or steel against corrosion.

Corrosion protection is also provided should the coating be broken. A galvanic cell between the zinc and the iron or steel is set up, in which the zinc corrodes sacrificially.

*Alloys.* The most important zinc alloys are brass and bronze.

*Zinc Oxide.* This is used in the manufacture of paints, rubber, rayons and yarns, inks, matches and chemicals, and in photocopying.

*Zinc Dust.* Zinc dust is used in printing, textile dyeing, fat purification and for cementing metals in metallurgical processing.

*Rolled Zinc.* This is used in ornamental work and batteries.

*Zinc Chemicals.* These include zinc sulphate and zinc chloride. The latter is a wood preservative. Zinc is also a constituent of some pesticides.

Figure 3 is a material flowsheet identifying the sources and uses of zinc.

## **2 INDUSTRIAL EMISSIONS**

### **2.1 Primary Copper and Nickel Production**

There were six primary copper smelters in Canada in 1972, three of which also produced primary nickel. One other company produced the remainder of the primary nickel and also a small amount of copper sulphide as a by-product. A small amount of copper matte was also produced as a by-product of primary lead production. In 1972, 801 690 tons of recoverable copper and 258 087 tons of nickel were produced in Canada (1,2).

**2.1.1 Process Description.** The type of process and the process stages required depend primarily on the characteristics and chemical composition of the ores.

The most common method of producing primary copper and nickel is the pyrometallurgical process and consists of the following basic process steps:

*Concentration.* Low-grade sulphide ores are concentrated by gravity or flotation.

*Roasting.* Concentrates are roasted to drive off most of the sulphur in preparation for subsequent smelting and converting reactions.

*Smelting.* In this stage the charge is melted, usually in a reverberatory furnace, where it separates into a matte and a slag. Matte is a mixture of recoverable metal sulphides, and slag is a mixture of discardable oxides.

*Converting.* The mattes are converted through a series of chemical reactions to the crude metals.

*Anode Furnace and Electrolytic Refining.* The crude copper or nickel is then cast into anodes to be refined by electrolysis.

*Cathode Melting.* Electrolytic copper is melted under reducing atmosphere in a shaft-type furnace to cast into billets, slabs, etc. for marketing.

Figure 4 is a typical flow diagram for the pyrometallurgical process.

Nickel is also produced by the hydrometallurgical process, which is practiced at one plant in Canada.

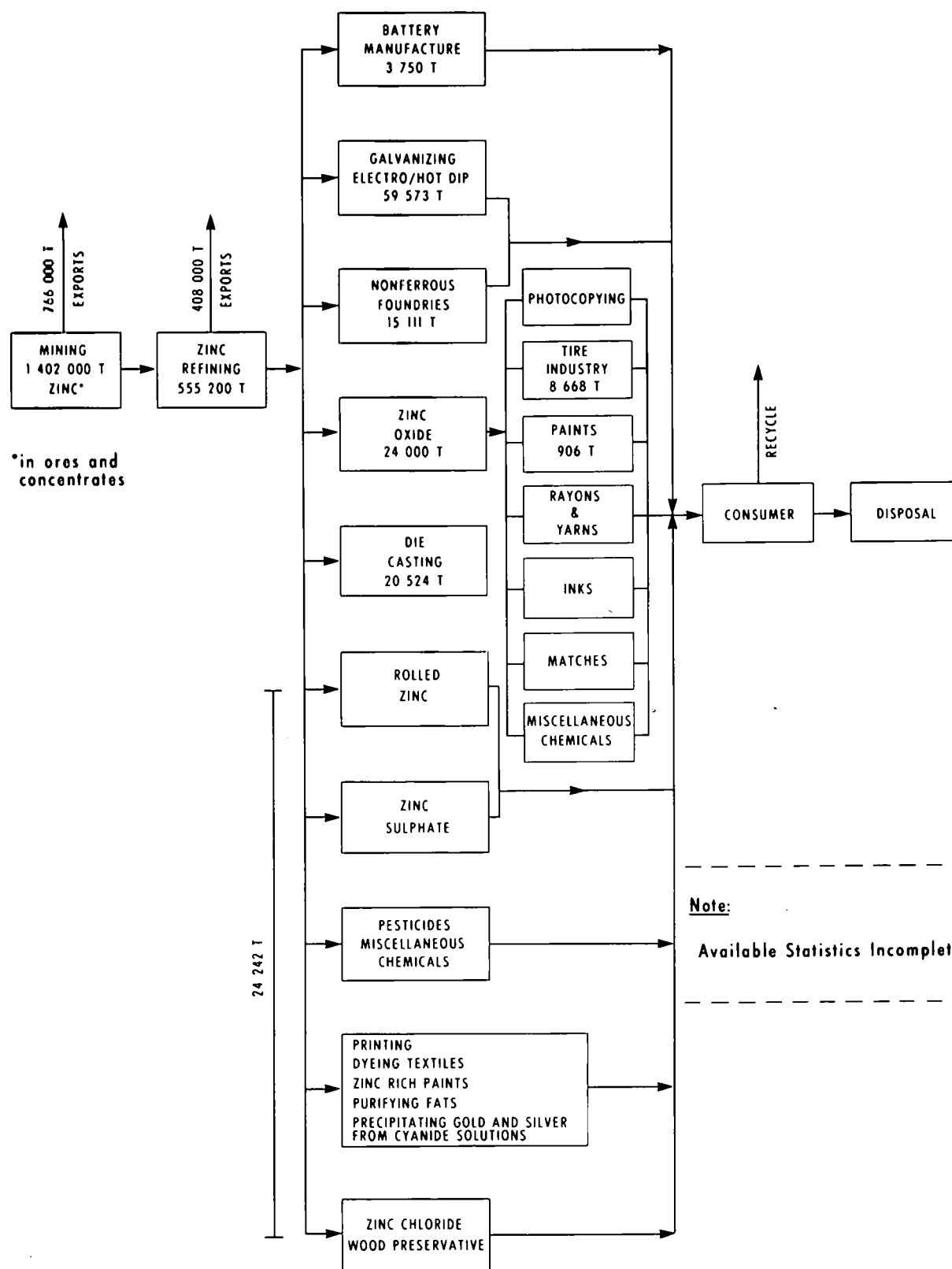


FIGURE 3 SOURCES AND USES OF ZINC, 1972

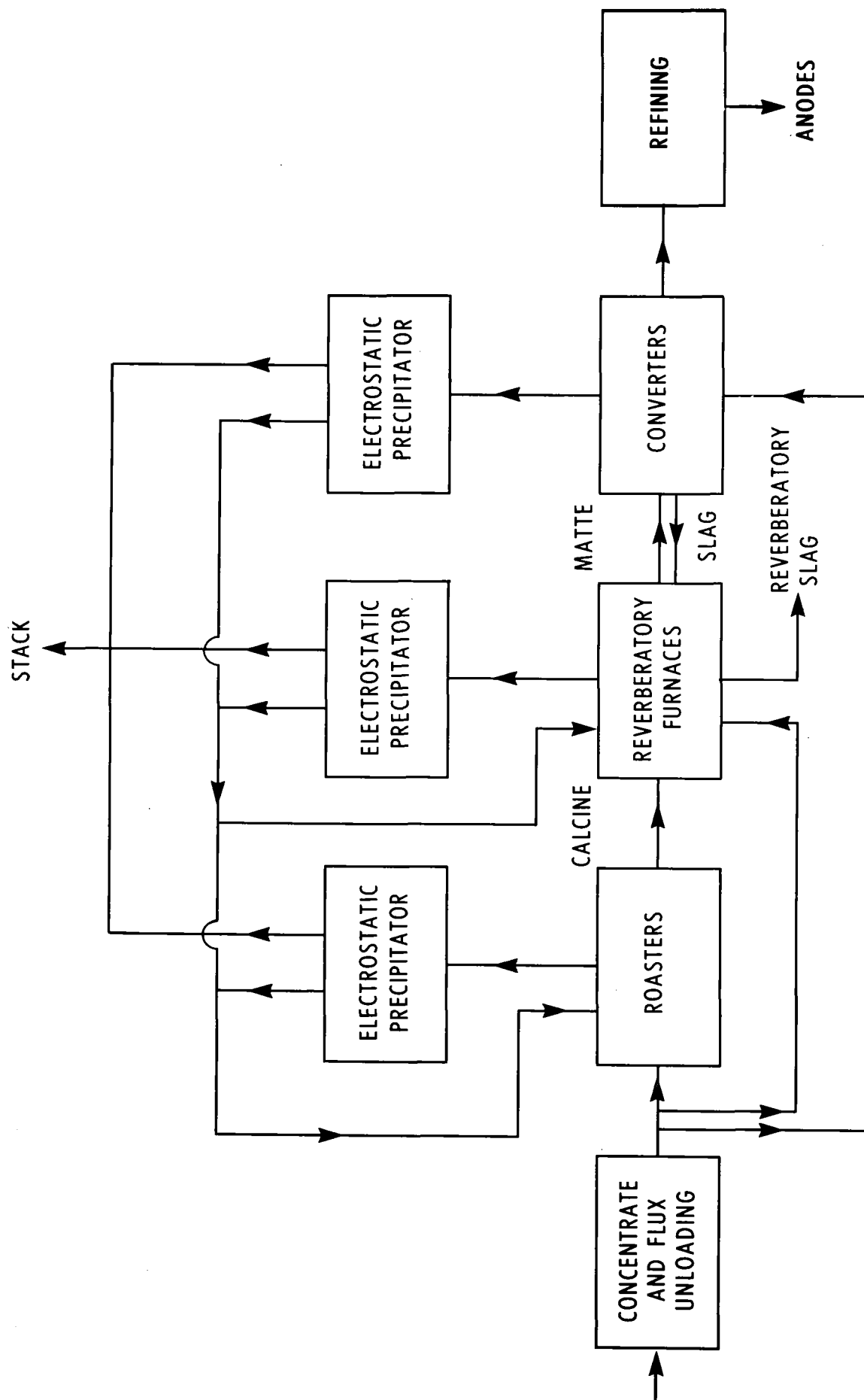


FIGURE 4 PRIMARY COPPER AND NICKEL PLANT FLOW DIAGRAM

**2.1.2 Emissions.** The main atmospheric emission sources in the production of primary copper and nickel are the roasters, furnaces, and converters. Emissions from operations such as ore handling and anode furnaces are negligible in comparison. Zinc is emitted mostly in the form of zinc oxide.

Because of process variations from one company to the other, emission factors for various process stages could not be compared.

Most of the companies surveyed reported source test data as a basis for calculating zinc emissions. A similar emissions inventory in the United States (3) does not consider emissions of zinc from primary copper and nickel production.

Total emissions of zinc to the atmosphere from primary copper and nickel production in 1972 are estimated at 2525 tons.

**2.1.3 Particle Size Distribution.** Table 2 summarizes information received on particle size distribution for particulate emissions from primary copper and nickel smelters.

## **2.2 Primary Lead Production**

There were two primary lead producers in Canada in 1972, producing a total of 204 452 tons of lead. Small amounts of copper matte, totalling 3677 tons, were a by-product of lead refining operations.

**2.2.1 Process Description.** Lead is extracted by first partially oxidizing the concentrate in a sintering plant. The concentrate may also be process-dried prior to sintering. The partially roasted concentrate is then smelted in a blast furnace where the lead sulphide is oxidized by air to lead oxide, lead sulphate and sulphur dioxide. The lead oxide and lead sulphate then react with carbon and carbon monoxide producing impure lead metal, carbon dioxide, sulphur dioxide, and a slag. The lead is further refined by either electrolysis or chemical precipitation from the molten metal.

**2.2.2 Emissions.** The main atmospheric zinc emission sources in primary lead production are:

**Sinter Plant.** One plant has an acid plant which results in low zinc emissions while the other plant has scrubbers. Emissions are in the form of zinc oxide. Total emissions of zinc to the atmosphere from this source in 1972 are 10 tons.

**Blast Furnace.** The average controlled emission factor for the blast furnaces is 0.49 lb zinc/ton lead produced. Emissions are in the form of zinc oxide. Both companies control their emissions with a baghouse. Total zinc emissions to the atmosphere from this source in 1972 are 50 tons.

**Refining.** Both the electrolytic and chemical precipitation processes are used in Canada. Emissions are in the form of zinc oxide. Total emissions of zinc to the atmosphere from this source in 1972 are 7 tons.

**Miscellaneous.** Zinc emissions from activities such as ore preparation, drying and handling are small compared to the other emission points. Depending on the process, zinc is emitted either as zinc sulphide, sulphate or oxide.

TABLE 2 PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM  
PRIMARY COPPER AND NICKEL SMELTERS

Source	Particle size (microns)	Weight of particulates (%)
Sinter plant	> 74	10
	37 - 74	18
	0.4 - 37	38
	< 0.4	34
Smelter plant A	> 74	19
	37 - 74	26
	0.4 - 37	30
	< 0.4	25
Smelter plant B	> 45	5
	21 - 44	10
	11 - 20	20
	< 10	65
Smelter plant C	44 - 100	5
	10 - 44	20
	< 10	75
Smelter plant D	4.8 - 11.7	19
	2.1 - 4.8	27
	0.5 - 2.1	14
	< 0.5	40

Total emissions of zinc to the atmosphere in 1972 from these sources are estimated at 1 ton.

*Slag Fuming.* At one plant the slag and the baghouse dust from the blast furnace operation are fumed to recover zinc. In this step, zinc is reduced to metal by carbon or carbon monoxide, vaporized, and reoxidized to form a zinc oxide fume which is collected in a baghouse. If the collected zinc oxide is

relatively pure it may be used as a final product, otherwise it is further treated in a zinc oxide fume leaching plant.

Zinc emissions from the slag fuming operation in 1972 are reported to be 7 tons.

*Zinc Oxide Fume Leaching Plant.* Zinc oxide fume from the slag fuming is leached and purified and the zinc sent for refining by electrolysis (section 2.3). The leach residue is returned to the lead smelter and the purification residue is sent to the cadmium plant in the zinc refinery.

The main source of emissions from this process is the solution cooling vent stack. Small emissions occur from the fume unloading and acid thickening vent stack. Zinc emitted from the acid thickeners and from solution cooling is in the form of zinc sulphate droplets, while fume handling emissions are in the form of zinc oxide. Zinc oxide emissions from the fume unloading are controlled with a baghouse. No controls are indicated for acid thickeners and solution cooling. Total emissions of zinc to the atmosphere in 1972 from zinc oxide fume leaching are estimated at 10 tons. Most of the emission estimates are based on source testing data reported by the companies surveyed. Some estimates are also based on information from equipment suppliers.

No other studies were found which reported zinc losses from primary lead production.

*Total Emissions.* The total estimated zinc emissions to the atmosphere for 1972 from primary lead producers are given in Table 3.

**2.2.3 Particle Size Distribution.** Neither of the companies responded with particle size distribution data and no other information was found in the literature.

## **2.3 Primary Zinc Production**

During 1972, 555 200 tons of primary zinc and 1538 tons of cadmium were produced in Canada by four plants.

**2.3.1 Process Description.** All the primary zinc in Canada is produced by the electrolytic process which consists of the following stages:

*Roasting.* Zinc sulphide ore is roasted to zinc oxide. The roasted ore is termed calcine and contains up to 3% sulphur.

*Leaching.* The calcine is leached with sulphuric acid to produce a neutral solution of zinc and other metal sulphates. The insoluble portion, which contains iron, is separated from the soluble portion and contains about 20% zinc as ferrite, when using the conventional electrolytic process.\*

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\* Two plants in Canada use the Jarosite Process which gives higher zinc recovery than the conventional method. In the Jarosite Process the insoluble portion contains up to 3% zinc as ferrite.



TABLE 3 ZINC EMISSIONS FROM PRIMARY LEAD PRODUCTION, 1972

Process stage	Zinc emissions (tons)
Sinter plant	10
Blast furnace	50
Refining (anode furnace)	7
Miscellaneous	1
Slag fuming	7
Zinc oxide fume leaching plant	10
TOTAL	85

*Purification.* Cadmium and other metals are cemented (precipitated) from the solution and the purified solution is cooled in forced draft cooling towers before going to the electrolysis plant. Arsenic trioxide and zinc dust are usually added to precipitate impurities.

*Electrolysis.* Zinc is plated from the solution. The temperature of the electrolyte is controlled by forced draft cooling towers.

*Melting and Casting.* The zinc cathodes are melted and cast into ingots.

*Zinc Dust Plant.* Zinc dust required for the purification step is made by melting some of the zinc followed by air atomization of the liquid metal.

*Cadmium Plant.* A by-product of zinc production is cadmium. It is precipitated (cemented) from the solution during the purification stage and is further purified to remove copper before being melted and cast into ingots.

Figure 5 is a typical flow diagram for a zinc plant.

**2.3.2 Emissions.** The main sources of zinc emission in the electrolytic zinc process are:

*Zinc Melting Furnace and Dross Mill.* A controlled emission factor for the melting furnace was calculated to be 0.083 lb zinc/ton of zinc processed. Emission control devices are either impingers

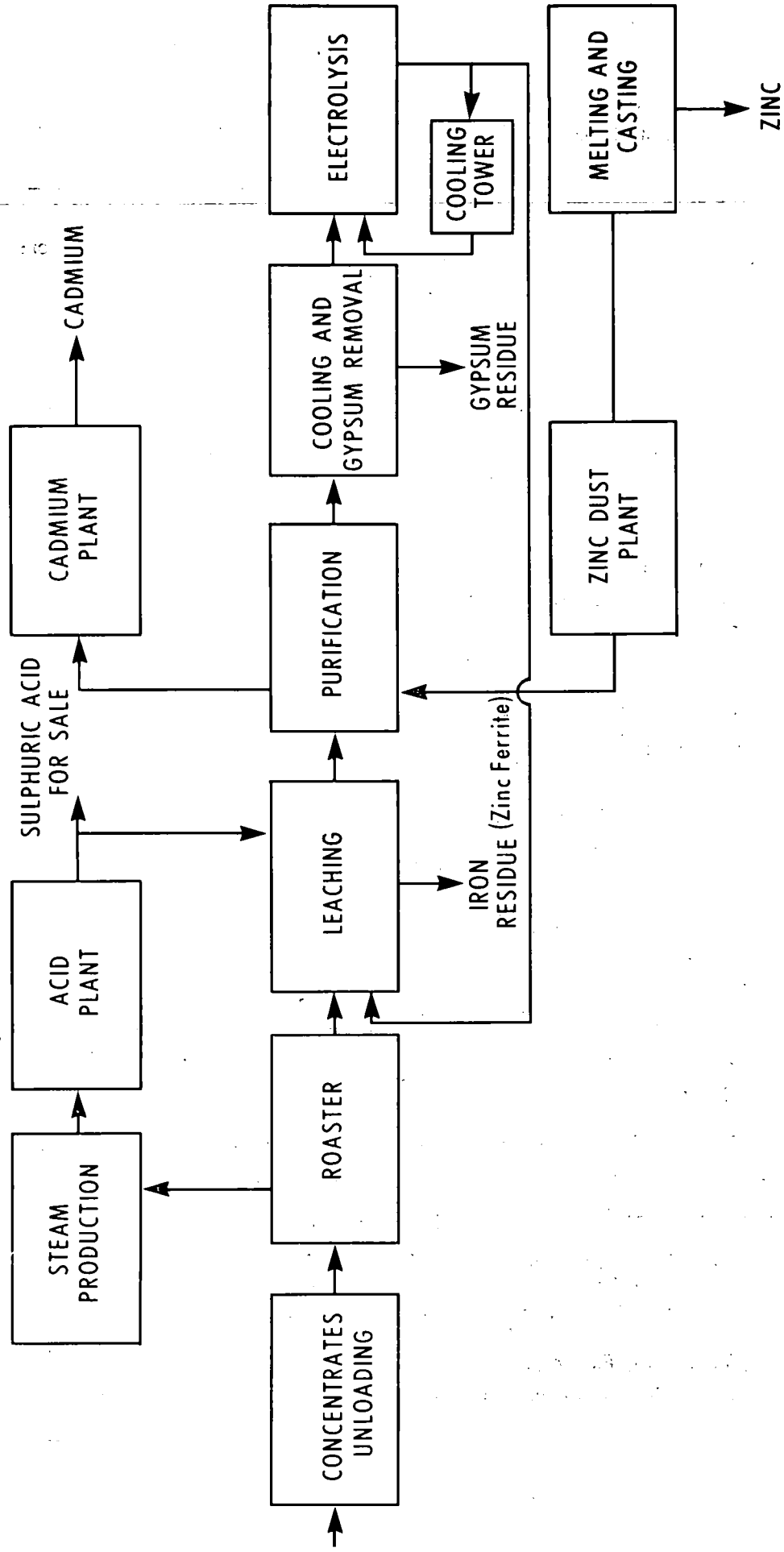


FIGURE 5 PRIMARY ZINC PLANT FLOW DIAGRAM

or cyclones and baghouses, but not all plants have controls. Emissions from the dross mill are negligible. Two of the companies combine their dross losses with the zinc melting furnace and the others indicate no emissions.

The chemical form of the zinc varies considerably indicating that it could be in the form of zinc metal, zinc oxide, zinc chloride and/or zinc sulphate.

Total emissions of zinc to the atmosphere from the zinc melting furnace are estimated at 457 tons in 1972.

*Neutral and Spent Electrolyte Cooling Towers.* All of the zinc plants in Canada have forced draft cooling towers which have a drift loss of approximately 0.003% of the solution flow. Controlled emission factors for zinc losses to the atmosphere, for the neutral and spent electrolyte towers combined, range from 0.050 - 0.234 lb zinc/ton of zinc produced with an average of 0.142 lb/ton of zinc produced. This emission factor was applied to companies not reporting losses.

The only control devices in these towers are mist eliminators. The type of cooling tower used affects the drift losses. Zinc is emitted in the form of zinc sulphate. Total zinc emissions from both the neutral and spent electrolyte cooling towers in 1972 are estimated at 33 tons.

*Zinc Dust Plant.* Zinc emissions to the atmosphere occur from the furnace and blowing operation.

Only two plants indicated losses of zinc. The average controlled emission factor is 0.038 lb zinc/ton of zinc product. Emissions are controlled with baghouses.

Zinc is emitted as elemental zinc. Total emissions from the zinc dust plants in 1972 are estimated at 13 tons.

*Roaster and Acid Plant Stack.* All of the primary zinc producers but one have acid plants for the production of sulphuric acid from the roaster gases. Before entering the acid plant, the gases are thoroughly cleaned by cyclones, electrostatic precipitators and in some cases acid scrubbers to remove particulate matter. The company without an acid plant has an electrostatic precipitator. Zinc losses from the acid plants are indicated to be in the range of 0 - 0.041 lb zinc/ton zinc product. The chemical form of the zinc was reported as zinc sulphate. Losses from roaster operations without acid plants are considerably higher.

Zinc losses to the atmosphere from the roasters and acid plant stacks for 1972 were 317 tons.

*Ore and Calcine Handling and Storage.* Emissions of zinc also occur from ore and calcine handling and storage. A controlled emission factor for these operations was calculated, from values reported by two companies, to be 0.038 lb zinc/ton of zinc handled. Emissions of zinc to the atmosphere from these areas for 1972 are estimated at 11 tons.

Most of the companies surveyed based their estimates on source test data; however, some of the information was based on information from equipment suppliers and mass balance calculations.

An uncontrolled emission factor for primary zinc smelters was calculated to be about 120 lb zinc/ton zinc produced. A previous study by the U.S. Environmental Protection Agency (3) reports zinc emissions from the electrolytic zinc process to be 60 lb zinc/ton zinc produced. A possible explanation for the discrepancy may be that the other study was based mainly on personal interviews rather than on source testing data.

Total estimated zinc emissions to the atmosphere for 1972 from primary zinc producers are given in Table 4.

TABLE 4 ZINC EMISSIONS FROM PRIMARY ZINC PRODUCTION, 1972

Process stage	Zinc emissions (tons)
Zinc melting furnace	457
Neutral and spent electrolyte cooling towers	33
Zinc dust plant	13
Roaster and acid plant	317
Ore and calcine handling and storage	11
TOTAL	831

TABLE 5 PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM PRIMARY ZINC SMELTERS

Source	Particle size (microns)	Weight of particulates (%)
Zinc dross	> 5	27
	< 5	73

**2.3.3 Particle Size Distribution.** The only information reported in the questionnaires for particle size distribution was that shown in Table 5.

## **2.4 Primary Iron and Steel Production**

There were 45 plants in Canada engaged in the production of primary iron and steel in 1972. Primary iron production capacity was about 12 million tons, and steel furnace plant capacity was about 16 million tons (7).

**2.4.1 Process Description.** The manufacture of iron and steel comprises some or all of the following steps.

*Iron Ore Pretreatment.* In certain cases iron ore is pretreated prior to the blast furnace operation. This process usually involves ore concentration followed by either sintering or pelletizing.

*Iron Production.* This takes place in the blast furnace. In this process, the iron-bearing materials (iron ore, sinter, pellets, mill scale, iron or steel scrap, etc.), fuel (coke), and flux (limestone and/or dolomite) are charged into the top of the furnace. Heated air (blast) and, in some instances, fuel (gas, oil or powdered coal) are blown in at the bottom. The blast air burns part of the fuel to produce heat for the chemical reactions involved and for melting the iron while the balance of the fuel and part of the gas from the combustion remove the oxygen combined with the metal.

A typical blast furnace charge, in Canada, per ton of product is:

Ore, Sinter, Pellets	1.6 tons
Coke	0.5 ton
Air	2.0 tons
Limestone/Dolomite	0.1 ton

The product from the blast furnace is known as either hot metal (molten) or pig iron (solid). Pig iron may be remelted with scrap in cupolas to produce cast iron.

*Steel Production.* Blast furnace product and steel scrap are charged to the steel furnace, where further refinement takes place. Careful control of the levels of contaminants such as silica, phosphorus, sulphur and carbon is necessary to impart the desired mechanical and chemical characteristics to the product steel. Chemical and mechanical properties may be changed by alloying with other metals such as nickel, chromium and manganese.

The steel furnaces used in Canada in 1972 were the basic oxygen, the basic open hearth and the electric arc, listed in decreasing order of overall production capacity. Open hearth furnaces are becoming obsolete and should eventually be replaced by basic oxygen furnaces. The availability of cheap hydroelectric power in certain areas may sometimes favor the use of electric furnaces.

*Steel Finishing.* This includes a large number of operations, depending on the required final product. The required product shape may be achieved by casting, or in rolling mills, bar mills, and railing mills. Other processes such as scarfing, pickling and galvanizing are employed to achieve desired surface properties.

**2.4.2 Emissions.** The main emission sources are the blast furnace and the steel furnace operations. Some emissions probably also occur from certain pretreatment processes, but these are employed only in specialized cases and emissions are assumed negligible.

Steel finishing operations are conducted at relatively low temperatures where the volatility of zinc is small. No evidence has been found to indicate that steel finishing is a source of zinc emissions.

*Blast Furnace.* The uncontrolled emission factor was estimated to average 0.07 lb zinc/ton product. Emissions arise principally from volatilization of the zinc contained in iron ore. The zinc content of particulate emissions was reported to be about 0.28%.

*Steel Furnace.* Emissions arise principally from volatilization of the zinc contained in the scrap metal charged to the furnace.

Uncontrolled emission factors are typically in the range of 1 - 3 lb zinc/ton product. There is, however, a considerable degree of variation from plant to plant. This may be due to the variation in the zinc content of scrap steel (0%-4%) and the relative quantities of pig iron and scrap in the furnace charge. The emission factor also varies with the type of furnace used. It is estimated that on the average, the uncontrolled emission factor for open hearth furnaces is 1.22 lb zinc/ton of product; about 1.31 lb zinc/ton of product for basic oxygen furnaces, and about 3.3 lb zinc/ton of product (3) for electric furnaces. The zinc content of open hearth particulate emissions was reported to be 2.5%. For particulate emissions from basic oxygen furnaces, this was reported as 3.4% after control equipment and 12.0% for emissions not contained by control equipment. Fumes from electric furnaces are reported in the literature to contain about 9.6% zinc (3).

Very few of the companies surveyed reported test data on zinc emissions. Some, however, reported measurements of total particulate emissions and of zinc content of particulate emissions.

A previous study (3) indicates uncontrolled emission factors for zinc as well as the percentage of zinc present in total particulate emissions which are in fair agreement with the data developed in this survey, considering the limited information available.

Emission estimates are based on (in order of preference):

- source testing data on zinc emissions;
- a percentage of total reported particulate emissions; and
- previously published emission factor data.

Total estimated zinc emissions from primary iron and steel production for 1972 are given in Table 6.

TABLE 6 ZINC EMISSIONS FROM PRIMARY IRON AND STEEL PRODUCTION, 1972

Process stage	Zinc emissions (tons)
Iron production	24
Steel production	2943
TOTAL	2967

**2.4.3 Particle Size Distribution.** Some companies reported measured particle size data, as summarized in Table 7.

TABLE 7 PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM ELECTRIC ARC STEELMAKING FURNACES.

Source	Particle size (microns)	Weight of particulates (%)
Electric furnace	<5	20-50
	5-10	30-50
	10-20	10-25
	>20	5-10
Electric furnace with oxygen lance	0.2-5	95

## **2.5 Brass and Bronze Foundries Including Copper Alloy Producers**

Canadian brass and bronze foundries processed approximately 15 111 tons of zinc in 1972(4).

**2.5.1 Process Description.** Brass and bronze are copper alloys. To prepare brass, zinc is usually added in amounts up to 40%. Alloying components in bronze are tin, lead, aluminum, silicon and sometimes zinc (not more than 10%).

The zinc added to copper for bronze and brass making can be either slab zinc or zinc recovered from scrap brass and bronze.

Larger foundries generally use reverberatory, rotary and electric induction furnaces. Smaller foundries melt the metals in crucible-type furnaces.

**2.5.2 Emissions.** Emissions of zinc from brass and bronze foundries vary with the type of furnace, the alloy and the foundry practice. Emissions of zinc oxide from brass foundries average 59% of the particulate matter contained in furnace stack gas. For bronze foundries, only traces of zinc are emitted (5). This is due in part to the relatively low zinc content of bronze.

There are four principal factors affecting the concentration of zinc fumes in brass furnace gases (5):

*Alloy composition.* The rate of zinc loss is approximately proportional to the percentage of zinc in the alloy.

*Pouring temperature.* For a given percentage of zinc, an increase of 100°F in temperature increases the rate of loss of zinc about three times.

*Type of furnace.* Other conditions being constant, direct-fired furnaces have higher emissions than the crucible type.

*Poor foundry operating practices.* Excessive emissions result from improper combustion, overheating of the charge, addition of zinc at maximum furnace temperature, flame impingement upon the metal charged, heating the metal too fast, and insufficient flux cover.

Most foundries produce both brass and bronze. Reported data, therefore, does not differentiate between emissions from brass and bronze founding operations. An average uncontrolled zinc emission factor for brass and bronze foundries is estimated to be 16.5 lb zinc/ton of zinc processed.

From the survey results it is estimated that only about 16% of the foundries have emission control devices. These are either baghouses or dust tube collectors with efficiencies from 98.5% - 99.0%.

Two companies indicated emissions from grinding operations after casting, but no values were given. These emissions are controlled by baghouses and are assumed to be negligible. Most companies based their emission estimates on source testing and mass balance calculations.



Zinc emissions in all cases were reported to be in the form of zinc oxide.

A similar survey done in the United States (3) indicates an industry-wide average controlled emission factor of 2 lb zinc/ton zinc processed, based on interviews and material balances.

Total zinc emissions in 1972 from brass and bronze foundries are estimated at 107 tons.

**2.5.3 Particle Size Distribution.** None of the brass and bronze foundries surveyed provided particle size distribution data. The Air Pollution Engineering Manual (5) mentions that photomicrographs of samples, taken when furnace emissions were heavy with smoke, resulting from improper combustion or melting of oily scrap, indicate that the smoke particles accompanying the fumes may be about 0.01  $\mu$  and smaller.

## **2.6 Die-Casting**

During 1972, the die-casting industry processed 41 million pounds of zinc (4).

Zinc-based die castings are now used extensively in the production of automobiles, home appliances, commercial machines and tools, builders' hardware, office equipment, business machines, optical and photographic equipment.

**2.6.1 Process Description.** This usually consists of two main process steps:

*Melting.* Raw materials are melted in a furnace.

*Casting.* The metals are cast into shape under pressure.

**2.6.2 Emissions.** There is no evidence to indicate that significant zinc emissions occur during casting. Emissions do occur, however, during the melting process (5).

It is estimated that total zinc emitted by the die-casting industry during 1972 amounted to 94 tons.

Estimated emissions are based on an uncontrolled emission factor of 9.19 lb zinc/ton of zinc processed. This factor was derived from similar melting operations in the primary zinc industry. A previous study (3) reports an uncontrolled emission factor of 10 lb zinc/ton zinc processed.

**2.6.3 Particle Size Distribution.** No information was received on particle size distribution.

## **2.7 Iron and Steel Foundries**

The total production in Canada in 1972 has been reported at 1 227 451 tons of iron and steel castings (6,7).

**2.7.1 Process Description.** Scrap iron and steel are melted in different types of furnaces and cast in molds usually made of sand. Cupola, electric induction and electric arc are the furnace types normally used for melting in iron and steel foundries. Metals such as zinc are contained as impurities in the furnace charge.

Most of the companies responding to this survey have emission control equipment, usually cyclones, baghouses or wet caps.

Very few data on zinc emissions were obtained in this survey. A number of companies, however, provided particulate emission data.

In a previous study (7) of five foundries in Ontario, both zinc and particulate emissions were measured and an average uncontrolled emission factor of 0.51 lb zinc/ton product was calculated. A similar survey made in the United States (3) estimates the uncontrolled zinc emission factor for foundries to be 0.24 lb zinc/ton of process weight. This value agrees favorably with the value of 0.51 lb zinc/ton of process weight used in this study.

The Air Pollution Control Directorate has made estimates of the degree of emission control in the various provinces (9).

**2.7.2 Emissions.** Total zinc emissions to the atmosphere from iron and steel foundries for 1972 are estimated at 124 tons.

**2.7.3 Particle Size Distribution.** Table 8 gives information on particle size received from one questionnaire and from an analysis done in the United States on grey iron cupolas (5).

TABLE 8                      PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM  
IRON AND STEEL FOUNDRIES

Source	Particle size (microns)	Weight of particulates (%)
Canadian cupola	0.01-0.1	5
	0.1 -1.0	20
	1.0 -10.0	75
United States cupolas	0-5	21.2
	5-10	6.5
	10-20	7.5
	20-44	17.4
	>44	47.4

## **2.8 Metallurgical Coke Manufacture**

There are seven coke manufacturing companies in Canada. Total coke production in 1972 was about 5.2 million tons (10).

**2.8.1 Process Description.** After crushing and blending to obtain the desired raw material properties, coal is charged to ovens and heated. The volatile material driven off (mainly coke-oven gas and some by-product chemicals) is scrubbed, cooled and collected. After coking is complete, the coke is 'pushed' from the ovens and quenched.

**2.8.2 Emissions.** Approximately half of the total particulate emissions occur during coal-handling operations, that is, storage, conveying and charging. Most of the balance occurs during coke-handling operations such as pushing and quenching.

It is assumed that most of the zinc contained in coal would be volatilized during the coking operation and probably removed in the scrubbing/cooling towers. Therefore, zinc emissions to the atmosphere would only occur during coal-handling operations. Since these are low-temperature processes, the zinc content of the particulate emissions would be similar to that of coal. It has been reported (11) that about 1.5 lb particulates are emitted to the atmosphere per ton of coke produced during coal-handling operations and that the zinc content of coal is about 50 ppm (3). No other information was found giving zinc emissions from coking operations.

Total zinc emissions from coke manufacturing in Canada during 1972 are estimated at about 0.20 ton.

**2.8.3 Particle Size Distribution.** No data was found or received on particle size distribution for coking operations.

## **2.9 Galvanizing**

In Canada, galvanized steel is used as roofing sheet, guttering, culverts, fencing, pipe, wire, pole-line hardware, nails, pipe fittings, switch boxes, electrical conduit, tanks, hot water heaters and structural steel members. A total of 59 573 tons of zinc was used for galvanizing in Canada during 1972 (4). None of the questionnaire replies gave any zinc emission data.

**2.9.1 Process Description.** Iron and steel can be galvanized by either hot dip or electro-galvanizing. The former accounts for 97% of all galvanizing.

*Electro-galvanizing.* In electro-galvanizing the zinc is plated on the metal surface by electrolysis where the zinc acts as the anode and the metal to be plated acts as the cathode.

*Hot Dip Galvanizing.* Hot dip galvanizing is the most common process used for coating clean iron and steel surfaces with zinc. There are two hot dip processes, one coats steel strip at high speed by passing hot strip through a zinc bath, the other is a batch process where individual pieces are dipped.

Prior to immersion in the kettle, the metal surface has to be degreased, rinsed, pickled, rerinsed and immersed in a tank of preflux.

Following the hot zinc bath, the metal surface is finished by shaking or centrifuging, water quenching, deburring and inspecting.

**2.9.2 Emissions.** Zinc emissions from galvanizing are as follows:

*Electro-galvanizing.* No zinc emissions were reported from the electro-galvanizing process. The temperatures involved are well below the melting point of zinc.

*Hot Dip Galvanizing.* Zinc emissions occur when fresh flux is added and when the flux cover is disturbed each time an article is immersed in the zinc bath. The uncontrolled zinc emission factor used is 4.0 lb zinc/ton of zinc processed for both the continuous and batch processes.

Although ammonium chloride is the principal pollutant, there are also significant quantities of zinc, zinc oxide and zinc chloride in the fumes. Only one of the plants replying to the survey indicated having emission control equipment (baghouse and cyclone).

Processing operations appear to be similar at the galvanizing plants although the practices followed vary. The flux cover is agitated more in some cases than in others and emissions are therefore greater.

Because no zinc emission data were reported in this survey, an arbitrary emission factor of 4 lb zinc/ton of zinc processed, already reported in a previous study (3), was used. Proration of emissions on a provincial basis was made assuming that zinc losses were proportional to the surface area of the galvanizing kettles. No better data were available.

Total zinc emissions from galvanizing are estimated at 114 tons during 1972.

**2.9.3 Particle Size Distribution.** None of the companies gave any information on particle size distribution and no other data were found.

## **2.10 Battery Manufacture**

During 1972, total Canadian consumption of zinc for use in battery manufacturing was about 7.5 million pounds (12).

**2.10.1 Process Description.** Batteries may be broadly divided into two categories:

*Primary batteries*, which are not rechargeable and are discarded after use.

*Secondary Batteries*, which are recharged by passing electric current through them in the reverse direction.

Use of zinc is restricted almost entirely to primary batteries. Zinc is the main component of the anodes of these batteries, and is also present (generally as zinc chloride) in the electrolyte.

**2.10.2 Emissions.** Zinc is emitted when zinc powder is formed into pellets for anode manufacture. It is probable that zinc emissions also occur during zinc melting and casting operations.

Only one company reported zinc emission data. These data were used to estimate an emission factor, which was applied to total Canadian zinc consumption. The emission estimate may therefore be subject to considerable error as a result of the scarcity of data. No previous studies on this topic were found.

A crude estimate indicates that, based on a controlled emission factor of 0.2 lb zinc/ton zinc consumed, total Canadian zinc emissions from battery manufacturers were about 720 lb in 1972.

**2.10.3 Particle Size Distribution.** Particle size distribution was reported as shown in Table 9.

TABLE 9 PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM BATTERY MANUFACTURE

Source	Particle size (microns)	Weight of particulates (%)
Zinc amalgam dust collector	<37	Trace
	37-44	0.86
	44-74	1.40
	74-149	8.70
	149-260	47.40
	>260	41.46

## 2.11 Rubber Manufacture

One of the largest consumers of zinc oxide in 1972 was the rubber industry which consumed approximately 38% of the zinc oxide produced in Canada.

Questionnaires were sent only to rubber tire manufacturers because they accounted for 90% of rubber production.

**2.11.1 Process Description.** The main process stage in rubber products manufacture is known as compounding and mixing. Mixing of compounded rubber and additives is performed in either Banbury mixers or rubber mills depending on the final product. Zinc oxide is used in rubber compounding as an activator for the vulcanization process and helps to protect rubber against atmospheric and light ageing because of its opaqueness to ultraviolet light and its high thermal conductivity. (3)

The remaining rubber process stages include forming, shaping and finishing. Small amounts of zinc oxide powder are used during these stages and to protect finished rubber goods.

**2.11.2 Emissions.** Zinc oxide emissions from rubber manufacturing occur when zinc oxide is compounded in Banbury mixers or rubber mills. Controlled emission factors were reported from 0.020 to 0.356 lb zinc/ton zinc oxide processed with an average of 0.214 lb of zinc/ton of zinc oxide processed.

All of the companies indicated that baghouses were used to control emissions at an average efficiency of 99.0%.

The emission estimate was based on information from equipment suppliers, mass balance calculations and data from production experience. No previous study on this topic was found.

Total zinc emissions from rubber manufacturing during 1972 are estimated at 1.14 tons.

**2.11.3 Particle Size Distribution.** One company indicated that all particles were below 5  $\mu$ , while another reported that 99.8% were between 30 and 45  $\mu$ . A previous publication from the United States (5) reports all particles to be smaller than 15  $\mu$ .

## **2.12 Zinc Oxide Production**

Approximately 24 000 tons of zinc oxide were produced in Canada in 1972 (13). Most of this was produced by one company located in Quebec.

**2.12.1 Process Description.** Zinc oxide is produced in large furnaces fired by natural gas. Zinc ingots are melted and the metal vaporized. In the vapour state the metal reacts with oxygen forming zinc oxide which is collected in baghouses.

**2.12.2 Emissions.** The only significant losses of zinc result from the melting and vaporization of the metal. A small amount of zinc oxide escapes from the baghouses.

Source testing data and mass balance calculations were used to determine emission factors. Data obtained from this survey indicate an uncontrolled emission factor of 0.20 lb zinc/ton zinc oxide produced for emissions escaping the baghouse, which is an integral part of the process for the plant surveyed in Canada. Another study, based on personal interviews, suggests that zinc emissions range from 20-170 lb/ton of zinc produced (3). The study does not mention if this rate was before or after the baghouse but it seems likely that it is prior to zinc oxide collection.

The total amount of zinc emitted to the atmosphere by the industry in 1972 is estimated at 2.4 tons. The baghouse collectors were 99% efficient. On this basis the zinc losses from the baghouses are calculated at 0.20 lb/ton of zinc oxide produced.

## **2.13 Mining Operations**

In 1972 there were 37 mining companies producing either zinc-bearing ores or concentrates on a regular basis. Ores and concentrates produced contained 1 402 000 tons of zinc destined for recovery (14).

**2.13.1 Process Description.** Zinc ores are mined by both open pit and underground mining. The zinc content of the ore averages 5% by weight.

The coarse ore undergoes primary and secondary crushing where the size of the ore is reduced for the subsequent grinding stage. The ore is then concentrated by a flotation process. Concentrated ore, after flotation and drying, averages 55% zinc.

**2.13.2 Emissions.** Some emissions occur during the mining operations from blasting, drilling, and ore transportation. However, no emission data on these stages were received. Very limited emission data were reported in questionnaire returns for the ore crushing and the concentrate drying stages. These operations are usually controlled by the use of cyclones, scrubbers or baghouses operating at anywhere between 70%-90% efficiency. Tailings are in the form of a liquid slurry from the flotation stage and do not present a major emission problem.

Emissions are in the form of zinc sulphide.

Emissions were based on an overall United States emission factor (controlled and uncontrolled) of 0.2 lb. zinc/ton zinc mined (3). This value covers all emissions from mining and milling operations that occur due to blasting, ore handling, crushing, as well as the wind loss from tailings. Better data were not available.

Zinc emissions from mining operations in 1972 are estimated at 140 tons.

**2.13.3 Particle Size Distribution.** The only information received on particle size was for the drying operation and is shown in Table 10:

TABLE 10      PARTICLE SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM  
A CONCENTRATE-DRYING OPERATION.

Source	Particle size (microns)	Weight of particulates (%)
Drying	<10	91
	10-37	6
	37-44	3

## **2.14 Petroleum Refining**

Data received in this study provided no evidence to indicate that zinc is discharged to the atmosphere during the refining process; however, zinc is present in crude oil (0.8 ppm on average) and is believed to remain in the heavy oils during refining. When these oils are burned as fuels, it is likely that the zinc is discharged with the combustion products. These emissions are described in sections 3 and 4.

Based on information received in questionnaires it is estimated that heavy oils have an average zinc content of about 0.032 lb/1000 imperial gallons.

One previous study (15) indicates the presence of zinc in light oils (gasoline). It concludes, however, that this resulted from contamination by contact with tanks and piping.

## **2.15 Miscellaneous Sources**

The survey identified many operations which either consume zinc or introduce it as an impurity in the raw materials.

**2.15.1 Paint Industry.** Approximately 906 tons of zinc oxide were used by the paint industry in 1972. A personal interview with the Canadian Paint Manufacturers Association (16) revealed that the zinc oxide is usually added from bags into a wet process. Some manufacturers add the zinc oxide as a paste. Most companies have ventilation systems but only some of the larger ones have baghouses coupled to the exhaust systems.

In a previous report (3), an overall emission factor (controlled and uncontrolled) of less than 1 lb zinc/ton of zinc oxide processed was indicated. This was an arbitrary assumption based on visual observation. As a consequence, zinc emissions from the Canadian paint industry are assumed to be negligible.

**2.15.2 Vinyl Plasticizers and Stabilizers.** Zinc oxide and other zinc compounds such as zinc stearate and zinc sulphide are used as stabilizers, plasticizers, and pigments in polyvinylchloride (PVC) compounds.

Two questionnaires were completed by PVC-extruding and molding companies. The process involves mainly mixing operations quite similar to those used in rubber manufacture. Zinc concentrations in the final product were indicated to be 0.02%-0.15% by weight. Estimated PVC produced in 1972 was 102 380 tons (17). The total zinc consumed was estimated to be 84 tons during the same year. It is assumed that emissions from these sources are very minor.

**2.15.3 Rolled Zinc.** Although this industry sector consumed a significant amount of zinc, the process consists only of physical rolling of the zinc metal well below the melting point of zinc. Therefore, no emissions are assumed to have occurred.

**2.15.4 Other Uses of Zinc.** Zinc consumption in sectors such as ink production, match-making and chemicals manufacture (other than industrial chemicals) was small. The use of zinc oxide in treating paper for photocopying was almost completely phased out in 1972. Pesticides containing zinc were not manufactured in Canada in 1972.



### 3 EMISSIONS FROM FUEL COMBUSTION - STATIONARY SOURCES

Stationary sources can be divided into the following categories:

- Power generation
- Industrial and commercial
- Domestic

The five principal fuel types used are gaseous (natural gas, propane, etc.) diesel oils, light oils, heavy oils and coal. Of these, only heavy oils and coal have a significant zinc content.

#### 3.1 Power Generation

In 1972, electricity generated by coal-operated facilities accounted for 62% of total thermal generation; petroleum fuels were responsible for 10%, natural gas for 15.7%, and nuclear fuels for 12.3%.

Estimates of zinc emissions from power generating stations during 1972 are listed in Table 11.

TABLE 11 ZINC EMISSIONS FROM POWER GENERATION, 1972

Source	Zinc emissions (tons)
Coal facilities	73
Heavy oil facilities	5
Total	78

For coal-fuelled generating stations, an emission factor (uncontrolled) of 0.071 lb zinc/ton coal is assumed based on a similar survey made in the United States (3). Very few Canadian data are available. It is estimated that, on average, the degree of emission control is approximately 88%. Therefore, the estimate is based on a controlled emission factor of 0.0085 lb zinc/ton coal.

For heavy oil facilities, an uncontrolled emission factor of 0.032 lb zinc/1000 imperial gallons is assumed (see section 2.14). Based on practice in industry (18,19) it is assumed that the ash

(slag) in heavy oil is carried up the stack by combustion gases and that very little remains behind as bottom ash or slag.

A study done in Alberta on a coal-fired generating station (20) indicates a zinc concentration in sub-bituminous coal of 12.7 ppm. The average zinc content of American coals is 54.6 ppm (3). Since the Canadian value is based on only one type of coal from one area, the American value is felt to be more representative. Also a large quantity of the coal used in Canada is imported from the United States (21).

The quantity of zinc in residual oils in the United States was reported to be 4.17 ppm and is based on unpublished data on an average of three analyses (3). The average quantity of zinc in residual oils in Canada was calculated, from data reported in the questionnaires, to be 3.2 ppm.

It was assumed in the United States survey (3) that all the zinc was emitted during combustion and the same assumption is made in this report.

Roughly 60% of the emissions occur during the winter months (22). This is dependent on climate and the extent to which electricity is used for heating purposes.

### **3.2 Industrial and Commercial**

The quantity of heavy fuel oil consumed for industrial and commercial purposes in Canada during 1972 was about 90 million barrels and the quantity of coal used was about 2.7 million tons. This figure does not include coal used for coke manufacture (see section 2.8).

Estimates of zinc emissions resulting from the combustion of industrial and commercial fuels during 1972 are listed in Table 12.

TABLE 12 ZINC EMISSIONS FROM INDUSTRIAL AND COMMERCIAL FUEL USE, 1972

Source	Zinc emissions (tons)
Coal combustion	19.3
Heavy oil combustion	48.6
Total	67.9

Estimates were based on uncontrolled emission factors of 0.032 lb zinc/1000 imperial gallons heavy oil and 0.071 lb zinc/ton coal. (see sections 2.14 and 3.1). There is not enough information at the present time on the quantity of zinc emitted into the ambient air, adsorbed in the ash, or adhered to the boiler tubes as zinc oxide. It is assumed, based on a similar survey in the United States (3), that all the zinc is emitted to the atmosphere. The degree of emission control is assumed to be insignificant for heavy oil combustion and averages about 80% for coal combustion (25) for industrial purposes. Emissions of zinc from this source are higher in the winter because the fuels are also used for heating purposes.

### **3.3 Domestic**

Light oils are generally used for domestic heating. A small quantity of heavy oils are used, mainly for apartment complexes. Only the latter have a significant zinc content (see section 2.14).

Approximately 3 million barrels of heavy oils were used in Canada for domestic heating in 1972 (23). Emissions occurred mainly in the winter months (October - April). The quantity of zinc emitted is estimated at about 2 tons. This estimate is based on an emission factor of 0.032 lb zinc/1000 imperial gallons (see section 3.1).

## **4 EMISSIONS FROM TRANSPORTATION SOURCES**

Transportation is considered under four headings:

- Motor vehicles
- Rail transport
- Shipping
- Aviation

### **4.1 Motor Vehicles**

Motor vehicles use either gasoline or diesel oil as a fuel, neither of which have a significant zinc content (see sections 2.14 and 3).

### **4.2 Rail Transport**

Rolling stock use diesel oil which, as described in sections 2.14 and 3, has an insignificant zinc content. Although railway companies purchase heavy oils and coal, these are employed for heating and power generation and the emissions are dealt with in the appropriate section of this report.

### **4.3 Shipping**

Marine vessels are fuelled with bunker oil, which contains zinc. (see sections 2.14 and 3). Approximately 11 million barrels of heavy fuel were purchased by shipping companies in Canada in 1972. It is estimated that about 20% of this is burned within Canadian territory. The remainder, which

is burned on the high seas, is not included in this inventory. Emissions are estimated using an uncontrolled emission factor of 0.032 lb zinc/1000 imperial gallons (see section 2.14). Emissions are substantially reduced during winter months when some inland waterways are closed.

Total zinc emissions in Canada from shipping in 1972 are estimated at 1.25 ton.

#### **4.4 Aviation**

Aircraft are fuelled with either aviation gasoline or kerosene, neither of which contain significant quantities of zinc.

#### **4.5 Tire Wear**

Zinc oxide is used extensively in tire manufacture as an activation agent in the vulcanization process and to protect the rubber against ultraviolet attack. As the tire wears, fine particles of rubber containing zinc oxide are released to the atmosphere.

The emission estimate is based on an average zinc oxide content of tires of 38 lb/ton of rubber, as reported in questionnaire replies, and on an average emission factor of 0.918 lb rubber/vehicle/1000 miles travelled (24). Other information used is the number of motor vehicles registered in 1972, by type of vehicle, and the assumption that cars travel 12 000 miles per year, trucks about 20 000 miles/year, and motorcycles 4000 miles/year.

Even though tire wear may be 50% greater during the winter months (24), the large volume of vacation traffic in the summer probably offsets this. Therefore, seasonal variations are likely to be small.

It is estimated that approximately 875 tons of zinc were released from this source in 1972.

### **5 EMISSIONS FROM SOLID WASTE INCINERATION**

In 1972, approximately 1.4 million tons of refuse were disposed of in 17 municipal incinerators (25) and about 134 000 tons of sewage sludge were incinerated in three cities (26).

A previous study indicates that zinc represents approximately 1.7% of the total particulates emitted from municipal incinerators (27). Based on this and on the known particulate emissions from Canadian incinerators (25), it is estimated that about 134 tons of zinc were emitted in 1972. Another study gives an average zinc content of sewage sludge of 2411 ppm (3). Based on this concentration and on the quantities of sewage sludge incinerated in Canada in 1972, it is estimated that 2.60 tons of zinc were emitted. A third study bases zinc emissions on an average 15 lb of particulate per ton of refuse burned and a zinc content of 2% (3). The present survey uses estimates of about 12 lb of particulate with a zinc content of 1.7%. Based on this it is estimated that about 137 tons of zinc were discharged to the atmosphere during 1972 from municipal and sewage sludge incinerators.

## **6 EMISSIONS FROM PESTICIDE APPLICATION**

The total quantity of pesticides containing zinc sold in Canada, in 1972, is estimated at 532 tons.

When considering the emissions resulting from the use of pesticides it is very important to delineate the parameters that determine the percentage 'drift' (drift being the amount of pesticide leaving the target area). The factors that affect drift are droplet size of the liquid, wind speed, temperature, foliage density, humidity, and operator skill.

Pesticide application is dependent upon chemical makeup and desired effect. Aerial application is used for treatment of large areas such as forests. Fruit tree spraying is usually from the operator upward whereas spraying of vegetable crops is from the operator downward. Fogging is used in certain cases that can take advantage of drifting. Pesticides are also used as components in wood preservatives and in baits and no emissions occur from these sources. Pesticides are usually applied during June and July.

Losses during aerial application range from 10%-50% depending on the factors mentioned above. In fruit tree spraying the air emissions may be 50% early in the season when the leaves are small. Other types of application have an average loss of about 10% (28).

Since pesticides containing zinc are usually organic or inorganic salts, there is no loss by volatilization (28).

No previous studies on this topic were found and estimated losses of pesticide during application were obtained from personal communications with specialists in the field (28,29).

Zinc emissions to the atmosphere from pesticide application are estimated at about 1.7 tons in 1972.

## REFERENCES

1. Cajka, C.J., *Nickel - 1972, Mineral Review No. 32*, Department of Energy, Mines and Resources, Ottawa (1973).
2. Shank, R.J. *Copper - 1972, Mineral Review No. 16*, Department of Energy, Mines and Resources, Ottawa (1973).
3. U.S. Environmental Protection Agency, *National Inventory of Sources and Emissions: Zinc - 1969*, Office of Air and Water Programs, Office of Air Quality Planning and Standards, Publication No. APTD - 1139 (1972).
4. Statistics Canada, *Metals and Minerals*, Service Bulletin Vol. 1, Nos. 11, 13, Publication No. 41-010, Ottawa (1973).
5. U.S. Environmental Protection Agency, *Air Pollution Engineering Manual 2nd ed.*, Office of Air Quality Planning and Standards, Publication No. AP-40 (1973).
6. Statistics Canada, *Iron Castings and Cast Iron Pipe and Fittings*, Publication No. 41-004, (Dec. 1972).
7. Statistics Canada, *Primary Iron and Steel*, Publication No. 41-001, (Dec. 1972).
8. Warda, R.D., Buhr, R.K., "A Method of Sampling Cupola Emissions", *A.F.S. Transactions*, 81, p. 24-31 (1973).
9. Environment Canada, Air Pollution Control Directorate, Mining, Mineral and Metallurgical Division (Unpublished Information).
10. Statistics Canada, *Coal and Coke Statistics Catalogue*, Publication No. 45-002, (1972).
11. Choquette, P.J., *Air Pollution Emissions and Control Technology. Metallurgical Coke Manufacturing Industry*, Environment Canada, Report EPS 3-AP-74-6 (Nov. 1974).
12. Statistics Canada, *Battery Manufacturers - 1972*, Publication No. 43-208, Annual, Ottawa (1972).
13. Zochem Ltd., (Personal Communication) (Nov. 1974).
14. Barry, G.S., *Zinc - 1972, Mineral Review No. 54*, Department of Energy, Mines and Resources, Ottawa (1973).
15. Lee, R.E., Von Lehmden, D.J., "Trace Metal Pollution in the Environment", *APCA Journal* 23, (10), (Oct. 1973).
16. Brown, P.S., Canadian Paint Manufacturers (Personal Communication)
17. Statistics Canada, *Manufacturers of Plastics and Synthetic Resins*, Publication No. 46 - 211, (1971).

18. Barron, N.A., Development Chemist, BP Canada Ltd. (Personal Communication)
19. Stebenne, P., Process Engineer, BP Canada Ltd. (Personal Communication)
20. Environment Canada, *Battle River Station*, Report BR-72-001, (1972).
21. Chrismas, L.P., *Coal and Coke - 1972, Mineral Review No. 13*, Department of Energy, Mines and Resources, Ottawa (1973).
22. Environment Canada, Air Pollution Control Directorate, Combustion Sources Division (Unpublished Information).
23. Statistics Canada, *Annual Refined Petroleum Products - consumption of petroleum products 1972*, Publication No. 45-208, (1972).
24. Subramani, J.P., *Particulate Air Pollution from Automobile Tread Wear*, University of Cincinnati, (1971) (Unpublished).
25. Environment Canada, *A Nationwide Inventory of Air Pollutant Emissions 1972*, Air Pollution Control Directorate (Unpublished).
26. Environment Canada, *National Inventory of Sources and Emissions of Lead* (1970), Air Pollution Control Directorate, APCD 73-7 (Nov. 1973).
27. Cross, F.L., Drago, R.J., Francis, H.E., "Metal and Particulate Emissions from Incinerators Burning Sewage Sludge and Mixed Refuse", *Proceedings of the 1970 Incinerator Conference*, P. 189 - 195 (1970).
28. Saha, J.G., Department of Agriculture, Chemistry and Biology Research Institute Canada (Personal Communication).
29. McKinlay, K.S., Saskatoon Research Institute Canada, Department of Agriculture (Personal Communication).

## BIBLIOGRAPHY

Athanassiadis, Yanis C., *Air Pollution Aspects of Zinc and its Compounds*, Litton Systems Inc., PB-188-072 (Sept. 1969).

Bashforth, G. Reginald, *The Manufacture of Iron and Steel - Vol. 2 Steel Production*, 2nd ed., Chapman & Hall Ltd, London (1959).

B.C. (The) Paint Manufacturers Association, *Summary of a Brief to the British Columbia Pollution Control Inquiry - Chemical & Petroleum Industries*, (March 15, 1972).

Brandt, D.J.O., *The Manufacture of Iron and Steel*, British Iron and Steel Federation, The English Universities Press Ltd, London, Third Impression (1964).

Bray, John L., *Non-Ferrous Production Metallurgy*, 2nd ed., John Wiley and Sons Ltd., New York, Sixth Printing (1959).

Canada Department of Agriculture, *Pesticides Listed by Active Ingredient Registered for Use in Canada, for 1972*, Catalogue No. A41-17/1972.

Canadian Machinery and Metalworking, *Metalworking Catalogue and Buying Directory 1974*, Maclean Hunter Publication (1974).

Christmas, L.P. and McMullen, M.K., *Coking Coal in Canada*, Department of Energy, Mines and Resources, Mineral Bulletin MR 135 (March 1973).

Department of Energy, Mines and Resources, *Canadian Minerals Yearbook 1968*, Mineral Resources Branch, Ottawa (1968).

Department of Industry, Trade and Commerce, *Brass and Bronze Foundries and Ingot Makers*, Resources Industries and Construction Branch, Ottawa (1974).

Department of Industry, Trade and Commerce, *Die Casting in Canada*, Manual and Directory, 4th ed., Information Canada, Ottawa (1972).

Department of Industry, Trade and Commerce, *Iron and Steel Foundries*, 3rd ed., Information Canada, Ottawa (1971).

Department of Industry, Trade and Commerce, *Iron and Steel from Canada*, Information Canada, Ottawa (1972).

Department of Industry, Trade and Commerce, *Protect your Investment with Canadian Galvanizing Manual and Directory of Galvanizing in Canada*, Ottawa.

Fulkerson, W. et al, *Cadmium - The Dissipated Element*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, (Jan. 1973).



Gauvin, M., *Lead - 1972, Mineral Review No. 23*, Department of Energy, Mines and Resources, Ottawa (Aug. 1973).

Hwang, Y.S., *A Commodity Consumption and Export Forecasting Technique Illustrated by Zinc*, Department of Energy, Mines and Resources, Mineral Bulletin Mr 119, Ottawa (1971).

Jens, W. and Rehm, F.R., "Municipal Incineration and Air Pollution Control", *Proceedings of the 1966 National Incinerator Conference* (1966).

Knox, Arthur C., "Air Pollution from Combustion Equipment and Fuels", *Combustion*, 44 (3): p. 11-12 (Nov. 1972).

Koepke, W.E., *Fertilizers and Fertilizer Minerals in Canada*, Department of Energy, Mines and Resources, Mineral Bulletin MR 115, Ottawa (1971).

Liddell, Donald M., *Handbook of Non-Ferrous Metallurgy: Recovery of the Metals*, 2nd ed. McGraw - Hill Inc., New York (1945).

Lugg, W.G., *Petroleum - 1972, Mineral Review - No. 33*, Department of Energy, Mines and Resources, Ottawa (June 1973).

Lund, Hervert F. (ed.), *Industrial Pollution Control Handbook*, McGraw - Hill, New York (1971).

Manitoba Hydro, *A Brief Description of Emissions to the Atmosphere at Brandon Generating Station*, (Nov. 29, 1972).

Mineral Resources Branch, *Coal Mines in Canada January 1973, Operators List 4*, Department of Energy, Mines and Resources, Ottawa (1973).

Mineral Resources Branch, *Metal and Industrial Mineral Mines and Processing Plants in Canada 1972 - Operators List 1*, Department of Energy, Mines and Resources, Ottawa (1972).

Mineral Resources Branch, *Metallurgical Works in Canada, Primary Iron and Steel, January 1973, Operators List 2*, Department of Energy, Mines and Resources, Ottawa (1973).

Minerals Resources Branch, *Metallurgical Works in Canada, Non-Ferrous and Precious Metals, January 1973 - Operators List 3*, Department of Energy, Mines and Resources, Ottawa (1973).

Rogero, Carlos E., "High Temperature Fluid Bed Roasting of Zinc Concentrates", *Transactions of the Metallurgical Society of AIME*, 227 p. 105-111 (Feb. 1963).

Ruddle, R.W., "Losses in Melting Copper-Base Alloys", *Modern Casting* 67-95, p. 91-98 (1968).

Schroeder, Henry A., *Air Quality Monographs*, Cadmium, Zinc, and Mercury Monograph # 70-16 American Petroleum Institute (1970).

Statistics Canada, *Annual, The Motor Vehicle, Part III, Registrations 1972*, Publication No. 64-202 (1972).

Water and Pollution Control, *Cross Canada Solid Waste Survey*, p. 21 (Jan. 1972).

Miniato, O., Technical Supervisor, Manufacturing Department, Shell Canada Ltd. (Personal Communication).

Lee, G.K., Department Energy, Mines and Resources, Canadian Combustion Research Laboratory (Personal Communication).

Dutton, M., Engineering Section, Canadian Pacific Railways (Personal Communication).

Spencer, E.Y., *Guide to the chemicals used in crop protection*, 6th ed., Publication No. 1093, Research Branch, Dept. of Agriculture, Ottawa, (1973).

National Incinerator Conference (1966).

Baum & Parker, *Solid Waste Disposal Vol I*, Ann Arbor science Publishers Inc. (1973).

Gough, W.K., Toronto P.W.D. (Personal Communication).

Service de Protection de l'Environnement du Québec, *La Gestion des Déchets Solides*, Gouvernement du Québec (Décembre 1972).

Statistics Canada, *Canadian Statistical Review*, Jan.-June 1973 and July-Dec. 1973, Quarterly estimates of population for Canada & Provinces, Publication No. 91-001 (1973).

Statistics Canada, *Coal Mines Calendar Year 1972*, Publication No. 26-206 (1972).

Statistics Canada, *Energy Statistics, Vol. 8 No. 11*, February 1973, Publication No. 57-002 6503-521 (1973).

Statistics Canada, Service Bulletin, *Energy Statistics, Vol. 8 No. 33*, June 1973, Publication No. 54-002 5-3301-521 (1973).

Steiner, J., "Inco's Superstack Emission", *Emissions from Smelter Operations and Their Effect on The Environment, Seminar* (Feb. 1974).

Stern, Arthur C., *Air Pollution Vol. III*, 2nd ed., Academic Press, New York (1968).

U.S. Environmental Protection Agency, *Guide for Compiling a Comprehensive Emission Inventory (revised)*, Office of Air and Water Programs, Office of Air Quality Planning and Standards, Publication No. APTD-1135.

U.S. Environmental Protection Agency, *Nationwide Air Pollutant Emission Trends 1940-1970*, Publication No. AP-115.

Walker, A.B. & Schmitz, F.W., "Characteristics of Furnace Emissions from Large Mechanically-Stoked Municipal Incinerators", *Proceedings of the 1966 National Incinerator Conference* p. 64-73 (1966).

Statistics Canada, *Annual Household Facilities and Equipment*, Publication No. 64-202 (April 1973).

Statistics Canada, *Rubber Products Industries*, Publication No. 33-206 (1971).

Statistics Canada, *Steel Ingots and Pig Iron*, Publication No. 41-002 (Dec. 1972).

Buhr, R.K., Energy, Mines and Resources (Personal Communication).

Thompson, Hazen, Environmental Protection Service, Ottawa (Personal Communication).

Johnson, R., Energy, Mines and Resources (Personal Communication).

United States Steel, *The Making, Shaping and Treating of Steel*, 9th ed., Pittsburg, Pa. (1970).

Lynch, T., Canadian Industries Limited (Personal Communication).

Report of the Commission Appointed to Inquire Into and Report Upon the Pollution of Air, Soil and Water in the Townships of Dunn Moulton and Sherbrooke (Haldamand County) Queens Printer, (1968).

Northern Miner, Canadian Mines Handbook.

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**APPENDIX - SURVEY OF QUESTIONNAIRE RETURNS AND QUALITY INDEX**

Sector	No. of questionnaires		Rate of response (%)	Quality index of questionnaires returned*					Average quality index
	Sent	Returned		1	2	3	4	5	
Primary copper & Nickel & assoc.	13	12	92	-	-	-	4	8	4.7
Primary iron & steel	45	28	62	2	2	5	7	12	3.9
Primary aluminum	6	6	100	-	-	-	-	6	5.0
Primary lead & zinc	6	6	100	-	-	-	-	6	5.0
Copper, brass & bronze foundries	84	27	32	2	4	7	8	6	3.4
Die-casting	91	51	56	4	18	14	10	5	2.9
Iron & steel foundries	194	88	45	10	16	25	24	13	3.2
Metallurgical coke	7	3	43	-	-	1	-	2	4.7
Phosphate fertilizers & elemental phosphorus	31	28	90	-	1	13	2	12	3.9
Galvanizing	46	26	57	2	3	10	10	1	3.2
Plating	83	25	30	7	9	3	6	-	2.3
Ferroalloys & assoc.	13	4	31	-	-	-	1	3	4.8
Pesticides	58	26	45	9	10	-	4	3	2.3
Ceramics and glass	105	44	42	1	8	6	18	11	3.7
Nonferrous alloys	20	11	55	1	2	-	5	3	3.6
Battery mfg.	5	2	40	-	-	-	1	1	4.5
Rubber mfg.	24	20	83	-	2	5	7	6	3.9
Zinc oxide	2	1	50	-	-	-	-	1	5.0
Mining	39	21	54	2	2	4	5	8	3.7
Porcelain & enamels	30	17	57	4	4	4	3	2	2.7
Clay products mfg.	57	21	37	7	4	3	4	3	2.6
Petroleum refining	47	35	74	4	5	11	-	15	3.5
Vinyl stabilizers & plasticizers	13	8	62	-	-	2	3	3	4.1
Welding rods mfg.	12	10	83	2	2	-	2	4	3.4
Miscellaneous	16	13	81	-	-	4	3	6	4.2
<b>TOTAL</b>	<b>1047</b>	<b>533</b>	<b>51</b>	<b>57</b>	<b>92</b>	<b>117</b>	<b>127</b>	<b>140</b>	<b>3.4</b>

\* A Quality Index of Questionnaires returned was based on the following rating:

1. No emissions reported, no back-up given
2. No pertinent information
3. Poor reply, data insufficient
4. Medium reply, emissions can be calculated
5. Good reply, emissions data given and documented

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