Environment Canada Environnement Canada

Environmental Contaminants Inventory Study No. 3

The Production, Use and Distribution of Lead in Canada

T. D. Leah

REPORT SERIES NO. 41

(Résumé en français)

INLAND WATERS DIRECTORATE, ONTARIO REGION,
WATER PLANNING AND MANAGEMENT BRANCH,
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Abstract

This study is the third in the Environmental Contaminants Inventory Series, and the first to present data in terms of watershed basins. The report begins with a literature review on lead in the environment and the effects of lead on human health. The flow of lead through the Canadian economy is then analyzed, focussing on the production of lead and the use of lead in manufacturing. Lead releases to the atmosphere resulting from these activities and the consumption of leaded gasoline are estimated in terms of aggregated watershed basins.

Background information is provided outlining the occurrence, physical and chemical properties, production processes, global economic significance, major uses of lead and future demand for lead. Lists of industries reporting lead consumption to Statistics Canada in 1972 and major Canadian producers of recycled lead are included.

Résumé

L'étude, la troisième de la série entreprise dans le cadre de l'inventaire des contaminants de l'environnement et la première à présenter des données touchant les bassins hydrographiques, débute par une revue des ouvrages portant sur le plomb dans l'environnement et ses effets sur la santé de l'homme. Vient ensuite l'analyse du cheminement du plomb dans l'économie du pays, dans laquelle on insiste sur la production de ce métal et son utilisation dans l'industrie. En outre, les rejets de plomb dans l'atmosphère par suite de ces activités et de la consommation d'essence à teneur en plomb font l'objet d'une évaluation par rapport à l'ensemble des bassins hydrographiques.

L'étude renferme également de la documentation de base sur les quantités, les propriétés physiques et chimiques, les processus de production, l'importance économique globale, les principales utilisations et la demande à venir du plomb, de même qu'une liste des industries consommatrices de plomb en 1972 (Statistique Canada) et des principaux producteurs de plomb recyclé.

Introduction

For at least 3,000 years, lead has been one of the most widely used metals. Since the industrial revolution, the quantities of lead released to the environment have increased dramatically in line with the production and use of the metal. Its physical and chemical properties ensure that it will continue to be a key material in a variety of uses. These facts, combined with its potential hazards to human health and to the natural environment, emphasize the need for an inventory of lead in Canada. Such information is an essential link in the chain of events currently under study, including pathways of lead in the environment, toxicity, local concentrations, and an assessment of the social costs and benefits that accrue from the use of the metal.

The purpose of this study is to develop an inventory of lead in Canada.[1] To achieve internal consistency, this involves an examination of lead production, the use of lead in the manufacture of products, the purchase and disposal of these products by the consumer, and the degree to which the lead content of the "used" products is recycled. Imports and exports of the metal and products must also be accounted for. In addition, the amount and chemical form of lead released to the environment as a result of these activities and the fate of this material in ecosystems must be assessed. Due to insufficient data, however, some aspects, notably the disposal of products containing lead and the final destination of lead released to the environment, have not been quantified.

In Chapter 2, an overview of the great quantity of literature concerning the effects of lead on the natural environment is provided. This includes presentation of data on lead levels, both natural and from man-made sources, in air, water, soil, vegetation and animal life. The various effects of lead on humans, currently the subject of vigorous debate in the scientific, medical and legal communities, are reviewed in Chapter 3.

In Chapter 4, an analysis of lead production and use in Canada is given. Examination of the data shows that these activities are carried on in a few localized geographical areas. For example, in 1972, mines in New Brunswick, British Columbia, the Yukon and the Northwest Territories produced 93% of Canada's lead mine output.[2] In the same year, 96% of the manufacturing involving lead occurred in factories in five provinces: Ontario, 64%; Quebec, 20%; Manitoba, 6%; Alberta, 5%; and British Columbia, 1%.

Chapter 5 concerns lead releases to the environment resulting from lead production, the manufacture of products containing lead, and the consumption of leaded gasoline. These data represent releases to the atmosphere only. More complete analyses would account for lead contained in effluents from industrial and domestic waste treatment facilities, and the lead content of solid wastes disposed of in landfill. These inputs have not been estimated owing to insufficient data. Atmospheric releases of lead from production and manufacturing have been estimated based on the quantities of lead produced in mines and smelters and used in

[1] The author wishes to point out that although the information given in this report was the best available when it was submitted for publication, recent scientific and legislative developments may render some of the material obsolete.

[2] Whenever used in this paper, the term ton refers to the short ton of 2,000 pounds avoirdupois.

manufacturing. The distribution of releases from the consumption of leaded gasoline has been assumed proportional to population and estimated on that basis. In 1972, estimated atmospheric releases totalled 18,700 tons, of which 1,965 tons (11%) resulted from lead-producing activities [mining, milling, smelting, refining, and secondary (recycled) lead production]. In the same year, atmospheric lead releases from manufacturing amounted to 175 tons, less than 1% of the total. Factories on the Canadian side of the Great Lakes and St. Lawrence drainage basins were responsible for 90% of the nation's releases from manufacturing. Consumption of leaded gasoline accounted for 13,260 tons (71% of the total). Approximately 7,930 tons of these releases (60% of the total from this source) occurred in the Canadian lower Great Lakes and St. Lawrence basins. The remaining 3,300 tons (18%) in the national total originated from miscellaneous sources such as fossil fuel combustion (coal and oil), solid waste incineration, and residuals from the production of other metals.

To gain better insight into the localized nature of lead releases, Canada has been divided into suitable watershed basins. These have been aggregated to a degree to allow publication of release data that would otherwise be confidential. In spite of the inaccuracy imposed by this aggregation, the figures give some indication of the relative lead contaminant loadings to individual watershed basins from production and manufacturing processes.

In Chapter 6, lead is put into historical perspective and its worldwide economic significance is outlined. Total world consumption of the metal was 3.83 million tons in 1973 and is forecast to reach 6.84 million tons by the year 2000.

Finally, and most importantly, this report constitutes the first attempt in the Environmental Contaminants Inventory Series to provide data in terms of watershed basins. Future reports will reflect improvements in the methodology of reporting data on this basis, which in turn will give a better insight into man's impact on the environment.

Lead in the Environment

INTRODUCTION

There are natural levels of lead in various forms in air, water and soil throughout the planet. These background levels are generally innocuous to plant and animal life which have adapted to them. Yet recent concern regarding the environmental effects of lead derives from two factors. First, as a result of human activity, lead levels have been increasing at a rate well in excess of that due to natural processes alone. Secondly, the detrimental effects of lead on humans have been correlated with this unnatural accumulation of lead in the environment. The effects of lead on humans are outlined in Chapter 3. In this Chapter, the following aspects of lead in the environment are discussed: 1) background levels; 2) man-made sources; 3) forms of lead in the environment; 4) lead in vegetation; 5) lead in aquatic organisms; 6) lead in wildlife; and 7) lead in livestock and other mammals.

BACKGROUND LEVELS

Since lead has been extracted and fabricated by man for so many centuries, it is difficult to establish natural background levels. Present-day distributions in soil, glaciers and water are indicative of a long and increasing addition of lead to the environment, with an exponential increase following the industrial revolution.

Air

Principal natural sources of airborne lead include volcanic eruptions and forest fires. Their impact, however, can no longer be measured owing to the great magnitude and mobility of industrial discharge. An indirect estimate of relative amounts of airborne lead in past ages has been made from analysis of ancient snow and ice in Greenland, which has risen from less than 1 ng Pb/kg (10^{-9} g Pb/kg) lead content in 800 B.C., 10 ng Pb/kg in 1750, 70 ng Pb/kg in 1940, to more than 200 ng Pb/kg at present. Lead in Antarctic ice has risen from below detection limits in 1940 to about 20 ng Pb/kg in the recent past (1, 2).

Water

In areas where limestone and galena ores are found, waters may contain lead in solution up to 0.8 mg Pb/l (3). Otherwise, surface waters contain significant amounts of lead only when subject to some special contamination. The National Water Quality Data Bank of the Department of the Environment reports lead concentrations at about 2,500 locations in Canada. The samples are all raw waters from rivers, lakes, wells or groundwater, and most have a concentration in the range 0-10 µg Pb/l with a few ranging up to 30 µg Pb/l. The World Health Organization has placed the maximum permissible level of lead in communal drinking water at 100 µg Pb/l.

Soil

Lead is ubiquitous in soils; its levels are subject to marked increases from contamination by man's agricultural, industrial and social activities. Although the average lead content of the earth's crust has been established at roughly 16 mg Pb/kg, much higher values have been recorded in densely populated areas, near industrial sites and in areas of geochemical deposits (4,5,6). Analyses of 60 Canadian soils indicate that they all contain some lead, usually between 0.5 mg Pb/kg and 5 mg Pb/kg, while soils over rock containing high amounts of lead may have as much as 25-300 mg Pb/kg (7). Surface samples of ten cultivated soils in eastern Canada contained 6-14 mg Pb/kg (8).

The soluble or readily available lead in crop soils probably accounts for as little as 1-10% of total lead present, since lead is rapidly fixed in soil by forming complexes with soil humic or fulvic acid fractions (9, 10). On the other hand, the availability of soil lead is increased under acidic conditions (low pH) in soils with low organic matter content. Hence, the addition of organic matter, lime (increases pH) and phosphate to soil reduces the availability of lead present and its subsequent uptake by plants (11).

MAN-MADE SOURCES

Air

Lead particulates in the atmosphere result from activities such as:

1) the mining and milling of lead ores,
2) the smelting and refining of primary and secondary lead,
3) the manufacture of lead chemicals, batteries, and other products,
4) the production of other metals, cement, and combustion of fossil fuel,
5) the consumption of lead products, notably leaded gasoline, and
6) the incineration of refuse and sewage sludge containing trace amounts of lead.

These releases are discussed in Chapter 5.

The combustion of leaded automobile gasoline is by far the largest single source of atmospheric lead contamination. Approximately one quarter of the lead added to gasoline is retained in the exhaust system, engine oil and filters of the automobile itself. The rest is discharged in the form of particulate lead compounds, about half of which fall to the ground within a short distance of the roadway. The remainder may be carried considerable distances before being precipitated. Concentrations of lead in urban air usually range from 0.3-2.5 μg Pb/m^3 with some levels reaching 40 μg Pb/m^3 near traffic in downtown locations, compared with up to 6 μg Pb/m^3 near rural roads. The Air Pollution Control Directorate (12) annual summary of monthly and annual geometric means of lead in air indicates that for 1971, values ranged from 0.25-1.35 μg Pb/m^3, with most near 1 μg Pb/m^3. Another report (13) states that overall average lead values for the period from 6:00 hours to 21:00 hours were 8.2 μg Pb/m^3, 8.4 μg Pb/m^3 and 4.0 μg Pb/m^3 in Vancouver, Toronto and Montreal (3 m from the curb), respectively.

In urban dwellings, the ratio of indoor to outdoor air concentration of lead was determined by Yocom, Clink and Cote (14) to be one or slightly lower in the summer, and about 0.5 in other seasons. In public buildings or air-conditioned offices with closed windows, the ratio was often lower than 0.5.

Water

Most of the man-made lead burden of water courses enters as lead oxide via atmospheric washout. Some also originates in effluent from sewage treatment plants, leaching from landfill sites and agricultural runoff. Oliver and Kinrade (15) have measured lead in the sediments of the Ottawa River (mean 26 μg Pb/kg) and its tributary, the Rideau (mean 42 μg Pb/kg). The lead values were far greater in certain locations, notably 390 μg Pb/kg near a sewage plant and 1,344 μg Pb/kg near a snow dump.

Lead may contaminate drinking water by way of lead chromate paints used on the inside of steel storage tanks, as well as through old lead pipe installations which still exist. Copper tubing used for the distribution of water throughout buildings and homes is commonly joined by lead solders, which can contribute significant amounts of lead to the water, depending on its hardness. The solubility of lead in water decreases with increasing hardness (see "Forms of Lead in the Environment" later in this Chapter).

Soil

The prime sources of lead contamination in soil are atmospheric fallout of the combustion products of leaded gasoline, sewage sludge, limestone, lead arsenate pesticides, phosphate rock fertilizers and wastes from metal-smelting establishments. To a large extent, activities which produce lead contamination in soils are confined to specific areas. Lagerwerff and Specht (16) found that lead contamination of soils owing to automobile exhaust varied inversely with distance from the highway. The surface layer (0-5 cm) had the highest concentrations. This and other studies (17, 18) confirm that the accumulation of lead next to heavily travelled highways is confined to the surface layers along a relatively narrow corridor adjacent to the highways. Sewage sludge may contain extremely high lead levels (19), and an agricultural limestone containing 45 mg Pb/kg was found in Ontario (20). The use of lead arsenate pesticides, although decreasing significantly (21), constitutes a direct environmental input and is known to cause localized accumulation of lead and arsenic in soils where they are applied (see "Lead in Vegetation" later in this Chapter).

FORMS OF LEAD IN THE ENVIRONMENT

Urban atmospheric lead contamination originates mainly in lead aerosols from the combustion of gasoline containing antiknock additives in the form of lead alkyls. These substances are in the form of various oxides such as PbO, Pb_2O_3, Pb_3O_4, and mixed salts such as PbClBr and $PbNH_2Cl$ which are derived from the additives tetraethyl lead and tetramethyl lead (22).

Lead and most of its compounds have negligible vapour pressures at environmental temperatures. Hence, all lead in air is in the form of particles. Tetraethyl lead is the only volatile lead compound likely to be present, and it is rapidly converted to a non-volatile oxide. Since particles of lead compounds are of high specific gravity, the larger ones settle out rapidly, whereas smaller particles (less than 1 μm in diameter) are kept in suspension by air movements and are removed from the atmosphere by agglomeration and precipitation.

In water, the solubility patterns of lead species appear similar to those of other metals. Osteryoung, in the appendix to a report by Davies and Everhart (23), states that the total solubility of lead is about 0.5 mg Pb/l in soft water (25 mg/l hardness) and about 0.03 mg Pb/l in hard water (370 mg/l hardness). Minimum solubility occurs about pH 9.

In more acidic (low pH) waters, the common forms are the sulphate and chloride, lead ion (Pb^{2+}), the cationic form of lead hydroxide, and the hydroxide itself [$Pb(OH)_2$]. In alkaline (high pH) conditions, the common species are the anionic forms of lead carbonate and hydroxide. Other forms of lead are present in organic suspensoids, as components of soluble organic matter, and absorbed into suspended matter. Theoretical concentrations of dissolved lead are seldom maintained in natural waters. Lead presumably collects in sediments, although absorption on suspended particles is sometimes thought to be a major factor in its removal from solution (24). Gregor (25) investigated the possibility of NTA (nitrilotriacetic acid, a substitute for phosphate in detergent formulations) solubilizing significant amounts of lead into water. When sediments containing insoluble lead deposited from automobile exhaust were shaken with water containing NTA, concentrations of up to 12 times the maximum permitted level were observed.

LEAD IN VEGETATION

Widely varying amounts of lead have been reported in plant materials. Kehoe, Cholak and Story (26) state that the natural lead content of vegetation rarely exceeds a fraction of a milligram of lead per kilogram, but that there is always a small quantity present. Schroeder et al. (27) report figures of generally less than 1 mg Pb/kg wet weight for vegetable crops and grains.

The amount of soil lead absorbed by the roots depends on the lead content, type, pH and organic content of the soil, along with the age and type of plant and growing conditions (28, 29).

Increased lead levels in plants are usually a result of lead in air and/or lead arsenate residues. Plants grown in close proximity to highways or in densely populated urban areas frequently show abnormally high lead concentrations. This is a result of both the increased lead content of the soil and the absorption of a percentage of the particulate lead that settles on the aerial portion of the plant. Warren, Delavault and Cross (30) reported lead contents of up to 2,000 mg Pb/kg of ash from stems of conifers growing in Stanley Park, Vancouver, and Chow (31) found roadside grasses containing 20-60 mg Pb/kg dry weight (290-825 mg Pb/kg ash). Lead arsenate is used principally on fruit trees for the control of insect pests, as well as on lawns and airport turf for control of earthworms. The compound is stable, and both lead and arsenic accumulate in soil as a result of its use. Crops grown on soils treated with the chemical have substantially higher lead contents than those grown on untreated soils (32, 33).

There are no conclusive findings regarding the toxic effects of lead on vegetation grown on high-lead content soils. It is known that some species display high tolerances to soil lead. Fine bent grass has been shown to adapt to soils containing 10,000 mg Pb/kg near an old mine in Wales (34, 35). It is probable that similar adaptability in tolerance to lead is found in other plant species.

LEAD IN AQUATIC ORGANISMS

Microorganisms

The phenomenon of lead uptake by algal forms is well known (36). Quantities of Cladophora in mine and mill waters have been found containing 5,000 parts per million (ppm). Zinc levels were approximately 1,000 ppm.

Stigeoclonium, more tolerant to heavy metals, has been found with associated lead at 7,400 ppm; zinc, 3,300 ppm; and copper, 1,200 ppm. Most of this lead is associated with entrapment or fixation on the surface of the algae rather than internal contamination.

Certain microorganisms are able to methylate mercury and arsenic, and copious amounts of data confirm this fact. Recent experiments by Wong, Chau and Luxon (37) have shown that under certain conditions, microorganisms are capable of converting trimethyl lead salts and inorganic lead salts such as the nitrate and chloride to the volatile tetramethyl lead, Me_4Pb. The pathways for this biological conversion of lead are not well understood. It was also found that the Me_4Pb, so generated, significantly inhibited primary productivity and cell growth of the alga *Scenedesmus quadricauda*.

Some species of bacteria are capable of absorbing lead with no apparent ill effects. Tornabene and Edwards (38) showed that *Micrococcus luteus* and *Azotobacter* species cells, grown in a broth in contact with a dialysis membrane containing lead bromide, immobilized 4.9×10^2 mg and 3.1×10^2 mg of lead per gram of whole cells, on a dry weight basis, respectively. Lead bromide, lead iodide and lead bromochloride in concentrations approaching solubility limits had no detectable effect on overall growth rate and cell viability.

Aquatic Insects

Aquatic insects display high resistance to lead, comparable with the most tolerant fish. Seven-day LC50's for typical mayfly, stone fly and caddis fly larvae ranged from 16-64 mg Pb/l in soft water (39). The freshwater crustacean *Daphnia* is sensitive to lead and has resistance similar to the pattern for salmonid fry. In Lake Superior water (hardness 45 mg Pb/l), the two-day LC50 was 0.45 mg Pb/l and the three-week LC50 was 0.3 mg Pb/l (40). This compares with a 2.7-day LC50 for *Daphnia* of 0.93 mg Pb/l in Lake Erie water (41).

Fish

Work done by the British Water Pollution Research Laboratory over a period of years indicates that lead is usually lethal to fish only in soft waters. The threshold lethal concentration in very soft waters (hardness 10 mg/l), often found in the Canadian Shield, is about 0.8 mg Pb/l, and about 1.2 mg Pb/l in soft waters of 50 mg/l hardness. A large quantity of data (42, 43) supports the fact that LC50's generally increase with increasing water hardness. In harder waters, not enough lead remains soluble to exert a lethal action.

It appears that under some circumstances, the suspended forms of lead may also be toxic. It is thought that particles of suspended, organic or colloidal lead compounds might be retained on the gills of fish or other animals. Due to increased carbon dioxide levels from respiration, there could be a drop in pH (rise in acidity) in the immediate vicinity of the gill tissue, and since the solubility of lead increases with rising acidity, this would allow the lead to dissolve and diffuse into the gill tissue. The result is suffocation due to gill damage. Exposure to sublethal concentrations of lead slows growth and development and causes anemia, behavioural changes and inhibition of specific enzymes. These changes occur at lead concentrations as low as 0.06% of the 96-hour LC50. Other effects include gradual impairment in the functions of the liver, kidney and spleen (44), and metabolic lesions in the intestine resulting in poor food utilization (45).

LEAD IN WILDLIFE

Waterfowl

The most significant aspect of lead poisoning in wildlife is the problem of spent shot from hunting activities, although the problem of atmospheric contamination and subsequent fallout of industrial lead into wildlife habitats is now beginning to receive attention. The problem occurs when in marshes heavily contaminated with shot, the pellets are picked up accidentally during feeding or intentionally for use as grit. The most susceptible species are certain diving ducks (ringneck, redhead, canvasback), dabbling ducks (mallard, blue-winged teal, pintail), whistling swans and Canada Geese. At Delta, Manitoba, the percentage of birds with lead shot in the gizzard ranged from 4.9% (blue-winged teal) through 15.6% and 18.4% (pintail and mallard, respectively) to 48.1% (redhead) (46). None of the birds examined, however, showed signs of lead poisoning. Karstad (47) estimates the lethal number of ingested pellets to be five or six for a mallard and 15 to 25 for a Canada Goose. The Canadian Wildlife Service is currently sponsoring research at the University of Guelph to develop a substitute for conventional lead shot. The National Research Council has recently developed a pellet made of an iron-lead mixture which is a viable alternative in that the amount of lead ingested is substantially reduced in addition to the fact that iron counteracts lead poisoning, i.e., the toxic effect of lead is reduced in the presence of iron (N. Perrett, personal communication).

Plants might also be a significant source of lead for ducks, since Hevesy (48) found that roots had the ability to bind and concentrate quantities of lead and to block upward transport to the leaves. The food of ducks ranges from 10-100% plant material (49), and industrial and automotive lead appear to contribute to the lead burden of marshes in areas exposed to these sources.

Various instances of lead poisoning in upland birds (as opposed to waterfowl) are reported by Locke and Bagley (50) and Hunter and Rosen (51).

Insects

In the analysis of terrestrial insects taken from high emission areas, there was a trend of increasing lead content from sucking, to chewing, to predatory insects (52). This trend was not apparent in low emission areas. Chewing insects likely ingested more lead from surface deposits on leaves than those sucking liquids from internal vascular tissue. Data on predatory insects that feed on herbivores containing lead suggest that lead is selectively retained in the body, leading to biological concentration of lead in these insect food chains. There was no evidence of biological concentration of lead by herbivorous insects.

LEAD IN LIVESTOCK AND OTHER MAMMALS

Lead poisoning is the most prevalent toxic hazard for livestock. Cattle exhibit strong curiosity and the child-like tendency to ingest strange materials (pica). The problem of lead poisoning originates with the negligent disposal of objects such as old batteries, surplus lead paint and used crankcase oil in areas to which the animals have access. The animals may also lick flaking lead paint on old barn walls. Poisonings from such activity have been reported in Ontario by Hatch and Funnell (53) and in Saskatchewan by Christian and Tryphonas (54).

The question of excessive lead levels in milk as a result of lead ingestion by cattle has not been studied in Canada. In West Germany, Stelte (55) showed that only one out of forty milk powder samples from regions of varying air pollution displayed critically high lead concentration. This was attributed to probable contamination during transport or dairy handling, but Stelte suggested that lead intake from milk consumption should be studied in connection with that from other foods. In Yugoslavia, Kerin and Kerin (56) analyzed the lead content of milk from animals grazing near a lead smelter and found it to be 10-20 times the normal concentration. Rameau (57) found no significant difference between the lead content of milk from cows grazing near a busy highway and that from cows grazing in more remote pastures.

Horses appear to be more susceptible than cattle to chronic poisoning from ingestion of lead. Aronson (58) indicates that although deaths involving cattle, horses and sheep occurred on account of lead poisoning in the vicinity of industrial lead operations, horses exposed to an estimated daily intake as low as 80 ppm (dry weight) in forage were poisoned. Aronson also states that it is unlikely that cattle or horses would eat sufficient quantities of roadside grass contaminated by lead fallout from automotive exhaust to result in clinical lead poisoning.

Hazards to livestock may be created by runoff water from lead mine tailings and plant effluents. The use of lead arsenate insecticides may also present a hazard. As a precaution, animals are kept away from treated areas for several weeks to allow removal of surface deposits by rainfall.

In some zoological parks, monkeys, parrots and other species of captive animals have been poisoned by leaded paint (59). Young dogs are frequently poisoned by chewing and ingesting old paint and linoleum.

Acute lead poisoning is characterized in animals by gastrointestinal and neurological disorders. Lead concentrations over 60 $\mu g/dl$ in the blood, 10 $\mu g/g$ in the liver and 25 $\mu g/g$ in the kidney cortex are considered diagnostic of acute lead poisoning.

Embryopathic effects (death or deformation of the embryo) owing to lead ingestion have been demonstrated in pregnant ewes by Allcroft and Blaxter (60). The injection of lead salts into pregnant hamsters caused selective teratological damage (deformation) in the offspring (61). Mutagenic effects (deformations which are genetic and can be passed on to succeeding generations) have not been described for domestic animals. Lead phosphate and lead acetate have been shown to be carcinogenic in rodents (62).

In a study relating body burden of lead in various species of mice to the source of contamination, Jennett and Rolfe (63) determined that the lead concentrations in the animals are positively correlated with nearby traffic density and, hence, the amount of lead discharged in automobile exhaust. Rodents breathing air containing 2-5 $\mu g\ Pb/m^3$ exhibited significant lead levels in bone tissue, but in no other tissue (64).

Little is known about the synergistic effects of lead with other substances. Six and Goyer (65) noted that a reduction in calcium in growing rats potentiated an increase in lead absorption and blood lead levels. The pattern of lead distribution in the body was altered.

Lead and Human Health

INTRODUCTION

Lead is the oldest and most important environmental poison created by man. Many hundreds of millions of people have been affected by its toxicity during the last 4,500 years, as mining slaves, as consumers of contaminated wine and food, or as breathers of urban air. Although classical lead poisoning has been well known for centuries, it was largely ignored as an issue by physicians and public health officials until the 1920's. It is only in the last ten years that public attention has turned toward lead poisoning, especially childhood lead poisoning.

As a result of this relatively recent concern about the toxic effects of lead on man, the volume of literature covering the subject has become extremely large. Since it is impossible to relate in detail all the aspects of the effects of lead on man within the confines of this paper, discussion is limited to overviews of the following:

1) sources of lead intake,
2) absorption, excretion and accumulation,
3) pathology,
4) health effects, and
5) epidemiology.

SOURCES OF LEAD INTAKE

Concise summaries of material on this subject have been provided by Warren (66) and the National Research Council of Canada (67). Figure 1 is a schematic diagram of lead in the environment and its effects on man.

Lead enters the body primarily by ingestion or inhalation. As most of it is not absorbed by the digestive tract and much of the lead inhaled is immediately exhaled, the term "absorbed lead" refers to the lead that actually enters the blood stream.

Sources of lead to which all individuals are exposed are air, drinking water and food. The degree of lead contamination in these varies with geographical location, but there is always at least a trace of background lead present. These sources are described in the following sections.

Air

There is conflicting evidence, both scientific and medical, as to the extent that lead in air poses a threat to human well-being. This arises partly because sampling procedures vary and, in most cases, climatic conditions are undefined. In the United States, a value for lead content of 0.05 $\mu g/Pb/m^3$ has been assigned to "normal" rural air (68) and 0.3-2.5 $\mu g/Pb/m^3$ to general urban environments (69).

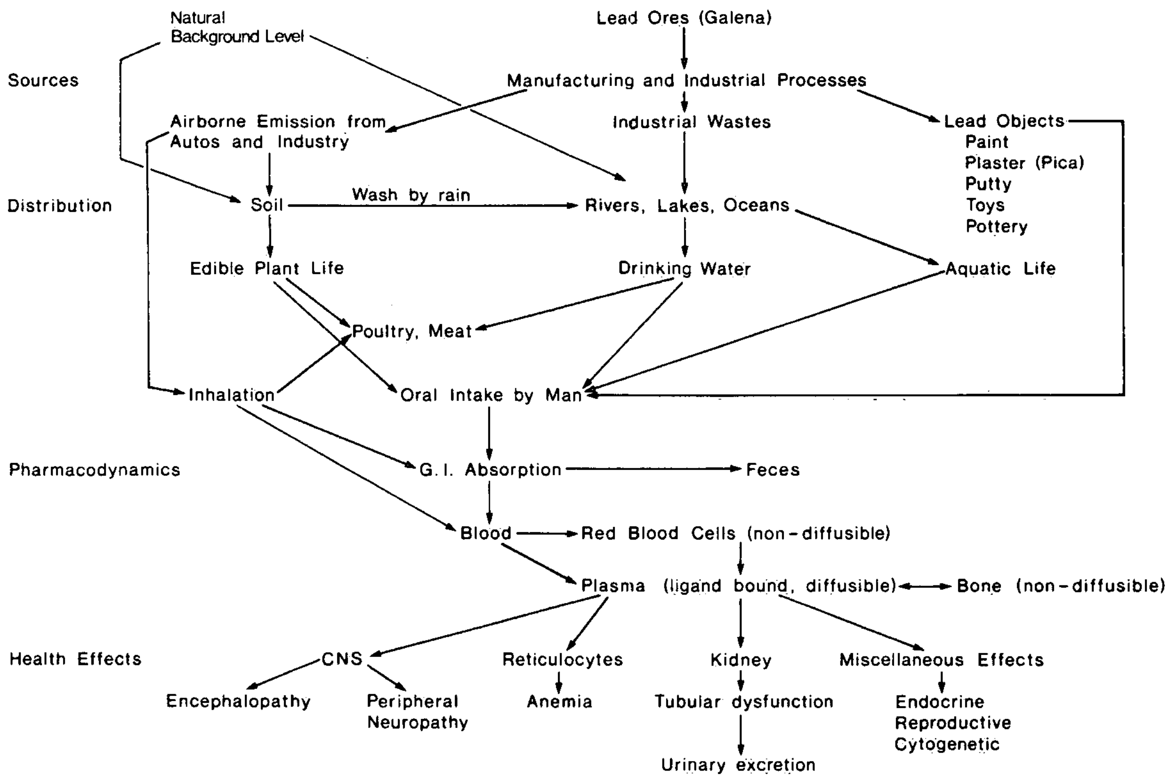


Figure 1. Ecodiagram of lead in the environment and its effects on man. Source: Metallic Contaminants and Human Health, 1972, Lee (ed.).

The Working Group on Lead, in a report to the Ontario Minister of the Environment (70), considers an ambient air quality objective for lead of 5 $\mu g/m^3$, based on a 24-hour average, to be adequate to maintain blood lead levels of most children at or below 25 $\mu g/100$ g. In an internal report of the Atmospheric Environment Service, Phillips and Sanderson (71) indicate that this objective is adequate to maintain the adult blood lead level at or below 30 $\mu g/100$ g.

Table 1. Some Atmospheric Lead Concentrations in Areas of Traffic

Cities	Sampling site locations	Time sampled (hr)	Average lead concentration ($\mu g/m^3$)
U.S.A.			
Cincinnati	4 sites, 5-21 m above ground	24-72	1.4
Los Angeles	8 sites, 1.5-29 m above ground	24-72	2.5
Los Angeles	Central city, 5 m above ground	24	3.6
New York	Central city, 8 m and 25 m above ground	24	2.1
Canada			
Vancouver	6 commercial sites, 1 m above ground	15	8.2
Toronto	6 commercial sites, 5 ft above ground	15	8.4
Montreal	6 commercial sites, 10 ft above ground	15	4.0

Source: Manson and De Koning (13)

The atmospheric lead concentrations of some major cities in Canada and the United States are shown in Table 1. The source of these data (72) indicates that these levels may be sufficiently high to produce adverse physiological effects in high-exposure population groups.

Depending on individual air intake and place of work, daily inhalation of lead may be estimated at 1-20 μg (73). Assuming 40% absorption (74), the daily lead intake from the atmosphere becomes 0.4-8 μg.

Drinking Water

The World Health Organization has established the maximum permissible level of lead in communal drinking water at 0.1 mg/l (ppm), or 100 μg Pb/l. Neri, Schreiber and Fortescue (75) have determined the lead concentration in drinking water from 247 locations in Canada. The range was from 0-320 μg Pb/l with a mean of 11.82 μg Pb/l. This information is given in Table 2.

Table 2. Lead in Canadian Drinking Water

Range (μg/l)	Number of samples	Percent
<10	156	63.2
10–25	71	28.7
25–50	16	6.5
50–100	1	0.4
>100	3	1.2

Source: Neri, Schreiber and Fortescue (75)

An average person's fluid intake is one to two litres per day (76). Assuming that it is all tap water, the lead intake from this source for 92% of the population will be below 50 μg Pb/day with the mean approximately 18 μg Pb/day. In some instances, depending on the hardness of the water (see "Forms of Lead in the Environment" in Chapter 2), this intake will be increased due to the use of lead solder in copper water pipes and electric kettles. In houses where old-fashioned lead pipes are still used to convey drinking water, the lead intake of the inhabitants could be substantial. Poisonings occurring in this way have been reported in Scotland (77) and Wales (78).

Food

With respect to ingestion, most writers rank food, rather than fluids, as the major source of lead. The range of lead content of some Canadian diets is presented in Table 3. From figures on the proportion of any food in the national diet and the mean concentration of lead in that food, the daily uptake of lead per capita from the food has been calculated. These figures have been found to vary from time to time and city to city. The largest sources of lead in the diet tend to be fruits, followed by cereals, meat and fish, and dairy products. The use of lead solder in tin cans is the main source of lead in canned foods. The Nutrition Survey of Nutrition Canada estimates the average per capita daily intake of lead from food to be 139 μg.

Table 3. Range and Total Lead Content of Canadian Total Diet Composites, 1971

Constituent of diet	Percent of constituent in national diet (wet wt.)	Lead in constituent Range (μg/g)	Lead in constituent Mean (μg/g)	Mean total lead intake from constituent (μg/person/day)
Milk and dairy food	27.7	0.01-0.08	0.044	22
Meat, fish, poultry	15.5	0.02-0.15	0.066	18
Cereals	10.7	0.05-0.19	0.122	22
Potatoes	10.7	0.02-0.10	0.053	11
Leafy vegetables	2.6	0.00-0.08	0.046	2
Legumes	1.8	0.04-0.31	0.133	5
Root vegetables	2.8	0.00-0.09	0.043	2
Garden fruits	4.5	0.03-0.19	0.100	8
Other fruits	10.7	0.06-0.39	0.188	36
Oils and fats	1.5	0.03-0.28	0.084	2
Sugar	8.0	0.02-0.14	0.069	10
Drinks	3.3	0.00-0.02	0.007	1
				139

Source: National Nutrition Survey, quoted in _Lead in the Canadian Environment_

The use of glazed containers such as china, pottery, stoneware and enamelware may constitute a source of lead contamination of foods stored therein. The best glazes are the lead silicates, and although lead bisilicate is relatively insoluble in diluted acids, its solubility characteristics can be altered drastically by improper formulation or application. Improperly glazed articles can release toxic levels of lead into acid media such as fruit juice and tomatoes (79). A fatal poisoning from this source was reported in Montreal (80).

The Department of Consumer and Corporate Affairs routinely screens dinnerware for leachable lead. Some products have been identified as releasing dangerously high levels of soluble lead, and although action is taken to recall these articles, it is certain that many homes contain vessels that are capable of substantially increasing the lead burden if used in the preparation or storage of acidic foods.

Some makes of electric kettles have recently been investigated regarding amounts of lead released owing to their solder content. The Product Safety Branch of the Department of Consumer and Corporate Affairs reports that manufacturers are now using lead-free alloys in place of the lead-tin alloy formerly used (H.C. Leitch, personal communication).

Total Daily Lead Intake

The total daily lead intake, although varying according to individual life habits, is estimated for the average Canadian in the following table.

Source	Intake (μg)
Food	140
Water	20
Air	20

A rough approximation for the average amount of lead absorbed would be:

Source	Intake (μg)
Food	14 (10% absorbed)
Water	2 (10% absorbed)
Air	8 (40% absorbed)
	24

There are several sources of lead to which an individual may be exposed, depending on personal habits and occupation. These are described in the following sections.

Industrial Operations

In the past, the production and processing of lead in the presence of poor hygiene practices have caused dangerous exposure to lead. Some of the occupations involving potentially hazardous exposure follow:

- the refining of lead scrap,
- the manufacture of electric storage batteries,
- the manufacture of pigments,
- the manufacture and blending of lead antiknock additives,
- the grinding of lead solders used in auto body work,
- the cutting and joining of metals coated with lead paints,
- the process of lead lining,
- the application of lead-based paints,
- the manufacture and pouring of lead alloys,
- the coating of tubes and cables with lead,
- the manufacture of lead stabilizers used with plastics, and
- the use of lead type metal in printing and engraving machinery.

In recent years, reputable industrial organizations and provincial departments of labour and health have introduced sensible precautions which have largely reduced chronic lead poisoning from occupational exposure. Nevertheless, the effects of long-term sublethal exposure to lead contamination through industrial environments are still under study.

Lead Paint

Although lead pigments are now forbidden by law for interior use and children's toys (see "Provincial Lead Consumption by Industry - Chemical

Industries," in Chapter 4), they are still prevalent in older substandard housing. The ingestion of flaking paint and chips from the interior surfaces of such housing constitutes the greatest single cause of childhood lead poisoning. Chisolm (81) states that

> "a chip of paint about the size of an adult's thumbnail can contain between 50 and 100 mg of lead, and so a child eating a few chips a day easily ingests 100 or more times the tolerable adult intake of the metal."

When old paint is scraped or burnt off the exterior of houses, it becomes a source of contamination in the surrounding soil.

Dust

The measurement of lead in dust is a crude, but simple, way of assessing local lead contamination. "Normal" dusts from average soils contain from 10-20 ppm lead. Values from 0.5-6% (5,000-60,000 ppm) lead in dust, however, are common in large cities. The danger of such concentrations to children has been cited by Bryce-Smith (82). He states that young children

> "are liable to inhale it and ingest it by sucking fingers, toys, etc. At 30,000 ppm, the daily ingestion of as little as 1/1000 ounce (30 mg) of dust would place a child at risk of developing clinical lead poisoning within a few months even without making allowance for the lead inhaled and taken in with normal food and drink."

Cigarette Tobacco

Horton (83) has stated that the intake of lead from cigarettes is estimated to be about 1 μg per cigarette. Thus a person who smokes twenty cigarettes a day, assuming an absorption in the lungs of 50% (84), could absorb 10 μg of lead a day.

Illicit Liquor

Next to leaded paint in old buildings, illicit liquor is the most common source of chronic lead poisoning in the United States (85). Distillation equipment used in the production of "moonshine" whiskey generally contains soldered joints, and the condenser is often a car or truck radiator. The resulting distillate may contain a substantial amount of lead (86). Officers of the R.C.M.P. and officials from the Department of National Health and Welfare have found that distillation equipment used in Canada is more sophisticated, and the analysis of impounded liquor has revealed very few samples that have appreciable amounts of lead (87).

Paint on Pencils

Pencils have been cited as a potential source of lead intake (88). Some manufacturers have used lead chromate as a pigment, and concentrations as high as 30% have been found by the Department of Consumer and Corporate Affairs. Regulations under the Hazardous Products Act have abolished the use of lead chromate as a paint pigment in pencils.

ABSORPTION, EXCRETION AND ACCUMULATION

Absorption

Lead is poorly absorbed from the alimentary tract. Only 10-15% of it is absorbed when daily dosage does not exceed 1-4 mg (89). Acute poisoning may develop following ingestion of a large dose of soluble salt, whereas poisoning may occur within several weeks if the adult daily dose is about 6-10 mg (90). In the respiratory tract, distribution of inhaled particles is a function of particle size. The rate of absorption from the respiratory tract into the blood depends on factors such as the permeability of the compound in the epithelium and endothelium of the respiratory tract, particle size and the nature of the interface between the particles and the respiratory membrane. There is no evidence of permanent accumulation in the lungs, as with silica. Consequently, whatever the original chemical or physical form, the lead compound is eventually absorbed or transferred to the intestinal tract.

Excretion

Approximately 90% of the lead ingested in food and beverages is excreted in the feces. Thirty-three percent of the finely divided inhaled lead particles are retained by the respiratory tract, the other 67% being exhaled. Significant amounts are also excreted in urine, sweat and other aqueous, mucus or lipoid secretions. Additional quantities are shed regularly in falling hair, desquamated skin and clipped nails.

Accumulation

The daily excretion of lead by way of feces, urine, sweat and hair closely approximates daily ingestion, so that most people are virtually in lead balance at a level that reflects total exposure. Lead can be called a "cumulative poison" when the rate of uptake exceeds the combined excretion rate through kidney, bowel and other routes. A relatively high rate of intake can result in toxic symptoms before a new equilibrium between intake, body burden and excretion can be established.

Of the lead retained by the body, over 90% resides in the skeleton and the balance is widely distributed. Red blood cells contain most of the lead in the blood; wet weight concentrations of lead in soft tissue are low.

PATHOLOGY

The most prominent adverse effects of lead involve three organ systems: the nervous system, the hematopoietic (red blood cell synthesis) system, and the kidney.

The effects of lead on the nervous system are both structural and functional, involving the brain and cerebellum, as well as the spinal cord and motor and sensory nerves leading to specific areas of the body. The effects on the central nervous system (lead encephalopathy) are varied. In adults, effects on the digestive system predominate, whereas in children the brain is primarily affected. Neural tissue is very sensitive to the toxic effects of lead, and in severe cases, the whole brain is swollen or edematous.

In the hematopoietic system, anemia occurs in lead poisoning probably from two basic causes: impairment of heme (a precursor of hemoglobin) synthesis and increased rate of destruction of red blood cells. In the former, lead may act at several stages in heme formation processes occurring within the mitochondrion, the energy producing organelle of the cell. A well-defined effect involves inhibition by lead of the enzyme delta-aminolevulinic acid dehydratase (ALAD), resulting in increased serum and urinary levels of delta-aminolevulinic acid (ALA). The measurement of urinary ALA is a method of determining the presence of excessive lead levels. In a subsequent step, lead impairs the incorporation of iron in heme, which renders it incapable of oxygen transport.

In addition to reducing the life span of red blood cells, lead also interferes *in vitro* with their ability to transport sodium and potassium ions, which are basic cell nutrients, into and out of the cells (91).

In the case of renal effects, the excretory function of the kidney commits this organ to active lead metabolism and susceptibility to adverse effects of lead. A characteristic response of the kidneys of humans and experimental animals exposed to large quantities of lead is the formation of intranuclear inclusion bodies, lead-protein complexes in which the lead is bound in a non-diffusible form, in renal tubular lining cells. Goyer and Chisolm (92) hypothesize that these bodies enable the kidney to excrete large amounts of lead without destroying the viability of the tubular lining cells.

HEALTH EFFECTS

Goyer and Chisolm (93) have described the following clinical syndromes of illness induced by lead poisoning in man:

- anemia of plumbism (anemia owing to high blood lead),
- syndrome of acute abdominal colic (intense abdominal pain),
- syndrome of acute encephalopathy (severe disorder of central nervous system),
- syndrome of chronic encephalopathy (mild disorder of central nervous system),
- syndrome of peripheral neuropathy (alteration of peripheral nerve function), and
- syndrome of late or chronic nephropathy (gradual impairment of kidney function).

At least 25% of the young children who survive an attack of acute encephalopathy sustain severe permanent brain damage (94). Chisolm and Harrison (95) report that if a child, following a single known attack of acute encephalopathy, is returned to the same hazardous home environment, the risk of severe permanent brain damage in that child increases to virtually 100%. Neurologic deficits and mental impairments, including lack of sensory perception and perseverance, are common.

In adults, the long-term sequelae (aftereffects) of lead poisoning include peripheral neuropathy and lead nephropathy, these being associated with prolonged excessive exposure to lead and a history of recurrent episodes of acute poisoning.

Evidence has been accumulated demonstrating adverse effects of lead on the endocrine system (96), reproductive system (97) and pulmonary system (98). Carcinogenic effects of chronic lead toxicity have been demonstrated in rats and mice (99). There is, however, no evidence that lead is carcinogenic in man.

Normal or "Natural" Level

All persons have very small, but measurable, quantities of lead in blood, urine and tissues. No essential metabolic requirement for the metal has been demonstrated. Blood lead concentrations are generally reported in micrograms lead per decilitre (100 ml) of whole blood, and occasionally in micrograms lead per 100 g of whole blood. The density of blood is about 1.06 g/ml, and values can be taken as approximately equivalent for the purpose of this report (40 μg/100 ml = 42.4 μg/100 g). In the case of adults, the range of blood lead values may be divided into three categories: below 40 μg Pb/dl is normal; between 40 μg Pb/dl and 80 μg Pb/dl indicates that lead uptake is above normal but has not reached toxic values; and above 80 μg Pb/dl indicates that toxic symptoms could appear. In the case of children, however, a level of more than 30 μg Pb/dl indicates undue lead absorption; children showing such levels need special attention and should be periodically checked (100).

No metabolic change has been found in adults with blood lead concentrations of less than approximately 40 μg Pb/dl. A negative correlation, however, has been found between blood lead concentration and the activity of ALAD in hemolysates of blood when assayed in vitro. The metabolic consequence of inhibition of ALAD activity in vitro is accumulation and increased excretion of the unused portion of the enzyme's substrate, ALA. The first detectable increase of ALA in urine can be seen as blood lead concentration increases from 40-60 μg Pb/dl (101). No impairment of organ function attributable to lead has been demonstrated in otherwise healthy adults with these findings.

The various effects of lead are shown in Table 4, together with the different ranges of blood lead levels associated with each type of effect.

EPIDEMIOLOGY

Based on the observation that clinical symptoms are observed in children at lower blood lead levels than adults, it can be said that children are more sensitive than adults to lead poisoning. The ingestion of paint chips is the greatest cause of childhood lead poisoning in the United States. The Bureau of Community Environmental Management of the United States Public Health Service (102) has estimated that there are between 200,000 and 400,000 children under five years of age with blood lead levels in excess of 40 μg Pb/dl in the United States. Some 10,000 to 20,000 will have symptomatic lead poisoning and require treatment. Some 200 children will die annually as a result of lead poisoning; 800 more will be so severely affected by encephalopathy as to require permanent hospitalization; and another 2,000 to 4,000 will develop some degree of neurological handicap, necessitating years of special care. The Environmental Protection Agency estimates that a total of five million individuals in the United States have blood lead levels in excess of 40 μg Pb/dl.

In Canada, the proportionate incidence of mental retardation, illness and death related to lead poisoning has not been encountered. Canadian pediatricians admit pica (the tendency to eat non-food substances, such as flaking paint and plaster) exists, but they are at a loss to explain the absence of lead poisoning episodes related to this habit, given that paints with high lead content have also been used in Canada.

The initial symptoms of lead poisoning are non-specific and hence presence of the disease could be overlooked. No satisfactory evidence of the possible extent of the disease in Canada can be achieved without some broad epidemiological survey, employing some objective clinical measurement such as blood lead levels.

Table 4. Effects of Inorganic Lead Salts in Relation to Absorption

	1	2	3	4		5
				Acute lead poisoning		
Types of effects	No demonstrable *in vivo* effect	Minimal subclinical metabolic effect	Compensatory biologic mechanisms invoked	Mild	Severe	Late effects of chronic or recurrent acute lead poisoning
A. Metabolic: (accumulation and excretion of heme precursors)	normal	slight increase in urinary ALA may be present	progressive increase in ALA, UCP, FEP	increased 5 to 100 fold		increased if excessive exposure recent, but may not be increased if excessive exposure remote
B. Functional injury: 1. Hematopoiesis	none	none	shortened RBC life span, reticulocytosis (±) (reversible)	shortened RBC life span and reticulocytosis with or without anemia (reversible)		Anemia (±) (reversible)
2. Kidney (renal tubular function)	none	none	?	aminoaciduria glycosuria (±) (reversible)	Fanconi syndrome (reversible)	chronic nephropathy (permanent)
3. Central nervous system	none	none	?	mild injury (??? reversible)	severe injury (permanent)	severe injury (permanent)
4. Peripheral nerves	none	none	?	rare	rare	impaired conduction (wrist, foot drop usually improve slowly, but may be permanent)
C. Clinical effects	none	none	non-specific mild symptoms (may be due in part to co-existing diseases)	colic, irritability, vomiting	ataxia, stupor, coma, convulsions	mental deficiency (may be profound) seizure disorder, renal insufficiency (gout) (permanent)

Pb = lead; ALAD = delta-aminolevulinic acid dehydratase; ALA = delta-aminolevulinic acid; UCP = urinary coproporphyrin; FEP = free erythrocyte protoporphyrin; RBC = red blood cell
Source: Metallic Contaminants and Human Health

The Ontario Ministries of Health and the Environment have published two reports concerning environmental lead levels and human health. The studies were undertaken after the discovery of high blood lead levels in persons living near secondary lead smelters in the city of Toronto. In one report, the Working Group on Lead (103) concluded that the smelters contribute to lead contamination of the surrounding environment "in excess of the degree of contamination found in urban areas due to other industrial and automotive sources." The Group also found that environmental lead levels adjacent to expressways and major arterial streets represent a risk of increased lead exposure to persons living and working in these zones. The other report, entitled The Effect on Human Health of Lead from the Environment (104), presents figures on the incidence of death and illness from lead poisoning in Ontario. There have been no deaths from lead poisoning in Ontario in the past 14 years. In the past four years, 60 persons were admitted to hospital in the Province with evidence of excessive lead absorption. In none of the symptomatic cases (apart from workers in a plant) was proximity to an industrial source thought to be a factor in the excessive absorption of lead. It is emphasized in the report that it was impossible to define clearly the full effects of lead on health or the degree of control required to safeguard people, and that for the present, "opinions have to be based on gross and incomplete information and action upon what appears to be the prudent course."

Structure of Lead Production and Use in Canada

INTRODUCTION

Despite the abundance and diversity of the Canadian resource base and in addition to the extremely large geographical area of Canada, activities involving the production, manufacturing and consumption of lead are localized in several regions that represent only a small fraction of the total area. To avoid the oversimplification which results from studying lead production and use on a national basis, an attempt has been made in this paper to reduce the area considered and thereby improve the understanding of the environmental implications of this use. The subdivision of national data on the basis of physical geographical units of environmental significance, such as major drainage basins, constitutes one means of achieving this reduction. In the case of lead production (mining, smelting and refining), this has been done with relative ease due to the limited number of establishments involved. Data on lead consumption by industry, however, are not available in a form that readily lends itself to this type of analysis. In addition, the large number of establishments involved and the lack of detailed information on specific lead consumption activities present a problem in attempting to aggregate suitable information.

In light of these limitations, data involving lead consumption in industry have been assembled for this paper on a provincial basis by Statistics Canada. By assuming that industrial activity has been confined to specific drainage basins within each province, an approximation is attained concerning the localized nature of this activity. Population data on the drainage basins have been developed which give an insight into consumption activities that are assumed to be directly proportional to population.

NATIONAL BACKGROUND INFORMATION

General information on a national basis is provided in Table 5, a summary of national data on production, trade and consumption of lead for 1961 to 1973 inclusive, and in Figure 2, a material flow chart illustrating the production and distribution of lead in the Canadian economy in 1972.

Graphs 1 and 2 present Canadian production and consumption of refined lead from 1951 to 1972 inclusive.

Exports

Most of Canadian lead output is exported either in ores and concentrates or as refined lead. For this reason, changes in domestic demand for lead have little influence on mine output of lead, whereas fluctuations in external demand exert considerable impact. The United States and Great Britain have been and continue to be Canada's two major customers of lead exports. Canadian exports of lead in ores, concentrates and refined form from 1951 to 1972 are illustrated in Graph 3.

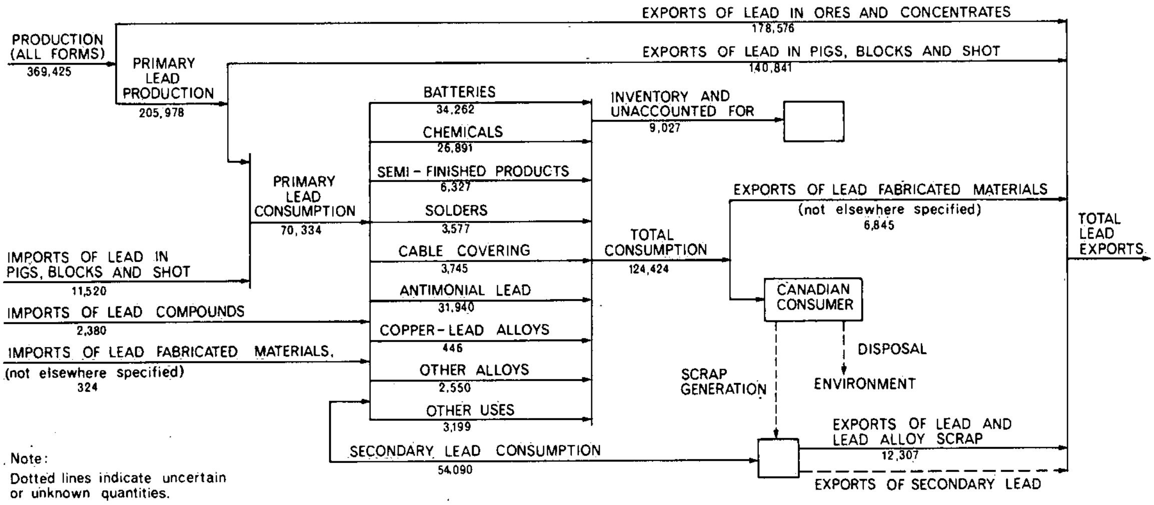
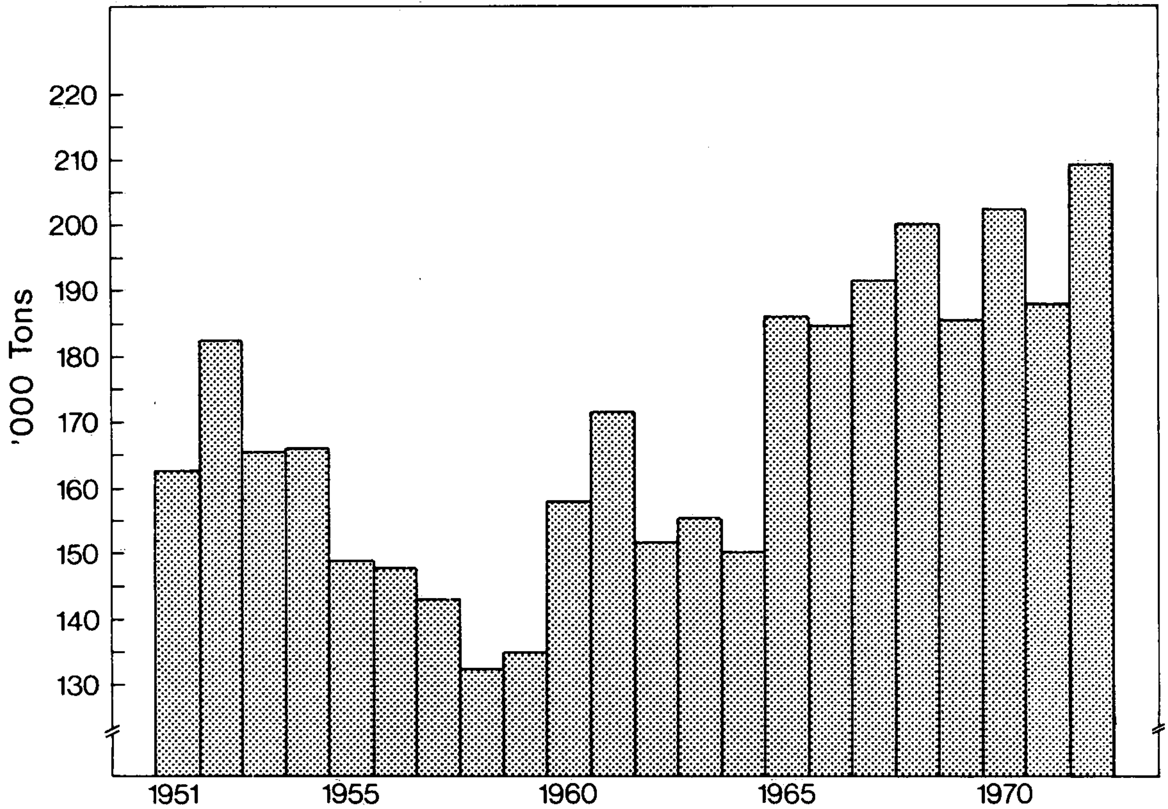


Figure 2. Material flow chart of lead in Canada, 1972 (short tons). Sources: Canadian Minerals Yearbook - 1972, Department of Energy, Mines and Resources; Report EPS 3-AP-74-1, 1974, Air Pollution Control Directorate, Department of the Environment.

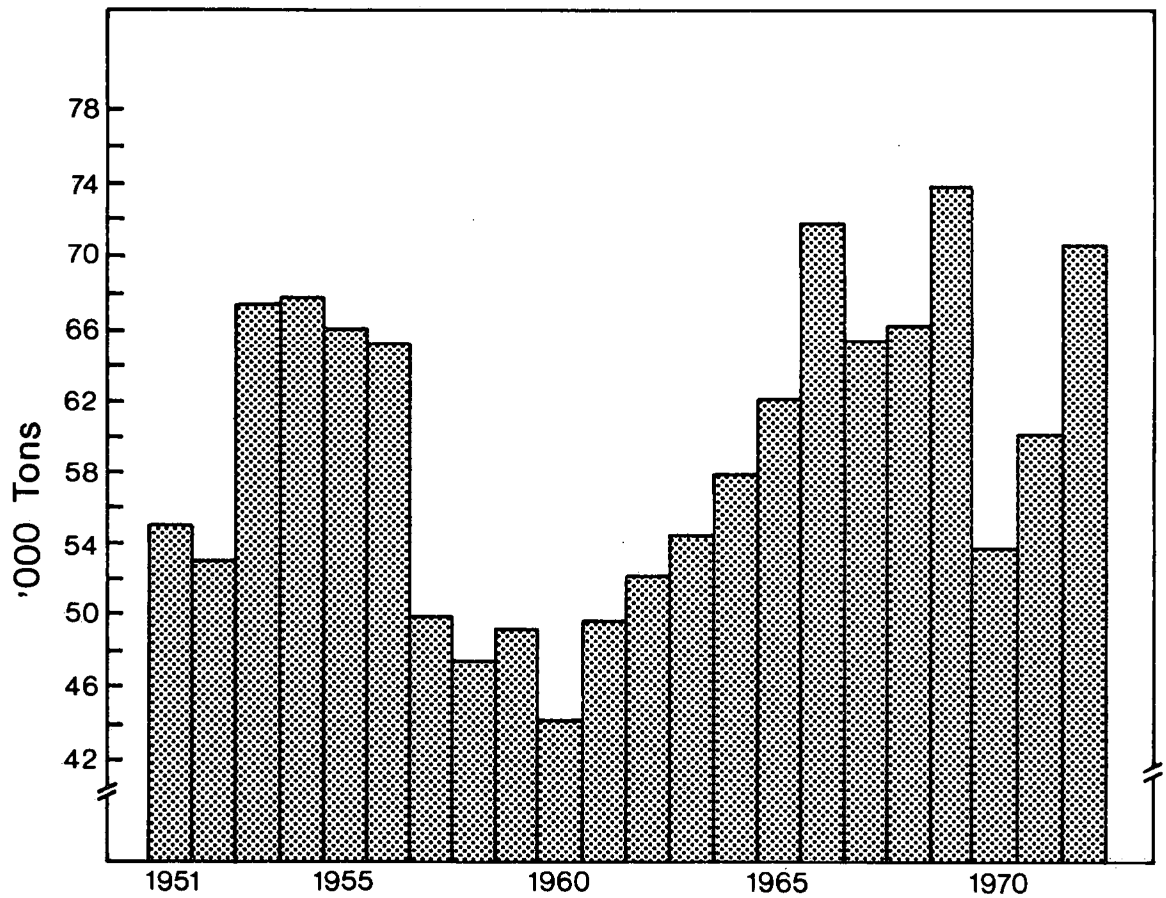
Table 5. Canadian Lead Production, Trade and Consumption, 1961 to 1973 (tons)

Year	Production			Exports			
	All forms*	Refined†	In ores and concentrates	Refined	Total	Imports Refined‡	Consumption§
1961	230,435	171,833	70,967	117,637	188,604	1,121	73,418
1962	215,329	152,217	59,495	125,802	185,297	578	77,286
1963	201,165	155,000	53,756	97,144	150,900	1,741	77,958
1964	203,717	151,372	80,357	95,867	176,224	73	82,736
1965	291,807	186,484	106,964	129,065	236,029	71	90,168
1966	300,622	184,871	112,934	106,468	219,402	626	96,683
1967	317,963	193,235	126,194	132,320	258,514	438	93,953
1968	340,176	202,100	143,853	138,781	282,634	152	94,660
1969	318,632	187,143	140,175	107,090	247,265	131	105,915
1970	389,185	204,630	165,912	152,821	318,733	2,199	105,543
1971	405,510	185,554	214,354	136,884	351,238	4,632	92,961
1972	369,425	205,978	178,576	140,841	319,417	11,520	124,424
1973P	385,864	206,012	222,407	125,181	347,588	4,011	119,082

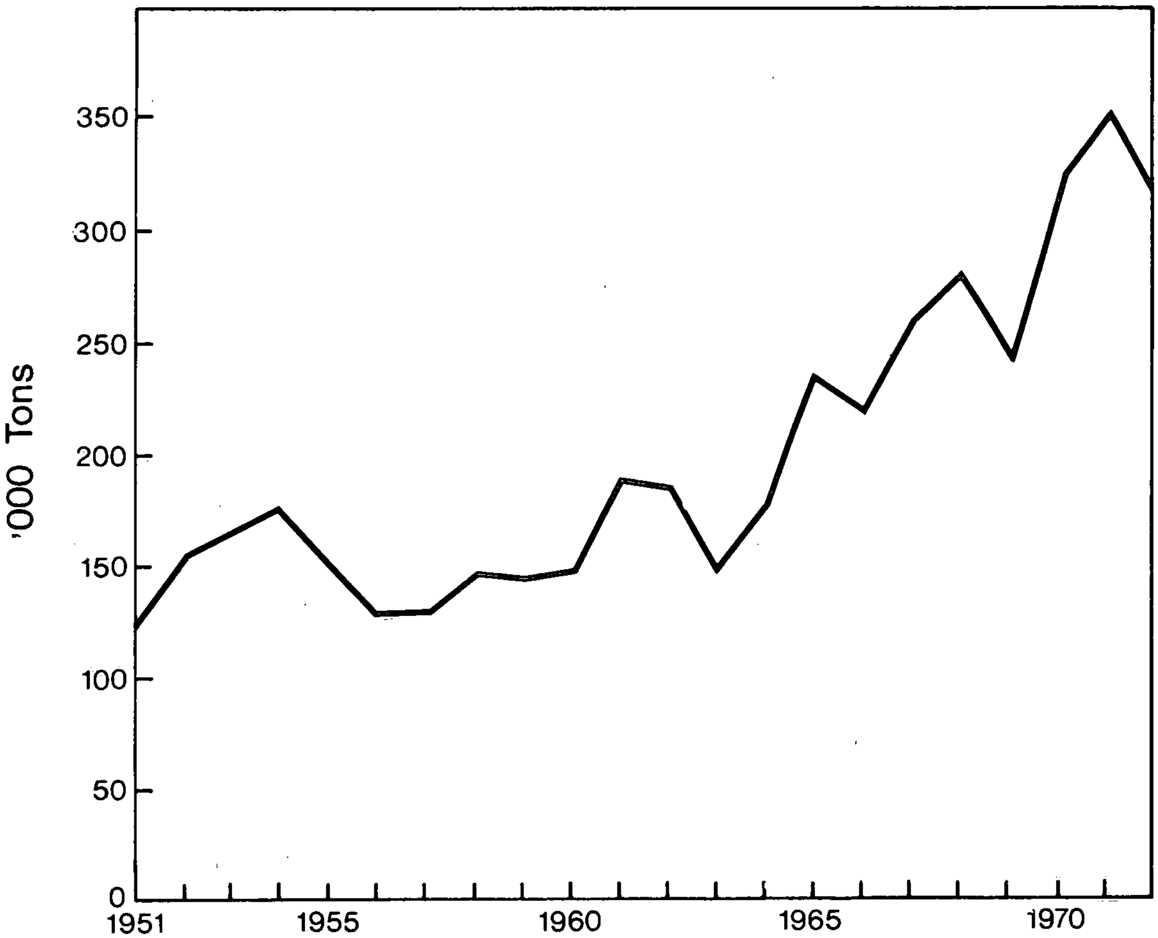
*Lead content of base bullion produced from domestic primary materials (concentrates, slags, residues, etc.) plus the estimated recoverable lead in domestic ores and concentrates exported
†Primary refined lead from all sources
‡Lead in pigs and blocks (see Table 7 for other imports)
§Consumption of lead, primary and secondary in origin
P - Preliminary
Source: Statistics Canada



Graph 1. Production of refined lead in Canada, 1951-1972 (short tons). (Refined lead is pig lead. The totals include lead from foreign ores.) Source: Mineral Resources Branch, Department of Energy, Mines and Resources.



Graph 2. Consumption of refined lead (producers' shipment to domestic consumers) in Canada, 1951-1972 (short tons). Source: Mineral Resources Branch, Department of Energy, Mines and Resources.



Graph 3. Canadian exports of lead in ores and concentrates and refined form 1951-1972 (short tons). Source: Mineral Resources Branch, Department of Energy, Mines and Resources.

Although exports of lead in ores, concentrates and refined form generally vary linearly with production (Table 5), this has not always been the case. For example, production of primary lead in all forms decreased by 7% from 1968 to 1969, while exports of lead in ores and concentrates fell by only 3% and refined lead exports, by 23% in the same period.

Exports of lead and lead products for the years 1971 and 1972 are presented in Table 6. Throughout these years, approximately 60% of exports of lead contained in ores and concentrates went to smelters in Japan, and most of the remainder was shipped to West Germany, the United States and Belgium.

Canadian lead exporters face increasing competition from expanding mine output throughout the world. The United States, which for many years has been Canada's most important foreign lead market, is becoming more self-sufficient. Mine output in the United States rose by 72% from 1967 to 1972, largely owing to record production in the "new lead belt" in Missouri. Surplus government stocks of lead represent an additional source of supply. As a result of these factors, the greater part of Canada's lead exports may require outlets in other countries.

Table 6. Canadian Exports of Lead and Lead Products, 1971 and 1972

	1971		1972	
	Tons	Value ($ 000's)	Tons	Value ($ 000's)
Lead in concentrates and ores	214,354	$35,760	178,576	$31,635
Lead in pigs, blocks, shot	136,884	30,664	140,841	34,555
Lead and lead alloy scrap (gross wt.)	5,848	1,190	12,307	1,880
Lead fabricated materials, NES	3,757	1,379	6,845	2,239
	360,843	68,993	338,569	70,309

Source: Statistics Canada

Imports

Imports of lead and lead products for the years 1971 and 1972 are presented in Table 7, and imports of refined lead for the years 1961 to 1973 are reported in Table 5. Refined lead imports were almost negligible in 1964 and 1965, gradually increasing to 11,520 tons in 1972. These figures reflect the effects of domestic demand for refined lead combined with foreign prices and tariffs.

Table 7. Canadian Imports of Lead and Lead Products, 1971 and 1972

	1971		1972	
	Tons	Value ($ 000's)	Tons	Value ($ 000's)
Lead in pigs, blocks, shot	4,632	$1,294	11,520	$2,929
Lead oxide, litharge, red lead, mineral orange	3,029	825	2,380	717
Lead fabricated materials, NES	371	238	324	204
	8,032	2,357	14,224	3,850

Source: Statistics Canada

CANADIAN LEAD PRODUCTION BY PROVINCE

Lead production is calculated as the lead in base (unrefined) bullion made from Canadian ores at Canadian smelters, plus the recoverable lead content in ores and concentrates exported. The value is then computed on the basis of the average price for refined lead, in Canadian dollars.

The production of lead in all forms by province for 1970 to 1972 inclusive is presented in Table 8. Lead smelting capacity and refined lead output for the same years are shown in Table 9. Table 10 presents a description of Canadian lead mining establishments, their milling capacities, grades of ore milled and outputs of ore and concentrates in 1972 and 1973. This Table is updated annually by the Department of Energy, Mines and Resources. In the case of some mines, the output of lead in concentrates and direct shipping ores appears small when compared with the quantity of ore produced and the lead content of this ore. In these mines, the recovery of other metals, for example, copper, has been determined economically attractive in spite of the attendant loss of efficiency in lead recovery. The extent to which this is done depends on current metal prices and the relative metal concentrations in the ore. The locations of principal Canadian lead mine producers and primary reduction plants are shown in Map 1 (in pocket).

Table 8. Production of Lead* by Province, 1970, 1971 and 1972

	1970		1971		1972	
Province	Pounds	Value ($ 000's)	Pounds	Value ($ 000's)	Pounds	Value ($ 000's)
Newfoundland	35,459,862	$ 5,610	26,961,000	$ 3,640	24,405,000	$ 3,765
Nova Scotia	2,597,766	411	829,640	112	-	-
New Brunswick	125,349,742	19,830	130,810,024	17,659	90,980,000	14,036
Quebec	4,317,274	683	1,293,568	175	3,351,000	517
Ontario	23,920,137	3,784	17,830,939	2,407	21,211,000	3,272
Manitoba	1,010,196	160	403,064	54	391,000	60
British Columbia	214,838,525	33,987	247,927,691	33,470	195,149,000	30,108
Yukon	131,670,010	20,830	217,336,142	29,340	222,922,000	34,392
Northwest Territories	239,206,099	37,842	167,628,110	22,630	180,440,000	27,838
	778,369,611	123,138	811,020,178	109,488	738,849,000	113,989

*Primary lead in base bullion produced, plus recoverable lead in ores exported
- Nil
Source: Statistics Canada, Catalogue 26-216

Table 9. Lead Smelting Capacity of Canada, 1970, 1971 and 1972

			Refined lead production (tons)		
Company	Number of blast furnaces	Annual capacity (tons of charge)	1970	1971	1972
Cominco Ltd.	2	670,000	184,558	163,138	169,998
Brunswick Mining and Smelting Corp. (Smelting Div.)	1	180,000	20,072	22,416	35,980
			204,630	185,554	205,978

Sources: Statistics Canada, Catalogue 41-214
Refined production obtained from M. J. Gauvin, Mineral Resources Branch, Department of Energy, Mines and Resources, personal communication, 1974

PROVINCIAL LEAD CONSUMPTION BY INDUSTRY GROUP

The data presented in this section were derived from figures provided by the Fabricated Metals Unit, Manufacturing and Primary Industries Division, Statistics Canada, by special request, and are essentially a provincial subdivision of the information published in the annual Census of Manufactures catalogues.[3]

In some instances, the sum of reported provincial figures on lead consumption for a particular industry or Standard Industrial Classification (S.I.C.) may fall significantly short of the national total published in the corresponding Census of Manufactures catalogue. This difference represents the total consumption of those provinces that individually contain too few establishments[4] to allow release of provincial statistics.

The information supplied by Statistics Canada is presented in tabular form throughout this section, along with brief descriptions of relevant industries. In viewing these data, it should be understood that S.I.C.'s included are only those covering establishments for which lead consumption was reported. Furthermore, the figures presented apply only to establishments reporting detail within these S.I.C.'s. In many other industries, lead is consumed for a variety of purposes in amounts too small to be reported. A list of the standard industrial classifications reporting lead consumption is provided in Appendix A.

On the basis of pounds of lead processed in 1972, Ontario establishments accounted for the largest percentage (64%), followed by Quebec (20%), Manitoba (6%), Alberta (5%) and British Columbia (1%). The remaining 4% is attributed to the other provinces. These provincial statistics are shown in Tables 11a and 11b.

Refined Metal Producers

Lead consumption in this industrial category is primarily for the production of lead alloys, lead-fabricated materials and primary and secondary refined lead. Provincial statistics are reported in Table 12. Although trace amounts of lead are consumed in the production of several metals, lead consumption is generally confined to the following industries.

1) Metal Rolling, Casting and Extruding (S.I.C. 298)

This industry covers establishments mainly manufacturing non-ferrous metals and their alloys in shapes such as bars, rods, plates, sheets and castings. Also included are establishments that recover non-ferrous metals from scrap. This industry is the source of lead-fabricated materials such as type metal, solder, babbitt and other lead alloys, as well as semi-finished lead products including pipe, traps, bends, plate and wire. In addition, secondary lead and antimonial lead are recovered by firms in this industry.

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[3] Census of Manufacturers catalogues used throughout this report are listed in Appendix A.

[4] In this report, the Statistics Canada definition of "establishment" is used, i.e., a single individual accounting unit capable of producing basic statistics such as employment figures and wages.

Table 10. Principal Lead (Mine) Producers in Canada, 1973 (1972)

Company and location	Mill capacity (tons ore/day)	Grade of ore milled (principal metals) Lead (%)	Zinc (%)	Copper (%)	Silver (troy oz/ton)	Ore produced (tons)	Lead in concentrates and direct shipping ores (tons)	Remarks
Newfoundland								
American Smelting and Refining Co. (Buchans Unit), Buchans	1,250 (1,250)	6.48 (7.18)	11.51 (12.89)	1.00 (1.13)	3.45 (3.73)	124,000 (291,000)	7,633 (19,791)	Production halted by strike from March 15 to October 3.
Nova Scotia								
Dresser Minerals Division of Dresser Industries, Inc., Walton	140 (140)	6.68 (–)	1.00 (–)	0.27 (–)	5.43 (–)	8,178 (–)	547 (–)	Milled surface stock-pile of ore. May possibly salvage small quantities in conjunction with barite operation.
New Brunswick								
Brunswick Mining and Smelting Corp. Ltd., Bathurst	9,850 (9,500)	2.81 (2.77)	7.00 (7.15)	0.34 (0.32)	2.53 (2.43)	3,288,081 (3,257,559)	66,415 (66,931)	A new shaft will be sunk at No. 12 mine to a depth of 4,300 ft and a hoisting capacity of 11,000 tons of ore a day.
Heath Steele Mines Ltd., Newcastle	3,100 (3,000)	1.64 (1.46)	4.90 (3.93	0.86 (1.13)	1.83 (1.70)	1,077,816 (835,867)	11,026 (7,739)	Presently sinking new shaft to 3,000-foot depth and expanding concentrator to 4,000 tons a day capacity.
Nigadoo River Mines Ltd., Bathurst	1,000 (1,000)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	Dewatered the mine and refurbished mill equipment in preparation to start production in 1974.

Quebec								
Manitou-Barvue Mines Ltd., Golden Manitou Mine, Val-d'Or	1,600 (1,600)	0.30 (0.33)	2.07 (1.16)	N.A. (N.A.)	N.A. (4.68)	197,312 (60,234)	400 (134)	The concentrator also custom treated copper ore from Louvem Mining Company Inc. and was operating near capacity at year-end.
Sullivan Mining Group Ltd., Cupra Division, Stratford Centre	1,500 (1,500)	0.66 (0.60)	4.88 (3.97)	2.41 (2.24)	1.09 (0.99)	89,814 (117,339)	327 (632)	Mill treats ore from the D'Estrie Division and Clinton Copper Mines Ltd. on a custom basis.
D'Estrie Mining Company Ltd., Stratford Centre	custom-treated	0.74 (0.72)	3.16 (3.28)	2.74 (2.70)	1.23 (1.21)	130,265 (109,138)	541 (706)	
Ontario								
Ecstall Mining Ltd., Timmins	10,000 (10,000)	0.33 (0.39)	9.78 (10.14)	1.61 (1.44)	3.72 (4.35)	3,609,657 (3,628,501)	8,080 (8,663)	Installation of underground crushing equipment complete. The mine was supplying 2,000 tons of ore per day to the concentrator at the end of 1973 and is expected to supply 1,000,000 tons in 1974.
Mattabi Mines Ltd., Sturgeon Lake	3,000 (3,000)	1.06 (1.27)	11.37 (11.97)	1.10 (1.27)	5.31 (4.99)	1,111,765 (438,838)	4,757 (987)	Completed first full year of operation. All ore was mined from the open pit and plans are being made to mine the underground reserves.
Noranda Mines Ltd., Geco Division, Manitouwadge	5,000 (5,200)	0.20 (0.15)	4.53 (4.30)	1.70 (2.12)	1.63 (1.93)	1,463,585 (1,815,164)	1,664 (2,095)	Production interrupted by a strike from April 12 to June 10.
Willroy Mines Limited, Manitouwadge	1,700 (1,700)	0.17 (0.14)	2.74 (3.27)	0.98 (1.10)	1.42 (1.41)	430,486 (431,067)	386 (320)	Surface exploration work curtailed. Ore reserves at year-end were 715,835 tons grading 0.34% copper, 3.98% zinc and 1.38 oz silver per ton.

Table 10. Concluded

Company and location	Mill capacity (tons ore/day)	Grade of ore milled (principal metals) Lead (%)	Zinc (%)	Copper (%)	Silver (troy oz/ton)	Ore produced (tons)	Lead in concentrates and direct shipping ores (tons)	Remarks
Manitoba-Saskatchewan								
Hudson Bay Mining and Smelting Co., Ltd., Flin Flon	8,500 Central mill at Flin Flon treats the ore from all the company's mines						163* (205)	Only Chisel Lake and Ghost Lake mines have appreciable lead content.
Chisel Lake mine, Snow Lake		0.39 (0.30)	9.40 (9.30)	0.60 (0.90)	0.95 (0.90)	182.447 (209,100)		
Ghost Lake mine, Snow Lake		0.31 (0.30)	11.71 (9.40)	1.90 (1.80)	1.20 (1.20)	99,719 (35,800)		
British Columbia								
Bradina Joint Venture, Houston	600 (600)	1.02 (0.89)	4.57 (4.45)	0.43 (0.42)	4.88 (5.31)	98,471 (111,024)	676 (611)	Operations suspended on August 31 owing to uneconomic operations.
Cominco Ltd., Sullivan mine, Kimberley	10,000 (10,000)	4.97 (10.8% combined Pb, Zn)	4.99	N.A.	1.76 N.A.	2,214,415 (1,925,099)	99,235 (93,253)	Production difficulties encountered due to spontaneous oxidation of sulphide ore in some sections of the mine.
H.B. mine, Salmo	1,250 (1,250)	1.6 (-)	4.2 (-)	- (-)	N.A. (-)	351,682 (-)	2,838 (-)	Production recommenced in February. The mine had been shut down since 1966.
Consolidated Columbia River Mines Ltd., Ruth-Vermont mine, Golden	500 (500)	3.69 (-)	5.08 (-)	0.09 (-)	5.02 (-)	26,957 (-)	640 (-)	Mine reopened and production started in October on a trial basis.

Kam-Kotia-Burkam Joint Venture, Silmonac mine, Sandon	150 (150)	5.36 (5.81)	5.41 (6.62)	- (-)	14.45 (16.44)	13,949 (27,429)	717 (1,503)	Continuing operations depend on current exploration and development work.
Reeves MacDonald Mines Ltd., Annex and Reeves mines, Remac	1,000 (1,000)	1.67 (0.59)	4.49 (7.07)	- (-)	1.06 (1.91)	191,438 (180,188)	2,822 (905)	Exploration in progress to determine if future operations warranted and tailing disposal facilities to be built.
Teck Corporation Ltd., Beaverdell mine, Beaverdell	115 (115)	0.62 (0.72)	0.61 (0.76)	0.003 (0.003)	12.36 (18.23)	37,202 (37,091)	229 (268)	Exploration and development continue to locate new ore.
Western Mines Ltd., Buttle Lake, Vancouver Island	1,000 (1,100)	1.28 (0.68)	8.29 (6.02)	1.39 (1.85)	4.60 (N.A.)	354,420 (374,022)	4,270 (2,545)	Exploration tunnel driven east from Myra Falls mine to explore adjoining Price property.
<u>Northwest Territories</u>								
Pine Point Mines Ltd., Pine Point	11,000 (10,000)	2.9 (2.7)	6.01 (6.2)	- (-)	N.A. (N.A.)	3,896,357 (3,809,729)	105,706 (96,025)	Concentrator modified to increase capacity and improve metallurgy.
<u>Yukon Territory</u>								
Anvil Mining Corp. Ltd. Faro	8,000 (8,000)	4.88 (4.63)	6.37 (6.22)	- (-)	N.A. (N.A.)	2,899,145 (2,905,530)	119,306 (117,561)	Expansion of concentrator facilities to 10,000 tons per day completed at end of year.
United Keno Hill Mines Ltd., Elsa, Husky, No Cash mines, Mayo District	550 (550)	4.00 (4.61)	1.00 (3.19)	- (-)	34.62 (34.23)	94,819 (80,646)	3,631 (3,516)	Reopened Keno 700 mine and will also develop the Shamrock ore zone from this mine.

*Lead content of lead concentrates only
- Nil
N.A. - Not available
Source: Company reports

Table 11a. Industry Group Consumption of Lead by Province,* 1972 (1971)

Nova Scotia

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Transportation	305.6 (1,069.1)	$ 55.0 (192.0)	7,736.4 (–)	$1,257.3 (–)	– (–)	– (–)	1,250.0 (–)	$205.0 (–)
Chemical	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Metal fabricating	– (2.7)	– (0.4)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Electrical products	– (0.8)	– (0.1)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Miscellaneous	107.1 (0.7)	19.4 (0.3)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)

Table 11a. Continued

New Brunswick

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Transportation	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Chemical	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Metal fabricating	1.7 (1.8)	$ 0.3 (0.4)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Electrical products	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Miscellaneous	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)

*Compiled from Statistics Canada data

Table 11a. Continued

Quebec

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	6,742.9 (5,197.8)	$ 1,032.2 (732.5)	424.0 (155.0)	$ 89.5 (31.5)	12,479.2 (4,760.7)	$1,377.0 (505.2)	365.5 (313.6)	$ 55.3 (42.4)
Transportation	5,082.8 (5,287.1)	762.4 (676.0)	22,328.9 (6,763.2)	4,731.6 (1,078.0)	- (-)	- (-)	- (-)	- (-)
Chemical	14,256.4 (11,807.0)	2,005.7 (2,028.1)	- (-)	- (-)	- (-)	- (-)	2.0 (830.6)	18.5 (116.6)
Metal fabricating	2,301.5 (2,831.7)	375.1 (405.5)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
Electrical products	3,831.1 (3,872.1)	605.9 (504.8)	585.0 (621.4)	142.9 (149.1)	- (-)	- (-)	812.0 (2,894.2)	520.8 (526.6)
Miscellaneous	382.5 (276.3)	59.2 (40.9)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)

Table 11a. Continued

Ontario

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	24,626.3 (22,689.3)	$ 3,560.5 (3,006.8)	680.9 (676.1)	$ 144.6 (147.3)	99,494.1 (86,593.1)	$ 6,922.0 (6,060.3)	415.5 (337.0)	$ 69.8 (61.3)
Transportation	31,811.6 (33,825.7)	4,679.8 (4,742.5)	10,001.7 (20,410.7)	1,560.0 (3,526.0)	- (-)	- (-)	685.0 (2,138.8)	102.6 (316.0)
Chemical	36,603.3 (35,888.2)	5,248.2 (4,859.4)	- (-)	- (-)	- (-)	- (-)	6,863.8 (5,970.6)	1,180.0 (897.9)
Metal fabricating	6,092.3 (5,151.3)	920.4 (921.1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
Electrical products	1,306.7 (3,209.6)	250.6 (300.2)	113.9 (65.2)	23.9 (20.8)	- (-)	- (-)	2,016.4 (1,928.4)	374.0 (373.1)
Miscellaneous	695.6 (781.2)	110.5 (112.8)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)

Table 11a. Continued

Manitoba

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	7,753.6 (5,700.6)	$1,135.6 (758.2)	– (–)	– (–)	6,586.1 (6,588.9)	$ 397.0 (340.9)	– (–)	– (–)
Transportation	– (0.3)	– (65.0)	7,302.4 (3,483.1)	$1,165.1 (505.0)	– (–)	– (–)	45.5 (78.0)	$ 7.3 (7.0)
Chemical	22.4 (–)	3.3 (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Metal fabricating	172.0 (2.0)	31.0 (0.6)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Electrical products	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Miscellaneous	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)

Table 11a. Continued

Alberta

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	17.6 (9.9)	$ 2.4 (1.1)	187.8 (138.0)	$ 43.7 (24.3)	6,358.2 (5,956.9)	$ 403.0 (356.0)	– (–)	– (–)
Transportation	7,101.3 (6,533.3)	997.4 (900.0)	4,889.3 (6,174.4)	774.8 (1,000.0)	– (–)	– (–)	282.6 (39.0)	$46.0 (6.0)
Chemical	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Metal fabricating	– (8.4)	– (1.3)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Electrical products	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Miscellaneous	7.2 (–)	1.4 (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)

Table 11a. Concluded

British Columbia

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	2,708.7 (2,811.3)	$ 404.6 (374.3)	1,581.8 (829.5)	$ 379.6 (182.4)	277.9 (531.0)	$ 30.0 (60.3)	4.0 (2.1)	$ 0.5 (0.3)
Transportation	– (–)	– (–)	– (1,918.1)	– (289.0)	– (–)	– (–)	– (–)	– (–)
Chemical	70.4 (30.0)	11.0 (4.6)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Metal fabricating	111.0 (81.6)	16.8 (12.9)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Electrical products	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Miscellaneous	67.8 (11.5)	13.0 (5.5)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)

Table 11b. Total Provincial Consumption of Lead by Industry Group

Industry group	Lead, pure		Lead, antimonial		Scrap		Other	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Refined metal producers	41,849.1 (36,408.9)	$ 6,135.3 (4,872.9)	2,874.5 (1,798.6)	$ 657.4 (385.5)	125,195.5 (104,430.6)	$ 9,129.0 (7,322.7)	785.0 (652.7)	$ 125.6 (104.0)
Transportation	44,301.3 (46,715.5)	6,494.6 (6,575.5)	52,258.7 (38,749.5)	9,488.8 (6,398.0)	- (-)	- (-)	2,263.1 (2,255.8)	360.9 (329.0)
Chemical	50,952.5 (47,725.2)	7,268.2 (6,892.1)	- (-)	- (-)	- (-)	- (-)	6,865.8 (6,801.2)	1,198.5 (1,014.5)
Metal fabricating	8,678.5 (8,079.5)	1,343.6 (1,342.2)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
Electrical products	5,137.8 (7,082.5)	856.5 (805.1)	698.9 (686.6)	166.8 (169.9)	- (-)	- (-)	2,828.4 (4,822.6)	894.8 (899.7)
Miscellaneous	1,260.2 (1,069.7)	203.5 (159.5)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)

Table 12. Provincial Lead Consumption by Refined Metal Producers, 1972 (1971)

		S.I.C. 298						S.I.C. 297		
		Lead pig, pure		Lead, antimonial		Lead, scrap				
Province	NE*	(000's lb)	($ 000's)	(000's lb)	($ 000's)	(000's lb)	($ 000's)	NE	(000's lb)†	($ 000's)
Quebec	13 (12)	6,742.9 (5,197.8)	$ 1,032.2 (732.5)	424.0 (155.0)	$ 89.5 (31.5)	12,479.2 (4,760.7)	$ 1,377.0 (505.2)	10 (11)	365.5 (313.6)	$ 55.3 (42.4)
Ontario	44 (40)	24,626.3 (22,689.3)	3,560.5 (3,006.8)	680.9 (676.1)	144.6 (147.3)	99,494.1 (86,593.1)	6,922.0 (6,060.3)	33 (34)	415.5 (337.0)	69.8 (61.3)
Manitoba	8 (8)	7,753.6 (5,700.6)	1,135.6 (758.2)	- (-)	- (-)	6,586.1 (6,588.9)	397.0 (340.9)	- (-)	- (-)	- (-)
Alberta	3 (3)	17.6 (9.9)	2.4 (1.1)	187.8 (138.0)	43.7 (24.3)	6,358.2 (5,956.9)	403.0 (356.0)	- (-)	- (-)	- (-)
British Columbia	9 (9)	2,708.7 (2,811.3)	404.6 (374.3)	1,581.8 (829.5)	379.6 (182.4)	277.9 (531.0)	30.0 (60.3)	6 (6)	4.0 (2.1)	0.5 (0.3)
Total	79 (74)	41,849.1 (36,408.9)	6,135.3 (4,872.3)	2,875.0 (1,798.5)	657.4 (385.5)	125,195.5 (104,430.6)	9,129.0 (7,322.7)	49 (51)	785.0 (652.7)	125.6 (104.0)

*NE - Number of establishments
†All forms

Ontario establishments account for the largest percentage (73% in 1972) of all forms of lead processed in this industry, although figures are reported for four other provinces.

2) Copper and Copper Alloy Rolling, Casting and Extruding (S.I.C. 297)

Included in this industrial category are establishments that manufacture copper and copper-base alloy products such as wire rods, pipe, plate and sheets. Lead is consumed in this industry primarily in the production of copper-lead alloys such as brass and bronze. Establishments in Ontario and Quebec accounted for virtually all of the 652,690 pounds of lead consumed in this industry in 1971.

Transportation Industries

The transportation industries group, which includes battery manufacturers and manufacturers of motor vehicles, accounts for the largest lead consumption of any group. This is primarily because the current lead content of the average motor vehicle is approximately 30 pounds, 20 pounds of which are contained in the lead storage battery, seven pounds in solders, and the remaining three pounds in miscellaneous items.

In 1972, approximately 52% of Canadian lead consumption was used in battery manufacture. This is presently the largest single end-use of lead. Lead use in battery manufacture is described in the following section entitled "Battery Manufacturers (S.I.C. 3391)." There is no substitute, presently nor in the foreseeable future, which can compare with this type of battery for performance, cost and simplicity.

As a result of concern regarding automobile air pollution and fuel consumption, electric systems are being developed as an alternative to the internal combustion engine. If such systems are adopted on a wide scale lead consumption could conceivably approach 100 pounds per vehicle (105). This would increase the present world demand for lead in battery manufacture by a factor of five, and would more than offset the impending loss of the market in gasoline additive manufacture (see "Chemical Industries" later in this Chapter). The rising use of battery-powered vehicles in industry and recreation is already increasing the demand for lead in battery manufacture.

Solder consumption in automobile manufacture is currently approximately seven pounds per vehicle. Body solders, which are high lead alloys containing approximately 2.5% tin and 3% antimony, account for five pounds of this. The use of body solders faces competition from less expensive plastic body fillers. Radiator solder contains up to 20% tin and is used at the rate of approximately two pounds per vehicle.

Miscellaneous uses account for a lead consumption of approximately three pounds per vehicle. Terneplate (steel sheet with a coating of alloy made up of 80% lead and 20% tin) is used in small amounts in the manufacture of gasoline tanks. Other uses relate to lead requirements in bearings, greases, corrosion-resistant paints and wheel balancing weights. In addition, the use of lead for noise shielding in automobiles is currently under investigation.

In 1970, the manufacture of storage batteries gave rise to approximately 3.4 tons of airborne emissions of lead (106), which was negligible compared with a manufacturing emission total of 106.5 tons.

The consumption of lead by the battery manufacturers in 1971 and 1972 is provided on a provincial basis in Table 13. Provincial lead consumption for the remaining transportation industries is shown in Table 14. The industries for which provincial lead consumption has been reported follow.

Table 13. Provincial Lead Consumption by Battery Manufacturers (S.I.C. 3391), 1972 (1971)

		Lead pig, pure		Lead pig, antimonial		Lead, other	
Province	NE*	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Nova Scotia	1 (1)	305.6 (1,069.1)	$ 55.0 (192.0)	7,736.4 (-)	$ 1,257.3 (-)	1,250.0 (-)	$ 205.0 (-)
Quebec	4 (3)	5,080.3 (5,287.1)	762.0 (676.0)	22,328.9 (6,763.2)	4,731.6 (1,078.0)	- (-)	- (-)
Ontario	11 (11)	16,643.6 (15,575.7)	2,343.8 (2,168.0)	10,001.7 (20,410.7)	1,560.0 (3,526.0)	685.0 (2,138.8)	102.6 (316.0)
Manitoba	2 (2)	- (0.3)	- (65.0)	7,302.4 (3,483.1)	1,165.1 (505.0)	45.5 (78.0)	7.3 (7.0)
Alberta	2 (2)	7,101.3 (6,533.3)	997.4 (900.0)	4,889.3 (6,174.4)	774.8 (1,000.0)	282.6 (39.0)	46.0 (6.0)
British Columbia	7 (7)	- (-)	- (-)	- (1,918.1)	- (289.0)	- (-)	- (-)
Total	27 (26)	29,130.8 (28,465.5)	4,158.3 (4,001.0)	52,258.7 (38,749.5)	9,488.8 (6,398.0)	2,263.1 (2,255.8)	360.9 (329.0)

*NE - Number of establishments

Table 14. Provincial Lead Consumption by the Transportation Industries (Excluding Battery Manufacturers), 1972 (1971)

		S.I.C. 323			S.I.C. 325		Total	
Province	NE*	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Ontario	9 (9)	14,900.0 (18,100.0)	$ 2,275.0 (2,540.0	165 (155)	268.0 (150.0)	$ 61.0 (34.5)	15,168.0 (18,250.0)	$ 2,336.0 (2,574.5)
Quebec	4 (4)	- (-)	- (-)	19 (18)	2.0 (-)	0.3 (-)	2.0 (-)	0.3 (-)
Total	22 (22)	14,900.0 (18,100.0)	2,275.0 (2,540.0)	211 (203)	270.0 (150.0)	61.3 (34.5)	15,170.0 (18,250.0)	2,336.3 (2,574.5)

*NE - Number of establishments

1) Battery Manufacturers (S.I.C. 3391)

This industry covers the operations of establishments primarily manufacturing storage batteries, including wet and dry batteries for automobiles, trucks and buses, as well as for farm use, communications systems and railroad equipment.

Lead is consumed in several forms in the manufacture of lead-acid storage batteries. The battery grids are fabricated by pouring molten antimonial lead (a lead-antimony alloy containing 5-12% antimony) into molds. Most antimonial lead used in battery manufacture is recycled. Modern alloys contain less antimony and small amounts of tin, arsenic or calcium to prevent self-discharge in the battery. These grids form the framework of the battery plates, providing mechanical strength for the active chemicals, as well as a conductive path for the current generated.

Corroding lead, lead oxides and other lead compounds are combined to produce a paste which is pressed onto the plate grids. These plates are then dried, cured, formed and assembled into cells, each of which is capable of delivering the required current at a potential of two volts. Cells are connected together in a rubber or polypropylene case, the top is sealed on, and the posts are attached. A finished automobile battery contains about 20 pounds of lead, with approximately equal amounts in the form of metal and compounds. Sulphuric acid may be added before or after shipment to dealers.

Lead consumption in battery manufacture is reported for a number of provinces, with establishments in Ontario accounting for the bulk of consumption. The use of lead oxides has not been provided on a provincial basis, but it is assumed that usage distribution follows the same pattern as the other forms.

2) Motor Vehicle Manufacturers (S.I.C. 323)

Included in this industry are establishments mainly manufacturing or assembling complete motor vehicles such as passenger and commercial vehicles, trucks and buses. A considerable amount of lead solder is used in this industry, as well as terne metal in the manufacture of gasoline tanks. Corrosion-resistant paints, babbitt metal and minor end products are other materials used which account for consumption of lead.

Ontario establishments accounted for all reported lead consumption in 1971 and 1972 in this industry.

3) Motor Vehicle Parts and Accessories Manufacturers (S.I.C. 325)

This industrial category includes establishments producing engines, brakes, clutches, transmissions, horns and similar parts and accessories, excluding batteries. It consumes a considerable amount of babbitt metal and solders, in addition to some lead metal for miscellaneous uses. Lead consumption in 1971 and 1972 was reported by establishments in Ontario and Quebec.

Chemical Industries

This group of industries is the second largest consumer of lead and accounted for approximately 22% of Canadian lead consumption in 1972. The most important lead compounds are the oxides used in lead storage batteries; the alkyl lead compounds used as gasoline additives; various lead pigments used in paint manufacture; and other lead chemicals employed in the manufacture of plastics, glasses and glazes. Figure 3 is a schematic diagram illustrating the origins and uses of lead chemicals. A description of some of these lead chemicals follows.

White lead [basic lead carbonate, $PbCO_3.Pb(OH)_2$] was once the main pigment for paints, but current use is restricted mainly to wood primers. The widespread use of lead-based paint in the past has resulted in lead releases to the environment from flaking and chalking and from particles containing lead being released when old painted wood is burned.

In Canada, legislation has been enacted, effective January 1, 1976, limiting the lead content of paint products used in or on homes, schools and other buildings used by children, as well as furniture and other products found in these buildings, to a maximum of 0.5%. In recent years, manufacturers have reduced the lead content of most interior (floor and wall) paints from as much as 18% (based on dried film solids) to approximately 0.5% in anticipation of these regulations. During this period, manufacturers of children's toys, cribs, etc., have begun using lead-free paint.

Red lead and other pigments with rust-inhibiting properties are still widely used as primers for iron and steel, while yellow lead chromate is used in exterior paint and road-marking compounds. Upon erosion, these paints constitute a source of lead entering the environment.

Lead bisilicate is used in glazing ceramics and may constitute a health hazard when improperly applied to containers that might be used for storing acidic foods and beverages (see "Sources of Lead Intake" in Chapter 3).

Miscellaneous uses include stabilizers for polyvinylchloride plastics, driers for paints and printing inks, and in anti-fouling paints and insecticides. In Canada, the use of insecticides containing lead, primarily lead arsenate, has decreased from just under three million pounds in 1947 to 300,000 pounds in 1971 (107). This use is a direct environmental input of lead.

The most significant use of lead in chemicals is in the manufacture of gasoline additives, specifically tetraethyl lead (TEL) and tetramethyl lead (TML). This constitutes the metal's second largest overall use and currently amounts to about 15% of total world consumption of refined lead. The elemental lead content of gasoline sold in Canada in 1972 has been estimated at 18,000 tons, based on gasoline sales and monthly samples from service stations.

Lead additives are presently the most convenient and economical method of increasing the octane number (measurement of the antiknock properties) of all gasolines, in particular, those required for use in engines with high compression ratios. A lead content of 3.1 g per Imperial gallon (2.6 g per U.S. gallon, 0.7 g per litre) of gasoline will raise the octane rating by six to eight numbers, making it possible to refine 92-94 octane fuel to the 100-plus octane grades required by these engines.

In 1970, automobile emissions accounted for almost three quarters of the total airborne emissions of lead in Canada (108). Under the Clean Air Act, regulations had been proposed to limit, from January 1, 1974, the lead content of gasoline to a maximum of 2.5 g per Imperial gallon. This was later revised to a maximum of 3.5 g per Imperial gallon, to come into effect January 1, 1976. The lead content of Canadian gasoline in 1972 ranged from 0-0.54 g per litre (0-2.45 g per Imperial gallon) for regular and 0.67-0.70 g per litre (3.04-3.18 g per Imperial gallon) for premium (109).

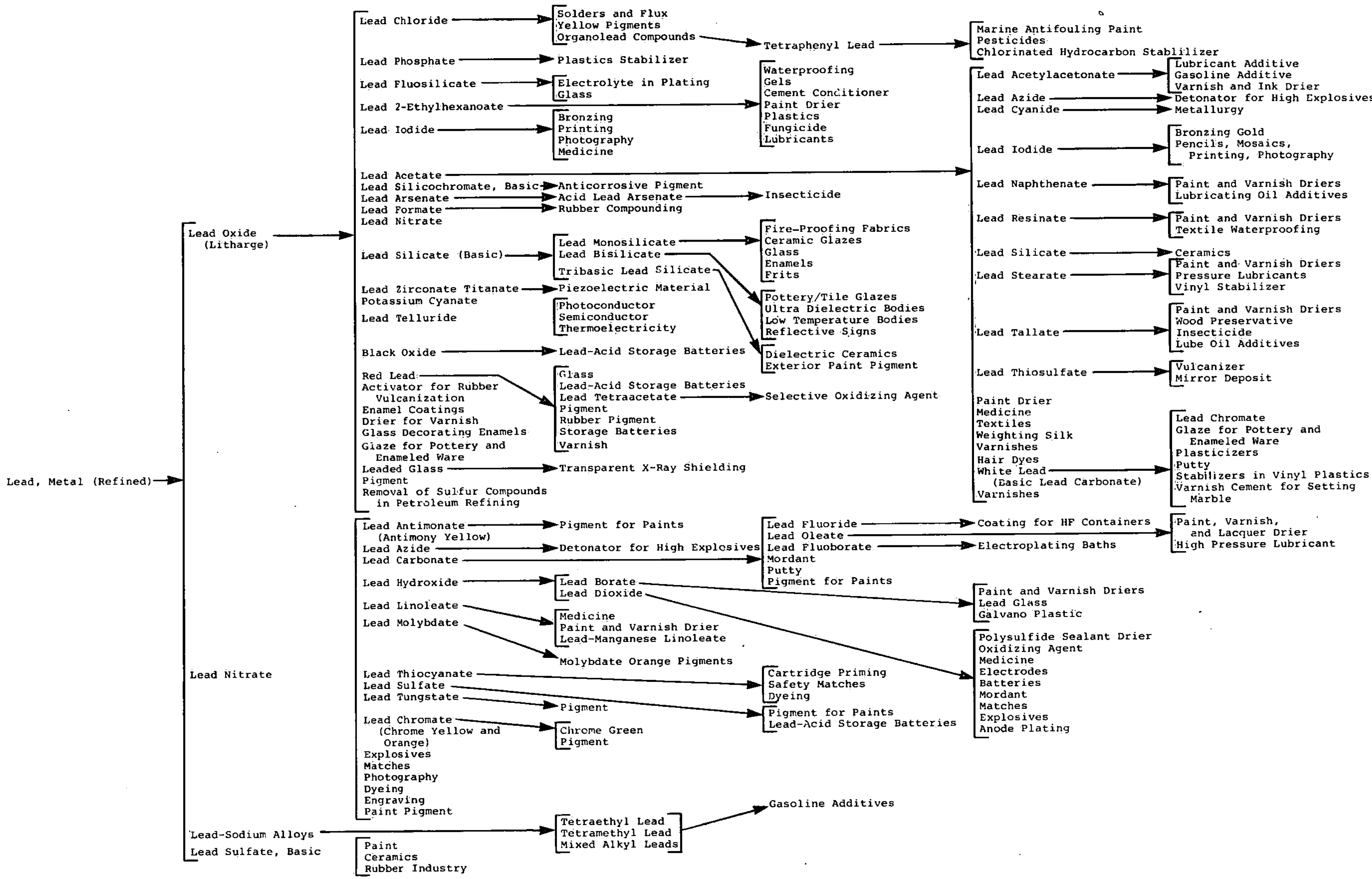

Figure 3. Origins and markets of lead chemicals. Source: Chemical Origins and Markets, 1967, Stanford Research Institute.

Lead entering the atmosphere in automobile exhaust may be reduced either by limiting the lead content of gasoline or by trapping the solid lead compounds in the exhaust system. If the lead content of gasoline is limited refining methods must be altered to maintain high octane ratings, which would result in increased crude oil consumption at the refinery. Alternatively, new engines have been designed to run on lower grade gasoline.

Devices have been developed to entrap lead and other solid particles. The use of such equipment is complicated because the catalytic control equipment necessary to reduce gaseous emissions of hydrocarbons, carbon monoxide and nitrogen oxides will not perform satisfactorily with leaded gasoline. This provides further support for the use of engines that run on low-lead and lead-free gasolines.

It is certain that the demand for lead in gasoline will be drastically reduced by the mid-1980's. The rate at which this will occur is subject to variables such as future regulations on emissions of lead, adoption of control devices and future gasoline consumption. Some requirement for leaded gasoline will continue until high compression engines are phased out of production and are no longer on the road.

Since at least 90% of the refined lead used by manufacturers of additives is primary (virgin, not recycled), it is the demand for primary lead that will be most affected by reductions in the use of additives. The main impact of this development will occur in the United States, where additive manufacture accounts for approximately 30% of primary lead consumption. Proposals by the Environmental Protection Agency to limit the lead content of gasolines would reduce primary lead consumption in additive manufacture in the United States from 230,000 tons in 1973 to 70,000 tons by 1979, and less than 20,000 tons annually by 1985. It is estimated that developments in other countries, which combined consume approximately 65,000 tons of lead annually, will follow a similar pattern, but with a time lag of at least five years.

In the United States, the recent development of new lead deposits has substantially increased domestic primary lead production. The loss of the additives market will cause an oversupply of primary lead, in the short term at least. This will alter the present balance between primary and secondary (recycled) lead as sources of supply, the result being less incentive to recover scrap.

These developments will, in all likelihood, occur in Canada as well, perhaps with a slight time lag but with the additional impact of the loss of a significant market for primary and secondary refined lead as well as lead scrap produced in Canada.

Provincial data on consumption of lead and litharge (PbO) in the chemical industries are presented in Table 15. In 1972, Ontario establishments accounted for 72% of lead consumption and virtually all of the litharge consumed in this industry group.

The industries for which lead consumption is reported on a provincial basis follow.

1) Manufacturers of Industrial Chemicals (S.I.C. 378)

Statistics Canada has implemented a revised standard industrial classification effective in the 1970 data year whereby this industry is divided into the three sub-industries described here.

a) Manufacturers of Pigments and Dry Colours (S.I.C. 3781) - This sub-industry covers establishments mainly manufacturing dry colours, pigments, iron oxide, titanium dioxide and lead oxides. Lead consumption in this sub-industry was reported by Statistics Canada for only Quebec establishments in 1971 and 1972, and litharge consumption was reported only in Ontario.
b) Manufacturers of Industrial Chemicals (Inorganic) (S.I.C. 3782) - This sub-industry covers those establishments manufacturing acids, alkalis, salts, compressed gases and other inorganic chemicals. Establishments in Quebec, Manitoba and British Columbia reported lead consumption in this category in 1971 and 1972.
c) Manufacturers of Industrial Chemicals (Organic) N.E.S. (S.I.C. 3783) - Included in this sub-industry are establishments producing organic chemicals such as aliphatic acids, alcohols and glycols by chemical processes. Establishments that manufacture alkyl lead compounds are included, and this accounts for the unusually high lead consumption in this sub-industry. Both Canadian producers of lead gasoline additives are located in Ontario.

2) Miscellaneous Chemical Industries (S.I.C. 379)

This industry covers establishments primarily manufacturing chemical products not specified elsewhere, such as germicides, adhesives, polishes and dressings. Products containing lead include explosives, ammunition and insecticide formulations that contain lead arsenate. Ontario and Quebec establishments reported lead consumption in 1971, while in 1972, consumption was reported by Statistics Canada for Quebec only.

3) Paint and Varnish Manufacturers (S.I.C. 375)

The greatest consumption of chemicals containing lead other than in the production of gasoline antiknock additives occurs in this industry, which comprises establishments mainly manufacturing paints, varnishes, lacquers, enamels and shellac, as well as other products including putty, oil stains and thinners. Many of the products manufactured by S.I.C. 3781 ("manufacturers of pigments and dry colours") are consumed by these establishments.

Data on consumption of some pigments containing lead at the provincial level are presented in Table 16.

Metal-Fabricating Industries

This group of industries is comprised of eight standard industrial classifications for which lead consumption is reported on a provincial basis. These industries are the source of a wide variety of products including wire products, hardware, structural and ornamental metal products.

Data on consumption of lead by province for this industry group are presented in Table 17. Over eight million pounds of lead were consumed by this group in 1972, with Ontario establishments accounting for 70% and Quebec establishments accounting for 27% of this usage. The remainder was attributed to establishments in five other provinces.

Table 15. Provincial Consumption of Lead and Litharge by the Chemical Industries, 1972 (1971)

		S.I.C. 378											
		S.I.C. 3781				S.I.C. 3782				S.I.C. 3783			
		Lead		Litharge		Lead		Litharge		Lead		Litharge	
Province	NE*	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)
Quebec	34 (27)	5,626.1 (4,344.5)	$ 817.8 (680.8)	– (–)	– (–)	1.7 (2.7)	$ 0.4 (0.8)	– (22.4)	– $(5.3)	– (–)	– (–)	– (–)	– (–)
Ontario	62 (64)	– (–)	– (–)	6,223.9 (4,857.6)	$1,060.6 (760.6)	– (–)	– (–)	– (–)	– (–)	36,603.3 (35,888.2)	$ 5,248.2 (4,859.4)	639.4 (797.7)	$ 119.4 (129.0)
Manitoba	5 (6)	– (–)	– (–)	– (–)	– (–)	22.4 (–)	3.3 (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
British Columbia	21 (18)	– (–)	– (–)	– (–)	– (–)	70.4 (30.0)	11.0 (4.6)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Total	152 (146)	5,626.1 (4,344.5)	817.8 (680.8)	6,223.9 (4,857.6)	1,060.6 (760.2)	94.5 (32.7)	14.7 (5.4)	– (22.4)	– (5.3)	36,603.3 (35,888.2)	5,248.2 (4,859.4)	639.4 (797.7)	119.4 (129.0)

Table 15. Concluded

Province	NE	S.I.C. 379				Total (378 and 379)			
		Lead pig, pure		Litharge		Lead		Litharge	
		(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)	(lb 000's)	($ 000's)
Quebec	116 (117)	8,628.6 (7,459.8)	$ 1,187.5 (1,346.5)	0.2 (807.0)	$ 0.1 (97.0)	14,256.4 (11,807.0)	$ 2,005.7 (2,028.1)	0.2 (829.4)	$ 0.1 (102.3)
Ontario	198 (194)	- (-)	- (-)	- (9.1)	- (1.7)	36,603.3 (35,888.2)	5,248.2 (4,859.4)	6,863.3 (5,664.4)	1,180.0 (890.9)
Manitoba	9 (10)	- (-)	- (-)	- (-)	- (-)	22.4 (-)	3.3 (-)	- (-)	- (-)
British Columbia	38 (36)	- (-)	- (-)	- (-)	- (-)	70.4 (30.0)	11.0 (4.6)	- (-)	- (-)
Total	394 (385)	8,628.6 (7,459.8)	1,187.5 (1,346.5)	0.2 (816.1)	0.1 (98.7)	50,952.5 (47,725.2)	7,268.2 (6,892.1)	6,863.5 (6,493.8)	1,180.1 (993.2)

*NE - Number of establishments

Table 16. Provincial Consumption of Lead Pigments by Manufacturers of Paint and Varnish (S.I.C. 375), 1972 (1971)

Province	NE*	Basic white lead carbonate, dry		Basic white lead silicate		Calcium plumbate		Red lead, 95%/96% Pb_3O_4	
		Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Newfoundland	2 (2)	3.9 (5.9)	$ 1.0 (1.4)	21.8 (20.9)	$ 4.5 (4.3)	- (-)	- (-)	- (-)	- (-)
Nova Scotia	1 (2)	5.0 (100.0)	1.2 (23.0)	2.0 (2.0)	0.4 (0.4)	- (-)	- (-)	- (-)	- (-)
New Brunswick	- (1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (65.1)	- $(12.1)
Quebec	40 (42)	1,144.6 (932.1)	240.3 (195.6)	239.7 (163.1)	59.5 (40.0)	17.1 (16.9)	$ 4.4 (4.2)	306.8 (206.1)	60.3 (34.7)
Ontario	75 (72)	99.1 (64.9)	21.7 (14.1)	162.3 (193.9)	40.6 (49.2)	14.0 (13.4)	3.9 (3.5)	552.3 (355.4)	130.3 (79.0)
Manitoba	5 (5)	10.2 (11.4)	2.6 (2.9)	58.8 (65.2)	12.6 (13.9)	- (-)	- (-)	5.2 (7.7)	1.2 (1.7)
Alberta	4 (5)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	10.0 (40.0)	3.0 (4.0)
British Columbia	19 (22)	2.5 (12.8)	0.7 (3.3)	70.1 (59.3)	16.8 (13.4)	71.2 (-)	15.0 (-)	1.3 (0.5)	0.3 (0.1)
Total	149 (154)	1,265.3 (1,127.1)	267.5 (240.3)	554.7 (504.4)	134.4 (121.2)	102.3 (30.3)	23.3 (7.7)	875.6 (674.8)	195.1 (131.6)

*NE - Number of establishments

Table 16. Concluded

Province	Red lead 97%/98% Pb_3O_4		Litharge		Other lead pigments	
	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Newfoundland	33.7 (24.6)	$ 7.7 (5.2)	0.5 (0.6)	$ 0.1 (0.2)	– (–)	– (–)
Nova Scotia	200.0 (180.0)	37.0 (33.3)	– (–)	– (–)	– (–)	– (–)
New Brunswick	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)
Quebec	65.9 (96.3)	13.6 (17.7)	39.5 (46.3)	8.9 (10.0)	54.0 (11.8)	$ 18.5 (34.4)
Ontario	225.0 (242.7)	46.5 (46.0)	28.7 (32.0)	6.8 (6.7)	81.6 (38.5)	34.2 (14.4)
Manitoba	3.1 (5.9)	0.7 (1.4)	2.6 (1.9)	0.6 (0.4)	12.9 (16.9)	4.2 (5.6)
Alberta	– (–)	– (–)	– (–)	– (–)	– (8.0)	– (2.3)
British Columbia	87.3 (151.6)	19.3 (27.8)	6.6 (5.2)	1.7 (1.2)	42.3 (67.0)	13.2 (21.4)
Total	615.0 (701.1)	124.8 (131.4)	77.9 (86.0)	18.1 (18.5)	190.8 (142.2)	70.1 (78.1)

Table 17. Provincial Lead Consumption by the Metal-Fabricating Industries, 1972 (1971)

Province	NE*	S.I.C. 301 Pounds (000's)	S.I.C. 301 Value ($ 000's)	NE	S.I.C. 302 Pounds (000's)	S.I.C. 302 Value ($ 000's)	NE	S.I.C. 3039 Pounds (000's)	S.I.C. 3039 Value ($ 000's)	NE	S.I.C. 3041 Pounds (000's)	S.I.C. 3041 Value ($ 000's)
Nova Scotia	2 (2)	- (-)	- (-)	2 (2)	- (-)	- (-)	3 (3)	- (-)	- (-)	3 (3)	- (2.7)	- $ (0.4)
New Brunswick	1 (1)	- (-)	- (-)	3 (3)	- (-)	- (-)	4 (3)	- (-)	- (-)	1 (-)	- (-)	- (-)
Quebec	15 (17)	5.5 (-)	$ 2.0 (-)	30 (27)	45.0 (45.0)	$ 7.0 (7.0)	185 (187)	11.0 (9.7)	$ 2.7 (2.0)	37 (37)	165.0 (188.0)	26.0 (26.0)
Ontario	38 (38)	- (-)	- (-)	69 (67)	- (-)	- (-)	175 (182)	1.7 (2.0)	0.4 (0.3)	112 (113)	47.6 (4.3)	11.8 (11.0)
Manitoba	1 (1)	- (-)	- (-)	5 (4)	- (-)	- (-)	14 (16)	- (2.0)	- (0.6)	3 (3)	- (-)	- (-)
Alberta	8 (8)	- (-)	- (-)	17 (17)	- (-)	- (-)	24 (25)	- (8.4)	- (1.3)	9 (8)	- (-)	- (-)
British Columbia	5 (7)	- (-)	- (-)	24 (22)	- (-)	- (-)	48 (50)	2.0 (2.6)	0.8 (0.9)	13 (12)	- (-)	- (-)
Total	71 (75)	5.5 (-)	2.0 (-)	156 (148)	45.0 (45.0)	7.0 (7.0)	464 (477)	14.7 (24.7)	3.9 (5.1)	178 (177)	212.6 (195.0)	37.8 (37.4)

Table 17. Continued

Province	S.I.C. 3042			S.I.C. 305			S.I.C. 306		
	NE	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)
Nova Scotia	3 (3)	– (–)	– (–)	1 (1)	– (–)	– (–)	2 (2)	– (–)	– (–)
New Brunswick	5 (7)	– (–)	– (–)	1 (1)	– (–)	– (–)	– (–)	– (–)	– (–)
Quebec	124 (145)	216.0 (141.0)	$ 32.4 (21.0)	66 (55)	1,487.0 (2,119.0)	$ 223.0 (287.0)	110 (105)	– (22.0)	– (4.5)
Ontario	279 (311)	862.0 (708.0)	131.0 (106.0)	152 (140)	727.0 (721.0)	106.0 (109.0)	427 (406)	16.0 (27.0)	3.2 (5.3)
Manitoba	24 (24)	– (–)	– (–)	6 (6)	– (–)	– (–)	6 (9)	– (–)	– (–)
Alberta	29 (32)	– (–)	– (–)	7 (6)	– (–)	– (–)	10 (11)	– (–)	– (–)
British Columbia	54 (56)	– (–)	– (–)	32 (30)	109.0 (79.0)	16.0 (12.0)	22 (19)	– (–)	– (–)
Total	528 (588)	1,078.0 (849.0)	163.4 (127.0)	265 (239)	2,323.0 (2,919.0)	345.0 (408.0)	578 (553)	16.0 (49.0)	3.2 (9.8)

*NE - Number of establishments

Table 17. Concluded

Province	NE	S.I.C. 309 Pounds (000's)	S.I.C. 309 Value ($ 000's)	Total Pounds (000's)	Total Value ($ 000's)
Nova Scotia	2 (2)	- (-)	- (-)	- (2.7)	$ - (0.4)
New Brunswick	4 (3)	1.7 (1.8)	$ 0.3 (0.4)	1.7 (1.8)	0.3 (0.4)
Quebec	90 (82)	372.0 (307.0)	82.0 (58.0)	2,301.5 (2,831.7)	375.1 (405.5)
Ontario	293 (306)	4,438.0 (3,689.0)	668.0 (689.5)	6,092.3 (5,151.3)	920.4 (921.1)
Manitoba	14 (13)	172.0 (-)	31.0 (-)	172.0 (2.0)	31.0 (0.6)
Alberta	22 (21)	- (-)	- (-)	- (8.4)	- (1.3)
British Columbia	56 (53)	- (-)	- (-)	111.0 (81.6)	16.8 (12.9)
Total	488 (488)	4,983.7 (3,997.8)	781.3 (747.9)	8,678.5 (8,079.5)	1,343.6 (1,342.2)

The industries included in this group are outlined here.

1) Boiler and Plate Works (S.I.C. 301)

This industry includes establishments primarily manufacturing heating and powerboilers, storage and pressure tanks, stacks and other boiler shop products. Lead is used in this industry as solder and caulking lead, and antimonial lead pipe and sheet lead for tank linings impart corrosion resistance. Lead consumption was insignificant in 1971, but totalled 5,500 pounds in Quebec establishments in 1972.

2) Fabricated Structural Metal Industry (S.I.C. 302)

This industry covers establishments whose principal products are fabricated shapes for bridges, buildings, large tanks and similar structures. The main use of lead in this industry is in the form of sheet manufacture of anti-vibration pads for buildings. Consumption in this industry is reported for Quebec only, amounting to 45,000 pounds for both 1971 and 1972.

3) Ornamental and Architectural Metal Industry (S.I.C. 3039)

Included in this industry are establishments mainly manufacturing ornamental metal work such as stairs and staircases, grills and metal partitions. Lead consumption, mainly in the form of foil or sheet for sound attenuation, reached 14,700 pounds in 1972. Establishments in Quebec accounted for most of this consumption.

4) Metal-Coating Industry (S.I.C. 3041)

This industry is comprised of establishments primarily engaged in the coating of metal and metal products, galvanizing and electroplating. In this industry, lead is used in coatings to impart corrosion resistance to metal surfaces. In 1972, Quebec accounted for 78% of the 212,600 pounds of the reported lead consumption.

5) Metal Stamping and Pressing Industry (S.I.C. 3042)

This industry covers establishments mainly manufacturing sheet metal products such as metal stamping for automobiles, and pressed metal products such as tin cans, metal awnings and eavestroughs. Lead is used in the form of solders for tin cans and awnings. Ontario accounted for 80% of reported lead consumption in 1972.

6) Wire and Wire Products Manufacturers (S.I.C. 305)

This industry includes establishments that draw wire from rods as well as manufacture nails, spikes and uninsulated wire and cable. Establishments in Ontario, Quebec and British Columbia reported lead consumption in 1971 and 1972. Reported lead consumption totalled 2,323,000 pounds in 1972, 64% of which was attributed to establishments in Quebec.

7) Hardware, Tool and Cutlery Manufacturers (S.I.C. 306)

Principal products of this industrial classification include axes, chisels, metalworking and garden tools, miscellaneous hardware not specified elsewhere, as well as bits, drills and cutting tools for machines and power-driven hand tools. Lead in the form of solder is used for minor applications in these products. Lead consumption totalled 49,000 pounds in 1971 and 16,000 pounds in 1972. Quebec and Ontario were the only provinces for which lead consumption was reported.

8) Miscellaneous Metal-Fabricating Industries (S.I.C. 309)

This industry includes establishments primarily engaged in manufacturing metal products not specified elsewhere such as weather stripping, guns, machinery fittings and wire goods. Other products include collapsible tubes, a percentage of which are made from lead ingots, plumbers' goods which include lead pipe and elbows, and sound and vibration control products incorporating lead sheet and plate. Lead consumption reached 4,983,700 pounds in 1972, 89% of which was reported by Ontario establishments.

Electrical Products Industries

This group of industries includes five standard industrial classifications for which lead consumption is reported on a provincial basis. They include establishments engaged in the manufacture of major appliances, communications equipment, electric wire and cable, and electrical industrial equipment.

Lead consumption figures on a provincial basis are provided in Table 18. Pure lead consumption reached 5.4 million pounds in 1971 and 5.1 million pounds in 1972. Antimonial lead, lead oxides (litharge, red lead) and other compounds were also used. Most manufacturing activity consuming lead occurred in Ontario and Quebec.

The industries included in this group are described here.

1) Manufacturers of Major Appliances (S.I.C. 332)

This industry includes establishments mainly producing household appliances such as stoves, refrigerators and laundry equipment. Solder is the major commodity containing lead used in this industry. Ontario is the only province for which lead consumption was reported in 1971 and 1972 by Statistics Canada.

2) Manufacturers of Lighting Fixtures (S.I.C. 333)

This industry covers firms primarily manufacturing electric lighting fixtures other than table and floor lamps. Lead consumption totalled 77,780 pounds in 1971, but was not provided on a provincial basis due to Statistics Canada restrictions.

3) Communications Equipment Manufacturers (S.I.C. 335)

This industry is comprised of manufacturers of radio and television transmitters, radar, telephone and telegraph equipment, and electronic control panels. Again, lead consumption is primarily in the form of solder. Lead consumption totalling 1,750,800 pounds in 1971 was attributed to Ontario establishments, and Quebec accounted for about 10% of the 1972 total.

4) Manufacturers of Electrical Industrial Equipment (S.I.C. 336)

This industry includes establishments mainly manufacturing electric motors, generators and other power equipment. Lead consumption in this industry, in pure, antimonial and other forms, was confined to Ontario establishments in 1971 and 1972. Antimonial lead in this industry is used as babbitt metal, and solder is also consumed in large quantities.

5) Manufacturers of Electric Wire and Cable (S.I.C. 338)

This industry covers establishments that manufacture electric wire and cable, both insulated or armoured and non-insulated. Lead-sheathed cable is frequently preferred over cable sheathed by synthetics, and pure lead consumption in this field exceeded five million pounds in 1972. In addition, some 602,000 pounds of antimonial lead and over 68,000 pounds of lead oxides were consumed in the same year. Establishments reporting lead consumption in 1971 and 1972 were confined to Ontario and Quebec.

6) Manufacturers of Miscellaneous Electrical Products (S.I.C. 3399)

Included in this industry are establishments primarily manufacturing electrical products not classified elsewhere, such as light bulbs and tubes, wiring devices, switchboards, conduit and fittings. Pure and antimonial lead, as well as other forms, were reported to be consumed in 1971 and 1972 by establishments in Ontario and Quebec.

Miscellaneous Industries

This group of industries includes six standard industrial classifications which cannot be conveniently aggregated with any of the previous industrial groups. Lead consumption for these industries has been reported for several provinces in 1971 and 1972, the total exceeding one million pounds for 1971 and 1.2 million pounds for 1972. Quantitative data on lead consumption in these industries are presented in Table 19.

The following is a brief description of the industries included in this group.

1) Iron Foundries (S.I.C. 294)

This industry includes establishments producing iron castings, including iron pipe, fittings and valves. Babbitt metal and solders are used in this industry and are separately reported. The lead consumption reported is in the form of plate, sheet and coatings to impart corrosion resistance to iron surfaces. Quebec establishments were responsible for 98% of reported lead consumption in 1971 and 1972.

2) Miscellaneous Machinery and Equipment Manufacturers (S.I.C. 315)

This industry includes establishments primarily engaged in the manufacture of machinery and equipment used in construction and mining operations, textile, and

Table 18. Provincial Consumption of Lead and Litharge by the Electrical Products Industries, 1972 (1971)

		S.I.C. 332			S.I.C. 335		Total	
Province	NE*	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Nova Scotia	– (–)	– (–)	– (–)	4 (2)	– (0.8)	– $ (0.1)	– (0.8)	– $ (0.1)
Quebec	6 (7)	– (–)	– (–)	47 (51)	7.8 (–)	1.5 (–)	7.8 (–)	1.5 (–)
Ontario	23 (23)	28.0† (33.0)	$ 28.0 (33.0)	143 (150)	63.0 (1,750.0)	49.0 (74.0)	91.0 (1,783.0)	77.0 (107.0)
Total	33 (33)	28.0 (33.0)	28.0 (33.0)	228 (235)	70.8 (1,750.0)	50.5 (74.1)	98.8 (1,783.8)	78.5 (107.1)

*NE - Number of establishments
†Estimated

Table 18. Concluded

Province	S.I.C.	Red Lead, 95%/96% Pb_3O_4		Litharge		Lead pig, pure		Lead pig, antimonial		Lead, other	
		Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Ontario	336	– (–)	– (–)	– (–)	– (–)	28.1 (40.4)	$ 4.2 (5.5)	84.8 (58.2)	$ 17.0 (19.1)	124.4 (69.9)	$ 65.9 (53.9)
	338	19.1 (18.0)	$ 7.3 (6.9)	29.8 (19.5)	$ 6.7 (3.8)	1,187.6 (1,386.2)	169.4 (187.7)	17.0 (–)	3.9 (–)	1,664.8 (1,627.9)	263.4 (265.4)
	3399	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	12.1 (7.0)	3.0 (1.7)	178.3 (193.1)	30.7 (43.1)
	Total	19.1 (18.0)	7.3 (6.9)	29.8 (19.5)	6.7 (3.8)	1,215.7 (1,426.6)	173.6 (193.2)	113.9 (65.2)	23.9 (20.8)	1,967.5 (1,890.9)	360.0 (362.4)
Quebec	338	18.2 (34.7)	9.5 (17.0)	1.3 (3.3)	0.3 (1.2)	3,823.3 (3,872.1)	604.4 (504.8)	585.0 (621.4)	142.9 (149.1)	91.9 (1,462.9)	159.1 (228.6)
	3399	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	700.6 (1,393.3)	351.9 (279.8)
	Total	18.2 (34.7)	9.5 (17.0)	1.3 (3.3)	0.3 (1.2)	3,823.3 (3,872.1)	604.4 (504.8)	585.0 (621.4)	142.9 (149.1)	792.5 (2,856.2)	511.0 (508.4)

Table 19. Provincial Lead Consumption by Miscellaneous Industries, 1972 (1971)

		S.I.C. 357			S.I.C. 392			S.I.C. 294	
Province	NE*	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)
Quebec	6 (6)	– (–)	– (–)	114 (109)	362.0 (249.5)†	$ 54.3 (34.6)	27 (28)	12.8 (9.9)	$ 3.2 (2.2)
Ontario	17 (17)	– (38.6)	– $ (7.0)	141 (132)	623.5 † (708.5)†	93.5 (99.2)	59 (58)	0.3 (1.0)	0.1 (0.6)
Total	23 (23)	– (38.6)	– (7.0)	291 (277)	985.5 (958.0)	147.8 (133.8)	115 (116)	13.1 (10.9)	3.3 (2.8)

		S.I.C. 315			S.I.C. 318			S.I.C. 327		Total	
Province	NE	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	NE	Pounds (000's)	Value ($ 000's)	Pounds (000's)	Value ($ 000's)
Nova Scotia	8 (10)	106.0 (–)	$19.0 (–)	– (–)	– (–)	– (–)	14 (16)	1.1 (0.7)	$ 0.4 (0.3)	107.1 (0.7)	$ 19.4 (0.3)
Quebec	140 (127)	4.7 (8.5)	1.0 (2.0)	3 (4)	2.4 (2.4)	$ 0.5 (0.5)	6 (7)	0.6 (6.0)	0.2 (1.6)	382.5 (276.3)	59.2 (40.9)
Ontario	450 (439)	49.7 (15.7)	13.0 (2.7)	(26) (24)	19.9 (16.0)	3.0 (2.7)	11 (11)	2.2 (1.4)	0.9 (0.6)	695.6 (781.2)	110.5 (112.8)
Alberta	36 (28)	7.2 (–)	1.4 (–)	– (–)	– (–)	– (–)	– (–)	– (–)	– (–)	7.2 (–)	1.4 (–)
British Columbia	88 (72)	66.0 (–)	12.2 (–)	3 (3)	– (–)	– (–)	19 (20)	1.8 (11.5)	0.8 (5.5)	67.8 (11.5)	13.0 (5.5)
Total	759 (711)	233.6 (24.2)	46.6 (4.7)	32 (31)	22.3 (18.4)	3.5 (3.2)	54 (59)	5.7 (19.6)	2.3 (8.0)	1,260.2 (1,069.7)	203.5 (159.5)

*NE – Number of establishments
†Estimated

processed food production. Also covered are the manufacturers of general-purpose engines, conveyor systems and woodworking machinery. A considerable amount of babbitt metal is used in this industry, as well as some solder for minor applications. Lead consumption totalled 24,200 pounds in 1971 and was reported for establishments in Ontario and Quebec only. In 1972, 45% of 233,600 pounds of lead consumed was used in Nova Scotia.

3) Office and Store Machinery Manufacturers (S.I.C. 318)

Establishments manufacturing equipment such as typewriters, cash registers, electronic computers and control devices are covered in this industry. Lead is used in the form of solder and babbitt. Consumption reported by establishments in Ontario and Quebec totalled over 22,000 pounds in 1972.

4) Shipbuilding and Repair (S.I.C. 327)

This industry covers the operations of establishments primarily engaged in building and repairing all types of ships of more than five tons displacement. Lead is used in this industry in the form of solders, lead weights and babbitt metal. Reported lead consumption totalled 5,700 pounds in 1972 and 20,000 pounds in 1971.

5) Abrasives Manufacturers Industry (S.I.C. 357)

Lead is consumed in this industry for bushings. Consumption exceeding 38,000 pounds was reported in 1971 for Ontario establishments. No consumption was reported for 1972.

6) Jewellery and Silverware Industry (S.I.C. 392)

This industry includes establishments primarily manufacturing articles of precious metals and alloys. The lead consumption of establishments in Ontario and Quebec has been estimated on the basis of value by the author at 958,000 pounds for 1971 and 985,000 pounds for 1972.

LEAD RECYCLING

The lead recycling industry comprises the collection, processing and refining of scrap lead. Scrap dealers collect, segregate and process the various grades of scrap lead for shipment to secondary lead smelters and refiners. Although most dealers collect other metals in addition to lead, there are some who specialize in lead scrap, particularly used batteries. A list of Canadian secondary lead producers is provided in Appendix B. The operations of establishments that produce secondary lead are mentioned in "Metal Rolling, Casting and Extruding (S.I.C. 298)" on page 27. Provincial consumption of scrap lead is shown in Table 12.

Equipment and facilities in the secondary lead smelting and refining industry range from small remelting pots to complex furnace operations. Various types of furnaces, such as sweaters, blast and reverberatory furnaces, refining kettles and special systems, are used to recover lead and alloy metals. On-site chemical analysis facilities are used to determine the composition of the purchased scrap and to adjust the composition of the refined lead to desired specifications. The National Association of Secondary Metal Industries (NASMI) has set standards for the composition of various grades of scrap.

The two categories of lead scrap follow:

1) Industrial scrap is generated in the manufacture of lead products and close to 100% is recycled. This occurs also with drosses, flue dusts and other materials produced during the smelting of secondary lead. Small amounts are lost in slags, while larger amounts (40 tons in 1970) (110) are discharged to the atmosphere, depending on the type of furnace used for the operation.
2) Obsolete scrap is generated through the use of lead products, and the extent of recycling varies from nil, in the case of lead oxides and tetraethyl lead, to nearly 100% in the case of type metal. The major sources of obsolete scrap are used automobile batteries, cable sheathing and solder. Lead scrap is also produced in the scrappage of old equipment containing lead and babbitt metal, and lead pipe is salvaged in the demolition of old buildings. The use of lead as a noise insulator in buildings is relatively recent and as yet is not a major source of scrap lead.

In Canada, over 90% of lead for recycling is derived from used automobile batteries, each of which yields approximately ten pounds of antimonial lead and ten pounds of lead oxides and other compounds equivalent to about 8.8 pounds of lead content. It is estimated that 85% of used batteries in Canada are recycled, the remainder being lost in disposal sites and abandoned cars. Batteries are collected at service stations and garages and are then shipped by the retailers to secondary smelters. The battery crushing operation may be carried out by the retailer, but is more commonly done at the smelter. Used batteries may be imported or exported, depending on market conditions. The amount collected in Canada, however, generally exceeds domestic demand.

Future developments in the lead recycling industry include increases in the percentage of lead recycled from sources such as used batteries, lead cable sheathing, solders, lead sheet, ballasts and pipe. Depletion allowances (subsidies given to the primary industry to compensate for depletion of reserves) reduce the recycling of lead, but it is not known to what extent. A similar subsidy for the secondary lead industry would promote the increased recycling of lead. The recycling of battery lead could be affected by the introduction of calcium lead alloys for storage battery parts. The costs of recycling would rise during the transition period as antimonial lead scrap was returned to the smelter. The antimony would have to be removed and calcium added to provide the new alloys required. This problem would be temporary, however, as the calcium lead batteries would be returning as scrap within a few years and the removal of antimony would no longer be necessary. An additional problem for the secondary lead industry is the reduction in demand for primary lead (specifically in gasoline additive manufacture - see "Chemical Industries") which will create a buyer's market for primary lead and, as a result, will discourage lead recycling.

Releases of Lead to the Environment

The release of lead as an environmental contaminant originates with man's activities, namely, the production of lead, the processing of lead into useful products (manufacturing), the use of these products by the consumer (consumption), and the final disposal or recycling of the obsolete (worn out) articles. This Chapter includes an attempt to quantify releases from production, manufacturing and consumption activities in terms of the watershed basins that are illustrated in Map 2. These basins have been aggregated into regions to comply with the confidentiality restrictions of the Statistics Act, since many watersheds contain too few establishments to allow publication of data.

There is a general lack of published information concerning releases of lead to the environment in terms of geographical or even political units. Working Group C of the International Reference Group on Upper Lakes Pollution (111) estimated the total lead loadings from Canada to Lakes Superior and Huron (Watershed 19) at 4,000 tons for 1974. This figure included loadings from municipal and industrial point sources on the lakes as well as tributaries to the lakes. The loading figure for a tributary reflects the lead inputs to the tributary from upstream urban, industrial and agricultural sources, in addition to the background lead content of the water.

The data in this report pertain to atmospheric emissions and were developed in the same manner as the 1970 data published by the Air Pollution Control Directorate (112). The forms and quantities of lead releases for 1972 are presented in Table 20. Atmospheric emissions have been calculated for the following:

1) lead production, including mining, milling, smelting, refining and secondary lead production. These releases are presented in Table 21 and illustrated in terms of aggregated watershed basins in Map 3;
2) the manufacture of selected lead products such as storage batteries, lead chemicals and semi-finished lead products. Releases are presented in Table 22 and illustrated in terms of aggregated watershed basins in Map 4; and
3) consumption of leaded gasoline, which accounted for 99% of the atmospheric lead releases from all consumption activities in 1970 (113). The consumption of solder, insecticides and paint accounted for less than 1%. In 1972, atmospheric releases from gasoline consumption totalled 13,260 tons. These releases are assumed to be proportional to population. Data are presented in Table 23 and illustrated in terms of watersheds in Map 5.

Total atmospheric lead releases by region are listed in Table 24 and illustrated in Map 6.

Miscellaneous sources of lead releases to the atmosphere include:

1) the residuals from production of other metals and alloys,
2) cement manufacture,
3) the combustion of coal, oil, wood, and
4) the incineration of refuse and sewage sludge.

Although the quantification of these releases was not attempted on a watershed basis, a national total of 3,300 tons has been accepted as reasonable for 1972, based on 1970 emission data (P. Choquette, personal communication).

Lead particulates in the atmosphere precipitate out on land or water. Some of the lead deposited on land will be carried into rivers and lakes by runoff water. For instance, lead particulates from urban automobile exhaust will be carried by storm water from city streets into sewer systems and finally to a receiving water body. It can therefore be said that most of the lead released to the atmosphere is eventually deposited in lakes and rivers and ultimately accumulates in the sediment.

It is impossible to determine precisely how much of the lead released to the atmosphere in a particular watershed will travel into the aquatic systems of that watershed. In general, depending on stack height, most of the larger particulates from industry and incinerators settle out within a short distance of their source. In the same vein, Dedolph et al. (114) and Motto et al. (115) show that the contamination of soil by lead from automobile exhaust is confined to a relatively narrow corridor along the highway.

Table 20. Releases of Lead to the Atmosphere, 1972 (tons)

Source of release	Total atmospheric release		Form of lead released
Lead production			
Mining	430		Rock dust (0.1-8% lead as lead sulphide)
Milling	610		Lead sulphide particulates
Smelting	775		Lead sulphide, oxides, metallic fumes
Refining	90		Lead oxide particles
Secondary lead production	60	1,965	Lead oxides, lead sulphate lead metal particulates
Manufacturing			
Storage batteries	5		Lead oxide, lead sulphate, lead metal particulates
Lead chemicals	80		Lead alkyls, lead oxide, lead metal particulates, selected compounds
Semi-finished products	90	175	Lead oxides, metallic dusts
Consumption			
Leaded gasoline		13,260	Lead oxides, halides, organo lead compounds
Miscellaneous		3,300	Lead oxide particulates
		18,700	

Table 21. Atmospheric Releases of Lead from Production Activities, 1972 (tons)

Region	Watersheds	Total lead releases*
1	1, 3, 4	390
2	5, 6	530
3	11, 13, 14, 16	10
4	17, 18	20
5	19, 20, 21, 22	65
6	25, 26	950
		1,965

Note: See Map 3 for further information
*Includes atmospheric releases from mining, milling, smelting, refining and secondary lead production

Table 22. Atmospheric Releases of Lead from Selected Manufacturing Activities, 1972 (tons)

Region	Watersheds	Total lead releases*
1	1, 2	7
2	7, 12, 13, 14	8
3	19, 20, 21, 22	157
4	25, 26	3
		175

Note: See Map 4 for further information
*Includes atmospheric releases from manufacture of storage batteries, lead chemicals and semi-finished products

Table 23. Releases of Lead from Consumption of Leaded Gasoline, 1972 (tons)

Watersheds	1971 Population* (000's)	Percent of total population	Lead content of gasoline consumed	Atmospheric releases
1	1,395	6	1,068	800
3	135	1	178	130
4	507	2	356	270
7	209	1	178	130
11	219	1	178	130
12	837	4	712	530
13	948	4	712	530
14	1,282	6	1,068	800
17	144	1	178	130
19	946	4	712	530
20	5,774	27	4,805	3,600
21	1,250	6	1,068	800
22	4,800	22	3,915	3,000
23	513	2	356	270
24	369	2	356	270
25	1,346	6	1,068	800
26	522	2	356	270
2, 5, 6, 8, 9, 10, 15, 16, 18†	480	2	356	270
	21,604	>99	17,620	13,260

Note: See Map 5 for further information

*Source: National Water Needs Study, Phase 1, unpublished draft report, July 1972

†Each watershed is arbitrarily assigned 30 tons of atmospheric releases

Table 24. Total Lead Releases, 1972 (tons)

Region	Watersheds	Releases from production activities	Releases from selected manufacturing activities	Releases from consumption of leaded gasoline	Releases from miscellaneous sources	Total lead releases
1	1, 2, 3, 4	390	7	1,230		1,627
2	5, 6	530	-	60		590
3	7, 11, 12 13, 14, 16	10	8	2,150		2,168
4	17, 18	20	-	160		180
5	19, 20, 21, 22	65	157	7,930		8,152
6	25, 26	950	3	1,070		2,023
7	8, 9, 10, 15, 23, 24	-	-	660		660
		1,965	175	13,260	3,300*	18,700†

Note: See Map 6 for further information
*Not analyzed in terms of watersheds
†Includes releases from miscellaneous sources

Assuming that airborne particulates from lead mining operations precipitate in a similar fashion, it is not unreasonable to state that a large percentage of the total atmospheric lead releases from all sources in a particular watershed will precipitate out in that watershed.

Some non-atmospheric releases to the environment are:

1) the disposal of tailings from lead milling operations,
2) the discharge of effluents containing lead from industrial and municipal waste treatment facilities,
3) the disposal of solid waste in landfill,
4) the application of used crankcase oil contaminated with lead to unpaved roads for dust control,
5) the use of lead arsenate insecticide, which is known to accumulate in orchard soils,
6) the application of sewage sludge containing trace quantities of lead to crop lands, and
7) the use of lead shot for hunting, notably in marsh areas.

Although no figures are presented on a watershed basis regarding these sources, some general statements can be made. The importance of lead releases that are linked to population ranges from considerable in densely populated watersheds to minute in remote, sparsely populated watersheds. Examples include emissions from solid waste disposal and effluents from municipal sewage treatment plants. Urban runoff laden with atmospheric fallout containing lead particulates from automobile exhaust is more significant as a source of contamination in watersheds with large urban populations. Watersheds with large agricultural areas will be susceptible to contamination from sludge disposal and applications of lead arsenate insecticide.

In conclusion, the information in this Chapter provides a general insight into the localized nature of the release of lead to the environment. More specific data in terms of individual watersheds are needed before the true social costs that accrue from the use of the metal can be ascertained.

Background Information

HISTORY

Lead was first used about 2500 B.C., at the beginning of the cupellation (separation) stage of metallurgy in southwest Asia, when it was discovered that small amounts of silver could be separated from lead metal smelted from lead ores. About 400 tons of lead in oxide form were produced for every ton of silver obtained by cupellation. With the advent of coinage in 650 B.C., silver became fundamental in the founding and operation of successive civilizations and lead production rose sharply.

From 2500 B.C. to 650 B.C., a variety of uses had been devised for the increasing amounts of lead. By classical Greek times, water was collected from lead-covered roofs and transported through lead metal gutters to lead-lined cisterns; ships were sheathed with lead metal to repel woodworms; cosmetics and paints were made with lead compounds; and lead-tin alloys were used to line the inside of bronze utensils to keep copper out of foods and liquids. Lead metal was also used by the Romans to make water pipes.

The industrial use of lead in Italy approached eight pounds per person per year during the first and second centuries A.D., which approximated the present use of 20 pounds per person per year in the United States. By A.D. 200, the Romans had exhausted the lead-silver deposits within their Empire. Since the economy was based on silver, economic chaos resulted when silver stocks became reduced. The rise and fall of classical Greek civilization from 650 B.C. to 350 B.C. is linked in a similar manner to the Laurion lead mines of Attica.

With the fall of Rome, world lead production collapsed and remained low for the following six centuries until after the ninth century A.D. During the late Renaissance, the production levels of the Romans were achieved through the enslavement of entire Indian nations in the lead mines of Mexico and Peru. Beginning with the Industrial Revolution, world lead production climbed exponentially from 100,000 tons per year in 1750 to 3.5 million tons per year in 1966. In terms of tonnage of ore smelted, lead presently ranks fifth, exceeded by iron, copper, aluminum and zinc.

CHEMICAL AND PHYSICAL PROPERTIES

Lead is a soft, heavy, bluish-grey metal. Its surface oxidizes very readily, and is then very resistant to corrosion. It is soluble in nitric acid, but not in sulphuric or hydrochloric acid. Lead is one of the most stable metals.

Lead (Pb) with atomic number 82 and atomic weight 207, is in group IV of the periodic table and is a member of the subgroup containing germanium and tin. The four naturally occurring isotopes and percent abundances are 208 (52.3%); 206 (23.6%); 207 (22.6%); and 204 (1.5%). Its atomic crystal structure is face-centred cubic. Lead has a specific gravity of 11.3, a melting point of 327°C and negligible vapour pressure at normal temperatures. It is malleable and has low tensile strength, about 700 kg/cm^2. Lead salts have specific gravities of about 6.

OCCURRENCE AND WORLD RESERVES

Geology

The most common ores of lead are the oxide, carbonate ore (cerussite, $PbCO_3$) and sulphate ore (anglesite, $PbSO_4$), but the most important commercial ore is the sulphide ore (galena, PbS). This is the source of practically all lead production, and the average grade of lead ore mined contains between 3.0% and 8.0% lead (116). Galena generally occurs in deposits with high zinc content, although compounds of iron, silver, copper, gold, cadmium, antimony, arsenic and bismuth may be present in various proportions.

Lead and zinc are deposited mainly by hydrothermal action from both sial and sima magmata, and deposits may be classified as follows:

a) deposits of predominantly lead ores,
b) deposits of predominantly zinc ores,
c) deposits of lead and zinc mixed ores, and
d) deposits of copper, zinc and other ores, in which the lead is a minor constitutent. (These ores may be extracted from silver, antimony, tin and pyrite ore deposits and from fluorite and barite deposits).

The deposits of lead-zinc ores contribute about 70% and 60% of the total mine output of lead and zinc, respectively. The overall ratio of zinc to lead in these ores is approximately 1.5:1. Deposits which contain predominantly lead ores account for about 20% of world lead production. The remaining 10% is obtained as a by-product from zinc, copper-zinc, and other deposits.

Proportions of the various types of lead ore vary from country to country. In Canada and Australia, almost all the lead production is extracted from mixed lead-zinc ores; in the United States, about 65% is derived from deposits of predominantly lead ores and about 30%, from mixed lead-zinc ores.

The genetic types of lead-ore deposits which are of commercial importance are:

a) hydrothermal veins, impregnations and replacement deposits (e.g., Broken Hill, New South Wales, Australia; Anvil Mine, Yukon Territory, Canada; and many deposits in the Andes Mountain range);
b) volcanic-sedimentary deposits, which occur partly as compact ore bodies and partly as impregnations (e.g., Sullivan Mines, British Columbia, Canada; Kuroko ores, Japan; Mount Isa, Queensland, Australia); and
c) hydrothermal or marine-sedimentary deposits in calcareous and dolomitic strata of the North American and European plateaux (e.g., Pine Point, Northwest Territories, Canada; "new lead belt," Missouri, United States; Upper Silesia).

Table 25 shows the proportion of the various genetic types of deposits in Canada, the United States and Australia.

Reserves by Country

On January 1, 1971, total lead reserves from the deposits of all countries were estimated at 93.4 million tons metal content, 78.9 million tons (84.5%) of which are located in the Western World. In 1971, the reserves of the Western World countries were quantified as follows.

The United States has the largest known deposits of lead (35.0% of global reserves). These reserves lie primarily in the southeastern part of Missouri; others are found in Idaho, Utah and Colorado. Canada accounts for 13.6% of global reserves, the most important deposits occurring in the Appalachian region of New Brunswick and in the mountains of the Northwest Territories and British Columbia. Mexico and Latin American countries combine to contribute 8.7%. Hence, North America and South America contained 57.3% of the world's total reserve of lead as of 1971. Deposits in Australia, which account for 12.6% of global reserves, are located at Mount Isa (Queensland), Broken Hill (New South Wales), and Read Roseberg (Tasmania).

The largest part of the Eastern Bloc's reserves (about 15.5% of global reserves) lies in the USSR (notably Kazakhstan, in the Altai and Karatau mountains).

Table 26 presents a comparison of world lead reserves in 1966 and 1971.

Recent Increases in Reserves

According to United States Bureau of Mines estimates, new discoveries increased the world's lead reserves by 49.7 million tons (113.7%) to 93.4 million tons, from 1966 to 1971 (Table 26). More than half the net increase occurred in the United States, where reserves increased by 27.3 million tons or 505.6%. This was largely attributed to the discovery of the "new lead belt" in Missouri, a series of mines covering a distance of 35 miles.

Most of Canada's contribution of 4.5 million tons is attributed to discoveries at Great Slave Lake (Pine Point, Northwest Territories) and Bathurst, New Brunswick, and in Australia, the largest new discoveries were made at Mount Isa, Queensland.

Table 25. Contribution to Total Lead Reserves by Type of Deposit in Canada, United States and Australia

	Canada		United States		Australia	
	Tons (millions)	Percent	Tons (millions)	Percent	Tons (millions)	Percent
Sima volcanic-sedimentary	6.4	50	insignificant		8.3	70
Sima hydrothermal or marine-sedimentary	2.5	20	26.2	80	-	-
Sial hydrothermal	3.8	30	6.5	20	3.5	30
Total	12.7	100	32.7	100	11.8	100
Contribution to world's reserves (%)		13.6		35.0		12.6

Source: <u>Supply and Demand for Lead</u>

Table 26. Comparison of World Lead Reserves, 1966 and 1971

	1966		1971	
	Tons (millions)	Percent	Tons (millions)	Percent
Canada	8.2	18.7	12.7	13.6
U.S.A.	5.4	12.4	32.7	35.0
Mexico	3.2	7.3	3.6	3.9
Peru	2.3	5.3	2.7	2.9
Rest of Latin America	0.5	1.1	1.8	1.9
Australia	5.4	12.4	11.8	12.6
Rest of Western World	11.2	25.6	13.6	14.6
Eastern Bloc	7.5	17.2	14.5	15.5
	43.7	100.0	93.4	100.0

Source: Supply and Demand for Lead

PRODUCTION PROCESSES

Mining

Lead and zinc ores are largely produced from underground mines where either open or supported stopes (mining areas) are generally used. Underground stoping includes block caving, room-and-pillar with and without rock bolts, shrinkage, cut-and-fill, and timbered stoping methods.

Continuous advances in mining technology since World War II have enabled some mines with low grade ore to remain competitive with mining operations in higher grade ore. Improvements in loading, transportation and explosives, as well as underground lighting and ventilation, have all contributed to increased output per man-shift.

Milling

Few lead ores are rich enough in lead or low enough in deleterious impurities to be smelted directly; consequently, the first step in the conversion of ore into metal or compounds is the physical separation of lead minerals from other valued ore constituents and from waste material. Simple lead ores, those that are high in lead content and contain few impurities, are concentrated after being crushed and ground to produce properly sized feed. Bulk or differential flotation of the slime products or of a reground middling product completes the process.

Complex sulphide ores consist of disseminated mixtures of fine-grained lead and zinc sulphides, and gold and silver in a quartz or quartz-calcite gangue. Such ores may be complicated further by partial oxidation of the sulphides and the presence of gangue minerals having high specific gravity, such as barite, siderite, and rhodochrosite. This type of ore is crushed and ground to a size at which the ore minerals are freed from the gangue minerals. When the ore minerals are interlocked, the usual practice is to make a bulk sulphide concentrate, followed by regrinding and selective flotation.

The sink-float method has been extended to include pretreatment of certain ores, permitting upgrading of ores diluted by nonselective mining methods. Present milling practices recover 85% to 94% of the sulphide lead and up to about 88% of the oxidized lead. Sulphide losses consist largely of the extremely fine particles.

Smelting

Lead is recovered from its ores almost exclusively by smelting in blast furnaces or ore hearths employing carbon fuels. Ores or concentrates that contain few impurities may be reduced to metal in roasting hearths. Air is used to oxidize the sulphides, and coke or coal to reduce the oxides.

A schematic diagram of lead smelting and refining is presented in Figure 4. In preparing the charge for lead blast furnace smelting, the sulphur in the concentrates, which normally contains 70% lead and a small zinc content, is removed by a roasting-sintering process, usually on a Dwight-Lloyd sintering hearth. The sintering equipment eliminates most of the sulphur and produces a blast furnace feed of desirable characteristics from the mechanically mixed concentrate. Undersized sinter particles and by-product dusts and fumes are collected in baghouses in the smelter. Normally, the charge to the lead blast furnace consists of sinter, coke, fluxes (such as silica and lime), and some lead-bearing furnace by-products. Air is blown through the charge, burning the coke to carbon monoxide and carbon dioxide and producing a temperature of approximately 1400°C. The carbon monoxide formed and the hot solid carbon reduce the oxidized lead compounds to bullion, which is tapped from the bottom (crucible) of the furnace. Any copper, iron, cobalt or nickel present in the ore combines with sulphur in the charge to form mattes, which are tapped from the front of the blast furnace for subsequent treatment. Zinc present in the ore accumulates in the slag. When such slags contain 6% or more zinc they are re-treated in slag-fuming furnaces to recover the zinc and any remaining lead. The lead bullion contains precious metals present in the ore and metallic impurities which are recovered in the refining operation. Imperial Smelting Corp. Ltd., England, has developed a blast furnace smelting process whereby a bulk concentrate is sintered and then reduced in the blast furnace to recover both lead and zinc simultaneously. The process is particularly useful for smelting mixed lead-zinc concentrates from those lead-zinc ores in which the components cannot be completely separated by froth flotation. The three products of this process are zinc metal, lead bullion containing the precious metals, and matte. Furnaces of this type are presently operating throughout the world.

Lead recoveries at primary lead smelters are approximately 97% to 99% of the lead contained in the ore and offer a relatively small margin for improvement. Recent modernization programs centre largely on charge preparation, roasting, dust collection, and material handling within the plants. Such programs have more than doubled the productive capacity of lead blast furnaces since 1925.

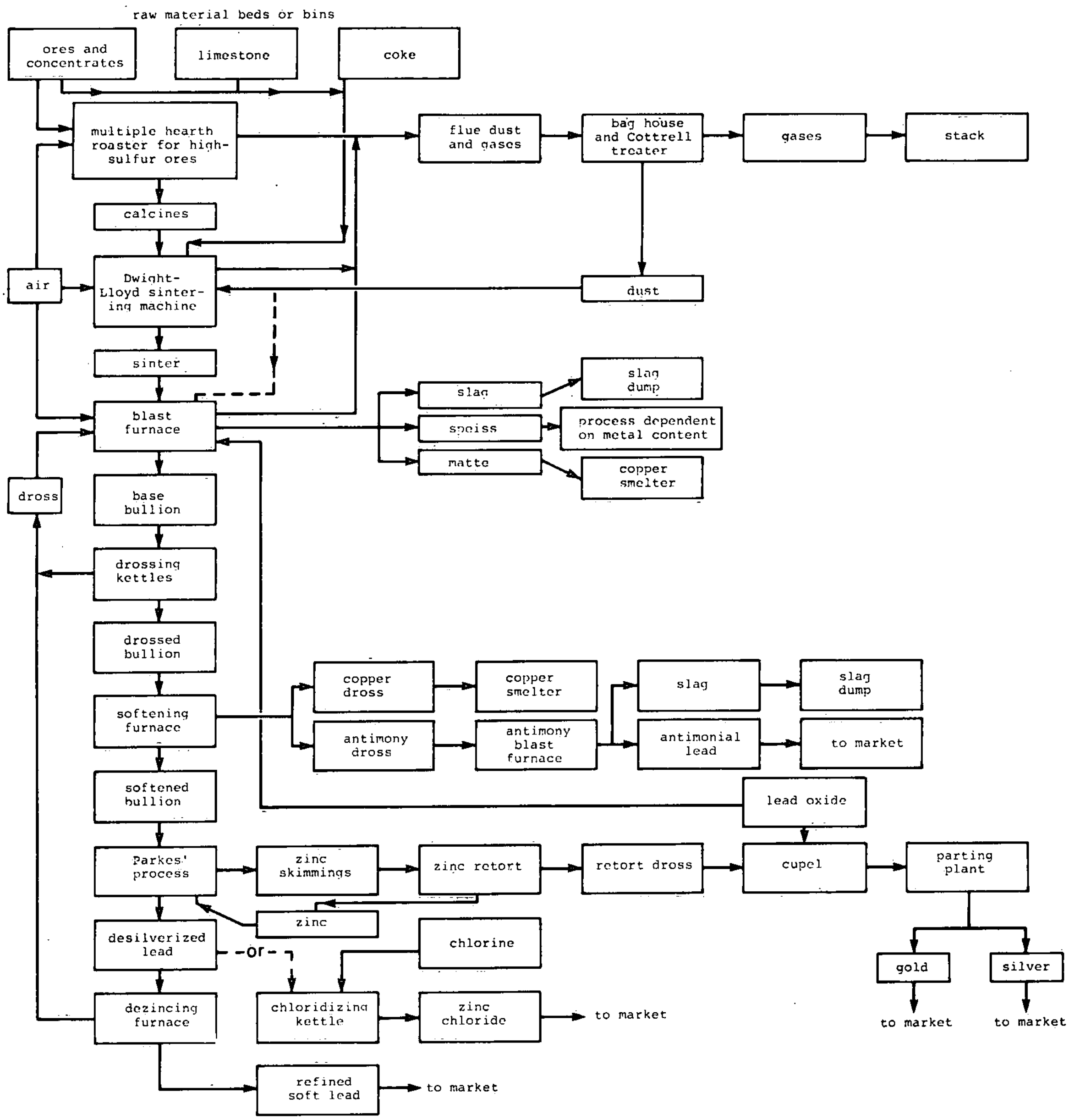

Figure 4. Lead smelting and refining. Source: McGraw-Hill Encyclopedia of Science and Technology, 1966.

Refining

A wide variety of processes for softening and desilverizing (removal of gold and silver) lead bullion from smelters and the recovery of by-products is in use throughout the world.

Softening consists of the removal of copper, tin, antimony and arsenic in a drossing or refining kettle. The copper is removed by maintaining the temperature of the bullion just above the melting point and skimming copper dross (the scum on the surface of the molten metal consisting of oxidation products and rising impurities) from the surface. Agitation, with addition of elemental sulphur, causes the remaining copper to rise to the surface as a black copper sulphide dross, which is skimmed off. After copper drossing, the temperature of the bullion is raised, and the bath is agitated to induce surface oxidation. The tin, arsenic and antimony are oxidized, and the oxides (being insoluble in the bath) rise to the surface with some lead oxide, which is skimmed off. The softened bullion usually is desilverized by the Parkes process of stirring metallic zinc into the bullion. Gold and silver combine with the zinc, and the resultant alloy, on cooling, rises to the surface and is skimmed off. The zinc remaining in the lead after desilverizing is removed by vacuum distillation or with caustic by the Harris process. If unacceptable concentrations of bismuth are present, the bullion is normally refined by either the Betts electrolytic process, as at Trail, British Columbia, and East Chicago, Indiana, or the Kroll-Betterton process after desilverization.

Refined lead is marketed in several grades that vary according to the content of impurities, which include silver, copper, arsenic, antimony, tin, zinc, iron and bismuth. The three principal grades are corroding (99.94%), chemical (99.90%), and common desilverized (99.85%). The corroding grade has the highest purity and is used chiefly in the manufacture of pigments, battery oxides and tetraethyl lead. Chemical lead possesses superior creep (elongation) and corrosion resistance and is ideally suited for cable sheathing, whereas common lead is most frequently used in industrial and home construction. Common and corroding lead both sell for the same price, but chemical lead, owing to its copper content, commands a premium above the other two grades.

WORLDWIDE ECONOMIC SIGNIFICANCE

Non-Communist World Production of Lead

From 1960 to 1970, approximately 75% of global lead mine output was produced in non-communist countries. Non-communist world mine production of lead from 1971 to 1973 inclusive is shown in Table 27. World production (excluding China, USSR, East Germany, North Korea, Czechoslovakia and Romania) of lead for the first half of 1974 was 1,388,000 metric tons (1,592,600 short tons) according to the United Nations Monthly Bulletin of Statistics (117). Lead mine production is forecast to exceed consumption in the next few years, and a surplus may develop unless some producers restrain production.

Non-communist world refined lead production for 1970 to 1973 inclusive is presented in Table 28.

Prices and Costs

Lead prices are influenced by supply-demand relationships, the resulting producer stock position and by foreign prices which determine the favourable level of competition for foreign lead in concentrates and marketing of foreign-produced metal. The North American market usually reflects a 2.5-3 cent per pound price above the European price to cover ocean freight, import duty and dock charges.

The grade of ore and by-product metals content influence the cost of producing a pound of lead. The direct mining cost ranges widely and is influenced predominantly by the geological and mineralogical aspects of the deposits, which dictate the mining method, mechanization and tonnage limitations, which in turn influence the cost per ton of ore. Price is also influenced by the availability of secondary (recycled) lead and government stockpile sales.

Table 27. Non-Communist World Mine Production* of Lead 1971, 1972 and 1973 (tons)

	1971	1972	1973P
United States	602,600	644,700	625,800
Canada	427,600	424,400	433,700
Australia	428,600	425,900	428,500
Mexico	191,500	196,000	183,000
Peru	162,500	176,400	197,300
Yugoslavia	119,600	117,200	123,800
Morocco	86,000	103,600	N.A.
Sweden	85,600	81,000	81,700
Republic of South Africa	80,700	65,000	69,700
Japan	77,800	69,900	58,300
Spain	77,400	72,800	68,400
Ireland	56,900	65,700	63,900
West Germany	46,700	45,500	42,900
Argentina	39,700	44,100	39,700
Italy	26,800	37,200	30,000
Zambia	37,400	34,600	N.A.
Other countries†	251,100	262,200	411,600
Total	2,798,500	2,867,000	2,858,300

*Total includes estimates for those countries for which figures are not available
†Excluding Bulgaria, China, Czechoslovakia, East Germany, Poland, Romania, North Korea, USSR
P - Preliminary
N.A. - Not available
Source: International Lead and Zinc Study Group, Monthly Bulletins, March 1973 and May 1974

Table 28. Non-Communist World Production* of Refined Lead, 1971, 1972 and 1973 (tons)

	1971	1972	1973P
United States	1,131,900	1,186,000	1,175,500
West Germany	339,700	299,200	329,200
Britain	290,600	298,300	272,700
Japan	237,100	246,200	251,900
Australia	212,100	229,800	242,500
Canada	185,300	208,600	206,100
France	174,700	206,000	205,500
Mexico	170,500	175,700	193,900
Yugoslavia	107,400	96,400	N.A.
Belgium	87,600	102,300	107,700
Italy	83,600	76,300	63,800
Spain	102,300	114,600	110,000
Peru	76,900	82,700	86,300
Republic of South Africa	74,400	75,000	73,500
Sweden	49,400	49,900	53,600
Argentina	N.A.	43,700	41,700
Other countries†	250,100	216,800	327,300
Total	3,565,600	3,707,500	3,741,200

*Total production by smelters or refineries of refined pig lead, plus the lead content of antimonial lead - including production on toll in the reporting country - regardless of the type of source material, i.e., whether ores, concentrates, lead bullion, lead alloys, mattes, residues, slags or scrap. Remelted pig lead and remelted antimonial lead are excluded.

†Excluding Bulgaria, China, Czechoslovakia, East Germany, Poland, Romania, North Korea, USSR

P - Preliminary

N.A. - Not available

Source: International Lead and Zinc Study Group, Monthly Bulletins, March 1973 and May 1974

Figure 5 illustrates lead price variations during the period 1960-1972. In 1973, the Canadian domestic price for primary refined lead (f.o.b. Toronto and Montreal) changed frequently and increased from 15 cents per pound in January to 17.5 cents per pound on December 31. By December 31, 1974, this price had risen to 21.5 cents per pound. In the United States, the price of Canadian lead rose from 19 cents per pound in January 1974, to 24.5 cents per pound in December 1974.

Figure 6 depicts the long-range time-price relationship for lead in the United States.

Major Uses

Due to its many useful chemical and physical properties, lead is used extensively in a variety of fields.

The use of lead in chemical manufacture and transportation has been described in some detail in "Provincial Lead Consumption by Industry Group," in Chapter 4. Other uses that cannot be readily described in terms of industry groups are the following.

In the construction industry, lead is being replaced in some areas by alternative materials. Lead sheet and foil, however, remain predominant in radiation shielding. Because of its unique sound damping characteristics, demand for the metal is increasing for both commercial and residential building sound insulation, as well as in the mounting of equipment such as air-conditioning systems. Corrosion-resistant lead paint is used to protect steel in buildings and highway structures.

In the field of communications, lead-gel storage batteries provide emergency power for telephone and radio service. Lead sheathing is widely used to protect underground and underwater cables, although the development of alternative plastic coverings and the increased use of air communications have reduced the demand for lead for this purpose.

Lead use in the packaging industry has been recently reduced by the development of new materials. Its continuing use derives mainly from the shipment and storage of radioactive materials and corrosive pastes. In addition, the canning industry is a major consumer of lead-tin solder for sealing tin cans.

The demand for lead in newspaper production is declining. Newspaper production by the "hot" letterpress operation, which involves the use of lead alloys, is being replaced by the "cold" method, where plastic or nylon plates are prepared photographically.

Although outlawed for warfare by the Geneva Convention, the consumption of lead in ammunition has recently been increasing due to a rising demand for sporting ammunition.

There are several miscellaneous uses of lead not readily distinguishable as to end-use. Low-melting lead alloys are used in the curing (drawing and fabrication) of various metals. Lead oxide is used in the manufacture of dyes, rubber substitutes, glass paints and other products. Lead arsenate is widely used as an insecticide, and many lead compounds are used as stabilizers in plastics. Other uses include fishing tackle, ship ballast, roofing systems, sprayed lead coatings, terne steel and various alloys, and lead-ferrite for permanent magnets in small electric motors. Relatively new uses are for leaded-porcelain enamel in coating aluminum and for radiation shielding against gamma rays in nuclear power reactors, nuclear-powered merchant ships and submarines. Continuing research has

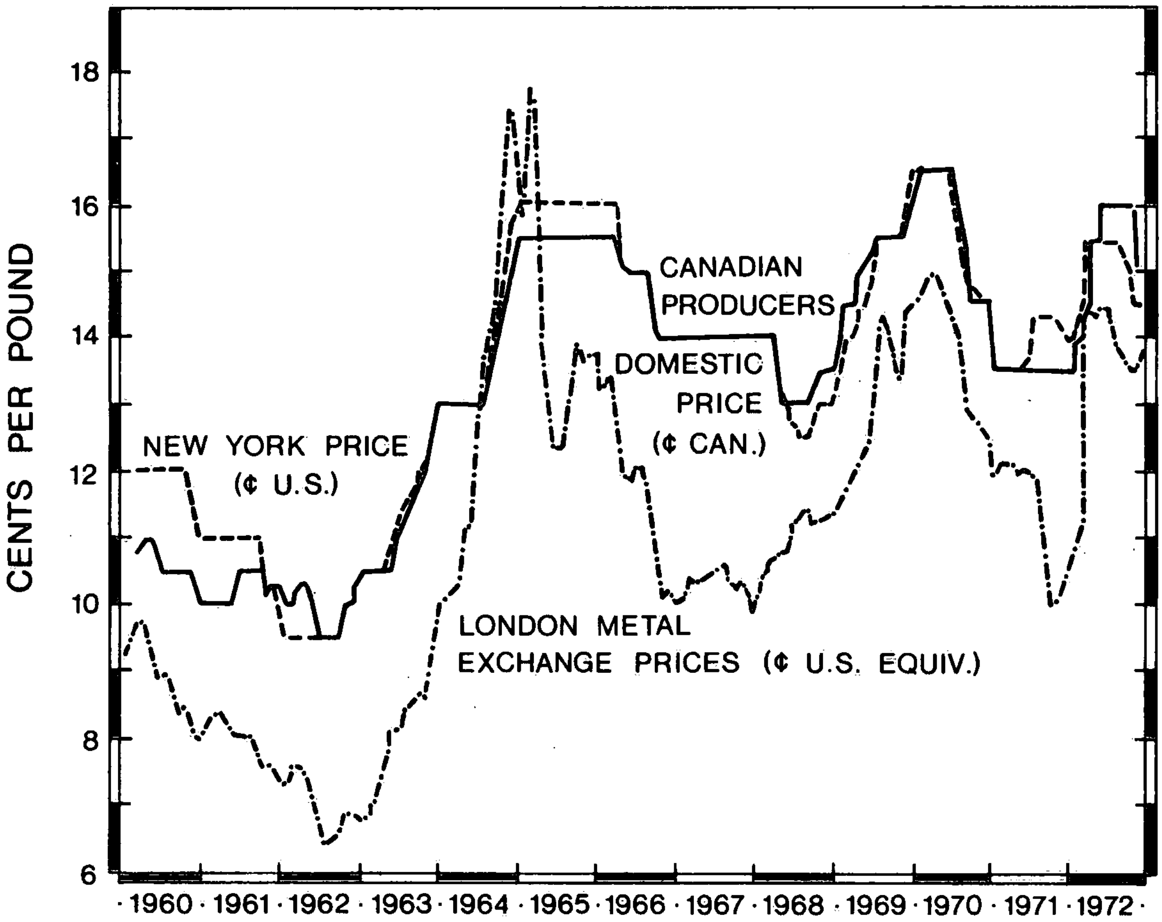

Figure 5. Lead prices. Source: International Lead and Zinc Study Group.

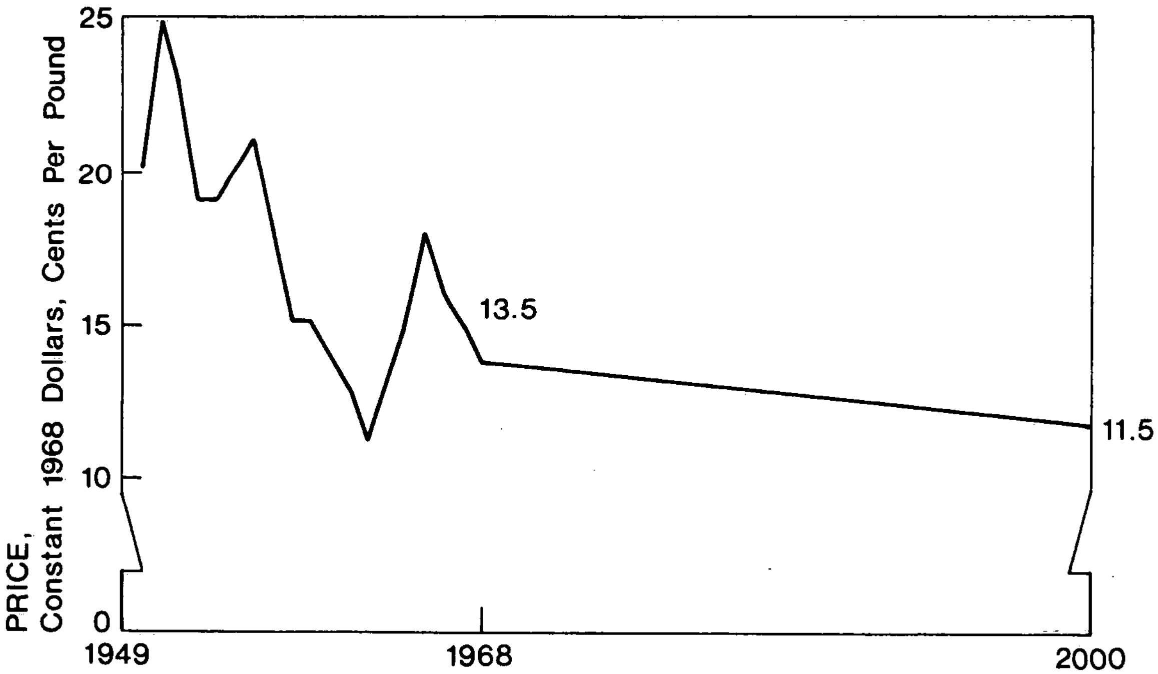

Figure 6. Time-price relationship for lead. Source: <u>Mineral Facts and Problems</u>, 1970, United States Bureau of Mines Bulletin 650.

developed new markets for organometallic lead compounds in antifouling paints, wood and cotton preservatives, lubricant-oil additives, polyurethane foam catalysts, molluscicides, antibacterial agents, rodent repellents and rot-resistant textiles.

Future Outlook

The demand for lead will most certainly decline as antiknock additives are phased out of use. Another possibility is that other sources of stored power could replace the lead-acid storage battery. Yet given the relative cost, and efficiency and performance of this device, such an event would seem to be, at the very least, many years away. Indeed, the development of battery-powered vehicles, the use of which would vastly increase lead consumption, is on the upswing (see "Transportation Industries" in Chapter 4).

World consumption of primary lead rose from 1,922,400 tons in 1950 to 3,802,100 tons in 1969, an increase of 98%. Forecast consumption in the year 2000 is 6.835 million tons (118), a demand which present reserves are inadequate to fulfill at current prices. These reserves may be augmented to meet future demand; hence the limiting factor is not availability, but the cost of access and recovery. Through technology, new ore deposits will be discovered and more efficient mining methods developed. The capital cost of this technology will be high, yet is essential for major cost reductions in the long run. As a result, the high cost of primary lead will stimulate the expansion of lead recycling operations and markets. In addition to improved mining procedures, a major demand on technology will be for new applications for the metal.

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Standard Industrial Classifications Reporting Lead Consumption in 1972

Industry	S.I.C.	Statistics Canada Catalogue	Description
Refined metal	298	41-215	Metal rolling, casting and extruding
	297	41-224	Copper and copper alloy rolling, casting and extruding
Transportation	3391	43-208	Battery manufacturers
	323	42-209	Motor vehicle manufacturers
	325	42-210	Motor vehicle parts and accessories manufacturers
Chemical	378	46-219	Manufacturers of industrial chemicals
	379	46-216	Miscellaneous chemical industries
	375	46-210	Paint and varnish manufacturers
Metal fabricating	301	41-223	Boiler and plate works
	302	41-207	Fabricated structural metal industry
	3039	41-221	Ornamental, architectural metal industry
	3041	41-227	Metal stamping, pressing and coating industry
	3042	41-227	
	305	41-216	Wire and wire products manufacturers
	306	41-208	Hardware, tool and cutlery manufacturers
	309	41-228	Miscellaneous metal fabricating industries
Electrical products	332	43-204	Manufacturers of major appliances
	333	43-211	Manufacturers of lighting fixtures
	335	43-206	Communications equipment manufacturers
	336	43-207	Manufacturers of electrical industrial equipment
	338	43-209	Manufacturers of electric wire and cable
	3399	43-210	Manufacturers of miscellaneous electrical products

Industry	S.I.C.	Statistics Canada Catalogue	Description
Miscellaneous	294	41-226	Iron foundries
	315	42-214	Miscellaneous machinery and equipment manufacturers
	318	42-216	Office, store machinery manufacturers
	327	42-206	Shipbuilding and repair
	357	44-202	Abrasives manufacturers
	392	47-211	Jewellery and silverware industry

The following S.I.C.'s have reported consumption of lead as metal and/or babbitt and solders, but consumption was not provided on a provincial basis. Since the quantities are relatively small, these industries have been omitted.

S.I.C.	Statistics Canada Catalogue	Description
3031	41-221	Ornamental, architectural metal industry
307	41-225	Heating equipment manufacturers
311	42-202	Agricultural implement industry
316	42-215	Commercial refridgeration, air conditioning equipment manufacturers
3741 3242	42-217	Truck body and trailer manufacturers
326	42-211	Railroad rolling stock industry
331	43-203	Manufacturers of small electrical appliances
334	43-205	Manufacturers of household radio and television receivers

Secondary Lead Smelters in Canada

Quebec

The Canada Metal Co. Ltd.,
6265 Notre Dame St. E.,
Montreal.

Federated Genco Ltd.,
1400 Norman St.,
Lachine.

Harbour Smelting and Refining Inc.,
6015 Côte de Liesse,
Montreal.

Metals and Alloys Co. Ltd.,
1611 Bercy St.,
Montreal.

Ontario

The Canada Metal Co. Ltd. (Head Office),
721 Eastern Ave.,
Toronto.

Federated Genco Ltd.,
1110 Birchmount Rd.,
Scarborough.

Tonnolli of Canada Ltd.,
2414 Dixie Rd.,
Mississauga.

Toronto Refiners and Smelters,
28 Bathurst St.,
Toronto.

Manitoba

The Canada Metal Co. Ltd.,
1221 St. James St.,
Winnipeg.

Canadian Bronze Co. Ltd.,
15 Bury St.,
Winnipeg. (Head Office - 1144 Montée de Liesse, Montreal)

Northwest Smelting and Refining Ltd.,
2185 Logan Ave.,
Winnipeg.

Alberta

The Canada Metal Co. Ltd.,
5524 4th St. S.E.,
Calgary.

British Columbia

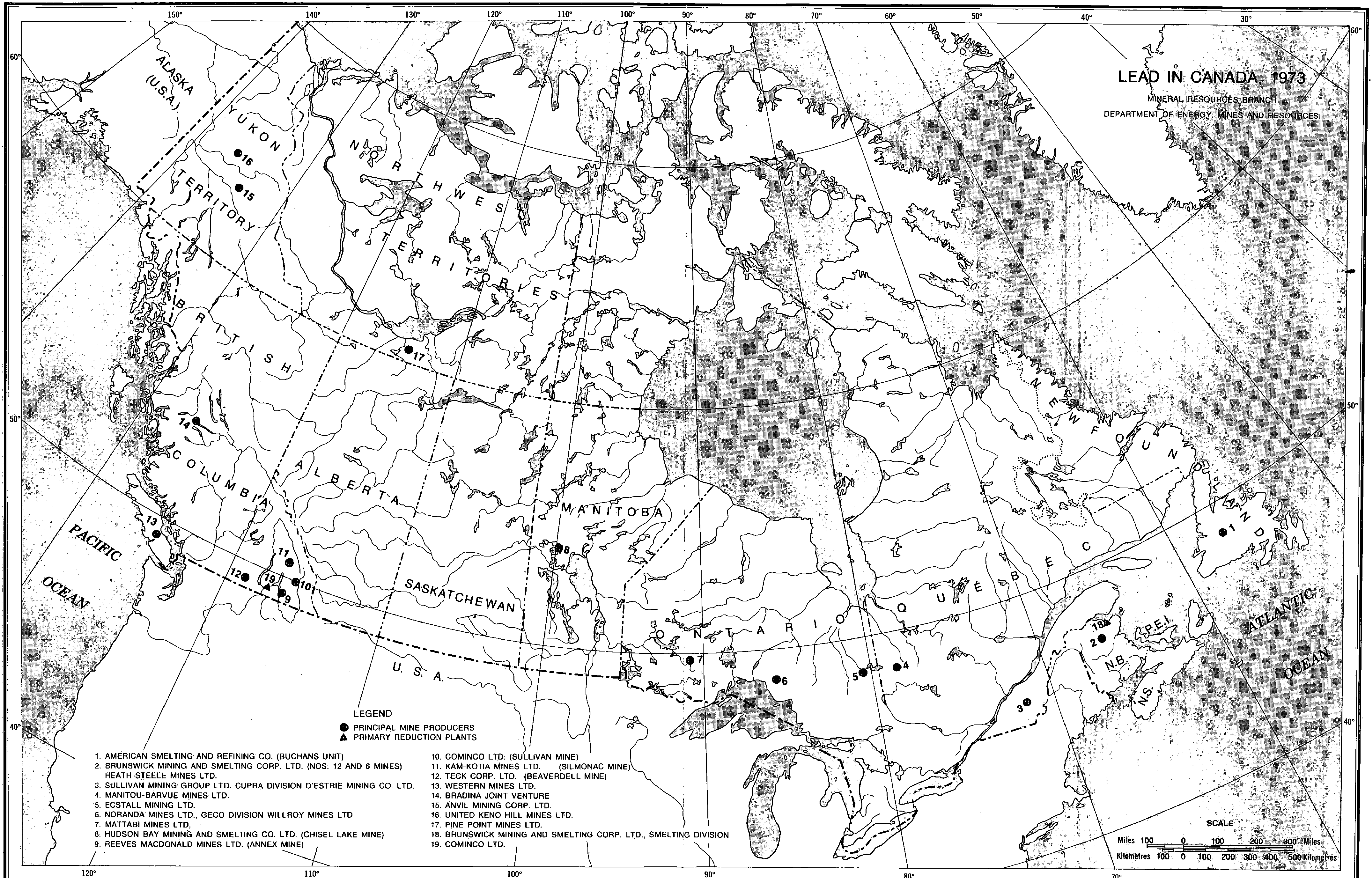
The Canada Metal Co. Ltd.,
1428 Granville St.,
Vancouver.

Metalex Products Ltd.,
251 No. 5 Rd.,
Richmond.

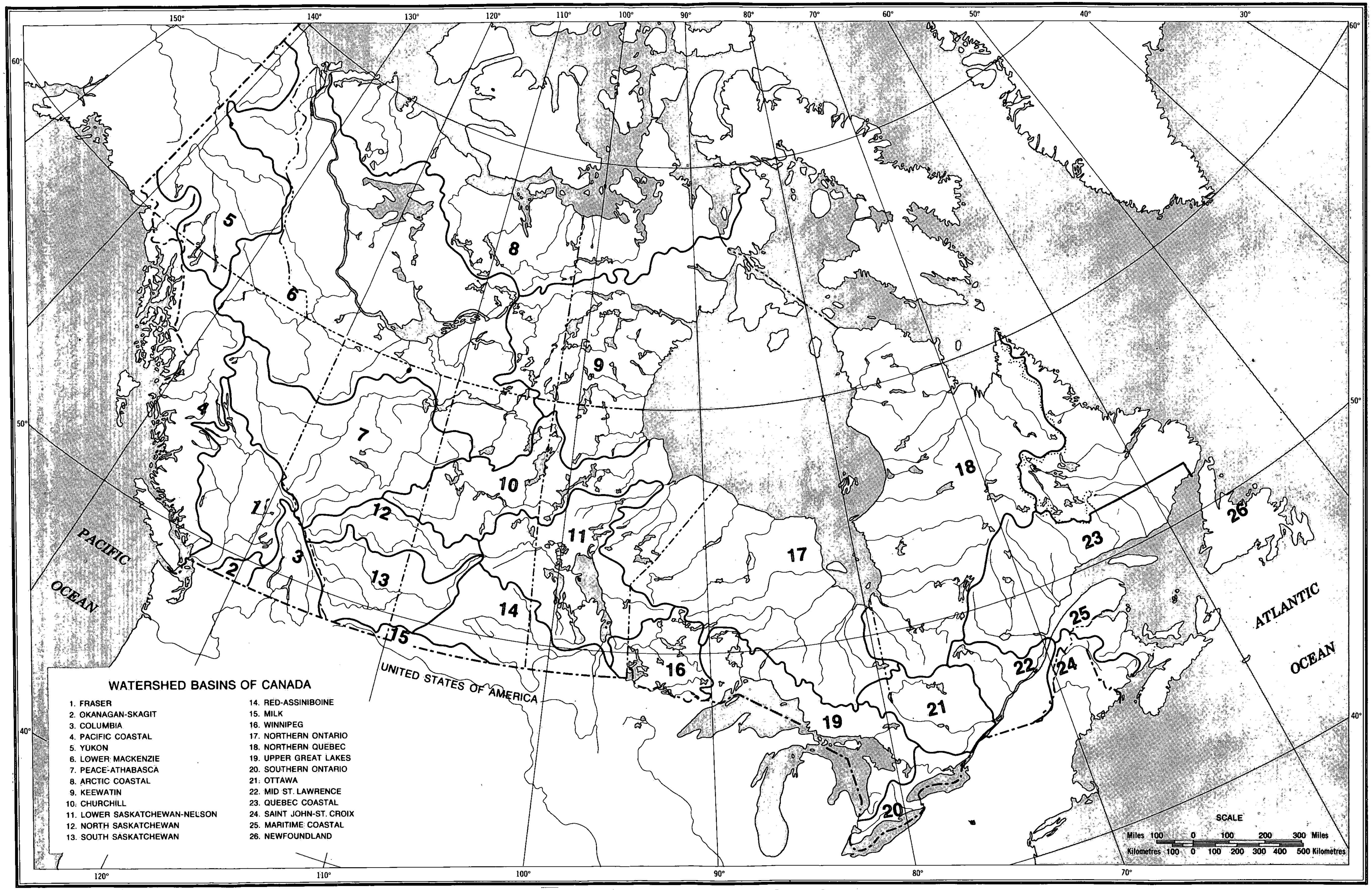
Commonly Used Units

mg/l	=	milligrams per litre	=	10^{-3} grams per litre
μg/l	=	micrograms per litre	=	10^{-6} grams per litre
ng/l	=	nanograms per litre	=	10^{-9} grams per litre
ppm	=	parts per million	=	mg/kg or mg/l
ppb	=	parts per billion	=	μg/kg or μg/l
ppt	=	parts per trillion	=	ng/kg or ng/l

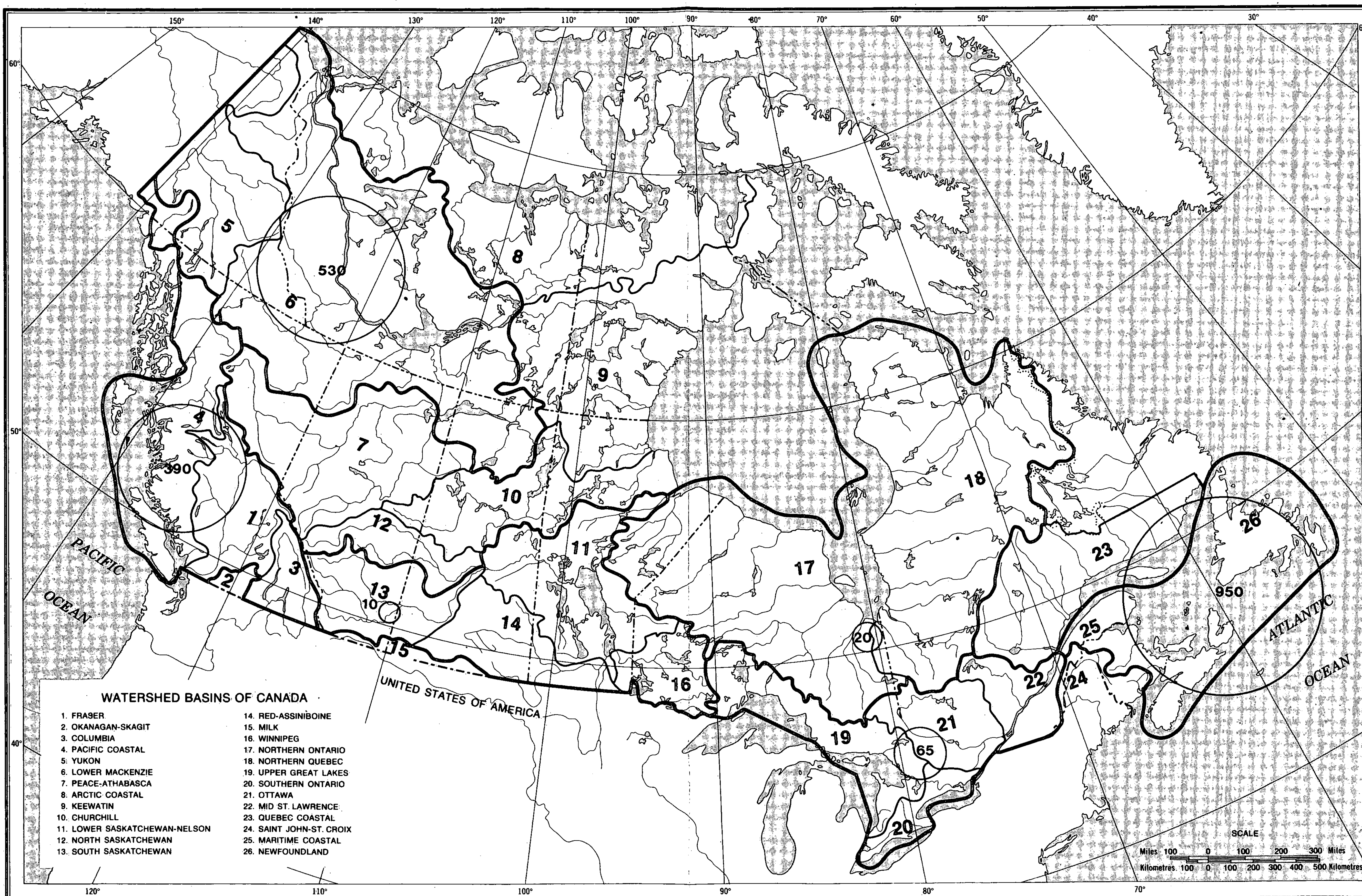
9390



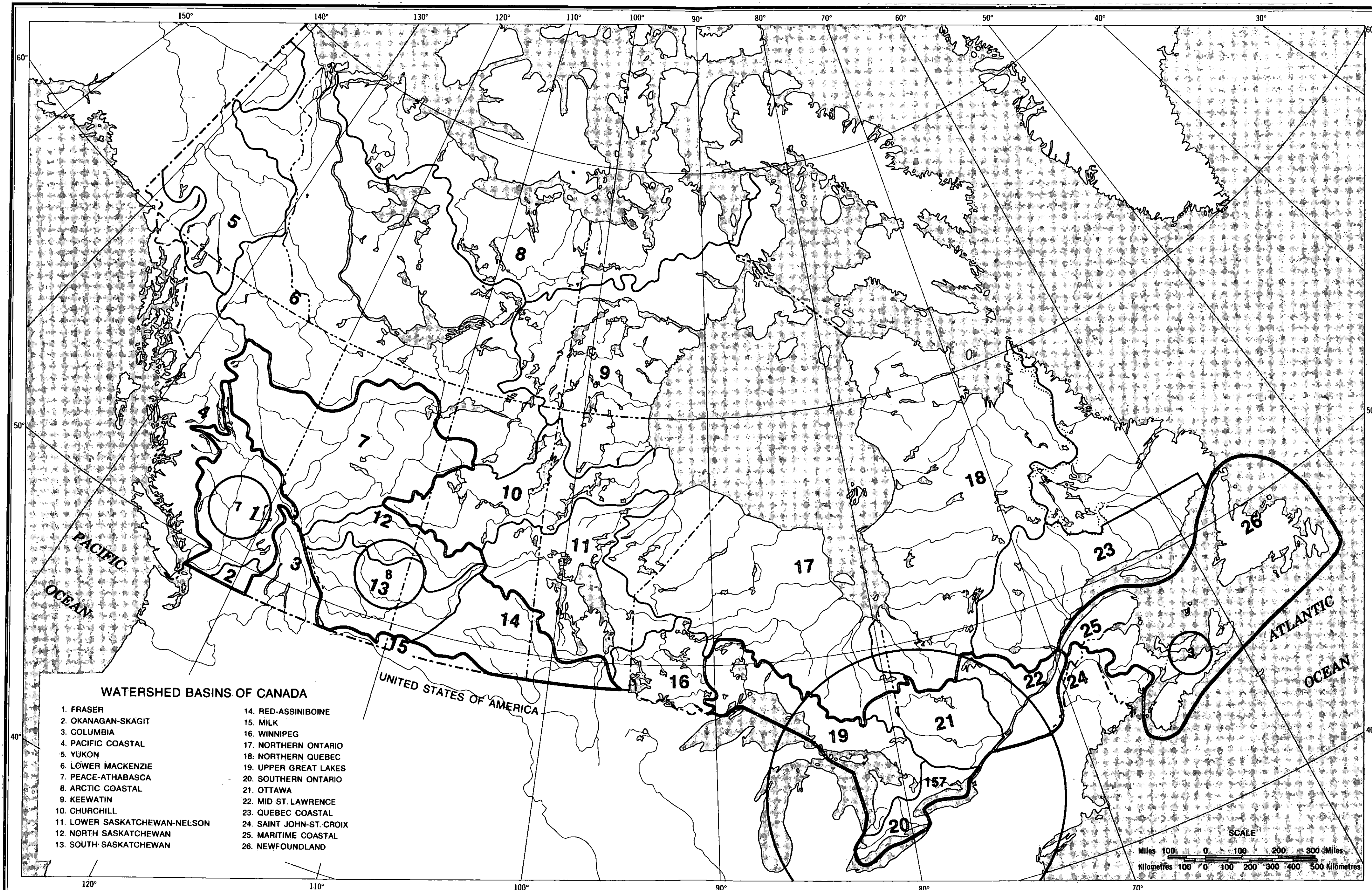
Map 1. Lead in Canada, 1973.



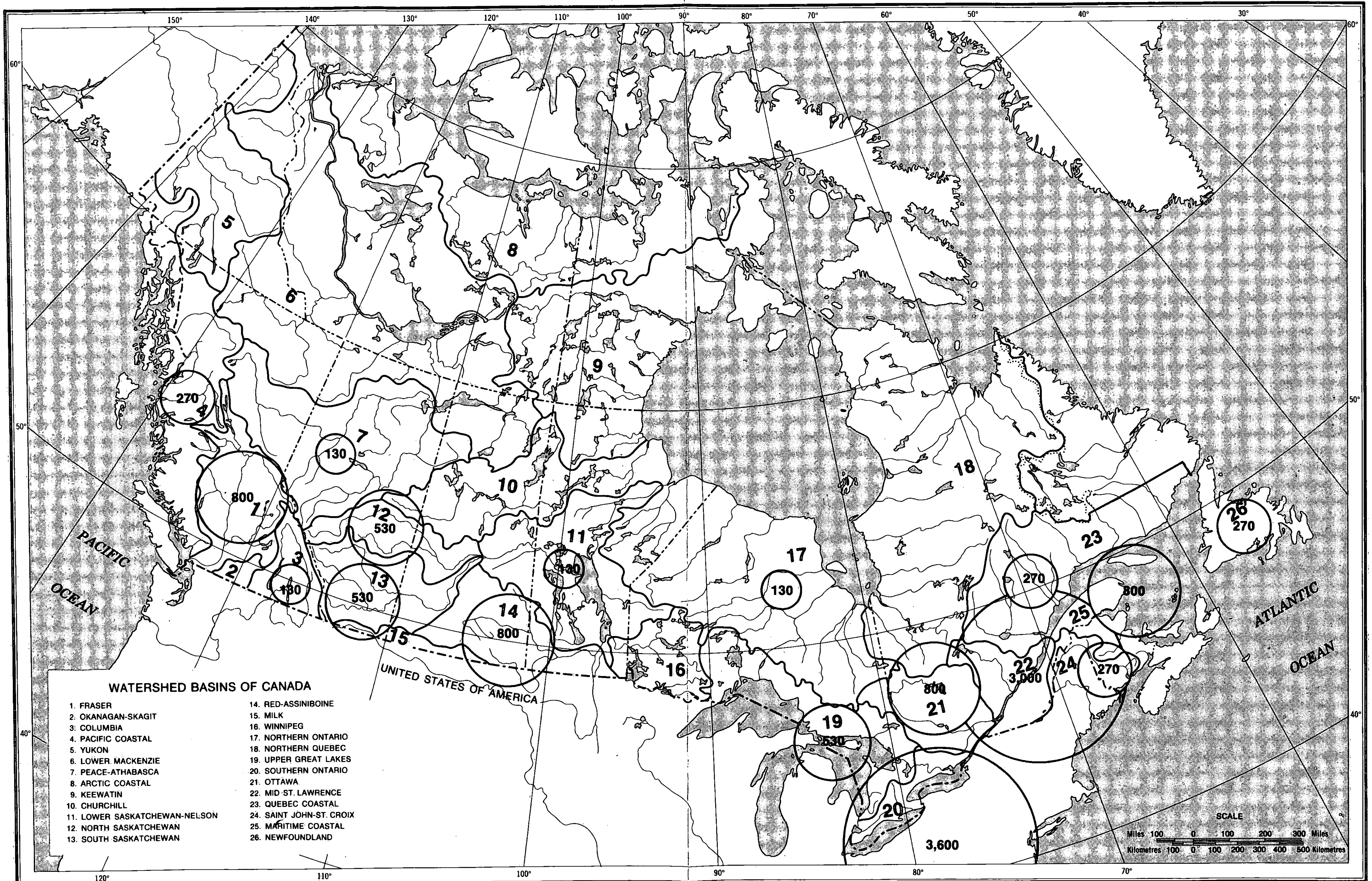
Map 2. The watershed basins of Canada.



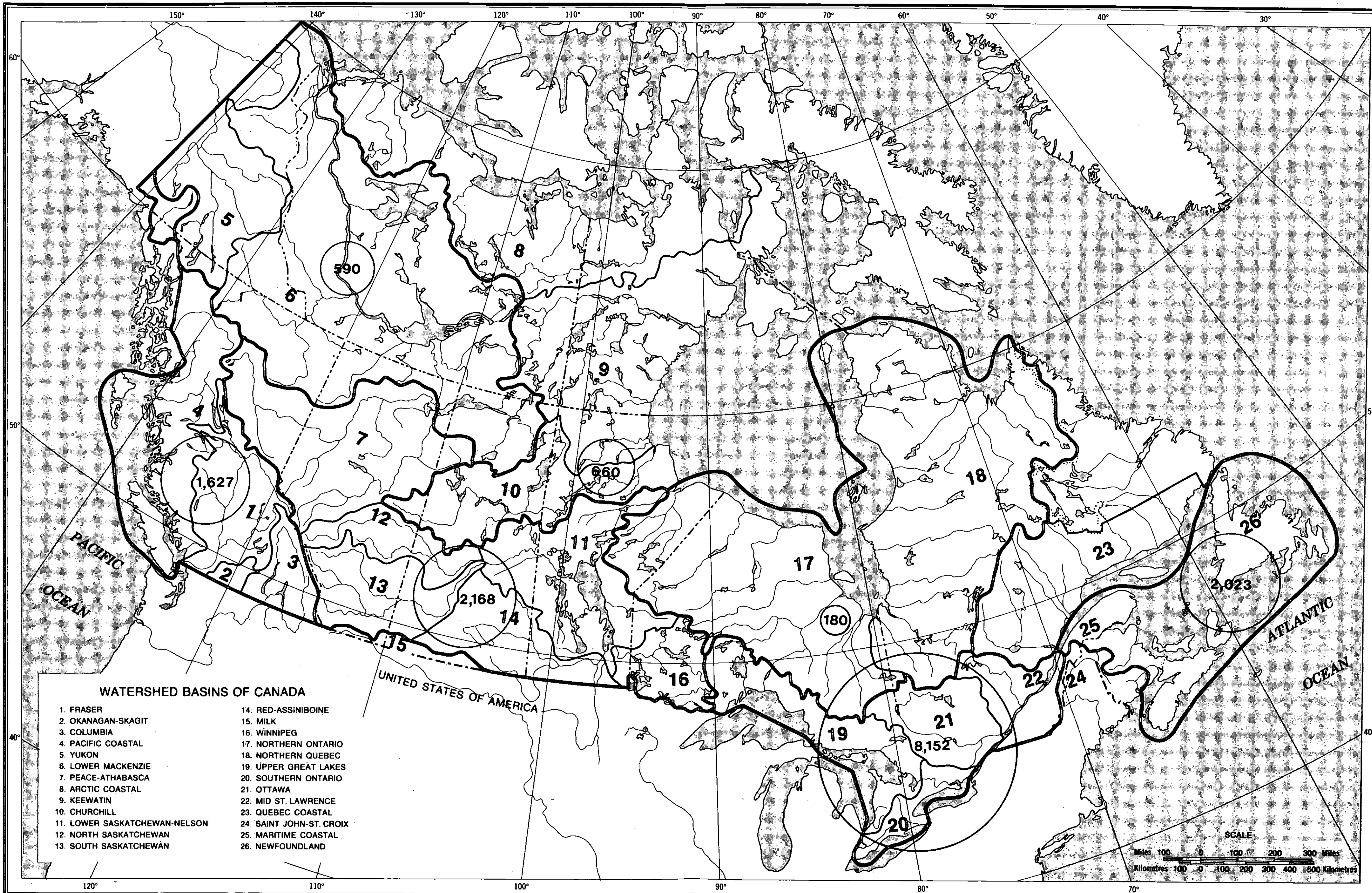
Map 3. Atmospheric lead releases from production activities, 1972.



Map 4. Atmospheric lead releases from manufacturing activities, 1972.



Map 5. Atmospheric lead releases from consumption of leaded gasoline based on watershed population, 1972.



Map 6. Total atmospheric lead releases, 1972.