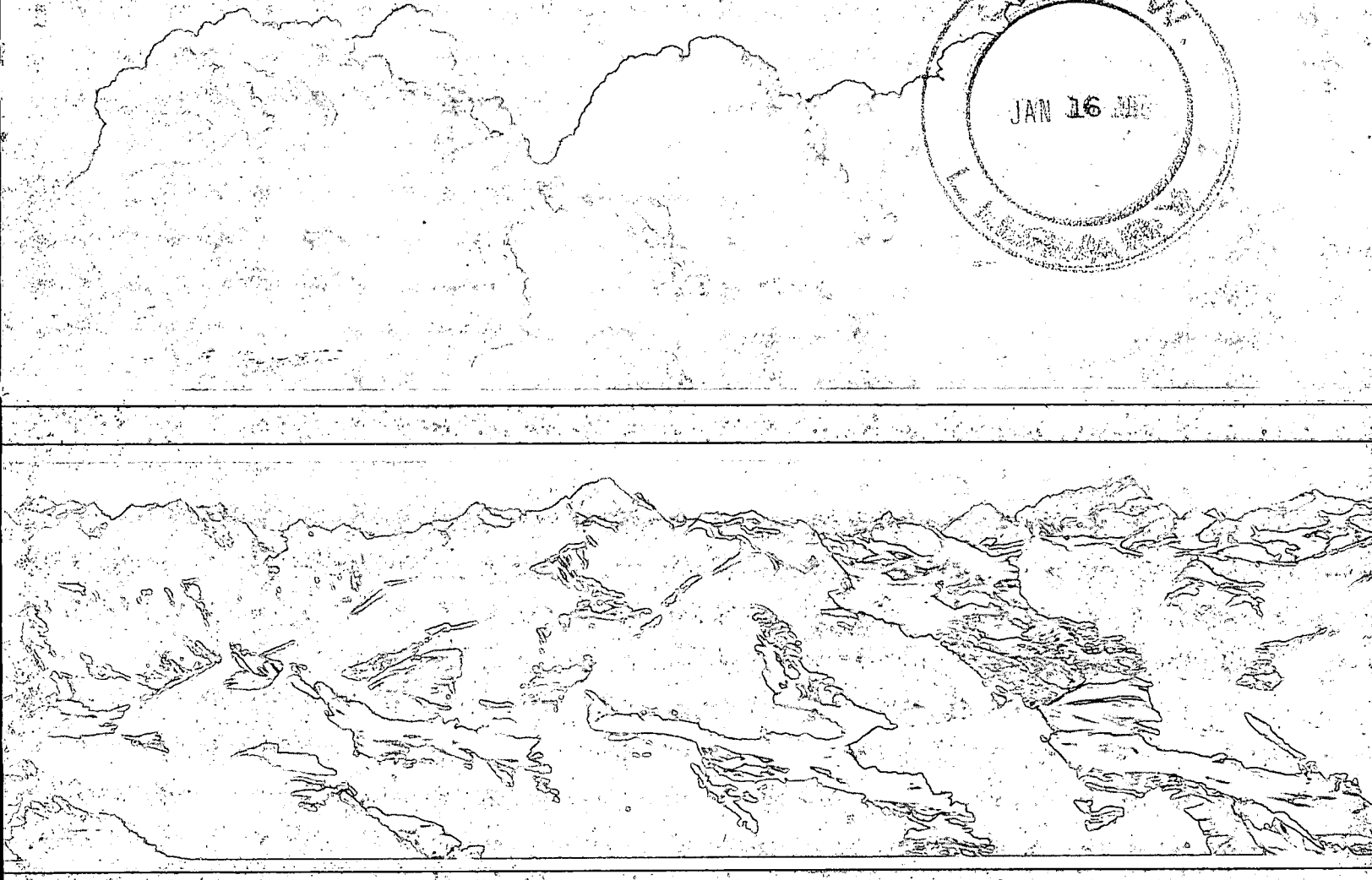
Environment Canada / Environnement Canada

Environmental Contaminants Inventory Study No. 2

The Production, Use and Distribution of Cadmium in Canada

D. B. Lymburner



REPORT SERIES NO. 39
(Résumé en français)

CANADA CENTRE FOR INLAND WATERS,
INLAND WATERS DIRECTORATE,
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ABSTRACT

In recent years there has been an increasing awareness of the need for research into the social and ecological consequences resulting from the production, use, distribution and discharge of environmental contaminants. Programs have been formulated to scrutinize all aspects of these substances, including identification and measurement, chemical and biological transport in aquatic systems, and toxicology to fish and other biota. Cadmium is one such contaminant; it is one of the elements not considered essential for the maintenance of life. These facts underscore the importance of developing internally consistent inventories on cadmium and other environmental contaminants.

The present study on cadmium begins with preliminary information on its occurrence, characteristics, production processes, global economic significance and major uses. The structure of cadmium production and use in Canada is then analysed using quantitative data on production, consumption by end use, imports and exports.

This information is illustrated by a material flow chart, and maps detailing the distribution of establishments involved in the production and consumption of cadmium are included. Throughout the analysis, environmental inputs are computed where possible.

Occupations entailing potential exposure to cadmium are listed and a selected bibliography of references on cadmium toxicity is provided.

RESUME

Au cours des dernières années, on s'est de plus en plus préoccupé de la nécessité de faire de la recherche sur les conséquences sociales et écologiques de la production, de l'utilisation, de la distribution et du rejet des contaminants environnementaux. On a mis sur pied des programmes visant à étudier tous les aspects de ces substances, dont l'identification et le mesurage, le transport chimique et biologique dans les systèmes aquatiques et les effets toxiques sur le poisson et autres biotes. Le cadmium, élément qui n'est pas considéré essentiel à la survie est l'un de ces contaminants. Ces faits soulignent l'importance de faire des inventaires consistants sur le plan intérieur en ce qui concerne le cadmium et autres contaminants environnementaux.

La présente étude sur le cadmium contient au début des renseignements préliminaires sur sa présence, ses caractéristiques, ses procédés de production, son importance économique globale et ses principaux usages. La structure de la production et de l'utilisation du cadmium au Canada est ensuite analysée grâce aux données quantitatives sur la production, la consommation d'après l'utilisation, les importations et les exportations de cadmium.

Un organigramme illustre ces renseignements et des cartes donnant des précisions sur la distribution des établissements engagés dans la production et la consommation de cadmium sont incluses. Au cours de l'analyse, les données sur l'environnement sont calculées dans la mesure du possible.

On donne la liste des postes qui peuvent éventuellement entraîner des expositions au cadmium ainsi qu'une bibliographie sur la toxicité du cadmium.

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INTRODUCTION

> "As far as the present knowledge goes, cadmium is not considered as an essential element for the maintenance of life in man or animals." [1]

In view of this statement and the fact that this toxic element can accumulate progressively in animal and probably in plant organisms [2], impetus is given to a study of the production and use of this metal in the Canadian economy. This is achieved through a description of the sectoral distribution of cadmium metal, alloys, and compounds in primary, secondary, and tertiary activities [3]; consideration is given to these economic activities and attention paid to environmental factors as well.

It is important to note that a complete quantitative description is not possible within the scope of this study. Statistics Canada, the major data source, does not supply data of the nature required for a complete quantitative analysis. This may be partly explained by the number of users associated with cadmium and its derivatives and the relatively small quantities needed for any particular use. This diversification of use and deficiency of quantitative data are especially evident in uses of cadmium alloys and compounds.

Also of significance is a consideration of both the direct and indirect effects of cadmium production and use in Canada. This study outlines direct effects only because the data and model-building information are not available, which are necessary for a comprehensive investigation of direct and indirect interrelationships. [4] An analysis of the various potential economic effects associated with changes in the use of this metal must take into account more than direct effects alone in order to provide a complete picture of economic ramifications.

Finally, it is emphasized that the data contained herein pertain to the nation as a whole. In light of the fact that the environmental significance deriving from the use of cadmium is proportional to the localized production and consumption levels of industrial products containing cadmium, it is intended to add to the present study a regional breakdown of these data.

PRELIMINARY INFORMATION

CADMIUM CHARACTERISTICS

Cadmium is a soft, ductile, silvery-white electropositive metal with a valence of +2. Some of its properties include insolubility in water, slow oxidation superficially by moist air and reaction of its vapour with steam to form cadmium oxide and hydrogen. It reacts readily with mineral acids, but more slowly with organic acids. Corrosion resistance is excellent in rural areas, but the presence of sulphur oxides in industrial areas results in the formation of cadmium sulphide.

OCCURRENCE

Cadmium is a relatively rare element in the earth's crust, ranking in abundance between mercury and silver, i.e., 0.1-0.5 parts per million (ppm). It occurs most commonly as the sulphide, greenockite, which is found associated with zinc sulphide ores, especially sphalerite, but it occurs also in most of the polymetallic ores and, consequently, accompanies the primary metals during refining passing into the corresponding concentrates.

Canadian zinc ores contain from 0.001% to 0.067% of recoverable cadmium, and the zinc concentrates contain as much as 0.7% cadmium. [5]

PRODUCTION PROCESSES

Cadmium is intimately associated with zinc minerals; this association continues during separation of ores containing several minerals, so that even with the concentration of lead, for instance, a small amount of zinc contained therein is accompanied by a proportionate amount of cadmium. This association of cadmium with zinc, as well as the by-product nature of cadmium during the production process, is vital to the understanding of potential environmental hazards attributable to this metal and the complex problems involved in the control of its fumes, dusts, and mists accompanying production processes.

Milling

This process involves grinding the ore to free lead and zinc sulphide materials from associated minerals. Coarse crushing is then followed by grinding of the material into a fine powder.

Concentration

Concentration is accomplished by froth flotation in which the zinc sulphide is separated from the gangue or unused parent material. Certain minerals are either activated or suppressed by the addition of organic and inorganic reagents, resulting in a separation which permits flotation concentrates to be skimmed off mechanically.

Refining

1. Electrometallurgical (Electrolytic Process)

This process is used by most of the cadmium producers in Canada. A number of stages are associated with it, including:

(a) Roasting - in which the roasted concentrate or calcine is heated to remove contained sulphur by conversion of the sulphide to zinc oxide.

(b) Leaching - in which the roasted concentrate or calcine is treated with sulphuric acid, so that cadmium and other elements are taken into solution.

(c) Purification - whereby zinc dust acting as a purifying agent precipitates impurities producing a precipitate rich in cadmium. This step is followed by oxidation and leaching by sulphuric acid and spent electrolyte to remove the cadmium. The filter leach liquor from this step is then treated with zinc dust which precipitates the cadmium, producing a cadmium sponge containing approximately 80% cadmium and less than 5% zinc. Following oxidation and leaching with sulphuric acid and spent cadmium electrolyte, the resultant cadmium sulphate solution is ready for electrolysis.

(d) Electrolysis - which is accomplished by using stationary aluminum cathodes and lead anodes.

(e) Melting - whereby the deposited cadmium is stripped from the cathodes, washed, dried, and melted under a flux, producing a grade of cadmium 99.95% pure (special processes yield a grade in excess of 99.999% purity).

Processing of concentrated lead smelter baghouse dust in the electrolytic cadmium plant is similar to the stages outlined above.

2. Pyrometallurgical Process

Two zinc refineries in Canada produce unrefined cadmium as a by-product using a pyrometallurgical method.

(a) The Imperial Smelting Furnace at Belledune, New Brunswick, treats concentrates from Brunswick Mining & Smelting Corporation. This process involves relatively low zinc grades and high waste content. Three products are produced that contain cadmium: zinc, which contains 0.07% cadmium; a cadmium-zinc alloy, which is produced for shipment to Europe for refining; and zinc-cadmium sponge, which is sent to Canadian Electrolytic Zinc in Valleyfield, Quebec, for further refining.

(b) The Fluid Column Process is used by The Sherbrook Metallurgical Co. Ltd. at Port Maitland, Ontario, to reduce the amounts of cadmium, lead, and sulphur in the zinc concentrates. Cadmium dust emitted from the roaster is collected in a cadmium fume bin and sold.

3. Hydrometallurgy

The Cominco refinery at Trail, British Columbia, uses this method to treat ores and concentrates from several mines. By this method, the cadmium precipitate from zinc refining is leached and the metal recovered by cementation.

Indications of the efficiency of the relative refining processes are given in the section "Structure of Cadmium Production and Use in Canada".

WORLDWIDE ECONOMIC SIGNIFICANCE

The world production and supply of cadmium is related directly to the production and supply of refined zinc. Estimated production of cadmium in 1970 amounted to 18,273 short tons. Canada ranked fourth at 2,123 tons, preceded by the U.S.S.R., Japan, and the United States, in ascending order. Table 1 accounts for the production of cadmium metal only and does not include the production of compounds directly from metallurgical by-products or quantities of flue dust or precipitate accumulated during the refining processes.

Based on a United States average value of 357.10 cents per pound [6] in 1970, the United States dollar value of known world production approaches 130,506,000 dollars, with Canadian production accounting for more than 12% of this value.

Internationally, cadmium was in relatively short supply during 1969 owing partly to increased demand in pigment production and the plastic stabilizer market. [7] In late 1969, and throughout 1970, this short supply was followed by an easing of demand related to the general decline of business activity, especially in the motor vehicle industry which accounts for two of the major uses of cadmium. Consumption declines were limited not only to the United States and Canada, but also affected Japan, Britain and the Federal Republic of Germany. [8] A slight decline in exports of ores, concentrates and refined metal from Canada is a reflection of the overall decline of business activity in recent years.

MAJOR USES

Metallic uses of cadmium in the United States have represented an average of 60-65% of the consumption of cadmium produced. Approximately 55% has been used in plating and 7% for alloys. The remainder of that produced -- 35-40% -- was used for cadmium chemicals, especially in pigments and nickel cadmium batteries. [9]

Comparative consumption percentages for major uses of cadmium in three countries are shown in Table 2.

TABLE 1

WORLD PRODUCTION OF CADMIUM

(SHORT TONS)

Country	1968	1969	1970*	1971*
United States	5,325	6,323	4,900	3,650
Japan	2,420	3,048	2,750	2,700
U.S.S.R.	2,425	2,480	..	..
Canada	1,039	2,606	2,123	405
Belgium	882	992	900	995
Federal Republic of Germany	377	873	750	770
Australia	506	629	600	645
Poland	551	606	..	..
France	608	577	600	595
Italy	..	465	250	425
Other Countries	1,524	1,771	5,400	5,315
TOTAL	16,010	20,370	18,273	15,500

.. Not Available * Estimated

Sources: World Bureau of Metal Statistics, Statistics Canada.

Note: Data are for production of cadmium as unwrought metal from domestic and imported materials. Secondary metal is included where known; it comprises less than one percent of world total. The 1970 figures are from U.S. Bureau of Mines, Commodity Data Summaries, January, 1971.

TABLE 2

MAJOR USES OF CADMIUM IN SELECTED COUNTRIES

(PERCENTAGES OF TOTAL CONSUMPTION)

Uses	United Kingdom (1967)	United States (1968)	Canada (1969)
Plating	36.2	41.0	74.4
Plating Salts	8.9		
Alloys	4.1	10.0*	
Solders	4.8		2.2
Batteries	9.2	7.0	
Colours	30.8	36.0	
Other Uses	6.0	6.0	23.4

* Combined consumption for alloys and solders

Sources: World Metal Statistics, August, 1971, Statistics Canada, U.S. Bureau of Mines, Minerals Yearbook.

Note: Lack of statistical data is reflected in the category "other uses" for Canada. In Canada "other uses" includes mainly chemicals, pigments, and alloys other than solder.

CADMIUM TOXICITY AND ENVIRONMENTAL POLLUTION

TOXICITY

Accumulating scientific evidence indicates that cadmium is toxic to the human organism. There are documented instances of cadmium poisoning deriving particularly from inhalation of its fumes. Exposure to cadmium and potential hazard to man exists in the following occupations: [10]

Alloy Making
Aluminum Solder Making
Cadmium Compound Collecting-bag Cleaning
Cadmium Compound Collecting-bag Handling
Cadmium Plating
Cadmium Smelting
Cadmium Vapour-lamp Making
Cadmium Working
Ceramic Making
Dental-Amalgam Making
Electric-instrument Making
Electroplating
Engraving
Glass Making
Incandescent-lamp Making
Lithography
Lithopone Working
Metallizing
Paint Spraying
Photoelectric Cell Making
Pigment Making
Small Arms Ammunition Making
Smoke-bomb Making
Soldering
Solder Making
Storage-battery Making
Textile Printing
Welding, Cadmium Alloy
Welding, Cadmium-plated Objects
Zinc Refining

Traces of cadmium are known to accumulate progressively in the human organism, especially in the kidney and liver, and there is a possible association of cadmium accumulations in the human body with hypertension, arteriosclerosis and carcinogenesis.

Additional information regarding toxicity is available and a selected bibliography of references is included at the end of the paper.

ENVIRONMENTAL POLLUTION

Potential environmental pollution occurs wherever cadmium metal and/or its alloys and compounds are used. Processing of the metal resulting in changes of state is particularly hazardous.

Potential pollution may be associated with any number of the varied uses cadmium has, and the hazard need not be related to the intensity or quantity of use. Unknown results with respect to reaction of the metal and compounds with other agents and superficial knowledge of the environmental role played by the various forms of this element combine to produce a threat of uncertain magnitude.

Less obvious than the known application of the metal or its compounds to certain uses is the occurrence of the element in rubber tires, motor oil, sewage sludge and fertilizers. Reported environmental inputs are related directly to the intensity of use or production of these materials.

The analysis of cadmium use in Canada will attempt to demonstrate the potentially hazardous use areas; comments are made to indicate the degree of environmental input from different uses.

EXPORTS AND IMPORTS OF CADMIUM

EXPORTS

Exports of cadmium represent a large proportion of the total domestic production. These exports occur in a variety of forms.

In 1970, an estimated 52% of reported cadmium production left the country as contained metal in ores and concentrates. The largest market for cadmium in this form is the United States which, in 1968, received approximately 878 short tons of the metal in 310,586 short tons of zinc ore. [11] It is significant that an estimated 60% of the United States' production of cadmium originates from imported material.

Exports of cadmium also occur in the refined pure metal state (99% pure) and sponge form (about 80% cadmium content).

Table 3 shows refined cadmium and sponge exports by weight and value to selected countries for 1968, 1969 and 1970.

Table 4 shows the annual aggregate of exports of refined cadmium by weight and value for the years 1939 to 1970. Refined cadmium and sponge comprise approximately 42% of total reported production according to available data and, therefore, more than 90% of the total domestic production leaves the country in the form of ores, concentrates, refined metal or sponge.

Exports of cadmium also result from the sale of cadmium commodities of unknown metal or compound content. Table 5 shows the type of commodity, the Statistics Canada classification, the quality of commodity, and the respective value. The nature of the Statistics Canada classification prohibits any estimate of actual cadmium content. Since the commodity merely represents a further degree of manufacture from the refined cadmium metal, however, its cadmium content will be included in the refined total.

Exports of cadmium also arise from its inclusion as an impurity in a variety of export materials. Polymetallic ores and concentrates, as well as those of zinc, may be exported with attendant cadmium impurities. No quantitative values can be assigned to exports of this type.

TABLE 3

CANADIAN REFINED CADMIUM METAL EXPORTS

1968 - 1970

(BY WEIGHT, BY VALUE)

Exports Cadmium Metals	POUNDS			DOLLARS		
	1968	1969	1970*	1968	1969	1970*
Britain	1,111,116	1,136,953	1,257,949	2,914,000	3,209,000	4,114,000
United States	661,666	527,112	270,395	1,559,000	1,558,000	1,063,000
West Germany	-	6,100	9,223	-	44,000	12,000
Sweden	..	-	5,000	..	-	22,000
France	..	1,800	3,500	..	8,000	15,000
Belgium and Luxembourg	15,308	5,000	2,060	43,000	22,000	9,000
Other Countries	14,690	9,608	908	40,000	37,000	3,000
TOTAL	1,802,780	1,686,583	1,549,035	4,566,000	4,878,000	5,238,000

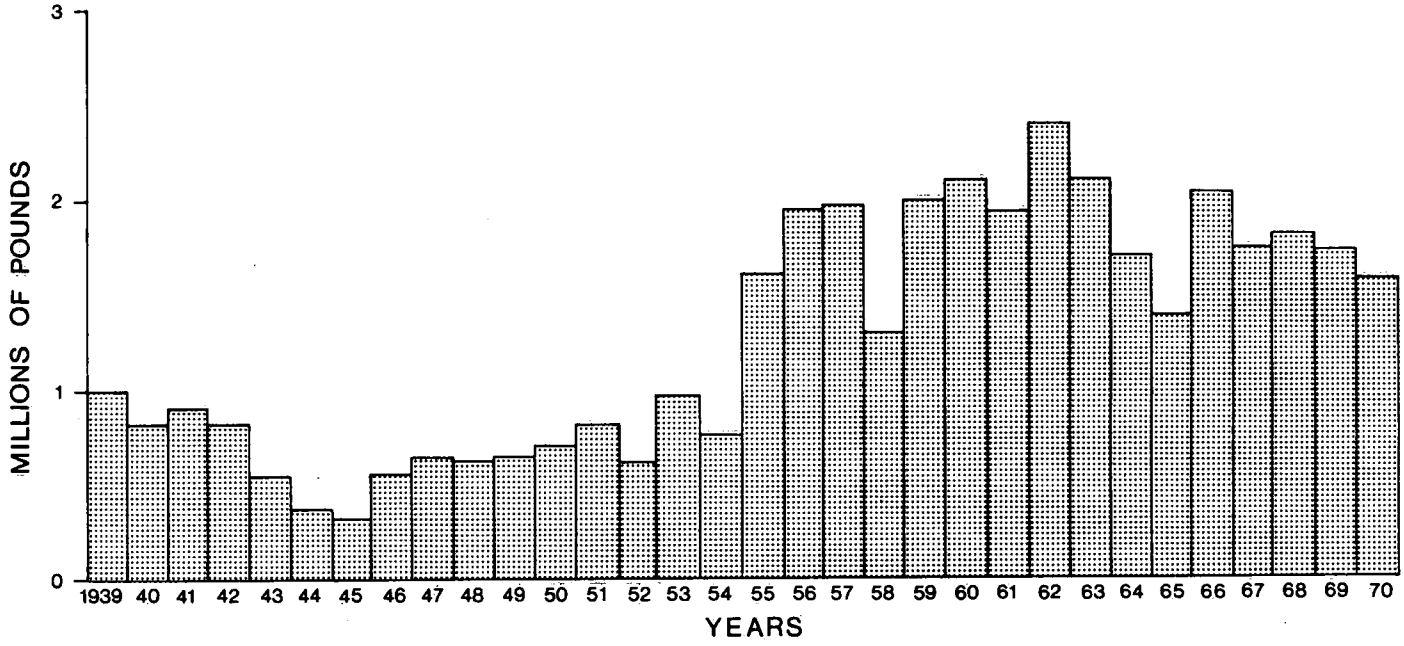
* Preliminary - Nil .. Data Not Available

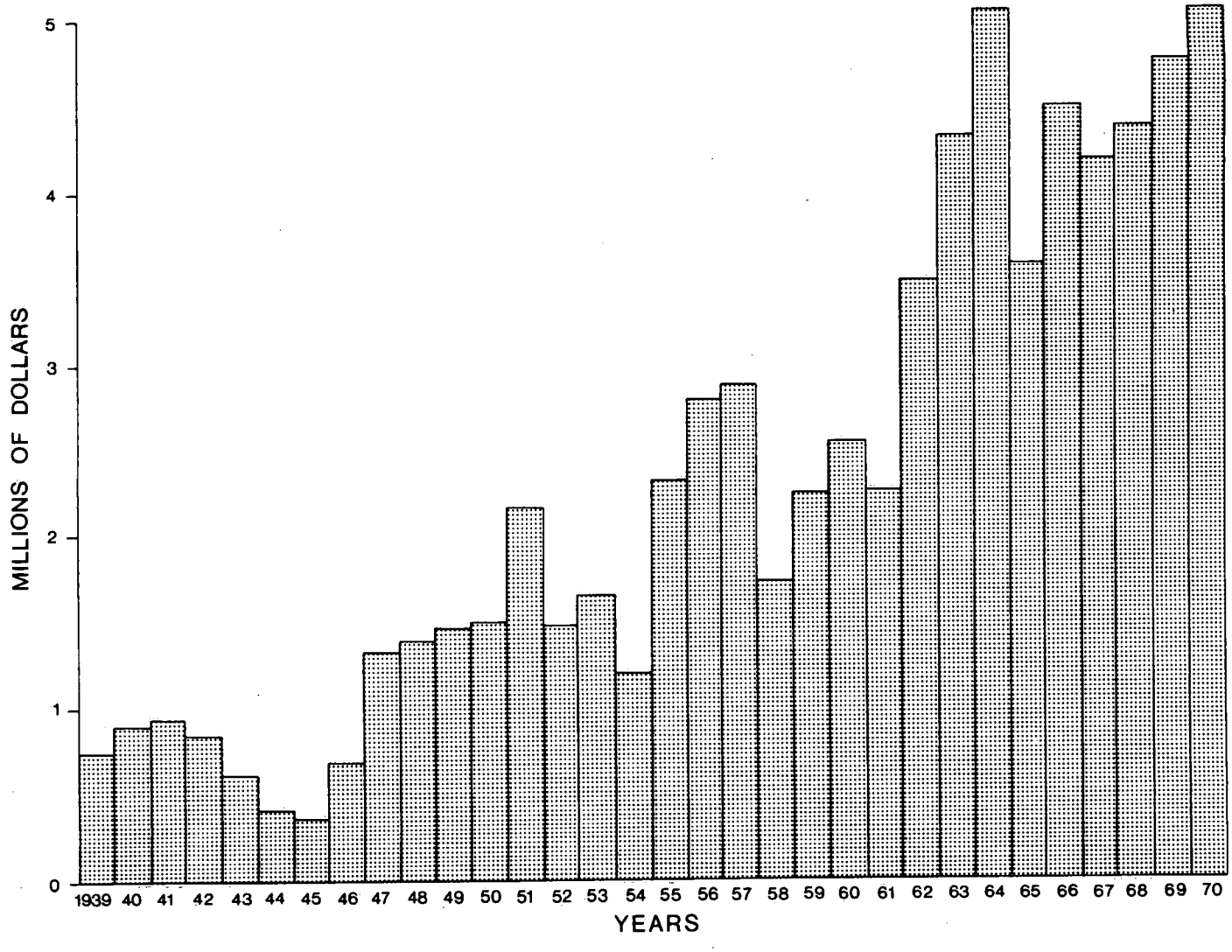
Source: Statistics Canada

Note: Exports may include quantities of cadmium sponge as there was no comsumption of cadmium in the sponge form in Canada past 1970. Exports represent reported quantities of the metal leaving the site of refining.

TABLE 4

CANADIAN EXPORTS OF REFINED CADMIUM (1939-1970)





Source: Canada - Trade Information Section, External Trade Division, Ottawa.

TABLE 5

CANADIAN EXPORTS OF CADMIUM COMMODITIES 1970

(CUMULATIVE TOTALS)

Commodity	D.B.S. Classification	Quality	Value
Cadmium Selenide	Class 404-99, metallic salts of inorganic acids	1,647,011 cwt.	$9,975,000
Cadmium in Lithopone	Class 429-29, cadmium in lithopone, dyestuffs, pigments, lakes and toners	32,217 cwt.	1,403,000
Powder, Bismuth Cadmium	Class 459-99, non ferrous metal alloys, N.E.S.	620,296 lb.	1,046,000

N.E.S. - not elsewhere specified

Source: Statistics Canada

Note: Available data do not permit an account of actual cadmium content in each D.B.S. Classification.

IMPORTS

The supply of cadmium in Canada results primarily from domestic production sources. In addition, cadmium is imported in a number of forms.

The reported production of refined cadmium in Canada includes domestic ore sources plus recoverable cadmium content in imported lead and zinc concentrates. It is conceivable that cadmium may be recovered by domestic refineries from ores and concentrates entering the country. Total production of cadmium from imported ores and concentrates, however, is considered to be small. In 1968, imports of zinc in ores, concentrates, and scrap totalled 256,200 pounds (45,000 pounds - January to July, 1970). [12] If it is assumed that the greater part of this concentrate contained an average of 0.2% cadmium [13], the proportionate weight would approach only 400 pounds of cadmium metal (approximately 80 pounds for January to July, 1970).

Available data indicate that there are no known imports of cadmium metal in the refined metallic form, and it is assumed that domestic production meets the metallic needs of this country.

Imports of cadmium result from the import of cadmium commodities of unknown metal content. A list of import commodities with cadmium content derived from manufacture of the substance in other countries is given in Table 6.

As with exports, imports of cadmium impurities in nickel, lead, zinc and other polymetallic products can occur, and no account of their actual significance can be made owing to the unknown quantity of these impurities.

TABLE 6

CANADIAN IMPORTS OF CADMIUM COMMODITIES 1970

(CUMULATIVE TOTALS)

Commodity	D.B.S. Classification	Quality	Value
Cadmium Oxide	Class 402-99, inorganic bases and metallic oxides	139,751 cwt.	$3,137,000
Cadmium Stabilizer	Class 429-72, Rubber plastic compounding agent N.E.S.	58,268,141 lb.	8,225,000
Batteries, Nickel Cadmium	Class 693-27, nickel cadmium and alkaline batteries	2,789,585 units	1,846,000
Barium Cadmium	Class 459-99, non ferrous metal alloy, N.E.S.	958,635 lb.	3,201,000

N.E.S. - not elsewhere specified

Source: Statistics Canada

Note: Available data do not permit an account of actual cadmium content in each D.B.S. Classification.

STRUCTURE OF CADMIUM PRODUCTION AND USE IN CANADA

PRODUCTION

Cadmium production in Canada has exhibited a fairly continuous increase over the years, with a marked upward trend since 1965. The preliminary production figures for 1970 are 4,246,200 pounds with a value of 16,058,900 dollars. This compares to a production of 2,357,497 pounds and a value of 3,347,646 dollars a decade earlier. The large increase in value over this period is quite remarkable. Possible explanations for such an increase may include inflation in recent years and the expanding demand for cadmium resulting from new uses in the face of a limited supply. Owing to the by-product nature of this metal, supply is inelastic. In addition, the cost of the metal to most users is a small part of the total cost of the final product and, consequently, demand for the metal is not closely related to cost. The implications here would suggest that changes in demand of even a single end use could have a profound influence on the cost of the metal. On the other hand, price changes would tend to have little effect on most areas of use. [14]

Figure 1 is a representation of the Canadian production of cadmium. It is shown as a proportion of the world output; the domestic composition of this production is also illustrated. Forty-two percent of the total production is refined and 6% of the refined production is consumed in Canada.

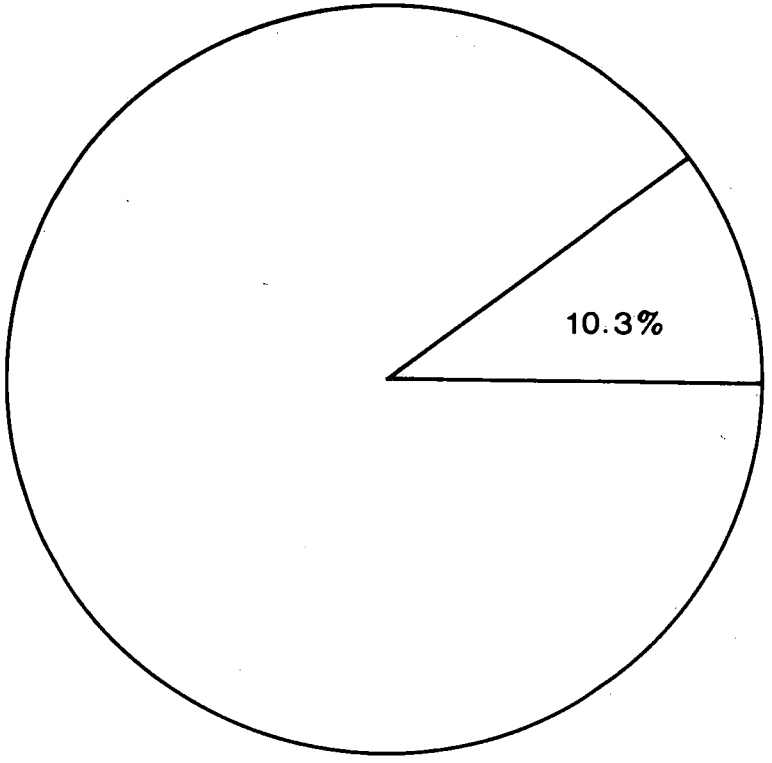
Reported production in terms of refined and other content is detailed in Table 7. Before 1965, the greater proportion of the total production was refined in Canada. Figures for recent years, however, seem to indicate that much of the cadmium reported is not refined in Canada. Instead, much of the total production leaves the country in ore and concentrate form.

Data compiled for these tables take into account only that amount reported by sources being credited for cadmium production. In comparison to the 5,213,054 pounds of cadmium reported by primary production sources, "it is estimated that there were at least 6 million pounds of cadmium contained in zinc concentrates produced in Canada in 1969". [15] Figures available represent the amount of

FIGURE 1

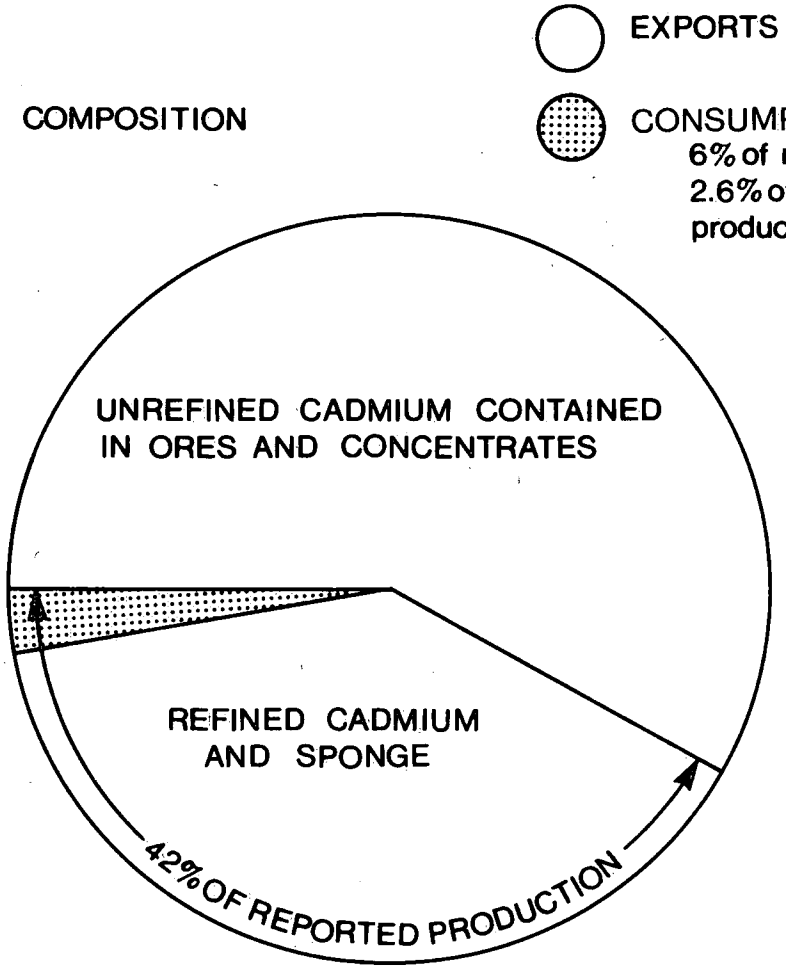
CANADIAN CADMIUM PRODUCTION

PERCENTAGE OF WORLD TOTAL PRODUCTION



THREE YEAR AVERAGE 1968 - 1970

COMPOSITION



THREE YEAR AVERAGE 1968 - 1970

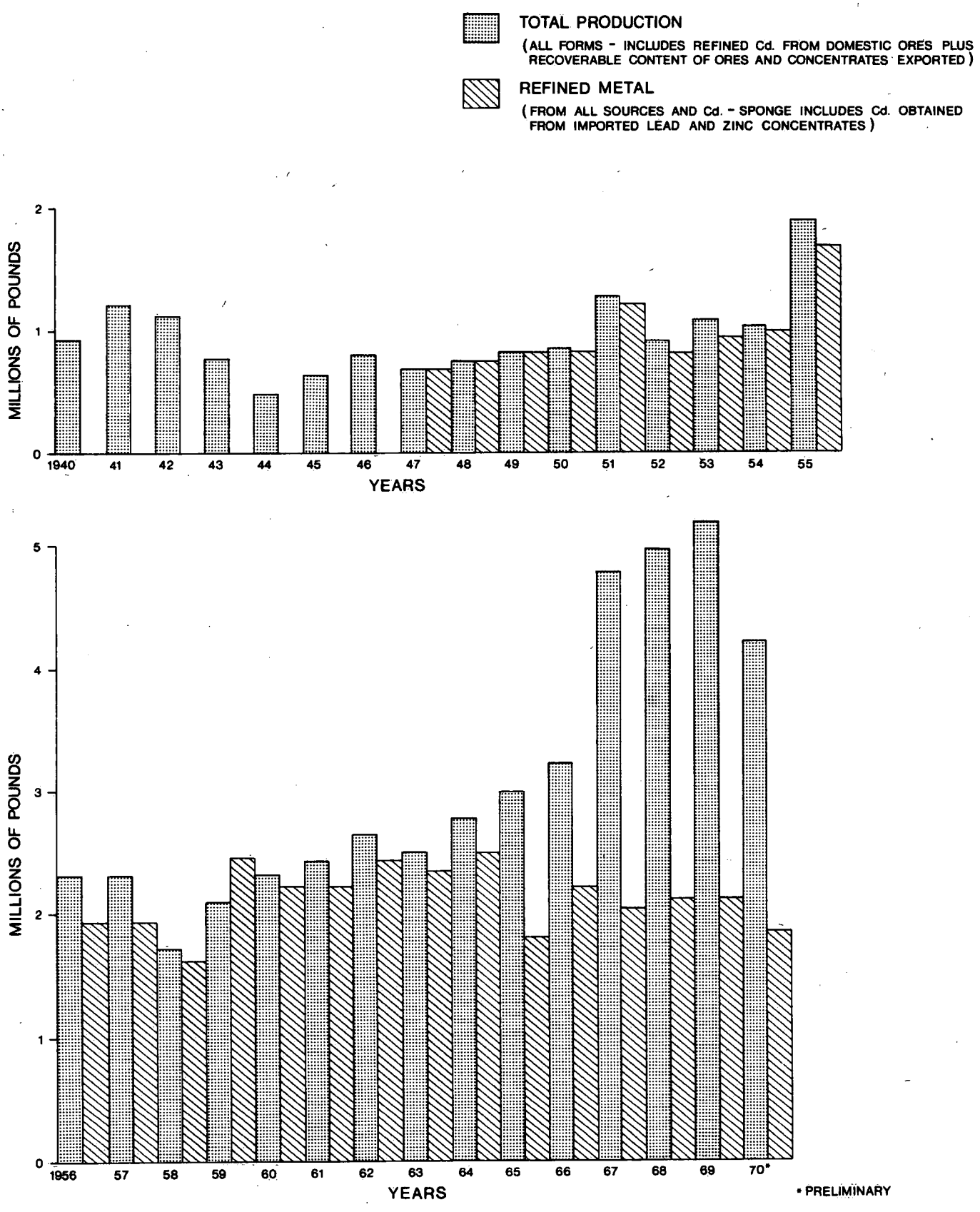
Percentages based on reported production, consumption.

N.B. Refined Cd. and Sponge includes that obtained from imported Lead and Zinc concentrates. Domestic composition of Cd. includes imports and exports of Cd. commodities and also unknown quantities of Cd. in Ni., Pb., Zn. Products.

TABLE 7

CADMIUM PRODUCTION IN CANADA 1940 - 1970

(TOTAL REPORTED PRODUCTION COMPARED TO TOTAL REPORTED REFINED PRODUCTION)



Source : D.B.S. cat. 26-219 & Canada Minerals Year Book

cadmium for which payment was received by the mines. It is possible that some domestic refined production was not credited to the mines and some smelter products exported for refining were not recorded, hence, the discrepancy in reported production and estimated production figures.

CONSUMPTION

Consumption data for cadmium in Canada are limited. The preliminary reported consumption of cadmium metal in 1970 amounted to 124,959 pounds. Consumption in 1969 totalled 132,136 pounds; in 1968, 125,546 pounds. This compares with an annual consumption in 1968 in the United States of over 13 million pounds. [16] Several factors are significant in deriving Canadian consumption statistics.

Firstly, reported consumption deals with the metal only. No attempt is made to account for consumption of cadmium in other forms, such as cadmium oxide or dust, etc. Secondly, consumption totals represent available data reported by consumers. There is the inherent tendency in this case to produce a total figure that is significantly lower than actual consumption.

Table 8 provides a historical overview of cadmium consumption in Canada. Where data are available, breakdowns of uses are provided. Prior to 1952, consumption data were collected at the producer level. Often, only one or two mines reported shipments to primary consumers who, in turn, could export. Consequently, with consumption recorded prior to export, there is a tendency towards overestimation of consumption figures.

In more recent years, however, although consumption data have been collected at the consumer level, there is a possibility that not all users are covered and not all cadmium use is reported. Accordingly, consumption figures would be under-reported. [17]

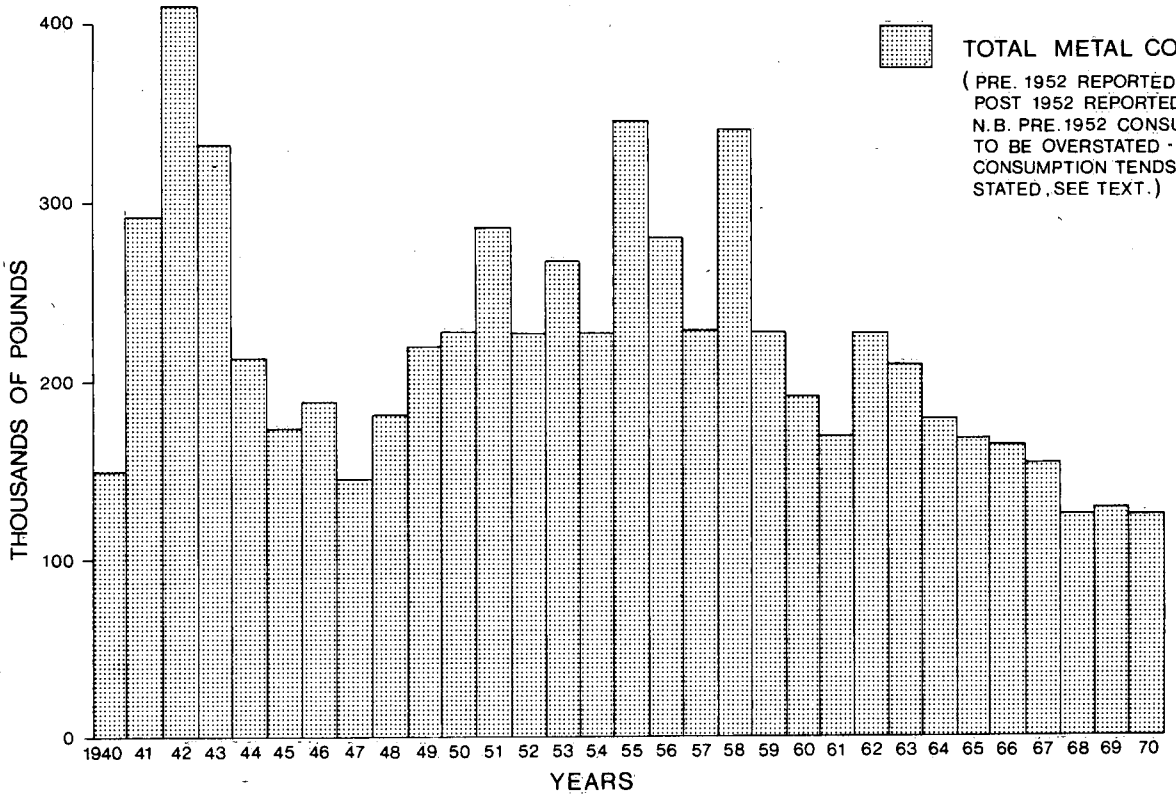
Generally, no consumption of unrefined cadmium occurs in Canada, though, in 1969 and part of 1970, some sponge was sold for consumption purposes. [18]

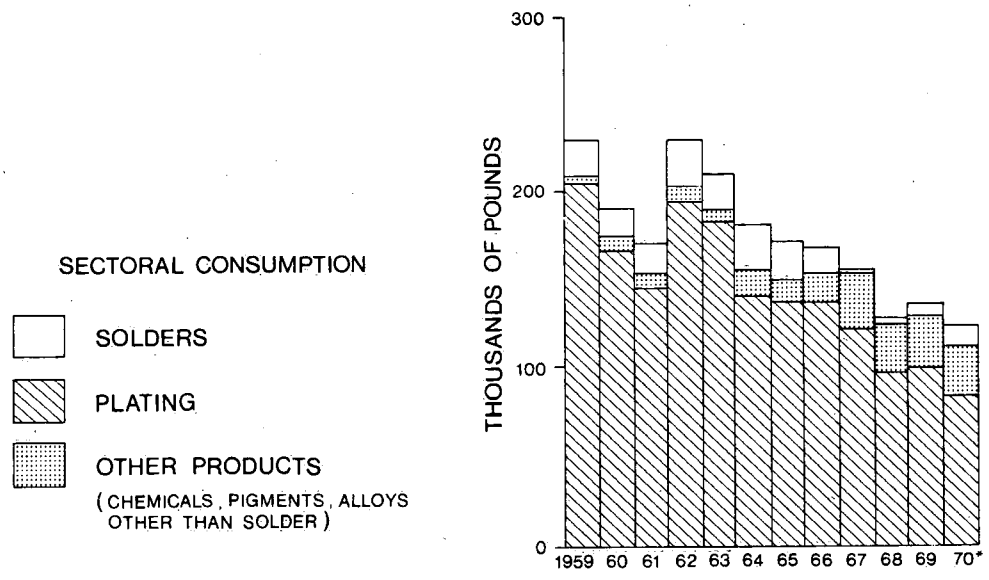
Cadmium metal is consumed in a number of forms. Balls, anodes, sticks, and bars are primary forms produced at refineries and sold to consumers. These forms are equal in cost whereas ovals and extrusions are more expensive, requiring manufacture beyond refining. The latter forms are not widely used, however.

TABLE 8

CADMIUM CONSUMPTION IN CANADA 1940 - 1970

(CADMIUM METAL)





* PRELIMINARY

Source: D.B.S. cat. 26-219 & Canada Minerals Year Book

MATERIAL FLOW CHART

A schematic account of cadmium flow through the Canadian economy for the year 1969 is given in Figure 2. Quantitative values are assigned where available. Weaknesses occur in this type of representation owing to incomplete data. Quantities reported do not necessarily give total accounts of all cadmium. Dotted lines reflect the unknown values associated with many of the consumption sectors.

No records are available to indicate secondary cadmium production in Canada. The nature of the products is believed, to some extent, to prohibit recycling and re-refining in Canada and, consequently, no recovery is made after the metal has been consumed. There is no evidence of any government stockpiling of the metal.

Although weaknesses resulting from a lack of quantitative data and a failure to account for possible losses of the metal during production and refining are evident in the flow chart (Fig. 2), the illustration does help to explain the general flow of cadmium metal through the Canadian economy.

The following account is intended to trace this flow. An attempt is made to elaborate upon the sectors mentioned in the flow chart and to provide additional information about less obvious uses or occurrences of the metal. Some indication of emission potential associated with each use is provided where possible.

PRIMARY SECTOR

Production Sources

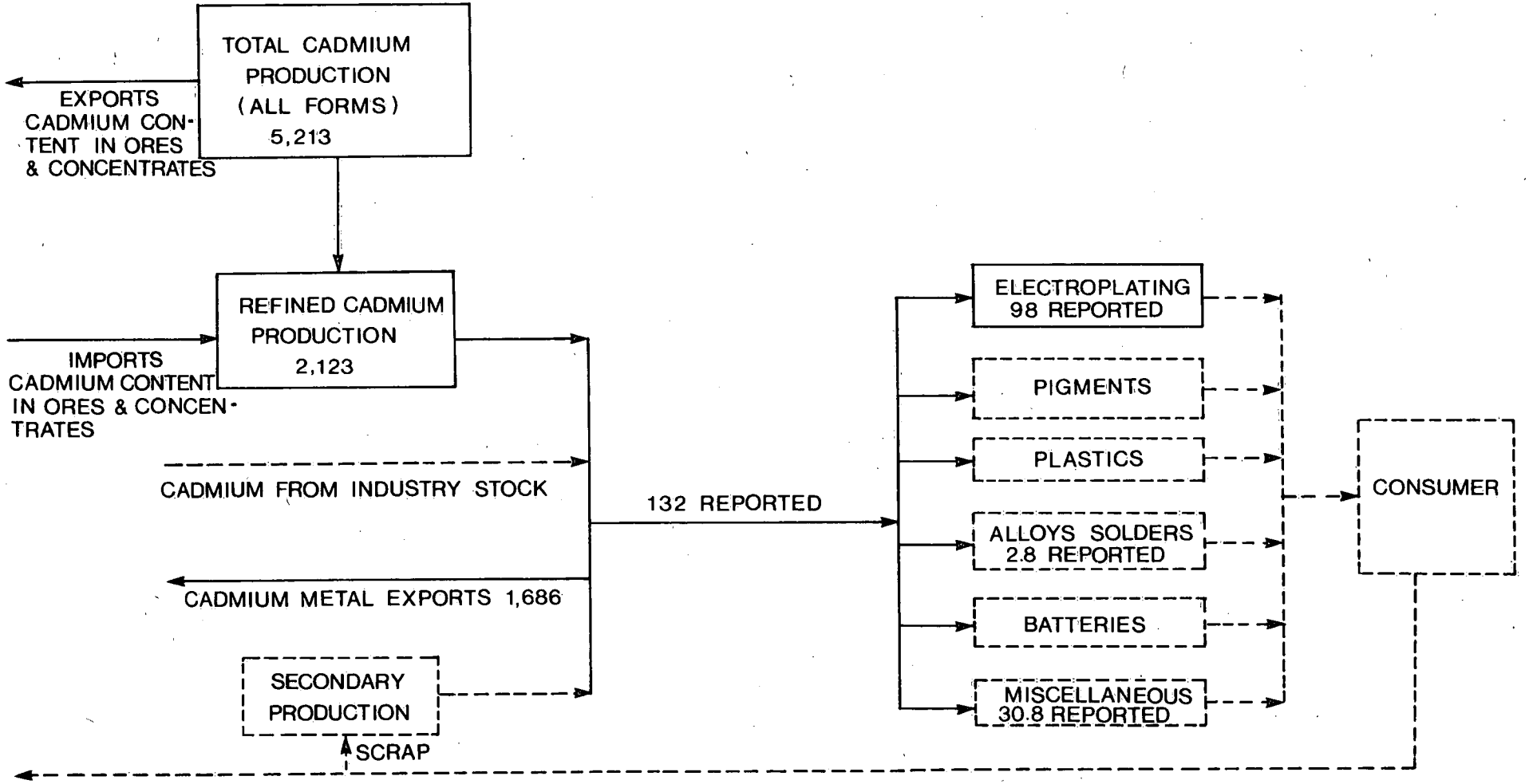
Primary production sources of cadmium in Canada are shown in Table 9. All mines reporting cadmium production are listed, in addition to those that produce zinc concentrates. The distribution of these primary production sources is depicted in Map 1.

The processing of ores, whether in underground or open pit mines, is basically the same -- removal, handling, crushing, grinding, and concentration; the latter is generally accomplished by a flotation process.

FIGURE 2

MATERIAL FLOW CHART OF CADMIUM IN CANADA 1969

(THOUSAND POUNDS)



NOTE: DOTTED LINES INDICATE UNKNOWN QUANTITIES

TABLE 9

CADMIUM PRIMARY PRODUCTION SOURCES IN CANADA 1970 (1969)

(INCLUDES MINES REPORTING AND CREDITED AND ALSO THOSE NOT CREDITED YET MAY OR DO PRODUCE ZINC CONCENTRATES)

COMPANY AND PROVINCE	ORE MINED	CAPACITY TONS/ORE/DAY	MILL PROCESS	APPROX. EMPLOYEE NUMBER	ZINC CONC. PRODUCED TONS	PER CENT CADMIUM IN ZINC CONC.	CONTAINED CADMIUM IN ZINC CONC. POUNDS	REMARKS
NEWFOUNDLAND								
American Smelting & Refining Co., Buchans Unit, Buchans	copper lead zinc	1250 (1250)	FLOTATION	500	64,325 (66,645)	.22	284,000 (290,000)	Zinc Concentrates are exported to Europe
NEW BRUNSWICK								
Sullivan Mines Group Nigadoo River Mines Ltd. Robertville.	lead zinc silver copper	1000 (1000)	FLOTATION	250	13,434 (13,503)	.71	178,377 (191,719)	Zinc Concentrates are exported to Japan and Europe. At time of writing, Jan/72,this mine closed for an indefinite period.
Brunswick Mining and Smelting Corp. Bathurst.	lead zinc	8000		600				Smelter produces cadmium in the form of Cadmium-zinc Alloy (127 Tons) in 1970 which was exported for refining to Europe and Japan. Retained some for own requirements.
Heath Steel Mines Ltd. Newcastle area.	lead zinc copper silver	3000 (3000)	FLOTATION			.10		Does not report cadmium production.
NOVA SCOTIA								
Dresser Industries Inc. Walton, Hants County	silver lead	1000						Concentrates produced may contain cadmium.
Walton Mine	copper zinc	140						
QUEBEC								
Quebec Mines - various mines in N.W.P.Q.	copper zinc silver gold	(5000)	FLOTATION			.06-.16		Generally cadmium amounts are too small to be paid for under smelter contracts. Refined cadmium from concentrates produced at Quebec mines is recovered by Canadian Electrolytic Zinc Ltd at Valleyfield. This metallurgical works also recovers cadmium from Geco mine (Manitouwadge, Ont.) concentrates.
Lake Dufault Mines, Noranda		1300						
Mattugami Lake Mines, Mattagami		3850			(232,125)			Total output by Canadian Electrolytic Zinc Ltd. was 625,000 pounds in 1969; 514,000 pounds in 1970 - reduced as a result of a strike.

TABLE 9 - CONTINUED

COMPANY AND PROVINCE	ORE MINED	CAPACITY TONS/ORE/DAY	MILL PROCESS	APPROX. EMPLOYEE NUMBER	ZINC CONC. PRODUCED TONS	PER CENT CADMIUM IN ZINC CONC.	CONTAINED CADMIUM IN ZINC CONC. POUNDS	REMARKS
QUEBEC CONT.								Output included refined cadmium and impure sponge.
ALSO:								
Coniagas Mines Ltd. (Abitibi East County)								
Manitou-Barvue Mines (Val d'Or)		1650		500				
Mines de Poirier Inc. (Amos, Poirier Twsp.)		1500						
New Calumet Mines (Calumet Is.)								
Normetal Mining Corp. (Normetal)								
Orchan Mines Ltd. (Mattagami)		1900			(39,755)			
Quemont Mining Corp. (Noranda)								
Sullivan Mining Group Ltd.								
1. Cupra Division (Wolfe County)	copper lead zinc silver	(1500)			(10,832)	.28	..	Three new levels are being opened.
2. Solbec Division (Hastings County)					(11.874)		(66,494)	Mine was on a salvage basis in 1969.
ONTARIO								
Texas Gulf Sulphur Ecstall Mining Ltd. Timmins	zinc copper lead	9000 (9000)	FLOTATION	800	582,844 (582,146)	.27	2,927,776 (3,012,957)	Smelters in U.S.A., Europe and Japan. This is the largest producer in Canada. An electrolytic zinc plant with cadmium refinery will have a capacity of 1 million pounds/yr. It is scheduled to begin production Dec/71
Noranda Mines Ltd. Geco Div. Manitouwadge	zinc copper silver lead	5000 (4000)	FLOTATION	400	79,479	.34	..	Milling plant has been expanded. Concentrates are shipped to Canadian Electrolytic Zinc Ltd at Valleyfield for refining.
Zenmac Metal Mines Ltd. Schreiber		(200)	FLOTATION		(8,277)	(.13)	(22,111)	Reserves exhausted, mine closed 1970.
Canadian Jamieson Mines Ltd. Timmins		600			(10,402)			Zinc concentrates produced are of low to moderate cadmium content.
Kam Kotia Mines Ltd. Timmins		2500			(37,906)			
Willecho Mines Ltd. Manitouwadge	zinc copper lead	1000						
Willroy Mines Ltd. Manitouwadge	gold silver	1700						

TABLE 9 - CONTINUED

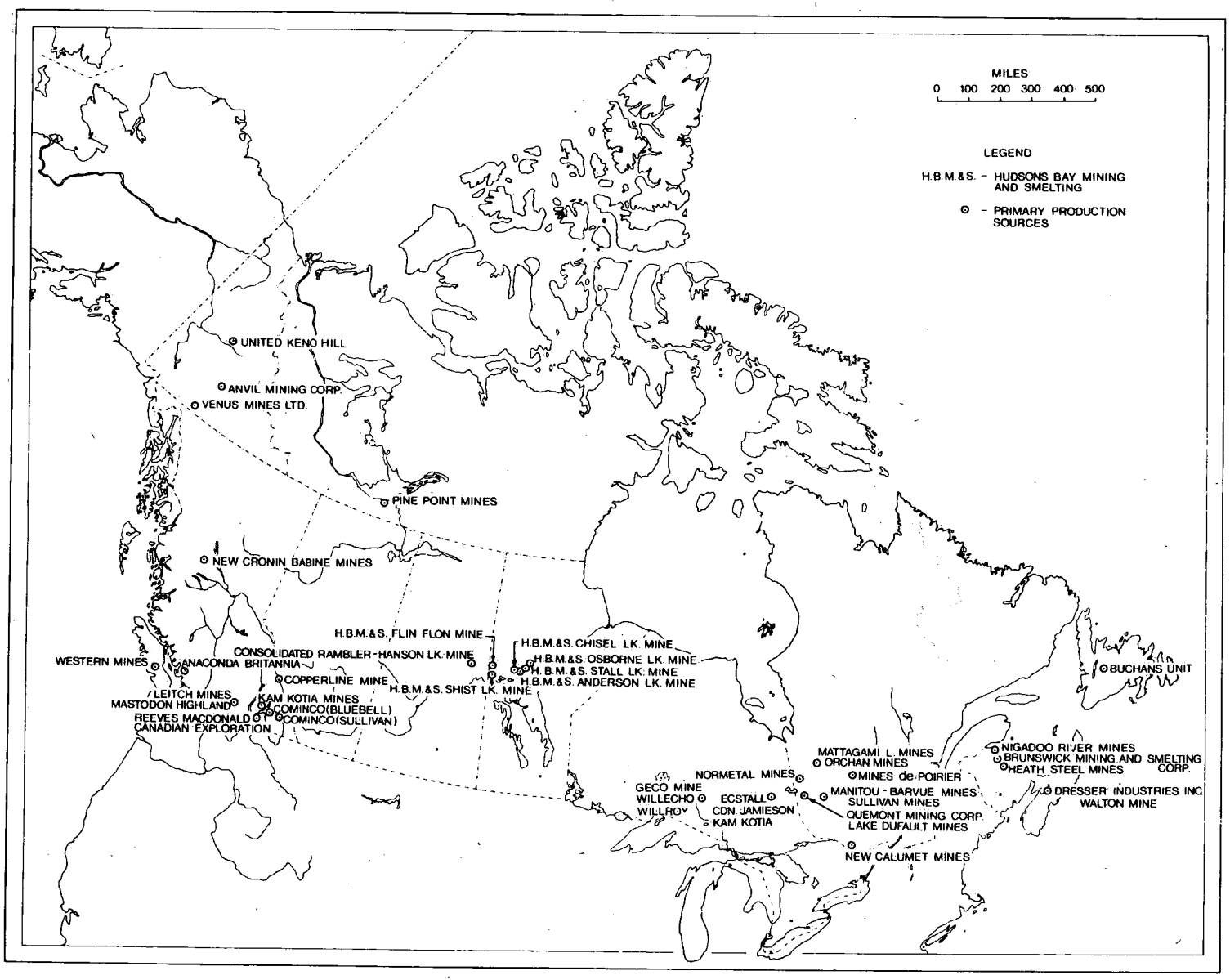
COMPANY AND PROVINCE	ORE MINED	CAPACITY TONS/ORE/DAY	MILL PROCESS	APPROX. EMPLOYEE NUMBER'	ZINC CONC. PRODUCED TONS	PER CENT CADMIUM IN ZINC CONC.	CONTAINED CADMIUM IN ZINC CONC. POUNDS	REMARKS
MANITOBA AND SASKATCHEWAN								
Hudson Bay Mining And Smelting Co. Ltd. Flin Flon.								All zinc Concentrates produced in these two provinces are treated at the electrolytic zinc plant of Hudson Bay Mining and Smelting Co. Ltd. Flin Flon. Production in 1970 was 338,343 pounds of cadmium.
1. Anderson Lake Mine Flin Flon	copper zinc							
2. Chisel Lake (SW of Snow Lake)	silver,zinc gold, lead copper							
3. Flin Flon Mine Flin Flon	copper,zinc gold,silver							
4. Osborne Lk. Mine (86 Mi.E. of Flin Flon)	silver copper zinc	6000 (6000)		500+	102,100 (119,800)		338,343 (333,959)	
5. Shist Lake Mine (3 1/2 Mi. S.E. of Flin Flon)	copper zinc							
6. Stall Lake (S.E. of Snow Lake)	gold,silver copper,zinc							
Consolidated Rambler Mines Ltd. Hanson Lake								Cadmium/zinc production was reported from main zone in 1967.
Western Nuclear Mine Ltd. Hanson Lake Sask. And Oils Ltd. Hanson Lake Sask.	Share Mines &	(350)				(.07)		Base metal mine with a capacity of 350 Ton /day shut down in Summer 1969. It was operated jointly by Western Nuclear Mines and Share Mines and Oils.
BRITISH COLUMBIA								
Canadian Exploration Ltd. Salmo	lead zinc	1900 (1900)	FLOTATION		9,830 (22,673)	.. (.46)	83,400 (207,086)	This zinc-lead operation ceased in August 1970.
Cominco Ltd.								
1. Sullivan Mine Kimberley B.C.	lead zinc silver	10,000 (10,000)	Crushing, sink, float grinding, flotation filtering, drying	800	204,357 (167,151)	(.12)	.. ..	In 1970, 630 Tons of metallic cadmium was recovered at the metallurgical works of Cominco Ltd. at Trail. Ores and Concentrates from its Sullivan and Bluebell Mines, from its subsidiary Pine Point Mines Ltd. (Yukon) and on a custom basis, from various mining operations in B.C. are treated by Cominco at Trail.
2. Bluebell Mine E. Kootenay Lk. Riondel B.C.	zinc lead	(700)	FLOTATION					
Copperline Mines Ltd. Golden	lead zinc silver	600 (-)		100	2,546 (-----)	.36 (---)	18,336 (------)	Operations began Oct. 1970. Zinc Concentrates are exported
Kam-Kotia Mines Ltd. Silmonac Mines Sandon B.C.	silver lead,zinc	133 (-)		20	1,343 (-----)	.43 (---)	11,640 (------)	Operations began Sept. 70. Zinc Concentrates are exported.
Mastodon-Highland Bell Mines Ltd. Beaverdell B.C.	silver lead zinc gold	(115)	Jig and FLOTATION		(578)	(.21)	(2,389)	Zinc concentrates are treated by the smelter at Trail.

TABLE 9 - CONTINUED

COMPANY AND PROVINCE	ORE MINED	CAPACITY TONS/ORE/DAY	MILL PROCESS	APPROX. EMPLOYEE NUMBER'	ZINC CONC. PRODUCED TONS	PER CENT CADMIUM IN ZINC CONC.	CONTAINED CADMIUM IN ZINC CONC. POUNDS	REMARKS
BRITISH COLUMBIA cont.								
New Cronin Babine Mines Ltd. 35 mi. N.E. of Smithers	silver	(50)	FLOTATION					
Leitch Mines Ltd. Beaverdell	silver lead zinc	115 (115)		30	444 (578)	.33 (.21)	2,938 (2,389)	Zinc concentrates are treated at Trail.
Reeves MacDonald Mines Ltd. Remac 1.Reeves Mine	silver lead zinc	1200 (1200)	FLOTATION	100	8,707 (16,172)	.32 (.33)	55,650 (106,388)	Operations at the Annex Mine began in August 70. Mining rate at the Reeves Mine is reduced. Zinc concentrates are exported.
2.Annex Mine					11,821 (------)	.65 (---)	150,207 (-------)	
Western Mines Ltd. Buttle Lk. Van. Is. Campbell River	copper lead zinc	1000 (1000)	FLOTATION	350	33,580 (46,251)	.26 (.26)	189,061 (239,927)	
Anaconda Britannia Mines Ltd. Britannia Beach	zinc copper	(3000)	FLOTATION		(497)	(.24)	(2,379)	Zinc concentrate is exported to the United States.
YUKON TERRITORY								
United Keno Hill Mines Ltd. Elsa	lead zinc silver	500 (500)	FLOTATION	500	7505 (6985)	.64 (.72)	104,876 (100,740)	This is the highest grade ore in terms of Cadmium content in Canada.
Venus Mines Ltd. Carcross	lead zinc silver	300 (---)		100	229 (---)	2.2 (---)	10,071 (------)	Operations began in Sept. 1970. Ceased in 1971.
Anvil Mining Corp. Ltd. 120 mi. E. of Carmacks	zinc	5500						Expansion to 6,600 Tons/day for production of bulk lead-zinc concentrates to Germany.
NORTHWEST TERRITORIES								
Pine Point Mines Ltd.	Lead zinc	(8000)	FLOTATION	500	(431,000)			Most of the zinc concentrates are smelted at the Cominco Plants at Trail. Some is shipped to the U.S., Japan and India.
						TOTAL -	4,354,675 (4,578,538)	

SOURCES: Canada Minerals Year Book
Canadian Mines Handbook; Northern Miner Press, 1970-1971.
D.B. Fraser, Head Non Ferrous Section, Mineral Resources Branch, Dept. Energy Mines, Resources.
' - Personal Communication with D.B. Fraser.
.. Not available; - Nil.

MAP 1



PRIMARY PRODUCTION SOURCES OF CADMIUM IN CANADA

(Includes mines credited for production and those not credited yet may or do produce zinc concentrates)

Emissions from the mining process are considered to be slight, arising for the most part from a wind loss from tailings. Based upon an estimated wind loss emission of 0.2 pounds of cadmium per ton cadmium mined [19], the total air emission count from Canadian primary sources in 1970 would approach 425 pounds.

SECONDARY SECTOR

Metallurgical Works

Metallurgical works involved in cadmium production in Canada are those works that may produce a cadmium by-product. They are listed in Table 10. Map 2 shows the distribution of these works in Canada.

Processing procedures vary somewhat with the metallurgical works involved, as indicated in Table 10. It is this difference in refining techniques, differences in dust and fume collection systems, type and condition of equipment, and differences in management practices that govern the rate of emission of cadmium from the metallurgical works. It is not unusual for metallurgical works buying zinc concentrates to pay for only 70% of the actual cadmium content; the remainder is allotted to potential loss during refining. The amount of this loss varies in that some may be recovered or find its way into waste slag and cadmium residuals. [20]

One estimate has indicated that "45% of cadmium loss to the air occurs during ore refining processes, such as the roasting and sintering of zinc concentrates to remove impurities, of which cadmium is one component". [21] Another source suggests that "in areas around cadmium-emitting factories, cadmium concentrations in air several hundred times greater than those in non-contaminated areas will be found". [22] It is significant that smelters and refiners processing lead and copper, for instance, may have high rates of cadmium emission, even though the cadmium content is very small. Explanations are that, since the cadmium concentration in the fume is low, much fume recycling takes place, resulting in high percentages of cadmium loss to the atmosphere during each recycling process. [23]

No data are available to quantify the rate of cadmium emission from metallurgical works in Canada. A

TABLE 10

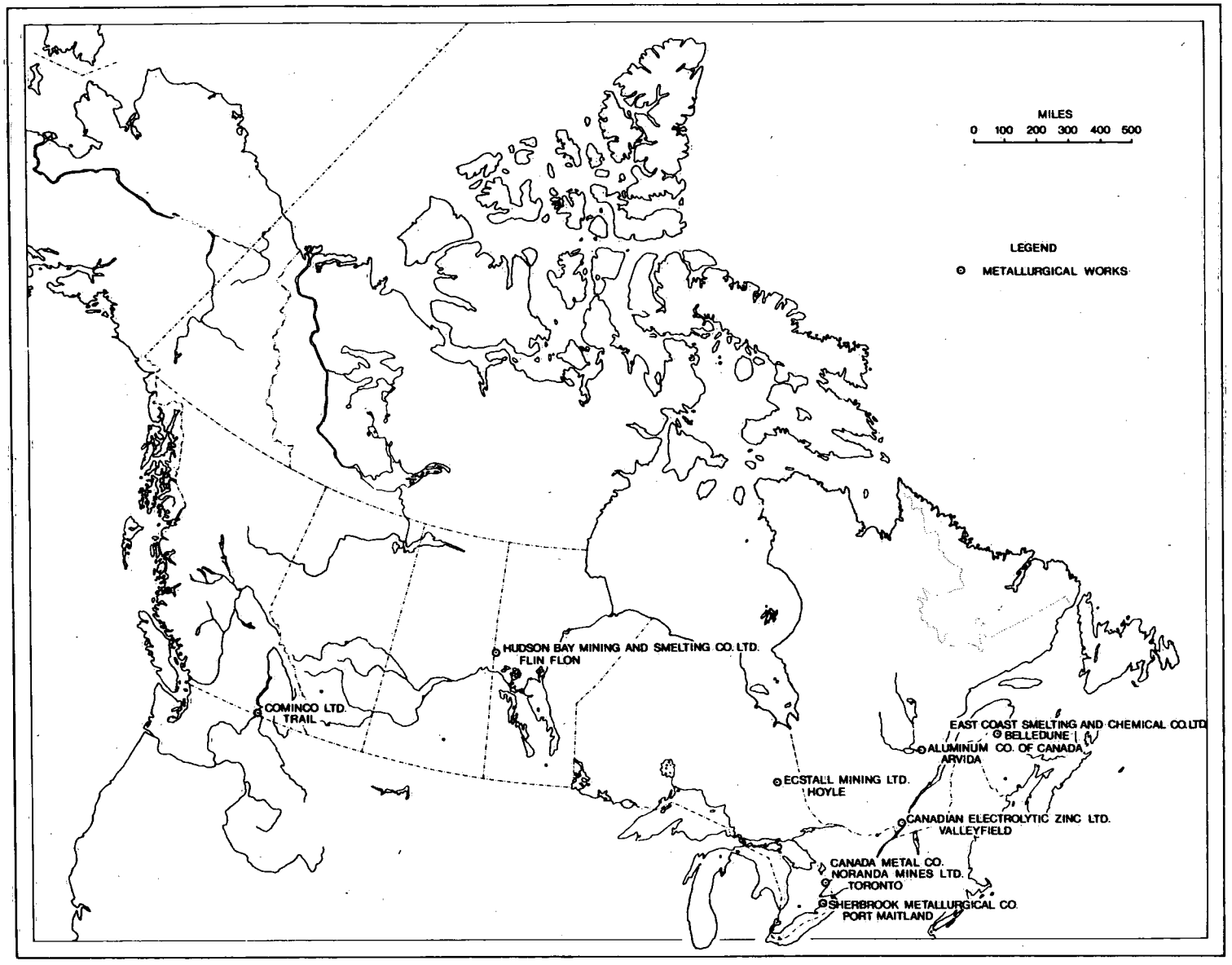
METALLURGICAL WORKS PRODUCING CADMIUM IN CANADA

(INCLUDES WORKS THAT MAY PRODUCE A CADMIUM BY-PRODUCT)

COMPANY AND LOCATION	CAPACITY TONS/DAY	METHOD	NATURE OF PRODUCT	REMARKS
CANADIAN ELECTROLYTIC ZINC LTD. VALLEYFIELD P.Q. Subsidiary - General Smelting Co. of Can. (Burlington).	400	ELECTROLYSIS	Metallic Cadmium in Stick Form and Impure Sponge	Cadmium precipitate from zinc refining is leached and the metal is recovered by electrolysis. This works recovers Cadmium from Quebec mines and the Geco Mine at Manitouwadge. Output was 625,000 lb. in 1969, 514,000 lb. 1970.
EAST COAST SMELTING AND CHEMICAL CO. LTD. BELLEDUNE N.B.		IMPERIAL SMELTING FURNACE	Cadmium in Form of Cadmium/Zinc Alloy	Produced 127 tons of cadmium zinc alloy in 1970 and exported for refining. Expects to produce refined cadmium in 1971.
TEXAS GULF SULPHUR ECSTALL MINING LTD. HOYLE ONT.		ELECTROLYSIS	Metallic Cadmium	Electrolytic zinc plant with cadmium refinery will have a 1 million lb/yr. capacity and is scheduled to begin Dec/71
HUDSON BAY MINING AND SMELTING CO. LTD. FLIN FLON. MAN.	180	ELECTROLYSIS Cadmium precipitate from zinc refining is leached and the metal recovered by electrolysis	Metallic Cadmium in Ball Anodes and Sticks	Treats all zinc concentrates produced in Manitoba and Saskatchewan. Production in 1970 was 338,348 pounds.
COMINCO LTD. TRAIL B.C.	900	CEMENTATION (Hydrometallurgical) Cadmium precipitate from zinc refining is leached and metal is recovered by cementation	METALLIC CADMIUM in balls, sticks, bars anodes, ovals and extrusions as required. Sold as "Tadanac Brand"	Treats ores and concentrates from its Sullivan and Bluebell Mines, its subsidiary at Pine Point and on a custom basis, from various mining operations in B.C. Produced 1,260,000 lbs. in 1970.
SHERBROOK METALLURGICAL CO. LTD. PORT MAITLAND ONT.		FLUID COLUMN PROCESS, Fluid Bed Roasting	DUST CONTAINING CADMIUM.	Byproduct of zinc-lead roasting is treated in the U.S.
CANADA METAL CO. TORONTO) (Subsidiary of Cominco).) ALUMINUM CO. OF CANADA ARVIDA P.Q.) NORANDA MINES LTD. TORONTO.)		MAY PRODUCE A CADMIUM BY-PRODUCT		

SOURCE : Dept. Energy Mines and Resources, NonFerrous and Precious Metals, Metallurgical Works in Canada, Operators List 1, Part 2, Mineral Resources Branch, Jan. 1971.

MAP 2



METALLURGICAL WORKS PRODUCING CADMIUM IN CANADA
(Includes works that may produce a cadmium by-product)

study of cadmium emissions in the United States, however, reveals a range of 25 to 1300 pounds of atmospheric emission per ton of cadmium processed. [24] The rate of emission varies with the type of plant examined.

Additionally, one cannot assess accurately the environmental impact owing to these emissions since numerous compounds, besides the oxide, may result from airborne cadmium reactions with other agents.

Cadmium Platers

Cadmium platers in Canada account for approximately 75% of the reported consumption of cadmium metal. Cadmium is generally electroplated on a base of ferrous metal to protect the base metal from corrosion. Application of the metal may also be accomplished by vacuum deposition, dipping, or spraying, but electrodeposition is the major type.

Properties of cadmium metal that make it appropriate for coating include:

(a) ease and high rate of deposition (uniformly on intricate objects);

(b) good corrosion resistance to alkali and salt water;

(c) high ductility (can be stamped or otherwise formed);

(d) good solderability; and

(e) high retention of silver-white lustre for extended periods.

The lesser cost and relative abundance of zinc and improvements in zinc electroplating have tended to reduce the consumption of cadmium for plating in recent years, yet plating continues to be the major use for cadmium in terms of quantity of metal consumed.

Cadmium plated articles are used in a number of applications, including automobile manufacture, household appliances, aircraft, radios, television sets, and electrical equipment. Practically all plating is carried out in a cyanide bath and the electrolytic efficiency from the standpoint of emissions is considered to be nearly 100%.

Consequently, emissions to the atmosphere as a result of electroplating operations are considered negligible. [25]

This does not exclude the possibility of emissions to water in waste effluent. This potential emission route is a function primarily of the type of plant, equipment and management practices. Control systems are available to recover cadmium from electrolytic wastes or to recycle the electrolyte, yet potential emissions arise from some plating plants with older equipment or from misuse of control equipment. [26]

A large number of users are involved in the electroplating industry. Many small users are located near small industry and are widely distributed, whereas large users may be associated with large industries such as the automobile manufacturers. Map 3 gives an indication of the geographical distribution and concentrations of known cadmium platers in Canada. There are some one hundred and sixteen known establishments involved in plating. This number is based upon firms listed and advertised in the following sources: -

(a) Canada's Custom Metal Finishers, Canadian Machinery and Metal Working, 1969.

(b) Canadian Manufactures Association, The Canadian Trade Index, 1971.

(c) Fraser's Canadian Trade Directory, 1971.

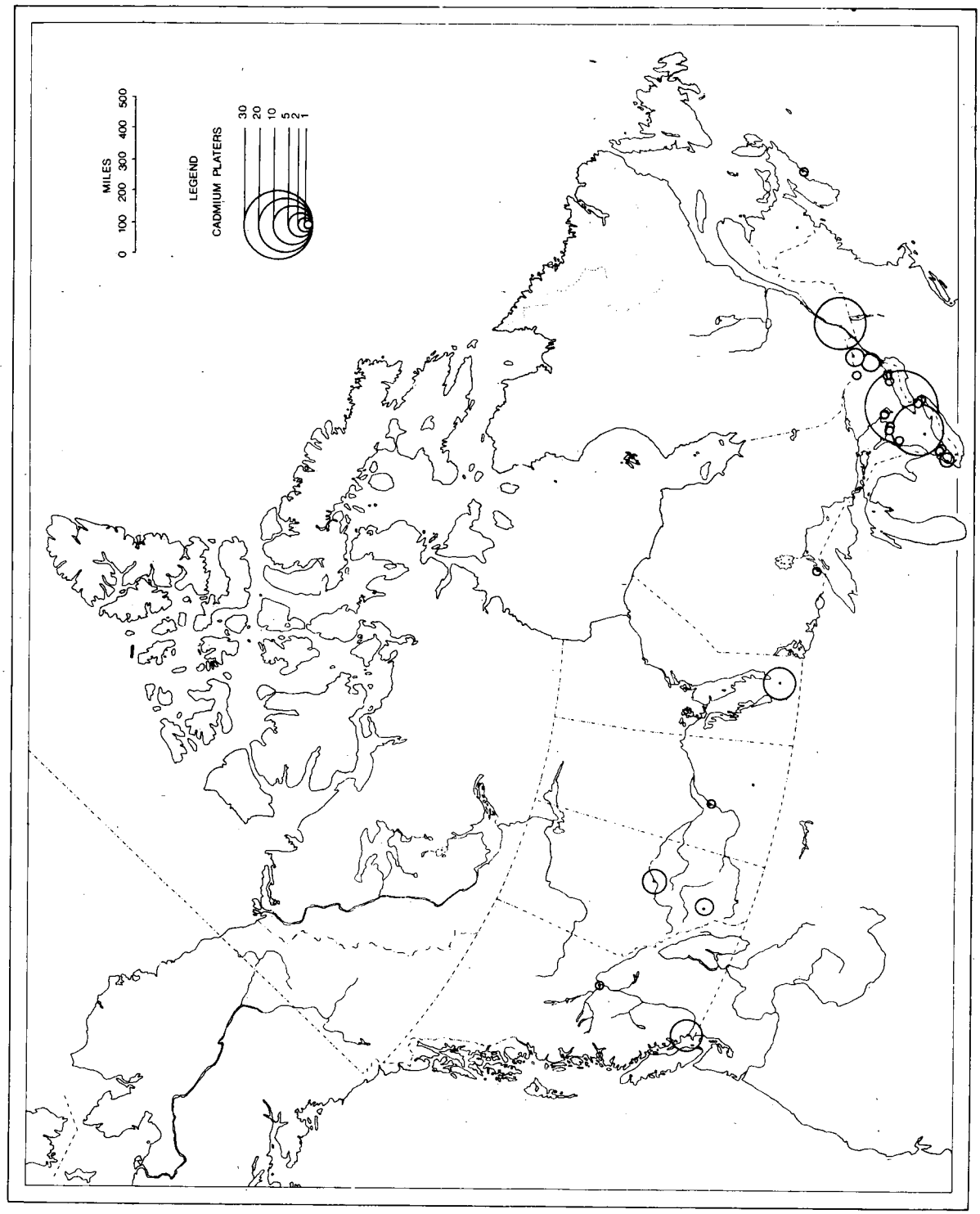
An additional number of cadmium platers may be found in Canada owing to the fact that only those platers advertising in the Trade Directories above were used for the data. Consumption of cadmium for plating in 1968, 1969 and 1970 was 94,728, 98,384 and 85,075 pounds, respectively.

Metal Rolling, Casting and Extruding N.E.S.

(Not elsewhere specified.)

This group includes firms engaged primarily in the manufacture of non-ferrous metals and their alloys, as well as establishments engaged in the recovery of non-ferrous metals from scrap (see Table 11).

MAP 3



DISTRIBUTION OF KNOWN CADMIUM PLATERS IN CANADA

TABLE 11

METAL ROLLING, CASTING AND EXTRUDING N.E.S.
1969 - CANADA

Number of Establishments	81
Employment (production)	3,696
Value Added by Total Activity	$58,812,000

Cadmium Materials Used	Quantity (lb.)	Cost ($)
Cadmium	26,762	62,000

N.E.S. - not elsewhere specified.

Source: Statistics Canada

The cadmium products of this industry include alloys and solders. Primary uses, as described below, include applications to bearings, solders, low melting alloys and silver brazing.

1. Bearing Alloys

Cadmium - 99%, nickel - 1%; or silver - 0.7%, copper - 0.6% and cadmium - 98.7%. These compositions in bearings impart a resistance to wear in high speed and high temperature applications.

2. Solders

Various combinations of cadmium-zinc, cadmium-silver, and zinc-tin-cadmium solders are used. These solders are used primarily in aluminum soldering.

3. Fusible Alloys

Low melting alloys and uses include:

(a) Bismuth-lead-tin-cadmium -- which finds use in pipe bending, fire protection devices, aircraft engines, foundry patterns, spotting fixtures, soldering and sealing. Melting point ranges from 158-190°F, depending on composition.

(b) Bismuth - 60%, cadmium - 40% -- which is used as a coating in selenium rectifiers. Its melting point is 291°F.

OTHER FUSIBLE ALLOYS

	COMPONENT	PERCENTAGE	MELTING POINT (°F)
i)	Bismuth	44.7	
	Lead	22.6	
	Tin	8.3	117
	Cadmium	5.3	
	Indium	19.1	
ii)	Tin	51	
	Lead	31	293
	Cadmium	18	
iii)	Cadmium	25	
	Indium	75	253
iv)	Bismuth	54	
	Tin	26	217
	Cadmium	20	
v)	Indium	44	
	Cadmium	14	200
	Tin	42	
vi)	Bismuth	52	
	Lead	40	198
	Cadmium	8	
vii)	Indium	62	
	Cadmium	8	144
	Bismuth	30	

4. Brazing Alloys

Most commonly used brazing alloys are the following:

(a) Silver - 20%, copper - 45%, zinc - 30%, cadmium - 5%; with a melting point of 1140°F.

(b) Silver - 35%, copper - 26%, zinc - 21%, cadmium - 18%; with a melting point of 1125°F.

5. Other Cadmium Alloys

These include:

(a) Cadmium-copper -- which is used in trolley and telephone wires and also acts as a replacement for silver-copper in radiator finstock.

(b) Cadmium-barium -- which is used to remove gas from radio tubes.

(c) Cadmium-zinc.

(d) Barium-cadmium-zinc.

(e) Calcium-cadmium.

(f) Cadmium-indium-silver.

Cadmium has also been used as a portion of a dental amalgam, often in conjunction with bismuth, lead, and mercury. This was used in technical laboratory procedures at one time, but is not commercially available for use in dental amalgams at the present time. [27]

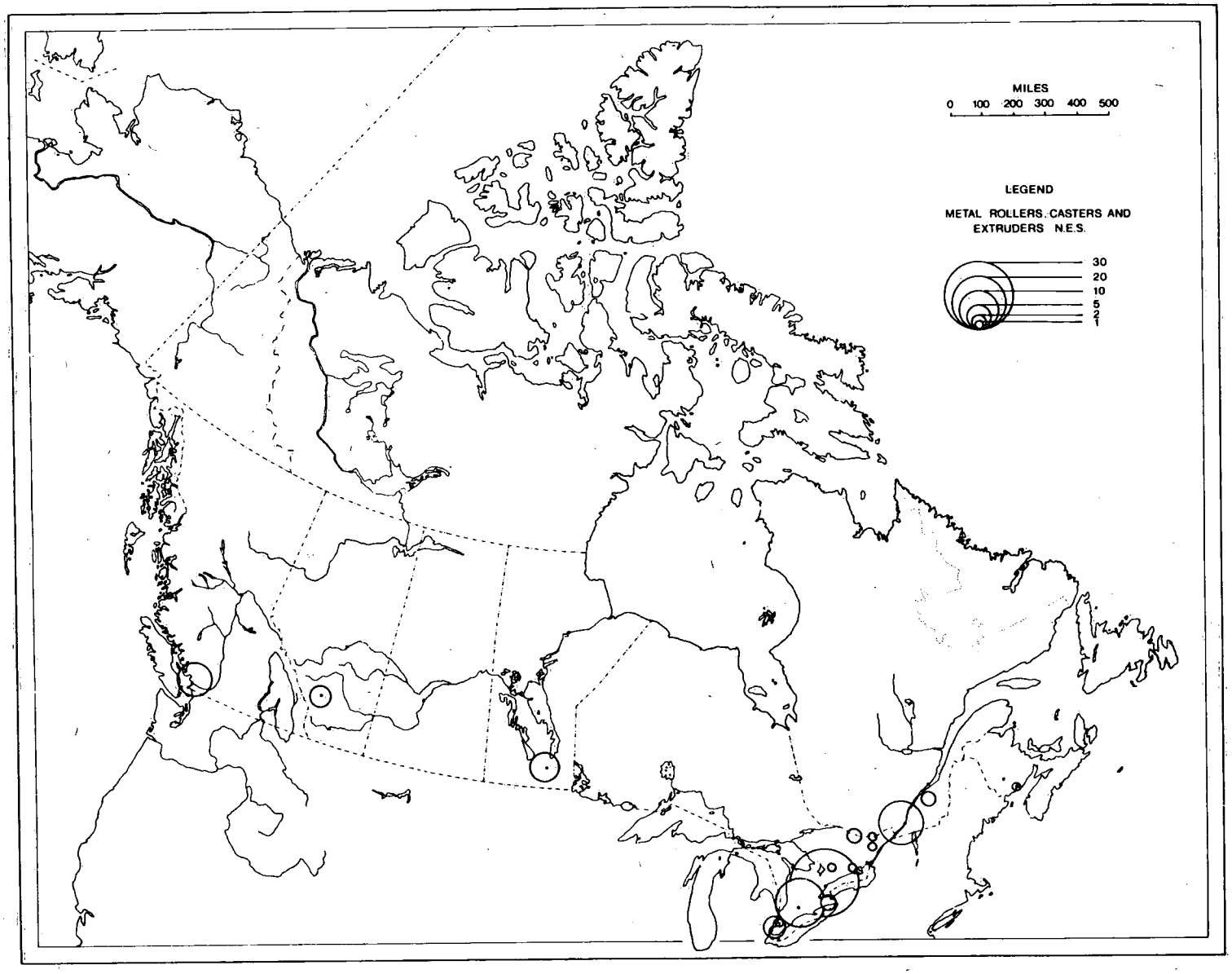
Map 4 provides an indication of the distribution and concentration of firms in Metal Rolling, Casting and Extruding N.E.S. in Canada. It must be emphasized that this map depicts all firms involved in this sector of industry; yet, not all firms are involved in cadmium use, hence the words "... Potential Cadmium Users ..." in the title.

A study assessing the emission rate from alloy manufacturers in the United States suggests an emission factor of 10 pounds of cadmium per ton of cadmium processed. [28] This emission factor is based on manufacturers' estimates. This factor applied to Canadian consumption of cadmium in alloy manufacturing would indicate an atmospheric emission of 135 to 250 pounds of cadmium annually, based on reported cadmium consumption in this sector for 1969 and 1968 respectively.

Paint and Varnish Manufacturers

This group of industries involves those firms engaged in the manufacture of paint and varnish, in addition to such products as putty, filler, oil stains and thinners (see Table 12).

MAP 4



DISTRIBUTION OF POTENTIAL CADMIUM USERS IN THE METAL ROLLING, CASTING AND EXTRUDING N.E.S. SECTOR IN CANADA

TABLE 12

PAINT AND VARNISH MANUFACTURERS
1969 - CANADA

Number of Establishments	156
Employment (production)	3,478
Value Added by Total Activity	$126,845,000

Cadmium Materials Used	Quantity (lb.)	Cost ($)
Cadmium Yellow Toner	1,586	4,000
Cadmium Lithopone Yellow	3,488	7,000
Cadmium Orange Tones	2,552	9,000
Cadmium Lithopone Orange	250	1,000
Mercury Cadmium Orange	9	-
Mercury Cadmium Red	938	3,000
Cadmium Lithopone Red	23,970	81,000
Cadmium Red Toner	16,906	58,000
TOTAL	49,699	163,000

Source: Statistics Canada

In 1968, the total cadmium compound weight consumed by this industry amounted to 66,927 pounds. Of this total, 89.25% was used within the Great Lakes Basin area. [29]

The firms classified to the paint and varnish industry (one hundred and fifty-six) represent all use of cadmium for pigments. Not all firms are necessarily involved in the use of cadmium, however. No data are available to indicate the actual number of firms using cadmium in this form.

The distribution and concentration of paint and varnish manufacturers in Canada are shown on Map 5.

The manufacture of pigments accounts for the second largest use of cadmium in Canada. Available data are insufficient to determine the actual quantity of cadmium metal consumed; it can be estimated, however, that 5 to 10 tons of the metal are used in compounding pigments. Based on an emission factor of 15 pounds of cadmium per ton of cadmium processed [30], potential atmospheric emissions from the paint and varnish industry in Canada in 1969 would range from 75 to 150 pounds.

Jewellery and Silverware Manufacturers

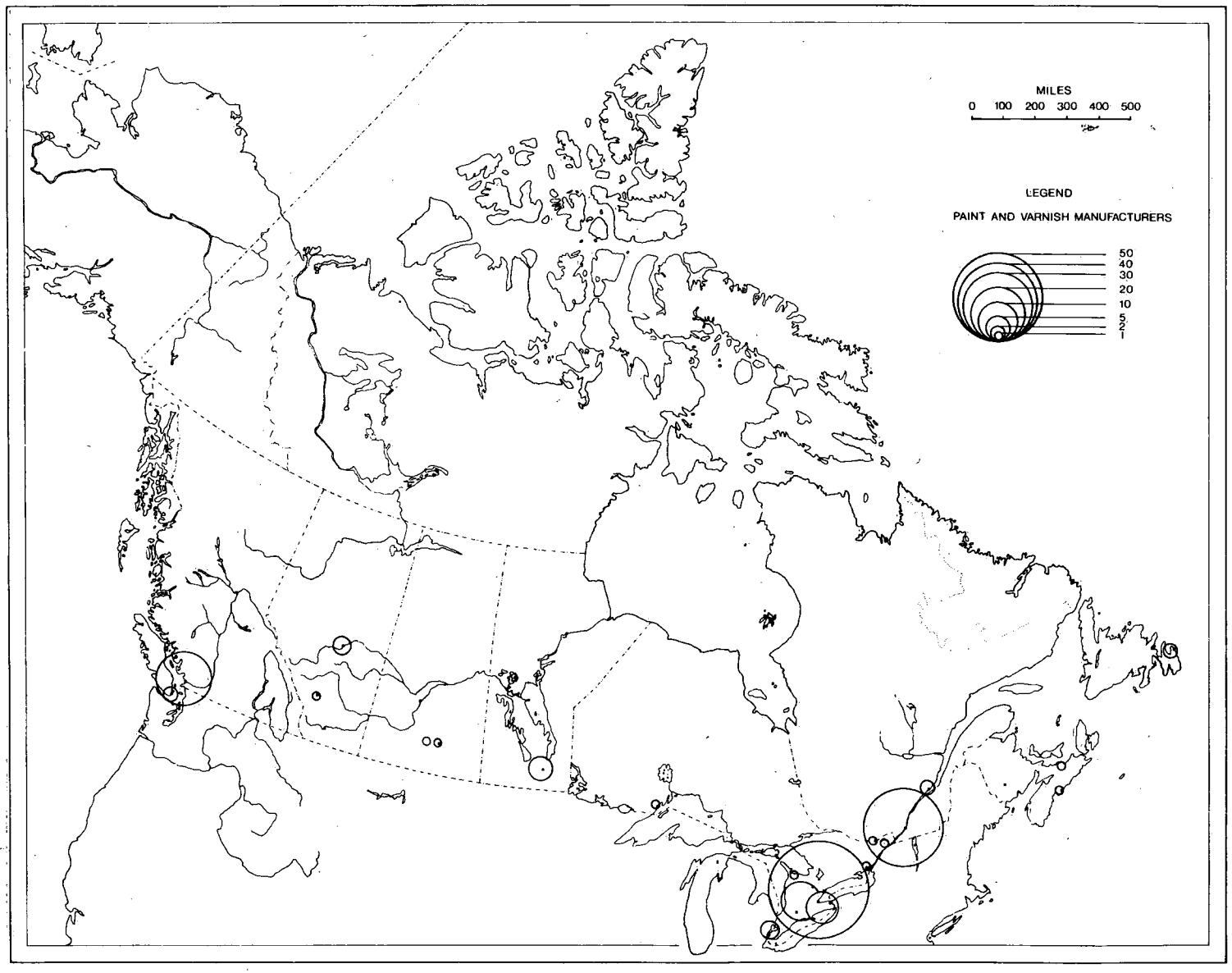
Cadmium use in this industry may be more properly defined as use in plating and alloy making.

The Annual Census of Manufacturers reports cadmium use in this industry in 1968 and 1969. In these years, two hundred and seventy-four firms were included in this industry, but not all firms used cadmium. Cadmium used in this industry in 1968 was valued at $17,000. This indicates an extrapolated weight of 6,200 pounds. No cadmium weight or value is reported for 1969. The use of cadmium in jewellery and silverware manufacture is fairly small per firm and no complete list of firms actually using cadmium is available. Emissions from this source would be negligible.

Nickel-Cadmium Battery Manufacturers

Nickel-cadmium batteries have a number of applications because of their long life characteristics, high peak power output, small size and superiority in low-temperature operation. Such properties make nickel-cadmium batteries suitable for use in airplanes, satellites,

MAP 5



DISTRIBUTION OF POTENTIAL CADMIUM USERS IN THE PAINT AND VARNISH SECTOR IN CANADA

missiles, and ground equipment for polar regions, as well as in many portable appliances and power tools.

Two types of batteries exist -- the sealed type and the vented type. It is estimated that approximately 60% are of the sealed variety, and 40% of the vented type. [31] The sealed cells are used mainly in convenience appliances and communications. They are also used for space applications. Reclamation of this type of battery is unlikely. The vented cells are used as storage batteries in aircraft, military applications, and power and lighting standby units. Reclamation of this type of battery is possible.

Known producers of nickel-cadmium batteries in Canada include:

(a) Alkaline Batteries (Canada) Ltd.,
Willowdale, Ontario.

(b) Cipel and Carbone Ltd.,
Valleyfield, Quebec.

(c) Clevite Canada Ltd., Burgess Div.,
Niagara Falls, Ontario.

(d) Exide Batteries, ESB Canada Ltd.,
Mississauga, Ontario.

(e) Globelite Batteries Canada Ltd.,
Scarborough, Ontario.

(f) Gulton Industries (Canada) Ltd., Herbert,
Gananoque, Ontario.

(g) Saft Batteries Ltd.,
Toronto, Ontario.

Environmental discharge from nickel-cadmium battery production depends upon facilities and management practices. One plant on a tributary of the Hudson River discharged cadmium and nickel to the extent that mud in the stream contained 16.2% cadmium and 22.6% nickel dry weight. [32]

The technology is available to recover cadmium and nickel from scrap batteries. A cyclic leaching process is capable of extracting 94% of the cadmium, in addition to nickel and cobalt impurities from scrap nickel-cadmium batteries. [33]

Atmospheric emissions in the manufacture of nickel-cadmium batteries are considered to be in the order of two pounds per ton of cadmium processed. [34] Available data in Canada, however, do not permit the determination of the actual quantity used for battery manufacture in Canada and, hence, no estimate of emission potential can be made.

MISCELLANEOUS

Cadmium Compounds

> "The use of cadmium compounds in recent years has expanded at a rate of 5 to 10% annually and is now the largest potential growth area." [35]

The actual cadmium content by weight in cadmium compounds is unknown, but, in any one compound, it is considered to be relatively small. The range in use and variety of application afforded by the compound form add to the potential environmental hazard. The probability that toxicity does not decrease in compound form and the widespread use of cadmium compounds serve to magnify the potential hazard over a broad spectrum. Studies indicate that the toxic hazard rating of cadmium compounds is high, meaning that short exposure to small quantities may result in death or permanent injury. This rating applies to cadmium compound ingestion, inhalation and resultant irritation. [36]

A partial listing of cadmium compounds and their principal uses follows:

Cadmium Compound	Principal Uses
Cadmium Acetate	Used in chemical testing for sulphides, selenides, and tellurides. Produces iridescent effects in glass, porcelain, and pottery; used in dyeing and printing textiles and in the purification of mercaptans in crude oils and gasolines by precipitation of the sulphur in these substances.

Cadmium Bromide	Used in photography, process engraving and lithography.
Cadmium Carbonate	Used as a starting compound for other salts, and as a catalyst for organic reactions. Has been used also as a fungicide ingredient.
Cadmium Chloride	Used in photography, dyeing, and printing; in the vacuum tube industry; in the manufacture of cadmium yellow; as an ingredient in fungicides; in galvanoplasty; in the manufacture of special mirrors; as an ice-nucleating agent; as a lubricant and in the analysis of sulphides.
Cadmium Chromate	Used as a pigment and/or a catalyst and is a potential antifouling agent.
Cadmium Cyanide	Used in copper bright electroplating.
Cadmium Fluoride	Has no extensive commercial use, but may be substituted for zinc fluoride in phosphors manufacture, and may also be used in nuclear reactor controls.
Cadmium Hydrate	Used in electroplating solutions.
Cadmium Hydroxide	Used principally in storage battery electrodes.
Cadmium Iodide	Uses similar to the other halides, namely in photography, lithography, process engraving, in photoconductors and as a lubricant.
Cadmium Napthenate	Soap used as a stabilizer in polyvinyl chloride plastics.
Cadmium Nitrate	Used principally by manufacturers of nickel-cadmium batteries, but may also be used in making other cadmium salts or in fluorescent lamp coatings and photographic emulsions.
Cadmium Octoate	Also used as a stabilizer in polyvinyl chloride plastics.

Cadmium Oxide	Used in electroplating and in storage battery electrodes. Other uses as source of cadmium for other compounds; in the manufacture of glass; in phosphors; in semiconductors; in the manufacture of silver alloys; and as a catalyst for inorganic reactions. Formerly used as an ascaricide for swine, but there is no indication of its use for this purpose in Canada at present. (See Table 13.)
Cadmium Salicylate	Has been used as an external antiseptic.
Cadmium Sebacate	Used in fungicide formulations.
Cadmium Selenate, Selenide, Selenite	Used in photoconductors, semiconductors, photoelectric cells and rectifiers. In addition, these compounds often contained in glass and ceramics.
Cadmium Stearate	Used as a stabilizer in polyvinyl chloride fungicides.
Cadmium Sulphate	Numerous uses in rotproofing; in the electrodeposition of cadmium, copper and nickel; in phosphors; in the manufacture of standard cadmium soaps for vinyl stabilizers.
Cadmium Sulphide	Used primarily as a pigment in paints. Also used to colour vulcanized rubber; in artists' colours; for colouring glass, soaps, textiles, paper, printing inks, and ceramic glazes. Is a pigment in epoxy resins and may be used with ultramarine to produce green colours. Is also a fluorescent pigment, and is used in phosphors and fluorescent screens; in scintillation counters, semiconductors and photoconductors.
Cadmium Sulphoselenide	Used in the production of pink-red-maroon lithopones.

TABLE 13

CADMIUM CONTAINING FUNGICIDES

1969 - CANADA

USE	TRADE NAME	CHEMICAL INGREDIENTS		SUPPLIER	
		NAME	%	NAME	LOCATION
FUNGICIDE SPRAY	ORTHO LAWN AND TURF FUNGICIDE	CADMIUM CARBONATE	5.00	CHEVRON CHEM. CAN. LTD. ORTHO DIV.	1060 INDUSTRY ST. OAKVILLE, ONT.
	No longer produced by the listed supplier. Not registered 1970 to present.				
SOLUTION	NATIONAL CHEMSEARCH C-A-D	CADMIUM CHLORIDE	20.1	NATIONAL CHEMSEARCH OF CANADA LTD.	172 WEST DR. BRAMALEA, ONT.
SOLUTION	CADEX - A LIQUID CADMIUM TURF FUNGICIDE	CADMIUM CHLORIDE CADMIUM EQUIVALENT	20.1 12.3	ALFCO ROKEDY CO. OHIO AGENT - D. McCraken	BOX 535, REXDALE, ONT.
SOLUTION	L.T.F. LIQUID TURF FUNGICIDE	CADMIUM CHLORIDE	20.1	CERTIFIED LABS. OF CAN.	Box 460, BRAMPTON, ONT.
WETTABLE POWDER	POLYGRAM-C TURF FUNGICIDE	CADMIUM CHLORIDE CADMIUM EQUIVALENT	15.9 7.7	NIAGARA CHEMICALS, DIV. F.M.C. MACHINERY CHEMICALS	1274 PLAINS RD. E. BURLINGTON, ONT.
WETTABLE POWDER	KROMAD BROAD SPECTRUM TURF FUNGICIDE	CADMIUM SEBACATE THIRAM	5.00 16.00	MALLINCKRODT CHEM. WORKS	600 DELMAR AVE. POINTE CLAIRE, QUE.
FUNGICIDE SPRAY	CADMINATE	CADMIUM CADMIUM SUCCINTAE	29.00 60.00	MALLINCKRODT CHEM. WORKS	600 DELMAR AVE. POINTE CLAIRE, QUE.
PESTICIDE ASCARIDE FEED PRE-MIX	Former Small Use. No longer is any cadmium compound (including oxide) used as a parasiticide in Canada.	CADMIUM OXIDE CADMIUM ANTHRANILATE		DOMINION VETERINARY LABS	800 MAIN ST. WINNIPEG, MAN.
SEED TREATMENT POWDER WETTABLE POWDER	PURA SEED PURA DRIN	PHENYL AMINO CADMIUM DILACTATE		METASOL CANADA LTD.	245 VICTORIA AVE. MONTREAL 6, QUE.
	No new production or imports to occur. To be removed from the registered list.			NIAGARA CHEMICALS, DIV. F.M.C. MACH. & CHEM.	1274 PLAINS RD. E. BURLINGTON, ONT.

SOURCES: INDICES AND LISTING OF CANADIAN PESTICIDE REGISTRATIONS 1970.
PERSONAL COMMUNICATION.

Cadmium Telluride	Used in semiconductor research and phosphors.
Cadmium Tungstate	Used in x-ray screens; in scintillation counters and as a catalyst for organic reactions.

Other cadmium compounds for which uses are uncertain or unknown include the following:

Cadmium Benzoate
Cadmium Bisulphate
Cadmium Bromate
Cadmium Chlorate
Cadmium Dichromate
Cadmium Ethylenediamine
Cadmium Ferrocyanide
Cadmium Fluoborate
Cadmium Formate
Cadmium Lactate
Cadmium Laurate
Cadmium Molybdate
Cadmium Neo-decanoate
Cadmium Oxalate
Cadmium Potassium Chloride
Cadmium Potassium Cyanide
Cadmium Potassium Iodide
Cadmium Propionate
Cadmium M-silicate
Cadmium Silicofluoride
Cadmium Tartrate
Cadmium Thiocyanate
Cadmium Zirconate

Group Uses of Cadmium Compounds

Certain uses lend themselves to the application of certain types of cadmium compounds.

Catalytic Uses

There are uses for cadmium salts of inorganic acids and chemically stabilized resins and their polymers; e.g., bis (alkylthio) cadmium is used as a stabilizer for vinyl chloride resins; cadmium carboxylate is used to form unsaturated primary alcohols and esters; ethylcadmium is used as a catalyst for the polymerization of alkylene oxides; diethylcadmium is used as a component for a catalyst for polymerization of vinyl compounds and propylene; cadmium is used in the coagulation of polyvinyl chloride latex; cadmium salts of carboxylic acids are used in curing organopolysiloxanes.

Fungicides

Cadmium compounds used for this purpose have included, in addition to those already mentioned, phenyl amino cadmium dilactate, phenylamine cadmium dilactate, and anilinocadmium dilactate. (See Table 13.)

Phosphors and Luminescent Materials

Cadmium compounds such as tungstate, silicate and borate give pink colours. Cadmium sulphide, when activated with copper or silver, gives colours over the entire spectrum. Cadmium phosphors and luminescent materials are used as visible indicators of invisible particles such as cathode rays, x-rays and ultra-violet photons. These applications include x-ray fluorescent screens, self-illuminating watch and instrument dials, theatrical black magic, television tubes and radar, fluorescent lamps, and flow indicators in liquids. The principal compound for these materials is the cadmium sulphide mixed with zinc sulphide.

Organometallic Compounds

> "The zinc and cadmium organometallic compounds are of interest since their mild reactivities toward certain organic functional groups give them unique synthetic potentialities." [37]

Several cadmium alkyls have been prepared. They include dimethyl-, diethyl-, di-n-propyl-, di-n-butyl-, diisobutyl-, diisoamyl-, and diphenylcadmium, cadmium salicylate, and cadmium ricinoleate.

Cadmium Lithopones

This group refers to the product formed by treating a solution of cadmium sulphate with a solution of barium sulphide. The pigments produced may vary in shade depending upon the mix of the solutions. Yellowish or reddish tints are most common. Cadmium lithopones are used in place of zinc lithopones because they do not oxidize as readily as zinc, especially in high temperature applications. Cadmium reds are made by treating the two solutions in the presence of selenium. Cadmium sulphide pigments and lithopones produce the following colours:-- primrose, lemon, golden,

orange, orange-red, light red, medium red, dark red and maroon.

Potential emission sources may be related to any one of the manufacturing procedures involved in cadmium compound production and may be associated with any of the great number of applications afforded by the compound form of the metal. Studies completed provide some indication of possible rates of emission arising from the use of compounds in the plastics and pigments industries. Estimates based on manufacturers' reports suggest an emission factor of six pounds of cadmium emission per ton of cadmium processed in the plastics industry, and 15 pounds of cadmium emission per ton of cadmium processed in pigment production. [38] Since complete data regarding cadmium compound consumption are lacking, however, no attempt can be made to quantify the emission potential from compound use in plastics and pigments in Canada.

Cadmium compound producers in Canada are the following:

(a) Anachemia Chemicals Ltd., Lachine

- Cadmium Nitrate, Cadmium Sulphate

(b) Cominco, Montreal

- Cadmium Oxide

(c) Kohnstamm Co. Ltd., Montreal

- Cadmium Selenide, Cadmium Sulphate, Cadmium Sulphide, Cadmium Sulphoselenide

(d) Lea Products Co. Ltd., Montreal

- Cadmium Oxide

(e) Nuodex Canada, Toronto

- Cadmium Benzoate, Cadmium Octoate

(f) Witco Canada, Brantford and Oakville

- Cadmium Stearate

Additionally, there are numerous suppliers of cadmium compounds in Canada. A partial listing is provided in Appendix I.

Fungicides

The most recent listing of cadmium containing fungicides registered in Canada is given in Table 13. Some twenty fungicides and pesticides containing cadmium are known, but only six are registered for production in Canada; three of these six are now being removed from registration or are slated for removal. Cadmium carbonate (Ortho Lawn and Turf Fungicide) has no recent listing. It was previously registered in 1969. Cadmium oxide (anthranilate salt), though previously used in small quantities as an ascaricide (in the treatment of worms), is no longer being used as a parasiticide in Canada. "Puraseed" and "Puradrin", which are mercurial seed treatments containing phenyl amino cadmium dilactate, were registered in 1970 and 1971 to dispose of existing stock, but no new production of these products will be undertaken nor new material imported in the future. [39]

The cadmium-containing fungicides registered in Canada are used primarily as turf fungicides and, consequently, use is relatively small.

Because it is possible for individuals to import fungicides and pesticides by permit for individual use, it is conceivable that certain other cadmium-containing fungicides and pesticides may enter the country. Emissions from fungicides during spraying depends upon spray particle size, wind velocity, and spray equipment. Cadmium emissions to the atmosphere are based on an estimated loss of 2% during application of the fungicides. [40] No data are available to assess the loss from cadmium fungicide applications in Canada.

CONSUMPTIVE USES

A number of products are in widespread use that contain cadmium as a contaminant.

Superphosphate Fertilizers

Some fertilizers contain cadmium, so that, consequently, fertilized soils contain more cadmium than unfertilized soils.

Sea water is considered to be the source of the cadmium content. Phosphate rock, the principal constituent in superphosphate fertilizers, is composed partly of the hard parts of marine animals, e.g., molluscs and crustaceans, which, through their alliance with the marine environment, become the apparent source of cadmium in phosphate rock.

Discrepancies exist as to the actual proportion of cadmium in superphosphate fertilizers. H. A. Schroeder suggests that superphosphate fertilizer contains as much as 8.9 ppm of cadmium. [41] J. H. Caro, on the other hand, suggests a cadmium content in superphosphates of 110 ppm. [42] It is known that this cadmium content does enter the soil and results in some uptake of the element by vegetable matter.

Most of the phosphate rock used for Canadian superphosphate production is imported from the United States. Manufacturers in 1969 used approximately 300,000 tons of superphosphate. [43] Based on a cadmium content of 100 ppm and an emission factor of 0.1% [44], atmospheric emissions resulting from the use of fertilizers that contain superphosphates would approach 60 pounds.

Rubber Tires

Evidence has shown accumulations of cadmium in conjunction with the wear and resultant soil concentrations of cadmium in relation to heavily travelled highways.

Cadmium in rubber is not purposely introduced during manufacture, but, owing to the close association of zinc and cadmium, its presence may be accounted for by the use of technical zinc oxide and zinc diethyl or dimethyl carbamate in vulcanization. Studies undertaken have indicated cadmium concentrations of 20 to 90 ppm in motor vehicle tires. [45]

Motor Oils

Motor oils commonly have zinc-containing additives, e.g., the antioxidant zinc dithiophosphate in lubricating

oil. This joint presence of zinc and cadmium in oils has been established, and cadmium emissions from this source are possible.

Atmospheric emissions of cadmium from both rubber tires and motor oils are a direct function of vehicle miles travelled. Total atmospheric emissions from these sources in the United States amounted to 13,200 pounds of cadmium in 1968. [46]

Comparative values for cadmium emissions in Canada have been derived from a basis of 84,651,000,000 vehicle miles of travel in 1970. [47] Use of the procedure established by the American study for emission rates [48] showed that atmospheric emissions from tires and motor oils in 1970 in Canada approached 1100 pounds of cadmium.

Tobacco

Recent investigations have discovered the presence of cadmium in tobacco and studies have indicated an inhalation of 2 to 4 micrograms of cadmium with every twenty cigarettes smoked. [49]

RECYCLING AND WASTE DISPOSAL

It is estimated that 52% of cadmium loss to air occurs during the incineration and disposal or reclamation of cadmium-containing products. [50] Owing to the nature of the products and the main uses of cadmium in Canada, no recovery of cadmium is made nor is there any indication of secondary cadmium production from scrap recycling. There may be, on occasion, instances where solder is recycled, but invariably the product would be re-constituted as solder. [51]

Available information indicates no attempt to recover cadmium in the steel processing of plated automobile parts or other products. It is believed that cadmium is not considered for its own properties in recycling, but may continue on in a new product form or be lost during the manufacturing process.

It is evident that a great deal of scrap material contains large amounts of cadmium and considerable losses are bound to occur in steel production from scrap material. The use of galvanized metal for this end would be only one example of potential emission during the recycling process.

The melting of scrapped automobile radiators to recover copper is another source of potential emissions. In addition, disposal by incineration of solid wastes such as plastic bottles, auto seat covers and numerous items containing cadmium in alloy or compound form accounts for sizeable amounts of emissions.

Further indication of the extensive presence of cadmium is provided by the knowledge that zinc and cadmium are intimately associated, such that cadmium may persist through to the end form of many zinc products. Such an association magnifies the spectrum of cadmium use, impedes the efficiency of possible control and complicates the role of any proposed substitute.

CONCLUSION

Forecast growth rates for worldwide cadmium demand are considered to range from 1.6 to 3.8% per year. [52] This would suggest a world demand for some 75,000,000 pounds of cadmium by the year 2000. [53] The diffuse use of the metal, the relatively small quantities used in any one area and the forces of technological change all contribute to the risk of projection.

In Canada, cadmium consumption bears little relation to its production in terms of quantity. This is explained, for the most part, by the large volume of exports of the metal. Cadmium consumption in Canada appears fairly small, but this may reflect the data deficiencies in this area. This deficiency is a key factor in prohibiting a thorough investigation of all cadmium uses and, hence, a complete definition of potential environmental hazards.

This fact strengthens the argument for an improved system of data collection on materials potentially hazardous to the environment. Such an improvement would facilitate an assessment of potential hazard areas arising from the use of cadmium in the Canadian economy, and assist in the determination of the magnitude of this hazard.

A comprehensive study of cadmium use in Canada and an account of potential environmental inclusion is not possible without a well defined consumption pattern, as well as total cognizance of all occurrences of the metal.

GLOSSARY

Concentrate - product(s) of concentration operations in which a relatively high content of metal has been obtained and is ready for treatment by chemical methods.

Gangue - portion of an ore which contains no metal; valueless minerals in a lode or vein.

Ore - term applied to any metalliferous mineral from which the metal may be profitably extracted.

Refining of Metals - operations performed after the crude metals have been extracted from their ores, in order to put them in a condition of higher purity.

Roast - heating a sulphide in the presence of oxygen to form an oxide.

Sinter - coalescing into a single mass under the influence of heat without actually liquefying.

Slag - top layer of a two layer melt formed during smelting and refining operations. In smelting, the slag contains gangue materials and flux; in refining, it contains the oxidized impurities.

Smelting - fusion of an ore or concentrate with suitable fluxes to produce a melt consisting of two layers - on top, a slag of the flux and gangue minerals; below, molten impure metal.

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APPENDIX I

CANADIAN SUPPLIERS OF CADMIUM COMPOUNDS

Compound Supplier	Compound*
Advance Solvents & Chemicals Corp. (Toronto)	(12)
Allied Chemical Canada (Montreal)	(1), (2), (3), (4), (5), (6), (8), (10), (11), (12)
Anachemia Chemicals (Lachine)	(1), (2), (3), (4), (6), (10)
Armalite (Toronto)	(10)
Blackford, H. F., Ltd. (Montreal)	(12)
British Drug Houses (Montreal)	(1), (2), (3), (4), (6), (8), (13)
Caledonia Chemicals (Montreal)	(7), (9), (12)
Canlab (Canadian Laboratories, Toronto)	(1), (2), (3), (4), (5), (8), (10), (11), (12), (13)
Central Scientific (Toronto)	(1), (2), (3), (4), (6), (8), (13)
Debro Chemicals (Dorval)	(11)
Fisher Scientific (Montreal)	(1), (2), (3), (4), (5), (6), (8), (10), (13)
Guardian Chemicals (Montreal)	(1), (2), (3), (5), (6), (7), (8), (9), (10), (11), (12), (13)

Compound Supplier	Compound*
Harrison and Crosfield (Montreal)	(7)
International Chemical (Montreal)	(12)
Johnson Matthey and Mallory (Toronto)	(10), (13)
Minerals and Chemicals Ltd. (Montreal)	(5), (12)
Mohawk Chemicals Ltd. (Sherbrooke)	(12)
Napco Chemical Canada (Hamilton)	(12)
Nuodex Canada (Toronto)	(7)
Paterson, A. S., Co. Ltd. (Toronto)	(11)
Penick Canada Ltd.	(12)
Pigment and Chemical Co. Ltd.	(11), (13)
Prescott (Montreal)	(10), (11)
St. Lawrence Chemical (Montreal)	(13)
Tennant (Weston)	(10), (11)
Thyrrenian (Montreal)	(2)
Van Camp Products (Toronto)	(10)
Weyrich Chemicals (Dorion)	(7), (9), (12)

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* Name and Number:

Cadmium Acetate	(1)	Cadmium Nitrate	(8)
Cadmium Bromide	(2)	Cadmium Octoate	(9)
Cadmium Carbonate	(3)	Cadmium Oxide	(10)
Cadmium Chloride	(4)	Cadmium Selenide	(11)
Cadmium Fluoborate	(5)	Cadmium Stearate	(12)
Cadmium Iodide	(6)	Cadmium Sulphate	(13)
Cadmium Napthenate	(7)		