

NATIONAL INVENTORY OF SOURCES AND
EMISSIONS OF MERCURY (1970)

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REVIEW NOTICE

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ABSTRACT

Atmospheric emissions of mercury from various sectors of the Canadian economy have been estimated for the year 1970. A summary of the data presented in this report is given in Table 1, along with estimates for the United States. Of the total 82.2 tons of mercury released through human activities into the atmosphere in 1970, 2.2% resulted from the primary and secondary production of mercury, 32.7% from the consumption of mercury metal, 2.7% from the consumption of mercury compounds, and 62.4% from the inadvertent release of small amounts of mercury in various fuels, wastes, and other materials. The largest single source of mercury emission was the chlor-alkali industry, which accounted for 32.1% of total emissions.

Generally, mercury vapour losses were uncontrolled, although in such operations as gold recovery and mercury distillation, condensers that formed part of the process acted as partial control equipment. Only in mercury beneficiation, the chlor-alkali industry, and alkaline battery production were wash towers and cyclones used specifically to limit mercury vapour and mercury compound dust losses.

Provincial mercury emissions are estimated in Table 2, and in more detail in Tables 3 - 6. Point sources are identified in Figure 1.

RESUME

On a évalué pour 1970 les émissions atmosphériques de mercure provenant de divers secteurs de l'économie canadienne. Le tableau 1 donne un résumé des données présentées dans le présent rapport ainsi que des données estimatives pour les États-Unis. Les émissions totales de mercure provenant des activités humaines en 1970, ont été évaluées à 82.2 tonnes, dont 2.2% proviennent de la production primaire et secondaire de mercure, 32.7% de la consommation de métal de mercure, 2.7% de la consommation de composés de mercure, et 62.4% de déversements accidentels de quantités minimes de mercure dans divers combustibles, déchets et autres matières. L'industrie du chlore et de la soude caustique, responsable de 32.1% des émissions totales, est la plus importante source d'émissions de mercure.

Règle générale, on ne prenait aucune mesure de protection contre les pertes de vapeurs de mercure. Toutefois, dans certaines activités comme la récupération de l'or et la distillation du mercure, les condenseurs employés assurent une protection partielle. Ce n'est que dans la préparation du mercure, l'industrie du chlore et de la soude caustique et la production de batteries alcalines qu'on a employé des tours de lavage et des cyclones pour limiter les pertes de vapeurs de mercure et de poussières de composés de mercure.

Les émissions de mercure par province apparaissent dans le tableau 2, et de façon plus détaillée, dans les tableaux 3 à 6. La figure 1 identifie les sources ponctuelles.

TABLE 1 1970 MERCURY EMISSIONS IN CANADA

	Emissions		Emission factor**	
	Tons	Percent	Present study	U.S. (21)
PRODUCTION				
Mercury mining	1.05	1.3	0.0053 (f)	0.012 (f)
Mercury beneficiation	0.76	0.9	0.0038 (f)	0.254 (f)
Secondary production	0.004	*	20 (a)	40 (a)
Distillation	<u>0.002</u>	<u>*</u>	0.06 (a)	-
Production total	1.82	2.2		
METALLIC MERCURY USE				
Chlor-alkali industry	26.4	32.1	0.11 (b)	0.0585 (b)
Dental amalgams	0.17	0.2	16.9 (a)	20 (a)
Electrical equipment	0.003	*	1.1 (a)	8 (a)
Gold recovery	0.28	0.3	1000 (c)	-
Pharmaceutical manufacture	0.0001	*	1.1 (a)	-
Instrumentation	<u>0.03</u>	<u>*</u>	16.9 (a)	1500 (c)
Mercury use total	26.88	32.7		
MERCURY COMPOUND USE				
Agriculture	1.5	1.8	1000 (a)	1000 (a)
Paint manufacture	0.036	*	7 (a)	-
Battery cathodes	0.008	*	0.9 (a)	-
Pharmaceutical use	<u>0.65</u>	<u>0.8</u>	1000 (a)	400 (a)
Mercury compound use total	2.20	2.7		
INADVERTENT EMISSIONS				
Paint use				1300 (a)
Interior	0.99	1.2	2000 (a)	
Exterior	5.04	6.1	1000 (a)	
Coal combustion	6.99	8.5	0.002-1.2 (d)	1 (d)
Petroleum combustion	20	24.3	0.6 (d)	0.09 (d)
Natural gas combustion	0.002	*	0.005 (e)	-
Wood combustion	2.87	3.5	0.1 (d)	-
Refuse incineration	4.44	5.4	4.8 (d)	1.4 (d)
Sewage sludge incineration	0.54	0.7	8.0 (d)	30 (d)
Fluorescent tubes	0.94	1.1	2000 (a)	-
Thermometer breakage	0.4	0.5	200 (a)	-
Zinc recovery	5.26	6.4	17-90 (d)	-
Copper recovery	3.42	4.2	23-35 (d)	-
Lead recovery	<u>0.40</u>	<u>0.5</u>	7.8 (d)	-
Inadvertent total	51.29	62.4		
TOTAL	82.19	100.0		

**Emission factor units: (a) pounds mercury per ton of mercury processed or used, (b) pounds mercury per ton of chlorine produced, (c) pounds mercury per ton of mercury makeup added, (d) pounds mercury per 1000 tons of material burned or processed, (e) pounds mercury per billion cubic feet of gas consumed, (f) pounds mercury per ton ore.

*Negligible (<0.1%).

TABLE 2 PROVINCIAL MERCURY EMISSIONS (1970)

Province	Emissions (tons)					Percent of total
	Mercury production	Mercury consumption	Mercury compound consumption	Inadvertent emissions	Total	
Newfoundland	-	0.002	0.046	1.12	1.17	1.4
Prince Edward Island	-	0.001	0.023	0.22	0.24	0.3
Nova Scotia	-	0.267	0.053	2.29	2.61	3.2
New Brunswick	-	1.724	0.049	1.38	3.15	3.8
Quebec	-	7.630	0.520	14.14	22.29	27.1
Ontario	0.006	12.835	0.715	16.27	29.83	36.3
Manitoba	-	0.008	0.150	6.18	6.34	7.7
Saskatchewan	-	1.276	0.218	2.08	3.57	4.3
Alberta	-	0.016	0.249	2.32	2.59	3.2
British Columbia	1.81	3.124	0.170	4.75	9.85	12.0
Yukon and N.W.T.	-	-	0.001	0.54	0.54	0.7
TOTAL	1.82	26.88	2.20	51.29	82.18	100.0

TABLE 3 MERCURY PRODUCTION EMISSIONS (1970)

Province	Emissions (tons)			
	Mining ^a	Beneficiation ^b	Secondary recovery ^c	Distillation ^d Total
Newfoundland	-	-	-	-
Prince Edward Island	-	-	-	-
Nova Scotia	-	-	-	-
New Brunswick	-	-	-	-
Quebec	-	-	-	-
Ontario	-	-	0.004	0.002 0.006
Manitoba	-	-	-	-
Saskatchewan	-	-	-	-
Alberta	-	-	-	-
British Columbia	1.05	0.76	-	1.81
Yukon and N.W.T.	-	-	-	-
TOTAL	1.05	0.76	0.004	0.002 1.82

^aSection 4.1.^bSection 4.2.^cSection 4.3.^dSection 4.4.

TABLE 4 METALLIC MERCURY CONSUMPTION EMISSIONS (1970)

Province	Emissions (tons)					Total
	Chlor- alkali ^a	Dental amalgams ^b	Electrical equipment ^c	Gold recovery ^d	Instruments ^e	
Newfoundland	-	0.001	-	-	0.001	0.002
Prince Edward Island	-	0.001	-	-	-	0.001
Nova Scotia	0.26	0.006	-	-	0.001	0.267
New Brunswick	1.72	0.003	-	-	0.001	1.724
Quebec	7.58	0.040	0.0015	-	0.008	7.630
Ontario	12.53	0.072	0.0015	0.22	0.011	12.835
Manitoba	-	0.007	-	-	0.001	0.008
Saskatchewan	1.27	0.005	-	-	0.001	1.276
Alberta	-	0.014	-	-	0.002	0.016
British Columbia	3.04	0.021	-	0.06	0.003	3.124
Yukon and N.W.T.	-	-	-	-	-	-
TOTAL	26.4	0.17	0.003	0.28	0.03	26.88

^aTable 11.

^bTable 14.

^cEqually divided between Ontario and Quebec (Table 15).

^dTable 16.

^eTable 18.

TABLE 5 MERCURY COMPOUND CONSUMPTION EMISSIONS (1970)

Province	Emissions (tons)				Total
	Agricultural chemicals ^a	Paint manufacture ^b	Battery manufacture ^c	Pharmaceutical used	
New Brunswick	0.03	-	-	0.019	0.049
Newfoundland	0.03	-	-	0.016	0.046
Prince Edward Island	0.02	-	-	0.003	0.023
Nova Scotia	0.03	-	-	0.023	0.053
Quebec	0.33	0.009	-	0.181	0.520
Ontario	0.45	0.022	0.008	0.235	0.715
Manitoba	0.12	0.001	-	0.029	0.150
Saskatchewan	0.19	-	-	0.028	0.218
Alberta	0.20	-	-	0.049	0.249
British Columbia	0.10	0.004	-	0.066	0.170
Yukon and N.W.T.	-	-	-	0.001	0.001
TOTAL	1.5	0.036	0.008	0.65	2.20

^aTable 22.^bTable 25.^cSection 6.3.^dTable 28.

TABLE 6 INADVERTENT MERCURY EMISSIONS (1970)

Emissions (tons)									
Province	Paint appli- cation ^a	Combustion					Miscel- laneous wastes ^g	Metal recovery ^h	Total
		Coal ^b	Petro- leum ^c	Wood ^d	Refuse ^e	Sewage sludge ^f			
Newfoundland	0.19	0.01	0.70	0.18	-	-	0.04	-	1.12
Prince Edward Island	0.02	*	0.14	-	0.06	-	-	-	0.22
Nova Scotia	0.21	0.64	1.10	0.03	0.27	-	0.04	-	2.29
New Brunswick	0.15	0.09	0.89	0.03	-	-	0.03	0.19	1.38
Quebec	1.21	0.32	6.43	0.42	2.27	-	0.30	3.19	14.14
Ontario	2.18	5.24	6.33	0.23	1.31	0.38	0.48	0.12	16.27
Manitoba	0.31	0.01	0.66	0.43	0.25	0.16	0.07	4.29	6.18
Saskatchewan	0.21	0.62	0.72	0.36	0.12	-	0.05	-	2.08
Alberta	0.75	-	1.09	0.16	0.16	-	0.16	-	2.32
British Columbia	0.80	0.06	1.81	0.62	-	-	0.17	1.29	4.75
Yukon and N.W.T.	-	-	0.13	0.41	-	-	-	-	0.54
TOTAL	6.03	6.99	20.00	2.87	4.44	0.54	1.34	9.08	51.29

^aTable 30.^eTable 38.^bTable 33.^fTable 40.^cTable 34.^gTables 41 and 42.^dTable 37.^hTable 43.

*Negligible.

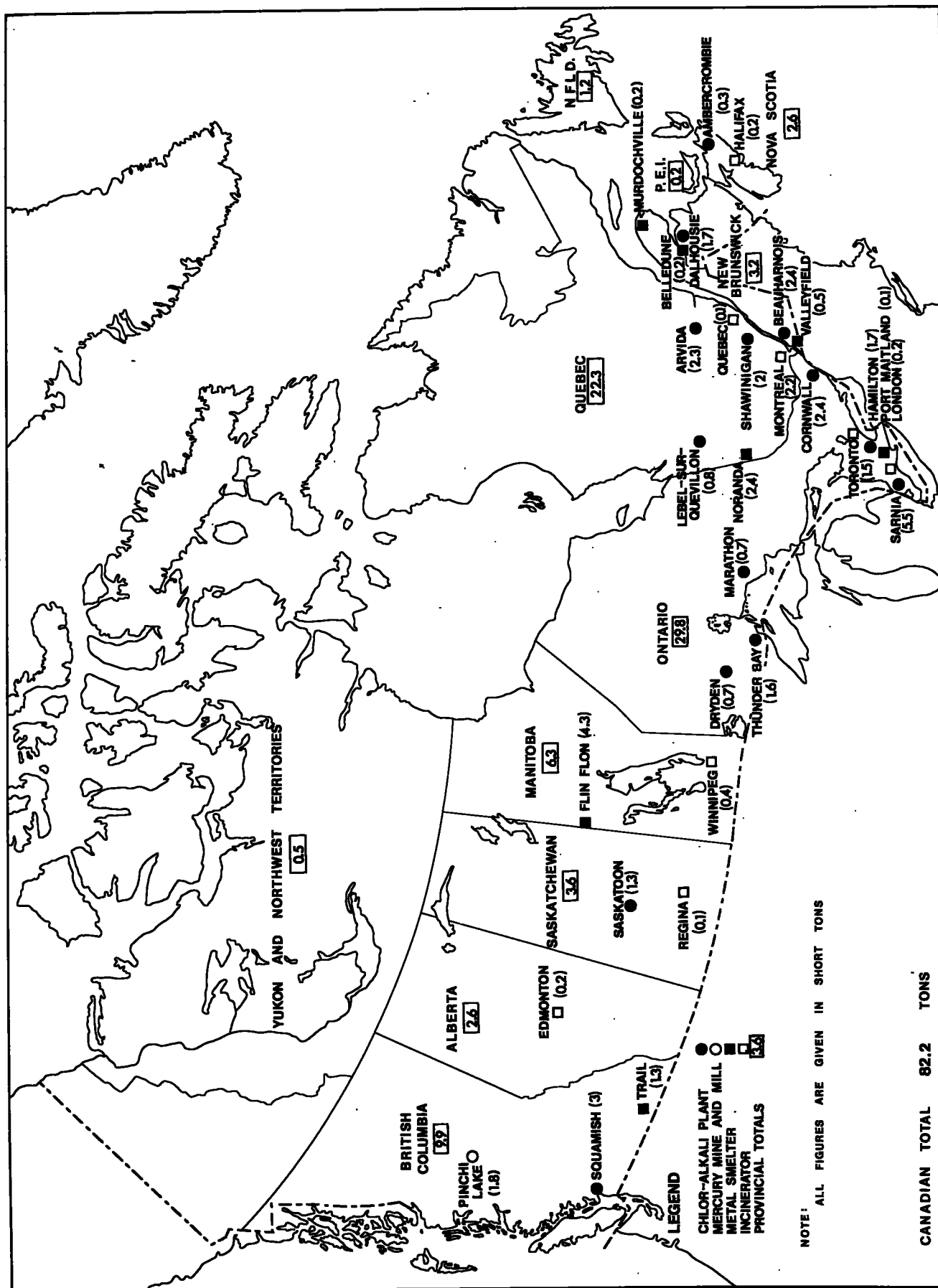


FIGURE 1: 1970 MERCURY EMISSIONS IN CANADA

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1 INTRODUCTION

1.1 Scope

The purpose of this report is to identify and quantify the major sources of emissions of mercury and mercury compounds in Canada for the year 1970. Data were drawn from government publications, reports of Statistics Canada, and numerous scientific papers. Particularly useful among these were the studies of Fimreite (19), Bangay (20), and Davis (21).

Most of the emission data given in this report were obtained, however, by sending questionnaires to companies and institutions that handle mercury. Virtually all major Canadian consumers and producers of mercury and mercury compounds are believed to have been contacted during the study.

1.2 Properties of Mercury and its Compounds

Mercury is a bluish white metal with a density 13.6 times that of water. With a freezing point of approximately -38°F and a boiling point of approximately 674°F , mercury is the only metal that is liquid under standard conditions. Its unique physical properties combining characteristics of both liquid and metal have led to the widespread use of mercury in medicine, science, and industry.

A mercury pool tends to vaporize until equilibrium between liquid and gaseous states is attained. As is illustrated by Figure 2, the saturation concentration of mercury in air at equilibrium increases sharply with temperature. Even at room temperature, vaporization produces a saturation concentration of approximately 13 mg/m^3 , which is well above the established threshold limit value of 0.05 mg/m^3 (1). The toxicity of mercury vapour as compared with the relative harmlessness of mercury liquid makes the vaporization phenomenon a vital one.

Air flows and mercury surface areas are generally such that the saturation concentration will not be reached. However, experiments have shown that an airflow of 1 litre/min over an area of 10 cm^2 of mercury becomes 15% saturated at room temperature (2). Significant vapour concentrations can therefore occur even when saturation is unlikely. To reduce this hazard, surface coatings such as sulphur powder and commercial

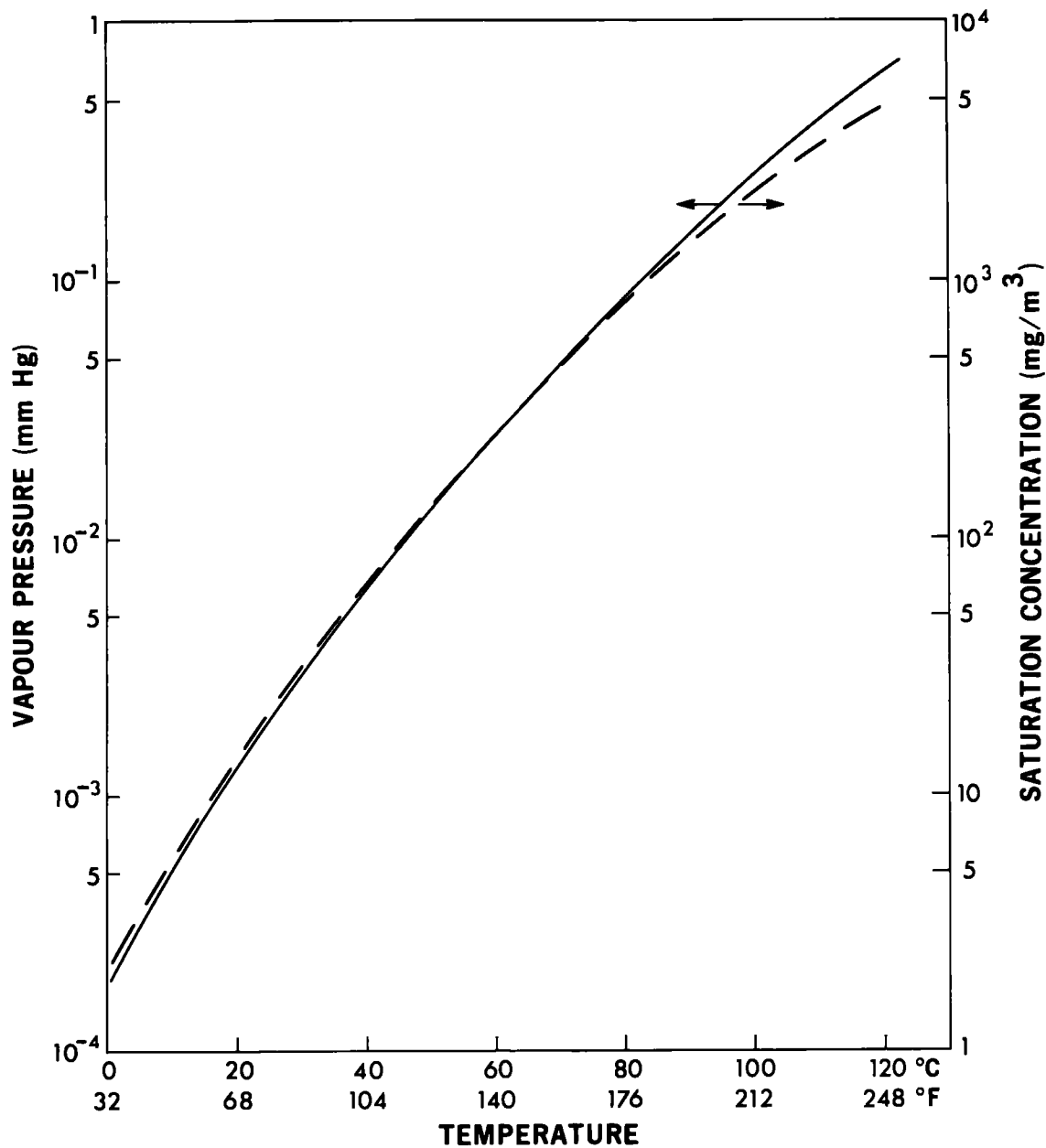


FIGURE 2 SATURATION CONCENTRATION AND VAPOUR PRESSURE OF MERCURY VERSUS TEMPERATURE (4)

hair spray can be used to decrease the vaporization rate (3).

Besides elemental mercury, modern society also uses numerous mercury compounds, both organic and inorganic. The properties of these compounds vary with their chemical makeup. Table 7 describes some of the more common mercury compounds in use. All mercury compounds are volatile, and most decompose to form mercury vapour. A few, however, notably the halides, sublime without decomposition (51).

Several mercury compounds occur naturally. Mercuric sulphide or cinnabar, for example, is the compound from which mercury metal is recovered. Microorganisms in underwater sludges have the ability to synthesize the highly toxic methylmercury compounds by combining elemental mercury with a one-carbon organic molecule. Human activities may significantly influence this process both by increasing the mercury levels in sludges and by discharging the nutrients on which the microorganisms thrive in sewage wastes (6). Subsequent biological concentration can lead to methylmercury levels in fish sufficient to cause fatal poisoning or permanent disability in humans if ingested. This phenomenon may have

TABLE 7 SOME MERCURY COMPOUNDS (4, 5)

Compound	Formula	Uses	Toxicity
Mercuric chloride (corrosive sublimate)	HgCl ₂	Agriculture, medicine	High
Mercuric oxide	HgO	Agriculture, paints, batteries	High
Mercuric sulphide (cinnabar)	HgS	Ore, pigment	Low
Mercurous chloride (calomel)	Hg ₂ Cl ₂	Agriculture, medicine	Low
Methyl mercuric propionate	CH ₃ HgC ₃ H ₅ O ₂	Agriculture	High
Phenylmercuric acetate	C ₆ H ₅ HgCOOCH ₃	Agriculture, paints	High
Phenylmercuric borate	(C ₆ H ₅ Hg) ₂ HBO ₃	Medicine	Low
Mercurin	C ₁₄ H ₂₅ HgNO ₅	Medicine	Low

played a role in the 1953 poisoning episode at Minamata Bay, Japan, as a result of the discharge of wastes containing mercury from a chemical plant (7). Much of the concern over the mercury hazard has resulted from the discovery of this natural methylation process.

1.3 Toxicity of Mercury and its Compounds

Toxic effects of mercury and its compounds vary widely. The elemental liquid itself and some mercury compounds can be ingested without harm (7). On the other hand, mercury vapour and other mercury compounds can produce both acute and chronic poisoning. Comprehensive reviews of toxicity levels and poisoning symptoms of mercury and its many compounds are available in several publications (4, 7, 8).

In acute cases, mercury vapour causes irritation and destruction of lung tissue with accompanying chills, fever, coughing, and tightness of the chest (7). Fatal cases of mercury vapour poisoning are relatively rare. Concentrations of 1.2 - 8.5 mg/m³ have resulted in acute poisoning (4).

Chronic poisoning effects are much more common, and occur in many industries where workers are exposed to low levels of mercury vapour for a long time period (7, 9). Symptoms include muscular tremors, inflammation of the gums, and general irritability (4, 7). In some cases, disability is permanent, although in others, reduced exposure combined with excretion of mercury by the body results in recovery.

Many salts and organic compounds of mercury are toxic. Some of the most toxic mercury compounds known are the methylmercury compounds, which occur both naturally and in many formulations in industry and agriculture. Once ingested, methylmercury is transported throughout the body by red blood cells. At blood levels above 1.4 ppm methylmercury fatal poisoning occurs (10). Between 0.4 ppm and 1 ppm, permanent brain damage occurs. Areas of the brain controlling balance, hearing, vision, and personality are involved. At these levels, fatal damage leading to cerebral palsy or mental retardation of an unborn child may also occur. For concentrations as low as 0.2 ppm methylmercury in blood, evidence of chromosome damage has been presented (7). Methylmercury poisoning has occurred in the Minamata Bay episode mentioned previously where contaminated fish were involved (11), and in a few isolated cases involving the

consumption of grain treated with methylmercury pesticides.

Threshold limit values have been set at 0.01 mg/m^3 for methylmercury compounds in air and 0.05 mg/m^3 for mercury vapour and all other mercury compounds (1). These levels have been established to protect persons working an 8-h day in industry, whereas the principal concern for the general population has been methylmercury intake via the food chain. Guidelines of 0.5 ppm mercury in food and 0.5 ppb mercury in water have been suggested by computing the acceptable daily intake of mercury for an individual on an 'average' diet (1, 12). Application of these guidelines has resulted in the banning of fishing in several areas across Canada (13, 18) where industrial wastes have apparently led to high mercury levels in fish, and in the banning of hunting of some types of birds in the prairies (14) where eating treated grain has apparently led to high mercury levels in these birds. Mercury levels in water (15) and in other foods (16) have been monitored, and are below the guideline concentrations.

Continuing study is being carried out on the persistence of methylmercury in the environment. Although mercury discharges have been and will continue to be reduced, methylation of mercury wastes released in the past will continue. High mercury levels in fish may therefore persist for decades (10). Various methods of removing or otherwise controlling mercury in lake-bottom sludges are currently under consideration (17).

2 NATURAL MERCURY BACKGROUND

Although human activities have produced high mercury concentrations locally and the rate of release of mercury by human activities has, for the last few years, been higher than that released by natural processes, nevertheless man's contribution to all the mercury contained in the air and oceans of the world has been negligible (22). Natural processes have, since time immemorial, resulted in the circulation of quantities of mercury through the environment.

Mercury concentrations in the earth's crust vary widely with location and rock type (23), but the overall mercury abundance has been

TABLE 8 MERCURY CONTENT OF ROCK (23, 26)

	Mercury (ppb)	
	Range	Average
IGNEOUS		
Ultrabasic	7-250	168
Basic extrusives	5- 40	20
Acidic extrusives	2-200	62
METAMORPHIC		
Amphibolites	30- 90	50
Hornfels	35-400	225
Marbles	10-100	50
SEDIMENTARY		
Sandstones	<10- 300	55
Carbonaceous shales	10-3250	437
Limestones	<10- 220	40

variously estimated at 50 ppb (23) and 80 ppb (22). Typical mercury concentrations in different rock types are given in Table 8. Significantly higher concentrations occur in the 'mercuriferous belts' of the earth's crust where most mercury mines, including the Canadian mine in British Columbia, are located. Isolated concentrations also occur outside the mercuriferous belts such as at Clyde Forks, Ontario (23).

Through weathering, erosion, volcanic activity, and other natural processes mercury is released into the atmosphere and hydrosphere. Precipitation will subsequently wash some atmospheric mercury into soils and watercourses. The rate of weathering for the entire earth has been estimated at 10^{10} tons/year (22), which indicates an annual mercury release of 500 - 800 tons. As Canada constitutes approximately 6% of the world's land area, it is estimated that 30 - 50 tons of mercury are released every year by natural processes.

Measured levels of mercury in soils, air, and water from this natural release are given in Table 9. Although initially released in inorganic form, some of the mercury in the environment will likely be methylated by microbiological action (6). The occurrence of methylmercury

TABLE 9 BACKGROUND MERCURY LEVELS (23, 26)

	Mercury	
	Range	Average
WATERS (ppb)		
Rain	0.05 -0.48	0.20
Snow	0.005-0.95	0.01
Oceans	0.03 -0.5	0.20
Streams, lakewaters	0.01 -0.10	0.03
Ground water	0.01 -0.10	0.05
SOILS (ppb)		
Soils	20-150	70
Tills, sand	20-100	50
Weathered crust	50-200	100
AIR (ng/m³)		
Atmosphere	0.2-10	
Over mercury deposits	30-1600	
Volcanic exhalations	100-9600	

in fish is therefore a natural process, and not only a result of human activities. This fact has been verified by the observation that mercury levels in museum specimens of tuna and swordfish are comparable to those found in today's specimens of ocean-going fish (24). However, museum specimens of fresh water fish from the Great Lakes have been shown to contain less mercury than do fish caught at present (25). These observations provide evidence of manmade mercury imbalances on a local scale that are not apparent on a global scale.

Even without human input, therefore, plant and animal life have been exposed to mercury. Natural mercury levels in plants of 300 - 700 ppb dry weight have been measured, although as much as 30 000 ppb may occur near mercuriferous belts (26). Similarly, terrestrial animals including man contain 1 - 100 ppb mercury (26). Concentrations in specific areas of the body will be higher than the figures quoted; for example, normal human kidneys contain up to 26.3 ppm mercury (27).

A final noteworthy point concerning natural mercury levels is that many raw materials and fuels contain trace amounts of mercury. Mercury concentrations in some of these materials are listed in Table 10. As

TABLE 10 MERCURY CONTENT OF RAW MATERIALS

Minerals (23, 26)	Mercury range (ppm)	Coals	Mercury range (ppm)	Other fuels	Mercury range (ppm)
Grey copper ores	5 - 500	General (23)	0.001-300	Residual fuel oil (31)	0.35 0.39 0.22 0.10
Galena	0.04- 70	West Virginia (28)	0.3		
Chalcopyrite	0.1 - 40	Alberta (29)	0.001	Wood (32, 33)	0.02-0.1
Native gold	1 - 100	British Columbia (30)	0.04	Natural gas (Alberta) (34)	<0.001-0.0015
Dolomite	0.1 - 50				
Quartz	0.01- 2				
Sphalerite	0.1 - 200				
Wurzite	0.1 - 200				

discussed in section 7.2 of this report, the inadvertent release of these trace amounts of mercury during processing or combustion operations constitutes a significant source of emissions.

3 FLOW OF MERCURY AND ITS COMPOUNDS THROUGH THE CANADIAN ECONOMY IN 1970

3.1 Metallic Mercury

In 1970, metallic mercury was both imported and produced domestically in Canada. Small quantities were also recovered from scrap dental amalgams. Principal uses were in the production of chlorine and caustic soda, the restoration of teeth with mercury amalgams, the production of electrical apparatus, and the recovery of gold. Mercury is sometimes purified by distillation before use. Estimates of the amounts of metallic mercury involved in trade and consumption, based on information from Statistics Canada (35), the Department of Energy, Mines, and Resources (36), and the results of our survey are summarized in Figure 3.

3.2 Mercury Compounds

Mercury compounds are used principally in agriculture, paint manufacture, alkaline battery manufacture, and medicinal applications. Based on Statistics Canada data (35, 37, 38, 39) and the results of our survey, the amount of mercury contained in these compounds is estimated in Figure 4. Details of the method of calculation of these figures are given in the discussion of emissions from each of these sources.

4 EMISSIONS FROM THE PRODUCTION OF MERCURY

4.1 Mercury Mining

In 1970, the only mercury mine in Canada was located in the Pinchi Lake area of British Columbia. Conventional underground mining techniques are employed to remove approximately 800 tons ore/day containing an average of 0.25% mercury as mercuric sulphide (cinnabar). Ore is broken by drilling and blasting, and is transported by truck up the main tunnel to the storage bins. In 1970, approximately 990 tons of mercury were recovered at Pinchi Lake.

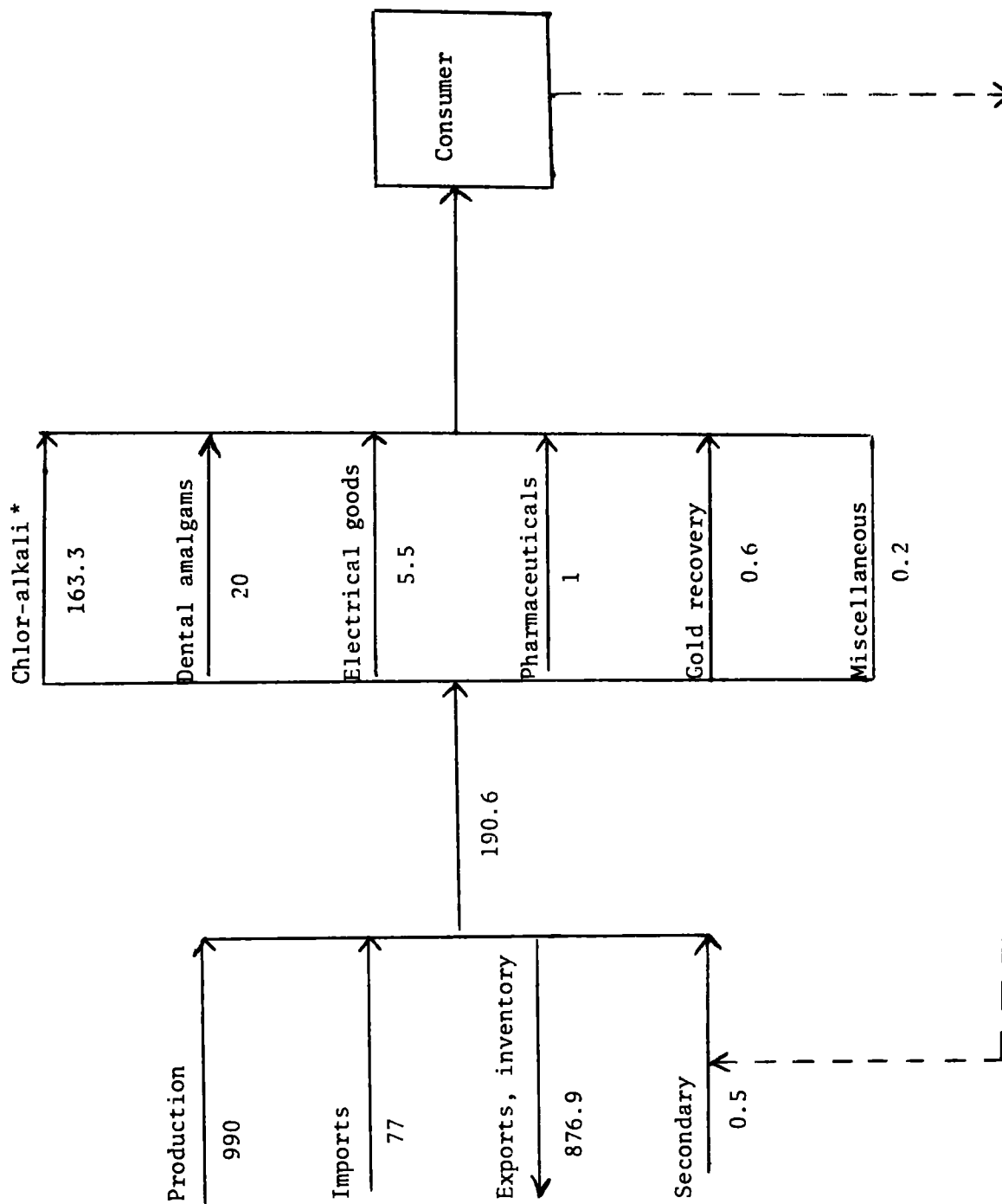


FIGURE 3 CANADIAN TRADE AND CONSUMPTION OF METALLIC MERCURY (1970) (SHORT TONS)

*Includes mercury usage for operational requirements, new equipment and installations, and stockpiles.

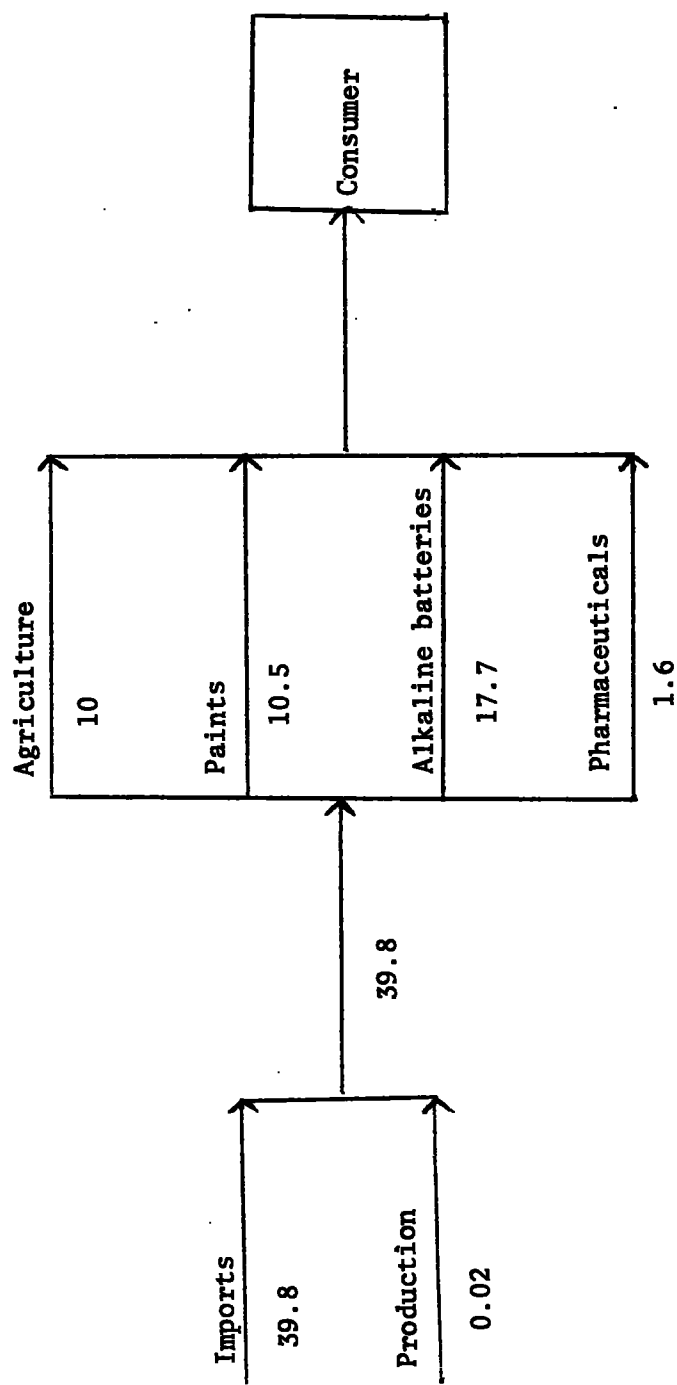


FIGURE 4 CANADIAN TRADE AND CONSUMPTION OF MERCURY IN MERCURY COMPOUNDS (1970) (SHORT TONS)

Extensive mine ventilation and rock wetting techniques are used to maintain low levels of cinnabar dust and mercury vapour for protection of the workers. Unlike some other mercury mines, no elemental mercury droplets are found in the ore at Pinchi Lake. Although cinnabar is not considered toxic, the mercury vapour hazard still exists, particularly during blasting operations when heat causes decomposition of the ore. Upon this writing in late 1972, good occupational health practices have resulted in the complete absence of mercury poisoning among workers at Pinchi Lake since the mine reopened in 1968 (40).

Emissions of mercury from the Pinchi Lake mine could not be supplied by the company involved. However, using the mine ventilation volumes supplied and assuming a mercury concentration of 0.05 mg/m^3 , which equals the threshold limit value, an annual mercury release of 115 lb has been estimated. The corresponding emission factor becomes 0.12 lb mercury/ton mercury produced. No controls are used on mine ventilation exhaust.

An additional emission will result from the handling and transportation of the ore outside the mine. This uncontrolled emission can be estimated using the Environmental Protection Agency figure of 2 lb/ton for emissions from rock handling processes (41).

Based on the foregoing analysis, emissions from mercury mining are summarized as follows:

Source	Emission factor		1970 emissions (tons)
	lb/ton ore	lb/ton mercury	
Mining operation	0.0003	0.12	0.06
Rock handling	0.005	2.0	0.99
TOTAL	0.0053	2.12	1.05

Information on the form of the emissions was also unavailable. The mercury is expected, however, to be released as mercuric sulphide dust and mercury vapour.

4.2 Beneficiation of Cinnabar Ore

Recovery of metallic ore from cinnabar ore also takes place at Pinchi Lake, British Columbia. Ore from the storage bin is subjected to

primary and secondary crushing before passing to grinding and flotation processes in the concentrator. Cinnabar concentrate is then filtered and roasted in a multiple hearth propane-fired furnace. Mercury vapour thus driven off is condensed along with soot impurities in air-cooled condensers. The condensed mercury is cleaned by agitation in a closed vessel and bottled in 76-lb flasks for shipment.

Atmospheric emissions from the beneficiation process consist of cinnabar dust and mercury vapour from the crushing operations and mercury vapour from the roasting operation. Mercury emissions are also carried with the ventilation air from the roaster building. A cyclone with an estimated efficiency of 80% is used on the mill exhaust whereas gases from the mercury condensers pass through a wash tower before being discharged into the atmosphere.

Solid wastes from the process consist of material from the flotation and filtration operations and calcine wastes from the roaster. These are sent to a tailings pond. Monitoring of mercury levels in adjacent Pinchi Lake have shown no change since operations were restarted (40).

Only partial data on milling emissions were available. A 1970 emission of 1068 lb mercury from the roaster stack, after the wash tower, was reported. The corresponding emission factor becomes 1.08 lb mercury/ton produced.

Emissions from the crushing of the ore were 275 lb. An emission factor of 0.28 lb mercury/ton mercury produced is estimated.

Finally, mercury emissions carried in ventilation air from the roaster building have been computed using data on airflow rates and mercury levels reported by the company. Accordingly, 175 lb mercury are estimated to be emitted annually from this source. The indicated emission factor becomes 0.18 lb mercury/ton produced.

Emissions from the beneficiation of cinnabar ore are summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Roaster	1.08	0.53
Crusher	0.28	0.14
Roaster ventilation	0.18	0.09
TOTAL	1.54	0.76

The estimate of emissions of mercury vapour and cinnabar dust above assumes that a wash tower is used for control on the roaster exhaust and a cyclone of 80% efficiency is used on the crusher exhaust. The figure of 0.25% mercury in the ore processed produces an emission factor of 0.0038 lb mercury/ton ore processed.

4.3 Secondary Production

A small amount of mercury was recovered from scrap dental amalgams in 1970. Typically, amalgam is heated in an iron retort and the mercury vapour is recovered in a water-cooled condenser. Only one company located in Toronto indicated that it produced such secondary mercury in 1970. The total amount produced was 847 lb.

Emissions from secondary recovery are uncontrolled, and consist of mercury vapour escaping from the iron retort and condenser. Data from the above company indicate a 2% mercury loss in these operations. One-half of this loss is assumed to become an atmospheric emission.

Emissions from the recovery of mercury from dental amalgams are accordingly summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Secondary mercury	20	0.004

4.4 Distillation of Mercury

The purity of mercury required for some applications requires that the prime virgin mercury be distilled before use. Distillation is required even though virgin mercury is the purest primary metal known, because impurities tend to form amalgams which float on the mercury surface. Under this scum, prime virgin mercury is typically 99.9% pure (5).

One company in Valleyfield, Quebec, and three companies in Toronto reported that they purified mercury by distillation. Emissions were reported to be negligible as the operation is totally enclosed. The largest distilled mercury supplier, however, did supply emission information. The indicated emission factor was calculated to be 0.06 lb mercury/ton distilled. Using this factor, and the reported total of 61.3 tons of mercury distilled, emissions are summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Mercury distillation	0.06	0.002

From reported quantities of mercury distilled, approximately 99.6% of the above loss was emitted in Toronto, and the remaining 0.4% was emitted in Valleyfield.

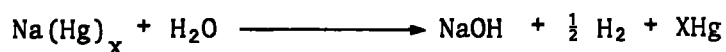
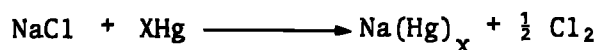
5 EMISSIONS FROM THE USE OF METALLIC MERCURY

5.1 Chlor-alkali Industry

As indicated in Figure 3, the largest use of mercury in Canada in 1970 was in the production of chlorine and caustic soda from brine. Before the 1930's, the diaphragm cell was used exclusively in this industry. Since then, however, mercury cells have captured a large share of the market. In 1970, about 57%, or 480 000 of the total of 840 000 tons of chlorine manufactured in Canada, were produced in mercury cells (42). The high power requirement of the mercury cell per ton of chlorine is offset by its ability to produce a stronger sodium hydroxide solution than does the diaphragm cell. The 50% caustic solution produced by mercury cells can be used without further treatment by the pulp and paper industry.

Typically, a plant producing 100 tons of chlorine per day has 40 cells, each having a sloping trough 50 ft x 3 ft in dimension containing 3000 - 4000 lb mercury. Brine solution passes between graphite anodes and a flowing mercury cathode. Chlorine ions migrate to the anodes, where they bubble off as chlorine gas. Sodium ions migrate to the cathode where they form a mercury amalgam. The depleted brine solution is resaturated with salt, filtered, and returned to the cell. The sodium-mercury amalgam enters a denuder section where a reaction with water at approximately 180 °F produces sodium hydroxide solution and hydrogen gas. Mercury from the denuder section is returned to the brine cell.

The chemical reactions of interest are given by (43):



Principal products are chlorine gas and sodium hydroxide solution. Hydrogen gas is usually considered a waste product and is vented to the atmosphere through a water-cooled condenser. Sometimes, however, hydrogen was used as a fuel or as a reactant in the production of other chemical compounds.

As electrolysis continues, small amounts of mercury are continuously lost in the products and effluents of the process. Every six to eight months, an individual cell is shut down to remove accumulated sludges as cleanliness is important in maintaining a uniform mercury film. At this time, the mercury volume in the cell is measured and adjusted to return the cell to its optimum operating point. Our survey revealed that from 10 to 50% of the mercury lost could not be accounted for by the amounts measured in the products and effluents of the cell. This unaccountable mercury is believed to be trapped in the walls, floors, and piping of the cell building itself (44). Accordingly, significant levels of mercury vapour may exist within the cell house despite high ventilation rates. Cases of mercury poisoning among workers have been reported (9).

Emissions from the chlor-alkali industry have been estimated on the basis of questionnaires returned by the plants listed in Table 11. Although a 100% response from the chlor-alkali industry was obtained, some

TABLE 11 MERCURY CELL CHLOR-ALKALI PLANTS (1970)

Location	Chlorine production (1000 tons) ^a	Percent of total
Dalhousie, N.B.	30.6	6.5
Abercrombie, N.S. ^b	4.8	1.0
Arvida, Que.	42.5	8.9
Shawinigan, Que.	36.0	7.5
Lebel-sur-Quevilon, Que.	14.9	3.1
Beauharnois, Que.	44.2	9.2
Marathon, Ont.	13.0	2.7
Cornwall, Ont.	43.2	9.0
Hamilton, Ont.	31.6	6.6
Sarnia, Ont.	99.6	20.7
Thunder Bay, Ont.	28.8	6.0
Dryden, Ont.	11.9	2.5
Saskatoon, Sask.	23.4	4.8
Squamish, B.C.	55.5	11.5
TOTAL	480.0	100.0

^a Estimates based on capacities and production data supplied in questionnaire returns and in Reference 42.

^b Started operation in August, 1970.

crucial figures were not released in those cases where companies were involved in legal actions; other plants could only supply partial information. However, as approximately 10 emission figures were available, meaningful averages could be computed. These average figures and the range of data reported are given in Table 12. Mercury vapour emissions are summarized on the basis of reported information as follows.

Source	Emission factor (lb mercury/ton chlorine)	1970 emissions (tons)
Hydrogen gas	0.03	7.2
Ventilation air	0.08	19.2
TOTAL	0.11	26.4

The degree of emission control represented by the above emission figures is difficult to assess. The wide range shown in Table 12 results partially from variations in the cells of different plants as well as from differences in control equipment. Several questionnaire returns also noted that 1970 was a year of transition for the chlor-alkali industry. The mercury hazard had been demonstrated, and steps to reduce mercury losses were being taken. These improvements are still continuing.

In Table 13, the results of our survey have been compared with data reported by Flewelling (45). The 1970 figures are in good agreement.

TABLE 12 MERCURY EMISSIONS FROM CHLOR-ALKALI PLANTS (1970)

Source	Mercury loss (lb/ton chlorine produced)	
	Range	Average
Products		0.03*
NaOH		0.03
Cl ₂		0.00003
Gaseous emissions		0.11*
H ₂	0.03 - 0.24	0.03
Ventilation		0.08
Liquid effluents and solid wastes		0.05*
H ₂ cooler		0.003
Drains		0.010
Solids		0.036
Unaccounted for	0.03 - 0.17	0.15*
TOTAL	0.08 - 0.87	0.34*

* The total is the sum of the values marked by asterisks.

TABLE 13 MERCURY EMISSION ESTIMATES FOR CHLOR-ALKALI PLANTS (1970)

Source	Mercury loss (lb/ton chlorine produced)	
	Present study	Flewelling (45)
Products	0.03	0.02
Gaseous emissions	0.11	0.10
Liquid, solid wastes	0.05	0.21
Unaccounted for	0.15	0.03
TOTAL	0.34	0.36

A large part of the mercury emissions that was unaccounted for in our questionnaire replies was lost through the drainage trenches, which transport most solid and liquid effluents from the cell house.

5.2 Dental Amalgams

To make dental fillings, mercury is mixed with a finely divided metal alloy to produce an amalgam that can be molded. Typically, the alloy powder contains 65 - 70% silver, 25% tin, <6% copper, <2% zinc, and <3% mercury. Mercury is added to produce a filling containing approximately equal parts of alloy material and mercury. After the amalgam is packed into a dental cavity, it sets to a mass sufficiently hard to carve in 90 s, becomes unmalleable in 2 h, and reaches a compressive strength of 30 000 to 50 000 psi in 24 h (46).

Data from dental suppliers indicate an average annual use of 7 lb mercury per dentist. The questioning of a few individual Toronto dentists has supported this figure, since mercury uses of 5 - 15 lb/year were reported. As there were 7156 dentists in Canada in 1970 of which approximately 5725 performed dental restorations (47), the estimated mercury consumption is 20 tons.

Mercury fillings in teeth have been shown to emit small amounts of mercury for only the first few days after treatment (48).

Danger to the patient is considered negligible, although in a few sensitive individuals reactions to mercury have occurred, requiring removal of the fillings (49).

The mercury hazard to dental personnel, however, is considered significant (50, 51). During mixing and handling of the amalgam material, mercury vapour is emitted. Fine amalgam dust containing mercury is created during drilling and grinding of both new and old amalgam materials. Excess amalgam is often trapped in the cuspidor and may be stored in the dental office for later processing by secondary recovery industries. In addition, dental office decor often makes cleanup of mercury vapour sources impossible, as small mercury droplets and amalgam dust penetrate cracks and coverings on floors and walls. Both American and Canadian Dental Associations have published several articles dealing with proper mercury handling procedures in an attempt to lessen the poisoning hazard (52, 53).

Data on emissions from dental offices could not be supplied by anyone in the dental field. As an alternative, a study that monitored mercury levels in the offices of 50 New York dentists was used to generate emission information. Including both mercury vapour and amalgam dust, mercury levels in these 50 offices averaged 0.045 mg/m^3 although 14% of the levels were above 0.1 mg/m^3 (51).

Ventilation rates in modern office buildings typically produce two fresh air changes per hour. However, as many dental offices are located in older buildings, it is assumed that one air change per hour is a more representative figure. For a 68 m^3 room (20 ft x 15 ft x 8 ft), the mercury carried into the environment with ventilation air during one year becomes:

$$0.045 \frac{\text{mg}}{\text{m}^3} \times 68 \text{ m}^3 \times 1 \frac{\text{air change}}{\text{h}} \times 24 \frac{\text{h}}{\text{day}} \times 365 \frac{\text{days}}{\text{year}}$$

$$= 26.8 \text{ g}$$

Assuming that 7 lb mercury are used during the year, the emission factor is then 16.9 lb mercury/ton used. Using this factor, emissions in 1970 are given in Table 14 and are summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Dental offices	16.9	0.17

TABLE 14 MERCURY EMISSIONS BY DENTISTS (1970)

Province	Dentists in private practice (47)	Percent	Mercury emissions (tons)
Newfoundland	48	0.8	0.001
Prince Edward Island	22	0.4	0.001
Nova Scotia	195	3.4	0.006
New Brunswick	104	1.8	0.003
Quebec	1343	23.5	0.040
Ontario	2410	42.1	0.072
Manitoba	244	4.3	0.007
Saskatchewan	179	4.1	0.005
Alberta	457	8.0	0.014
British Columbia	723	12.6	0.021
TOTAL	5725	100.0	0.17

5.3 Electrical Equipment Manufacture

The properties of mercury have been found useful in many electrical applications. In silent switches, a drop of mercury is used to complete the circuit. In power tubes, the ionization of mercury permits the flow of high currents. A mercury-zinc amalgam forms the anode of the alkaline battery. The vacuum requirements of electrical lamps and tubes may be produced by a mercury diffusion pump. Mercury forms a part of fluorescent tubes, neon lighting, and mercury vapour lamps.

TABLE 15 ELECTRICAL COMPANIES USING MERCURY (1970)

Location	Products containing mercury
Drummondville, Quebec	Lamps
Trois Rivieres, Quebec	Lamps
Mississauga, Ontario	Alkaline batteries
Oakville, Ontario	Lamps
Toronto, Ontario	Lamps Alkaline batteries

The locations of electrical companies reporting the use of mercury in 1970 are given in Table 15. In Canada, the major uses are in the manufacture of lamps and batteries. Silent switch manufacture was also reported in a questionnaire return, but, in this case, the mercury was imported from the United States already enclosed in a capsule that forms part of the switch. No emissions resulted in this use.

To manufacture a standard fluorescent tube, glass tubes are cleaned and filled with phosphor materials in a water suspension. The solution is removed and the tubes are dried to leave a phosphor coating on the interior surface. After the end-caps are attached, the tubes are evacuated through a small glass line in one of the caps. The system is then flushed with argon several times. A small amount of argon is left in the tube, producing about 0.5 psi pressure. At this point approximately 50 mg of mercury are added automatically, and the glass line is sealed.

In use, the low pressure mercury vapour gives off ultraviolet radiation when an electric current passes through the tube. This ultraviolet radiation causes fluorescent of the phosphor coating. Light quality is improved by the visible light emissions of the argon in the tube. In 1970, 2500 lb mercury were estimated to be used in the manufacture of fluorescent tubes by Canadian companies (54).

The manufacture of mercury vapour street lamps is similar. A quartz tube of typical size 4 in. long by 3/5 in. in diameter is evacuated, and backfilled with argon. On average, 90 mg mercury are then added, although this amount might vary from 15 to 300 mg depending on lamp size (54). The quartz tube is subsequently sealed and placed inside a glass envelope, which is evacuated and filled with nitrogen. This inert atmosphere prevents oxidation of the electrodes at the high temperatures produced in operation.

The high power and mercury vapour pressure associated with the mercury vapour lamp result in the generation of visible radiation along with smaller amounts of ultraviolet radiation. Phosphor coatings are sometimes applied to the glass envelope to utilize the ultraviolet component, but often only clear glass is used. In 1970, 88 lb mercury were estimated to be used in mercury vapour lamp production in Canada (54).

Mercury vapour also plays a role in neon lighting. For example, green and blue lighting is obtained by using mercury vapour in combination with argon and neon at low pressures (55). Only small specialty companies are thus employed in Canada. The amounts of mercury involved are believed to be negligible (54).

The use of metallic mercury in the manufacture of alkaline dry cell batteries is limited to the manufacture of the anodes. Small amounts of mercury are amalgamated with zinc to prevent hydrogen overvoltage at the anode. From questionnaire replies, 8500 lb mercury are estimated to have been used in battery manufacture in 1970.

Concern with occupational exposure has prompted the monitoring of mercury vapour levels by some electrical companies. It has been assumed that, since handling operations involving mercury are similar in different segments of the industry, the emission factor calculated from these monitoring programs can be applied to the entire industry. Accordingly, uncontrolled mercury vapour emissions are summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Battery anode manufacture	1.1	0.0023
Fluorescent tube manufacture	1.1	0.0007
Mercury vapour lamp manufacture	1.1	0.00002
TOTAL		0.003

Atmospheric losses constitute 0.055% of the mercury handled.

5.4 Recovery of Gold

In the past, large quantities of mercury were used in gold recovery. During processing of raw ore, gold forms an amalgam with the mercury. Subsequent heating volatilizes the mercury and leaves the gold behind. Although condensers recover most of the mercury for re-use, the mercury volume must continuously be adjusted, indicating that some mercury is lost in the effluents of the process.

Today, the cyanidation process has replaced amalgamation at all but a few mining locations. At these locations, cyanidation and amalgamation are usually both employed. In 1970, only 1155 lb mercury were consumed in gold recovery operations (35). The location of mines reporting such use are given in Table 16.

TABLE 16 MERCURY EMISSIONS FROM GOLD RECOVERY (1970)

Mines using mercury (35)	Mercury emissions (tons)
Cadwallader Creek, B.C.	0.06
Balmertown, Ontario	} 0.22
Madsen, Ontario	
Cochenour, Ontario	
South Porcupine, Ontario	
TOTAL	0.28

The mines contacted were unable to supply any emission data. Typically, the only figures available were the makeup volumes added to the process. In the absence of emission data, 50% of the mercury added has been assumed to become an atmospheric emission of mercury vapour. The remaining 50% is assumed to be contained in liquid and solid wastes of the process. On this basis, mercury emissions from gold recovery are summarized as follows.

Source	Emission factor (lb/ton mercury makeup)	1970 emissions (tons)
Gold recovery	1000	0.28

Provincial emissions have been estimated in Table 16 according to the number of mines reporting mercury use.

As all other metals except iron form an amalgam with mercury, recovery by amalgamation has also been practised for such metals as silver and zinc (56). No such uses were reported in replies to our questionnaire, however. This fact, coupled with the declining use of mercury in gold recovery, suggests that mercury and amalgamation processes in mining operations are likely to remain unimportant or perhaps may even disappear in the next few years.

5.5 Pharmaceutical Manufacture

Several mercury compounds are used in medicine as antiseptics or diuretics. These compounds are discussed in more detail in section 6.4. In this section, we are concerned with losses incurred during the manufacture of mercury pharmaceuticals from liquid mercury.

In 1970, Statistics Canada indicated that 1962 lb mercury were used by the pharmaceutical industry (35). The one major company involved, located in Quebec, was contacted during the study, but could not supply emission figures. However, reasonable estimates can be made using the 0.055% loss calculated in section 5.3. On this basis, emissions are summarized as follows.

Source	Emission factor (lb/ton mercury)	1970 emissions (tons)
Pharmaceutical manufacture	1.1	0.0005

5.6 Mercury Compound Production

The use of mercury compounds in agriculture, paint manufacture, and battery manufacture is discussed in section 6. In this section, we are concerned with losses from the production of the compounds used by these industries.

Statistics Canada reports that only 76 lb mercury were used in the manufacture of chemicals in 1970 (35). This small figure confirms the conclusion reached in our survey that essentially all mercury compounds used in Canada are imported, primarily from the United States. Only one company, located in Toronto, reported the manufacture of mercury compounds in 1970. Emissions were considered to be well controlled, and of negligible magnitude (69).

As summarized in Figure 4, mercury compounds containing about 40 tons of mercury were used in Canada in 1970. Emissions from the production of these compounds will be confined largely to dust created during repackaging of chemicals imported in bulk. On this basis, emissions are concluded to be negligible.

5.7 Instrumentation

Metallic mercury is a vital part of numerous industrial and scientific instruments. A few of these are described in Table 17.

Emissions from these instruments are mainly in the form of mercury vapour losses during operation and during cleaning and refilling. Losses from thermometers, which will occur only during manufacture and not through normal use, are believed to be insignificant in comparison with losses from instruments containing mercury open to the air, or instruments whose mercury is periodically cleaned.

TABLE 17 INSTRUMENTS USING MERCURY (60, 61)

Instrument	Use
Thermometer	Temperature measurement
Barometer	Atmospheric pressure measurement
Manometer	Pressure measurement
McLeod gauge	Vacuum measurement
Diffusion pump	Vacuum technology
Coulter counter	Red blood cell count
Van Slyke apparatus	Gas content of blood measurement
Cantor tube	} Clearance of intestinal obstructions
Miller-Abbot tube	
Scholander gas analyzers	Gas analysis
Polarograph	Electolytic analysis

Many papers have been published regarding the mercury vapour hazard in schools (57, 58), universities (59, 60), and hospitals (61, 62). In these publications mercury levels similar to those measured in dental offices have been reported. Emissions are therefore calculated using the dental emission factor found previously.

Although a relatively small amount of mercury, estimated at 300 lb, was purchased for instrumentation in 1970, emissions result from the re-use of old mercury as well as the use of new mercury. Following Biram (63), a 4% inventory loss through spillage etc. may be considered reasonable. This indicates that 3.8 tons of mercury were in use in instrumentation in 1970, since 300 lb were required to make up losses.

Mercury vapour emissions from instrumentation therefore are estimated as follows.

Source	Emission factor (lb/ton mercury used)	1970 emissions (tons)
Instruments	16.9	0.03

Provincial figures are estimated according to population in Table 18.

TABLE 18 MERCURY EMISSIONS FROM INSTRUMENTS (1970)

Province	Population (98) (x1000)	Percent	Mercury emissions (tons)
Newfoundland	524	2.4	0.001
Prince Edward Island	111	0.5	*
Nova Scotia	770	3.6	0.001
New Brunswick	632	2.9	0.001
Quebec	6030	27.8	0.008
Ontario	7815	36.1	0.011
Manitoba	988	4.5	0.001
Saskatchewan	928	4.3	0.001
Alberta	1634	7.6	0.002
British Columbia	2196	10.1	0.003
Yukon and N.W.T.	53	0.2	*
TOTAL	21681	100.0	0.03

*Negligible.

6 EMISSIONS FROM THE USE OF MERCURY COMPOUNDS

6.1 Agricultural Chemicals

Mercury compounds have been found effective treatment against a variety of plant diseases (19, 64). Some of the diseases treated with inorganic mercurials are listed in Table 19, and organic mercurials used in Canada are described in Table 20.

As was mentioned in section 5.6, essentially all mercury compounds used in 1970 were imported in bulk and repackaged for sale in Canada. Powder, drill-box, and liquid preparations were available.

The major uses of mercury compounds were as turf and horticultural fungicides and seed treatments. For the control of turf diseases in lawns, golf courses, bowling greens etc., compounds

TABLE 19 USE OF INORGANIC MERCURIALS (HgCl , Hg_2Cl_2)^a IN AGRICULTURE (64)^b

Crop	Disease controlled	Method
Calla lily	Root rot	Soak rhizomes
Canna	Bud rot	Soak corms
Celery	Leaf blight	Treat seeds
Cabbage etc.	Black rot, club root	Treat seeds, seedlings
Pepper	Bacterial spot	Treat seeds
Potato	Scab	Treat seed potatoes
Rose .	Crown gall	Treat soil
Tomato	Bacterial leafspot	Treat seeds
Turf	Brown patch	Spray turf

^aSold in compounds containing 2 - 73% mercury (19).

^bSuppliers and detailed chemical and agricultural properties are given in Reference 65.

containing 6 - 73% mercury are applied. As much as 15 lb mercury/acre may be used. In horticulture, mercurials have been used to treat such diseases as scab in apples and pears, late blight in potatoes, and leaf mould in tomatoes (19). Organic mercurials, usually containing 1 - 2% mercury (65), are applied to grain seeds to prevent such diseases as common bunt in wheat, loose and covered smut in oats, covered smut in barley, and seed rot and seedling blight in wheat, oats, barley, and flax (19). Typically, the chemical is added in liquid form to the grain as it is augered into a truck or seed bin (64, 66). Unfortunately, as can be seen in Table 20, most seed treatments consist of the highly toxic methylmercury compounds.

Statistics Canada publishes sales of mercury pesticides in Canada (38). By using these figures, and assuming a typical 1.5% mercury content for seed treatments and 50% mercury content for fungicides (Tables 19 and 20), the total amount of mercury involved is estimated to be 10 tons (Table 21).

TABLE 20 USE OF ORGANIC MERCURIALS IN AGRICULTURE (64, 65)^a

Compound	Mercury (% by weight)
SEED TREATMENTS ^b	
Methylmercuric acetate	1.5 - 2.25
Methylmercuric benzoate	1.75
Methylmercuric dicyandiamide	0.6
Oxine methylmercury	0.8 - 1.25
Methylmercury pentachlorophenolate	1.5
Methylmercury 2,3-dihydroxy propyl mercaptide	1.5 - 2.25
Methylmercury propionate	1.25
Phenylmercuric acetate	1.25
Phenylmercury formamide	0.95 - 1.85
Phenylmercuric lactate	0.95
Ethylmercuric chloride	1.25 - 2.0
Ethylmercury p-toluene sulfonanilide	0.8
FUNGICIDES ^c	
Phenylmercuric acetate	6.0
Hydroxymercurichlorophenol	6.7 - 16.8

^aSuppliers and detailed chemical and agricultural properties are given in Reference 65.

^bFor the prevention of a variety of grain diseases.

^cFor the prevention of turf diseases.

Data on emissions from the application of mercury compounds in agriculture were not available. Atmospheric emissions will consist of mercury compounds lost during spraying operations and mercury vapour given off by mercury compounds on the foliage, fruit, or soil surfaces. Seed treatments will lead to atmospheric emissions only during actual application. Planting of the seeds will effectively stop any further loss to the atmosphere. On the other hand, all of the mercury contained in fungicides apparently will eventually either be released to the atmosphere or be washed into the soil. Only a small amount is left as residue on the fruit (19).

TABLE 21 MERCURY CONTENT OF AGRICULTURAL CHEMICALS SOLD IN 1970

	Amount (lb)	Mercury content (lb)
SEED TREATMENTS ^a		
Powders ^b	28 111	422
Drill boxes	70 401	1 050
Liquids ^c	892 090	13 400
TOTAL	990 602	14 872
FUNGICIDES ^d		
Drill boxes	-	-
Liquids ^c	10 500	5 250
TOTAL	10 500	5 250

^a1.5% mercury assumed.

^bTaken from 1968 Dominion Bureau of Statistics as data for 1970 was not available.

^cAssumed density 10 lb/gal.

^d50% mercury assumed.

Lacking any definitive information, agricultural releases of mercury have been calculated by assuming (i) that atmospheric emissions during application of seed treatments are of the same magnitude as emissions during repackaging, which were calculated in section 5.6, and (ii) that 50% of the mercury contained in fungicides becomes an atmospheric emission. On this basis, losses of mercury to the atmosphere from agricultural operations are summarized as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Seed treatments	1.1	0.004
Fungicides	1000	1.5
TOTAL		1.5

Provincial figures are estimated according to farm income statistics in Table 22.

TABLE 22 MERCURY EMISSIONS FROM AGRICULTURAL CHEMICALS (1970)

Province	Farm income (99) ^a (\$1000)	Percent	Mercury emissions (tons)
Newfoundland	700 ^b	2.0	0.03
Prince Edward Island	555	1.6	0.02
Nova Scotia	716	2.1	0.03
New Brunswick	705	2.1	0.03
Quebec	7 397	21.6	0.33
Ontario	10 323	30.2	0.45
Manitoba	2 784	8.1	0.12
Saskatchewan	4 348	12.7	0.19
Alberta	4 530	13.2	0.20
British Columbia	2 178	6.4	0.10
TOTAL	34 236	100.0	1.5

^aFruit and vegetable sales only.

^bEstimated from Nova Scotia and New Brunswick figures.

The use of mercurials in agriculture started to decline in the late 1960's as the mercury hazard became apparent. Numerous companies in replying to our questionnaire reported that they had stopped handling mercurials in 1967 or 1968.

Emissions from this source are expected to disappear as the Canadian Department of Agriculture has banned the use of mercurials starting in January 1973 (66).

6.2 Paint Manufacture

Paint manufacture involves mixing powdered pigment with a vehicle, grinding and diluting the paste, tinting, testing, straining, filling, and packaging. The inorganic compounds mercuric oxide and mercuric sulphide are used as red pigments, and the organic mercurials described in Table 23 are used as preservatives and fungicides to combat the feeding of microorganisms on the oils and proteins in paint. Organic mercurials also inhibit the staining of paint by sulphide pollutants in the air.

TABLE 23 MERCURY COMPOUNDS IN PAINTS (67, 68)

Compound	Use	Mercury content (% by weight)
Phenylmercuric acetate	Fungicide, can preservative	18
Phenylmercuric acetate	Fungicide, can preservative	30
Phenylmercuric oleate	Fungicide, mildewcide	11
Diphenylmercuricdodecenyl succinate	Fungicide	10
Diphenylmercuricammonium propionate	Fungicide	
Phenylmercuric borate	Fungicide, mildewcide	
Mercuric oxide	Fungicide, toxicant, pigment	
Mercuric sulphide	Pigment	

Conversations with paint manufacturers (67, 68) suggest that mercurials are used in interior and exterior water-based paints, in exterior solvent-based paints, and in marine anti-fouling paints. This latter use is very small, as copper and other compounds have replaced most mercurials.

It has been estimated that 60 - 70% of paints produced contain mercury, in amounts varying from about 0.1 to 1% by weight. Variance by product and by company makes it difficult to establish mercury content by paint type (68).

Table 24 summarizes the use of mercury compounds by the paint industry in 1970. Not all products are listed as several proprietary compounds are employed (69). A total use of 123 000 lb mercury compounds containing about 21 000 lb mercury is suggested (68).

TABLE 24 USE OF MERCURIALS BY PAINT MANUFACTURERS (1970)

Compound	Consumption (39) (lb)	Mercury content (lb)
Mercuric oxide	1 997	-
Phenylmercuric acetate	35 800	-
Others	85 203	-
TOTAL	123 000 (68)	21 000 (68)

Information on atmospheric emissions during paint manufacture was not available. However, an overall manufacturing loss of 0.7% of the mercury used was reported by the Canadian Paint Manufacturers' Association (60). Assuming that one-half of this amount becomes an atmospheric emission leads to the following estimates.

Source	Emission factor (lb/ton mercury used)	1970 emissions (tons)
Paint manufacture	7	0.036

Provincial emissions are estimated in Table 25.

TABLE 25 MERCURY EMISSIONS FROM PAINT MANUFACTURE (1970)

Province	Plants	Value of shipments (million dollars)	Percent	Mercury emissions (tons)
Newfoundland	2	1.1 ^a	0.5	-
Prince Edward Island	1	0.6 ^a	0.2	-
Nova Scotia	2	1.1 ^a	0.5	-
New Brunswick	1	0.6 ^a	0.2	-
Quebec	43	59.2	24.5	0.009
Ontario	75	143.7	59.4	0.022
Manitoba	5	8.1	3.3	0.001
Saskatchewan	2	1.1 ^a	0.5	-
Alberta	3	1.8 ^a	0.7	-
British Columbia	22	24.5	10.2	0.004
TOTAL	156	241.8	100.0	0.036

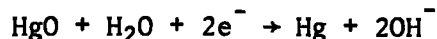
^aThese figures were not given by Statistics Canada. The 6.3 million dollars unaccounted for in the total has been divided according to the number of plants.

Although substitutes for mercury compounds are being sought, the use of mercurials in paints will probably continue for the next few years. Many paint companies have already stopped using mercury, and figures for 1972 are expected to be only 50 - 75% of those reported for 1970. Within the near future, it is expected that mercurials will no longer be used in paints.

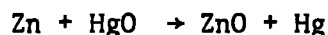
6.3 Alkaline Battery Manufacture

Section 5.3 discussed the use of mercury metal in alkaline battery anodes. In this section, we are interested in the use of mercuric oxide in alkaline battery cathodes.

Mercuric oxide takes part in the power-producing reaction at the cathode:



while it combines with the mercury-zinc amalgam anode to produce the overall reaction (70):



The metallic mercury reaction product is retained in the battery by a double steel case.

A premium for scrap batteries of \$1/lb has resulted in approximately 25% of the batteries being returned (70). The remainder will be disposed of as garbage.

Two companies in Toronto reported the manufacture of alkaline batteries. An estimated 38 300 lb mercury were used for the purpose. Emission data were supplied by one of these companies regarding losses from their cathode production facilities. A baghouse of 99.9% efficiency was used for control. On this basis, the controlled emission of mercuric oxide dust, which decomposes to form mercury vapour, and mercury vapour itself were calculated as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Alkaline battery cathodes	0.9	0.008

Including both metallic mercury losses from anode manufacture (section 5.3), and mercuric oxide losses from cathode manufacture, total emissions from battery manufacture are estimated as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Anode manufacture	1.1	0.0023
Cathode manufacture	0.9	0.008
TOTAL	2.0	0.01

Use of mercury and mercuric oxide is expected to continue to grow as the long life and reasonable cost of the mercury battery lead to its increased use.

Mercurous sulphate (Hg_2SO_4) is another mercury compound used in batteries as a component of Clark and Weston standard cells, which are used as reference cells in scientific work (70). Quantities involved and corresponding emissions are believed to be negligible.

6.4 Pharmaceutical Use

Mercury compound pharmaceuticals are summarized in Table 26. Major uses are as antiseptics, ointments, and diuretics (5, 70). In 1970, many of these compounds were imported, although a few were produced domestically (35).

TABLE 26 MERCURY PHARMACEUTICALS (5, 70, 71)^a

Compound	Use	Mercury (% by weight)
Blue ointment (metallic mercury)	Skin preparation	1 - 2
Yellow mercuric oxide	Ophthalmic ointment	1
Mercuric amido chloride (ammoniated mercury)	Parasiticide, skin bleach	4
Merbromin (mercurochrome)	Antiseptic, skin sterilization before surgery	2 - 2.5
Merthiolate	Skin sterilization before surgery	2 - 2.5
Nitromersol (metaphen)	Antiseptic	
Mercurophen	Antiseptic	
Mersalyl (meralluril)	Diuretic	
Mercaptomerin (thiomerin)	Diuretic	
Meralluride	Diuretic	
Chlormerodrin	Diuretic	

^aChemical composition and further discussion can be found in References 5 and 70.

Table 27 presents the only available figures on imports of pharmaceuticals. These data indicate a consumption of at least 9900 lb mercury pharmaceuticals in 1965 (71). Taking 10% of the United States figure suggests that 0.3 ton mercury was contained in diuretics and 1.3 tons mercury were contained in other preparations (21).

TABLE 27 1965 IMPORTS OF SOME MERCURY PHARMACEUTICALS (71)

Pharmaceutical	Amount (lb)
Mercaptomerin	3900
Yellow mercuric oxide	3800
Ammoniated mercury	2200
TOTAL	9900

The mercury contained in these pharmaceuticals will be lost to the sewer or to the atmosphere after application. Assuming that diuretics produce no atmospheric emissions, and that one-half of the mercury contained in other preparations becomes an atmospheric emission leads to the following estimates.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Application of pharmaceuticals	1000	0.65

Provincial emissions are estimated in Table 28.

TABLE 28 MERCURY EMISSIONS FROM PHARMACEUTICAL USE (1970)

Province	Population (98) (x1000)	Percent	Mercury emissions (tons)
Newfoundland	524	2.4	0.016
Prince Edward Island	111	0.5	0.003
Nova Scotia	770	3.6	0.023
New Brunswick	632	2.9	0.019
Quebec	6 030	27.8	0.181
Ontario	7 815	36.1	0.235
Manitoba	988	4.5	0.029
Saskatchewan	928	4.3	0.028
Alberta	1 634	7.6	0.049
British Columbia	2 196	10.1	0.066
Yukon and N.W.T.	53	0.2	0.001
TOTAL	21 681	100.0	0.65

6.5 Pulp and Paper Industry

During pulp and paper manufacture, a suitable environment for the growth of microorganisms is created. Feeding on water-soluble sugars, starches, and cellulose from the wood and minerals from the water, numerous stringy, pasty, gelatinous, hard, or horny slimes are produced. The combination of these fungi growths with dirt results in deposits which periodically break off and eventually become part of the paper web. Weak spots thus produced in the paper cause breakage and a subsequent downtime of up to 7% on the paper-making machinery (72).

To control these growths, mercurial fungicides such as phenylmercuric acetate, methoxyethylmercuric acetate, and diphenylmercuric ammonium propionate were used for a number of years. Concern over mercury contamination of foods through paper wrappings caused a ban on the use of these fungicides in the United States. Canadian manufacturers apparently followed this ban, since no pulp and paper companies reported use of mercurials in 1970.

Paper still contains trace amounts of mercury, estimated at 20 - 100 ppb (32), as a result of the mercury content of wood, water, sodium hydroxide, and other raw materials used by the pulp and paper industry.

6.6 Miscellaneous Preservatives

Mercury compounds are sometimes used in low concentration as preservatives in such products as adhesives, waxes, and plastics. The amounts involved and corresponding emissions are considered negligible.

7 INADVERTENT MERCURY EMISSIONS

In this section, emissions from sources not directly involved with the consumption of mercury and mercury compounds will be estimated. Such emissions occur during the application of paints containing mercury additives, the burning of fuels containing trace amounts of mercury, the disposal of wastes, and the recovery of base metals from ores containing trace amounts of mercury.

7.1 Paint Application

As discussed in section 6.2, many paints contain mercury compounds in concentrations varying from approximately 0.01 to 1% mercury by weight. The purpose of this section is to examine emissions from these paints during and after application.

Studies have shown that mercury concentrations as high as 0.1 mg/m³ occur in the air of interior rooms while paints containing mercury are wet. As these dry, levels are reduced well below acceptable limits (73). However, radiometric experiments have indicated that mercury emissions continue after the paint film has dried. The rate of loss is greater for exterior applications of paints, for paints subjected to rainfall or washing, and for such compounds as phenylmercuric acetate as opposed to others such as phenylmercuric dodecylsuccinate. Interior paints typically lose 20 - 60% of their phenylmercuric acetate within 250 days, whereas exterior paints lose 80 - 100% within about 20 days (74, 75).

TABLE 29 CONSUMPTION OF READY MIXED-PAINTS (1970)

	Domestic production (39, 76) (gal)		Trade (gal)	
	Interior	Exterior	Imports (77)	Exports (78)
1968	15 418 266	16 545 675	1 039 108	269 584
1969	14 650 336	14 632 642	1 195 174	172 824
1970	14 042 594	13 917 212	1 354 204	161 398
AVERAGE	14 703 732	15 031 843	1 196 492	201 269

NOTE: Assuming net exports are equally divided among interior and exterior paints and that paint weighs 10 lb/gal, net average use is 155 294 540 lb (exterior) and 152 013 430 lb (interior).

For the purposes of this study, it has been assumed that the mercury contained in paints will be lost over a period of two to three years. All the mercury in interior paints is assumed to become an atmospheric emission whereas only 50% of the mercury contained in exterior paints is assumed to enter the air. The remaining 50% is assumed to enter the soil in rainwater.

Table 29 summarizes paint sales for 1968, 1969, and 1970. Mercury losses in 1970 will result from paints applied during the preceding three years. To estimate this figure, the average annual paint consumption from 1968 to 1970 is computed, and the emission factors outlined above are employed. The average mercury content of all paints is estimated by dividing the amount of mercury used by the paint industry in 1970 by paint production, assuming that exterior paints on average contain 10 times more mercury than do interior paints. Thus, the average mercury content of all interior paints is estimated at 0.0013% whereas the average content of all exterior paints is 0.013%. These low figures reflect the fact that several paint companies do not use any mercurials. On the basis of the foregoing analysis, mercury emissions from paint application are summarized as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Interior paints	2000	0.99
Exterior paints	1000	5.04
TOTAL		6.03

Provincial emissions are estimated in Table 30 according to the value of construction performed in 1970 in each province.

TABLE 30 MERCURY EMISSIONS FROM PAINT APPLICATION (1970)

Province	Construction value (100) (million dollars)	Percent	Mercury emissions (tons)
Newfoundland	440.8	3.2	0.19
Prince Edward Island	43.4	0.3	0.02
Nova Scotia	471.7	3.5	0.21
New Brunswick	326.7	2.4	0.15
Quebec	2 741.5	20.1	1.21
Ontario	4 912.3	36.0	2.18
Manitoba	702.0	5.2	0.31
Saskatchewan	480.0	3.5	0.21
Alberta	1 697.9	12.5	0.75
British Columbia Yukon, and N.W.T.	1 806.5	13.3	0.80
TOTAL	13 622.8	100.0	6.03

7.2 Combustion Processes

Table 10 has summarized mercury levels in common fuels from natural processes. In this section, the release of these trace amounts of mercury by combustion processes is estimated.

7.2.1 Coal Combustion. As indicated in Table 10, mercury content of coals used in Canada varies from 0.001 ppm for Alberta coals to 0.3 ppm for West Virginia coals. For coals with an unknown mercury content, the figure of 0.3 ppm has also been used.

Although some studies have indicated that up to 10% of the mercury in coals may be retained in the coal ash (79, 80), for the purposes of this report all the mercury is assumed to be emitted during combustion as mercury vapour. On this basis, mercury emissions in 1970 from coal combustion, using consumption figures of Statistics Canada given in Table 31, are summarized as follows.

Source	Emission factor (lb mercury/1000 tons coal)	1970 emissions (tons)
Coal combustion	0.002 - 0.6	6.99

Major coal uses are given in Table 32 and provincial estimates using Statistics Canada data for the disposition of coals of various types are given in Table 33.

TABLE 31 MERCURY EMISSIONS BASED ON COAL SOURCES OF SUPPLY FOR COMBUSTION (1970)

Source	Mercury content (ppm)	Quantity ^a (1000 tons)	Emission factor (lb mercury/ ton coal)	Mercury emissions (tons)
Nova Scotia	0.3 ^b	1 390	0.0006	0.42
New Brunswick	0.3 ^b	260	0.0006	0.08
Saskatchewan	0.3 ^b	2 500	0.00035	0.75
Alberta	0.001	4 440	0.000002	0.004
British Columbia	0.04	2 280	0.00008	0.09
West Virginia	0.3	18 847	0.0006	5.65
TOTAL		29 717		7.0

^aEstimates from production and consumption data in References 81 and 82.

^bLevels assumed in the absence of published values.

TABLE 32 MAJOR COAL CONSUMERS (1970) (81)

Use	Consumption (%)	Mercury emissions (tons)
Thermal electric plants	51	3.6
Coke production	32	2.2
Others	17	1.2
	—	—
TOTAL	100	7.0

TABLE 33 MERCURY EMISSIONS FROM COAL COMBUSTION (1970)

Province	Mercury emissions (tons)
Newfoundland	0.01
Prince Edward Island	*
Nova Scotia	0.64
New Brunswick	0.09
Quebec	0.32
Ontario	5.24
Manitoba	0.01
Saskatchewan	0.62
Alberta	*
British Columbia	0.06
	—
TOTAL	6.99

*Negligible.

7.2.2 Petroleum Combustion. Trace amounts of mercury are found in crude petroleum. Two conflicting views on the fate of this mercury during refining have been found during this study. On one side, mercury is believed to behave like other heavy metals such as vanadium and become concentrated in the heavy oil fractions (83). Mercury vapour would then

be emitted only from residual fuel oil combustion and not from the combustion of other refinery products. On the other hand, measurements in Sweden have indicated that mercury levels of the same order of magnitude are found in both distillate fuels and residual fuel oils (84). This view is supported by data supplied in an oil refinery questionnaire return, and also seems reasonable considering the volatile nature of mercury and its compounds.

Unfortunately, no measurements of the mercury content of Canadian gasolines could be found. Residual fuel oil has, however, been analyzed and levels of 0.1 - 0.39 ppm have been published (31) (see Table 10).

For the purposes of this study, all petroleum products are assumed to contain mercury levels equal to the levels measured in residual fuel oil. Additional information may modify this conclusion in the future.

Using consumption data supplied in Table 34, and assuming that the average 0.3 ppm mercury content of petroleum products is completely emitted as mercury vapour during combustion, leads to the following emission data.

Source	Emission factor		1970 emissions (tons)
	lb mercury/ ton fuel oil	lb mercury/ 1000 bbl fuel oil	
Aviation fuel	0.0006	0.077	0.70
Motor gasoline	0.0006	0.077	6.45
Diesel oil	0.0006	0.088	2.10
Light fuel oil	0.0006	0.088	4.55
Heavy fuel oil	0.0006	0.10	5.34
Stove oil	0.0006	0.088	0.85
TOTAL			20.00

TABLE 34 CONSUMPTION OF PETROLEUM PRODUCTS (1970) (1000 bbl) (85)

Province	Aviation fuel	Motor gasoline	Diesel oil	Light fuel oil	Heavy fuel oil	Stove oil	Mercury emissions (tons)
Newfoundland	740.6	2 348.4	2 410.1	2 578.3	5 988.0	1 321.0	0.70
Prince Edward Island ^a	76.1	775.4	305.0	760.1	1 228.1	236.7	0.14
Nova Scotia ^a	547.4	5 579.8	2 195.0	5 469.1	8 837.0	1 703.2	1.10
New Brunswick ^a	442.2	4 507.2	1 773.0	4 417.7	7 138.1	1 375.8	0.89
Quebec	5 281.3	42 147.8	8 124.0	38 507.9	45 743.6	6 334.8	6.43
Ontario	4 866.6	60 957.3	10 673.1	40 645.4	27 473.1	3 569.3	6.33
Manitoba	1 269.9	7 795.6	2 864.6	1 925.6	986.4	1 154.8	0.66
Saskatchewan	408.2	9 864.9	4 102.1	1 658.8	475.1	1 166.6	0.72
Alberta	1 791.4	16 590.9	6 612.3	934.1	510.7	550.5	1.09
British Columbia	2 152.6	16 448.9	7 685.9	6 083.8	8 351.8	1 622.8	1.81
Yukon and N.W.T.	485.1	481.6	1 132.9	427.9	114.2	224.0	0.13
TOTAL	18 061.4	167 497.6	47 878.0	103 408.6	106 846.1	19 259.6	20.0

^a Statistics Canada reports only a total Maritimes figure. Estimates have been made according to population.

If we assume that only residual fuel oil contains mercury, the emission figure would be reduced to 5.34 tons.

7.2.3 Natural Gas Combustion. The Energy Resources Conservation Board has analyzed the effluents of natural-gas-processing plants for mercury content (34). These results, which are summarized in Table 35, indicate that mercury levels in natural gas vary from <0.1 ppb by weight to 1.5 ppb by weight. For the purposes of this study, a 0.1 ppb mercury concentration has been assumed for natural gas. It has also been concluded that significant atmospheric emissions will only occur during gas combustion and not during gas purification. Using the consumption figures given in Table 36 and assuming that all the mercury in natural gas is emitted as mercury vapour during combustion, the emissions from this source in 1970 are summarized as follows.

Source	Emission factor (lb mercury/billion ft ³ gas)	1970 emissions (tons)
Natural gas combustion	0.005	0.0023

7.2.4 Wood Combustion. Trace amounts of mercury in wood, estimated at 0.02 - 0.1 ppm (32, 33), will be released as mercury vapour during combustion. The major sources of wood combustion and resulting mercury emissions are given in Table 37, assuming that wood contains 0.05 ppm mercury. Sources considered are forest fires, slash burning operations of the lumber industry, and wigwam burners which are used in the disposal of sawmill wastes. Mercury emissions are summarized as follows.

Source	Emission factor (lb mercury/1000 tons wood)	1970 emissions (tons)
Forest fires	} 0.1	2.10
Slash burning		0.37
Wigwam burners		0.40
TOTAL		2.87

TABLE 35 MERCURY CONCENTRATIONS IN GAS-PROCESSING PLANTS IN ALBERTA (1970) (34)

Field	Mercury concentration (ppb by weight) ^a		
	Gas	Condensate	Formation water
Andreson	N.D.	-	-
Ferrier	N.D.	Tr	N.D.
Waskakigan	N.D.	N.D.	12.5
Jaffre	Tr	-	-
Provost	N.D.	N.D.	40.0
Marten Hills	N.D.	-	N.D.
Pembina	0.6	Tr	N.D.
Cessford	N.D.	13.0	-
Paddle River	N.D.	14.0	N.D.
Virginia Hills	N.D.	N.D.	-
Brageau River	1.5	Tr	N.D.
Pincher Creek	N.D.	N.D.	N.D.
Galling Lake	N.D.	-	N.D.
Strachan	Tr	-	-
Bigstone	N.D.	-	Tr
Kaybob South	N.D.	45.0	N.D.
Mitsue	0.4	N.D.	-

^a A dash indicates no sample taken; Tr indicates mercury present, but less than 0.1 ppb; N.D. indicates no mercury detected in gas and <10 ppb in liquids.

TABLE 36 MERCURY EMISSIONS FROM NATURAL GAS (1970)

Province	Gas consumption (86) (million ft ³)	Percentage	Mercury emissions (tons)
New Brunswick	62	-	-
Quebec	50 705	5.5	0.00013
Ontario	405 982	44.2	0.00102
Manitoba	51 546	5.7	0.00013
Saskatchewan	79 660	8.7	0.00020
Alberta	232 670	25.4	0.00058
British Columbia	96 786	10.5	0.00024
TOTAL	917 441	100.0	0.0023

TABLE 37 MERCURY EMISSIONS FROM WOOD COMBUSTION (1970)

Province	Wood burned (1000 tons) (87)			Mercury emissions (tons)
	Forest fires	Slash burning	Wigwam burners	Total
Newfoundland	3 404.4	170.0	7.5	3 581.9
Prince Edward Island	-	-	2.9	2.9
Nova Scotia	122.1	332.0	220.3	674.4
New Brunswick	233.9	-	325.4	559.3
Quebec	2 528.1	2638.8	3265.5	8 432.4
Ontario	2 291.0	1529.3	768.8	4 589.1
Manitoba	8 550.2	32.4	34.7	8 617.3
Saskatchewan	6 903.2	121.1	86.2	7 110.5
Alberta	2 676.2	97.2	347.6	3 121.0
British Columbia	7 188.3	2444.9	2919.7	12 552.9
Yukon and N.W.T.	8 141.7	-	-	8 141.7
TOTAL	42 039.1	7365.7	7978.6	57 383.4
				2.87

7.3 Waste Disposal

Mercury contained in manufactured products may be released during disposal of these products. Emissions from refuse incineration, sewage sludge incineration, and other miscellaneous sources will be examined in this section. Refuse and sludge disposal by landfill and operations other than incineration are assumed to produce negligible atmospheric emissions of mercury.

TABLE 38 MERCURY EMISSIONS FROM REFUSE INCINERATION (1970)

City	Refuse burned (1000 tons)	Mercury emissions (tons)
Charlottetown, P.E.I.	26.0 ^a	0.06
Dartmouth, N.S.	26.0	0.06
Halifax, N.S.	88.4	0.21
Montreal, Quebec	898.0 ^a	2.16
Quebec, Quebec	45.0 ^a	0.11
Toronto, Ontario	547.9	1.31
Winnipeg, Manitoba	105.7	0.25
Regina, Saskatchewan	51.7	0.12
Edmonton, Alberta	65.8	0.16
TOTAL	1854.5	4.44

^aEstimates taken from Reference 88.

7.3.1 Refuse Incineration. In Table 38, quantities of refuse incinerated in 1970 are estimated on the basis of questionnaire replies and data of Reference 88. Although information on the mercury content of refuse in Canada was not available, studies in the United States have found a 0.6 - 11.15 ppm range, with an average concentration of 2.4 ppm (89). Typical refuse components are listed in Table 39. Many of the materials indicated are known to contain trace amounts of mercury. Mercury emissions from refuse incineration in 1970 are summarized as follows, assuming a 2.4 ppm mercury level which is totally emitted as mercury vapour during incineration.

Source	Emission factor (1b mercury/1000 tons refuse)	1970 emissions (tons)
Refuse incineration	4.8	4.44

TABLE 39 TYPICAL MUNICIPAL REFUSE COMPOSITION (88)

Component	Percentage
Paper	
Newsprint	3.5
Cardboard	8.1
Other	24.8
	<hr/>
	36.4
Organics	25.0
Wood	14.9
Metals	
Ferrous	0.8
Cans	6.6
Coloured	0.8
	<hr/>
	8.2
Glass	7.2
Rock and rubble	3.6
Textiles	2.5
Plastics	1.7
Tires	0.5
	<hr/>
TOTAL	100.0

7.3.2 Sewage Sludge Incineration. Trace amounts of mercury have been measured in sewage sludges. Studies at two incinerators in the United States have found 3 - 4.5 ppm mercury in sludge (90). Although Canadian studies on several heavy metals in sludges have been performed (91), mercury measurements were not available.

TABLE 40 MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATION (1970)

City	Sludge burned (tons)	Mercury emissions (tons)
Toronto, Ontario	36 500	0.15
London, Ontario	57 400	0.23
Winnipeg, Manitoba	40 000 ^a	0.16
TOTAL	133 900	0.54

^aEstimate only; no questionnaire reply received.

Questionnaires were sent to the three municipalities in Canada that operate sludge incinerators. Using the tonnage figures supplied, and assuming that 4.0 ppm mercury are emitted during combustion, mercury emissions are given in Table 40, and are summarized as follows.

Source	Emission factor (lb mercury/1000 tons sludge)	1970 emissions (tons)
Sewage sludge incineration	8	0.54

7.3.5 Miscellaneous Sources. Two sources of mercury emissions from solid waste disposal are worth noting. First, in the disposal of spent fluorescent tubes, it is virtually certain that the tube will be broken and the mercury vapour lost to the atmosphere. This breakage will likely occur in all methods of waste disposal. In refuse incineration, the tubes are assumed to be broken before reaching the incinerator.

In section 5.3, 2500 lb mercury were estimated to be consumed in fluorescent tube manufacture in 1970. This figure is consistent with the manufacture of approximately 23 million tubes (92) each containing on average 50 mg mercury (54). Approximately 75% of these tubes are assumed to be used to replace spent tubes. Mercury emissions are therefore summarized as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Broken fluorescent tubes	2000	0.94

Provincial emissions are estimated according to the construction value in Table 41.

TABLE 41 MERCURY EMISSIONS FROM FLUORESCENT TUBE BREAKAGE (1970)

Province	Construction value (100) (million dollars)	Percent	Mercury emissions (tons)
Newfoundland	440.8	3.2	0.03
Prince Edward Island	43.4	0.3	-
Nova Scotia	471.7	3.5	0.03
New Brunswick	326.7	2.4	0.02
Quebec	2741.5	20.1	0.19
Ontario	4912.3	36.0	0.34
Manitoba	702.0	5.2	0.05
Saskatchewan	480.0	3.5	0.03
Alberta	1697.9	12.5	0.12
British Columbia, Yukon, and N.W.T.	1806.5	13.3	0.13
TOTAL	13622.8	100.0	0.94

Secondly, mercury is lost from the large number of thermometers that are broken in hospitals annually. Part of this mercury will enter the air, and the remainder will be lost to the sewer. It has previously been estimated that 1.8 million medical thermometers containing about 8000 lb mercury are broken each year (93). Questionnaire replies from three hospitals suggested that between 7 and 12 thermometers are broken annually per bed in the hospital. As Canadian hospitals have a bed capacity of 211 401 (94), the indicated annual thermometer breakage lies between 1.48 million and 2.54 million, and the estimates made previously are apparently realistic.

TABLE 42 MERCURY EMISSIONS FROM THERMOMETER BREAKAGE (1970)

Province	Hospital capacity (94) (1000 beds)	Percent	Mercury emissions (tons)
Newfoundland	4.05	1.9	0.01
Prince Edward Island	1.14	0.5	-
Nova Scotia	7.35	3.5	0.01
New Brunswick	6.40	3.0	0.01
Quebec	59.98	28.4	0.11
Ontario	72.12	34.1	0.14
Manitoba	9.77	4.6	0.02
Saskatchewan	10.56	5.0	0.02
Alberta	19.47	9.2	0.04
British Columbia	20.04	9.5	0.04
Yukon and N.W.T.	0.61	0.3	-
TOTAL	211.49	100.0	0.4

Emissions from thermometer breakage have been calculated by assuming that 10% of the 8000 lb mercury lost enters the atmosphere. Provincial figures are estimated according to hospital bed statistics in Table 42 and are summarized as follows.

Source	Emission factor (lb/ton contained mercury)	1970 emissions (tons)
Broken thermometers	200	0.4

7.4 Base Metal Recovery

As mentioned in section 2, trace amounts of mercury are found in virtually all minerals. Generally higher levels are associated, however, with sulphide minerals such as sphalerite (ZnS), wurzite (ZnS), chalcopryrite (CuFeS₂), and galena (PbS) from which base metals are recovered (see Table 10). During recovery processes, mercury may accordingly be released into the environment.

Typical operations required for the beneficiation of base metal ores include crushing and concentration of the minerals at the mine site, followed by the recovery of metal from the ore concentrate at a few Canadian smelters. Substantial quantities of concentrate are also exported for smelting outside Canada. As the mercury is associated with the sulphides, it remains in the concentrates and is mostly lost during the smelting process, which consists of roasting and sintering steps to convert the sulphide to oxides, followed by pyrometallurgical treatment to recover lead and copper, or electrolytic processes to recover zinc.

Studies have shown that the mercury content of various concentrates is variable, but that, in general, zinc concentrate contains the most mercury, while lead and copper concentrates contain relatively less (95). Questionnaire replies reported that, at one smelter, zinc concentrate contained 3 ppm mercury, and copper concentrate contained 0.7 ppm mercury. In nickel ores, no mercury was detected. Figures for lead concentrates were not available.

Only one smelter could supply mercury emission data. Based on the information supplied, controlled emission factors of 8.4 lb mercury/1000 tons zinc produced, and 3.9 lb mercury/1000 tons lead produced were calculated. Although some mercury condensed out of the gas stream as the gases cooled, the degree of control represented by the above emission factors was not available.

Most of the mercury is expected to be vapourized during initial roasting and sintering steps. As the gaseous effluents from these processes require cooling and particulate removal treatment before being washed to make sulphuric acid, the degree of control on mercury vapour is not necessarily low. One questionnaire reply indicated that the sulphuric acid product contained 0.8 ppm mercury, and another indicated that residues in flues were periodically reclaimed for mercury. It is evident, therefore, that some of the mercury is removed from the gas stream.

TABLE 43 MERCURY EMISSIONS FROM BASE METAL RECOVERY (1970)

Plant	Production (96) (1000 tons)	Mercury emissions (tons)
ZINC		
Belledune, N.B. ^a	36.1	0.15
Valleyfield, Que. ^a	124.1	0.52
Port Maitland, Ont. ^a	29.7 ^{b, c}	0.12
Flin Flon, Man.	78.6	3.54
Trail, B.C. ^a	221.6	0.93
<hr/>		
Zinc Total	519.8	5.26
COPPER		
Noranda, Que.	210.9	2.43 ^d
Murdochville, Que.	69.8	0.24
Flin Flon, Man.	42.8	0.75
<hr/>		
Copper Total	323.5	3.42
LEAD		
Belledune, N.B. ^a	20.8	0.04
Trail, B.C. ^a	183.8	0.36
<hr/>		
Lead Total	204.6	0.40
<hr/>		
TOTAL		9.08

^aAcid plant associated with operations.

^bEstimated zinc contained in concentrates, assuming operation at 50% capacity (capacity of 300 tons concentrate, containing 55% zinc (97)).

^cZinc as oxide.

^dApproximately 67% of mercury from imported concentrate. Concentrate no longer imported from this source.

Uncontrolled mercury emission factors of 16.8 - 90 lb/1000 tons zinc produced, 23 - 35 lb/1000 tons copper, and 7.8 lb/1000 tons lead produced have been applied to Canadian production figures where necessary. These calculations are shown in Table 43, and are summarized as follows.

Source	Uncontrolled emission factor ^a (lb mercury/1000 tons metal)	1970 emissions (tons)
Zinc recovery	16.8 - 90	5.26
Copper recovery	23 - 35	3.42
Lead recovery	7.8	0.40
TOTAL		9.08

^aBased on 50% removal of mercury in acid plants.

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