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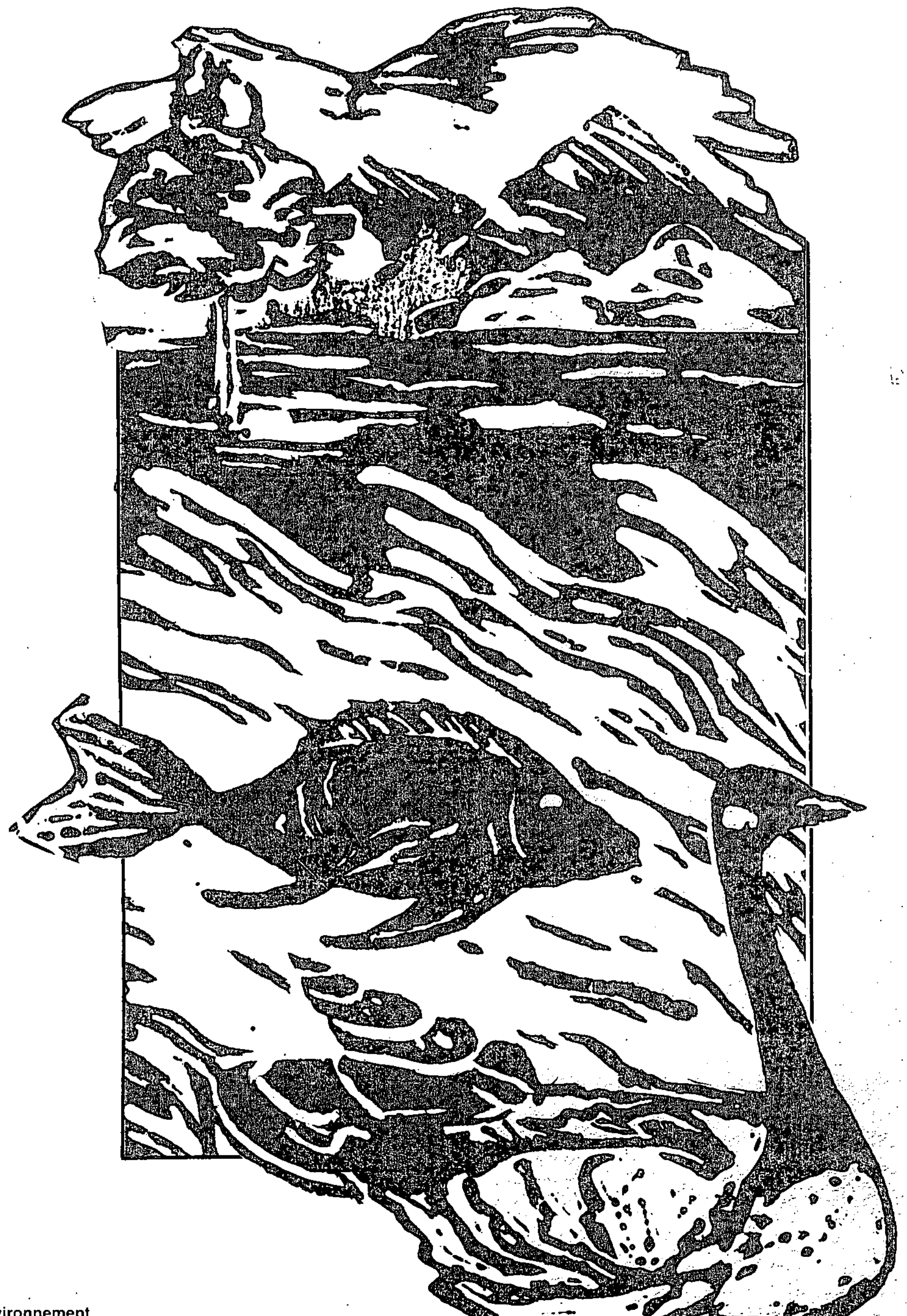
# LEAD



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DEPARTMENT OF THE ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC AND YUKON REGION

# CHEMICALS IN THE ENVIRONMENT
# PACIFIC AND YUKON REGION

## IV. LEAD

By

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May, 1985

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# TABLE OF CONTENTS

# 1. INTRODUCTION

This report is one in a series entitled "Chemicals in the Environment - Pacific and Yukon Region" prepared by the Environmental Protection Service. The objective of these reports is to provide the technical guidance necessary for: a) the interpretation of environmental quality data on specific chemicals, and b) the assessment of potential impacts resulting from the release of these chemicals into the environment.

The series will focus on both naturally occurring and man-made compounds whose release to the environment is of concern due to their persistence, toxicity and/or bioaccumulative abilities.

These reports discuss highlights of existing environmental quality data for B.C. and Yukon and provide information on environmental dynamics, potential impacts on the environment, and pertinent legislation and guidelines controlling both releases to the receiving environment and environmental quality.

This report is adapted from Garrett, C.L. et al, "Overview of Lead in the Pacific and Yukon Region", Environmental Protection Service, Pacific and Yukon Region, in preparation. For additional information refer to this document.

## 2. USES AND SOURCES OF RELEASE

Lead is a heavy bluish white element which occurs naturally in the earth's crust. Lead and its compounds are used in making pipes, tank liners, roofing and sound attenuating materials, electric storage batteries, shielding material for X-ray and atomic radiation, solder, ceramic glazes, ammunition; as an additive in gasoline, rubbers, plastics and paints; in plating metal objects; and in metallurgy, to improve the characteristics of alloys.

Losses to the environment may occur at mining, smelting and metal plating operations; during gasoline and coal combustion; and from the disposal of batteries, paint wastes and various consumer products. Elevated lead concentrations have been detected in the environment as a result of these releases. Recent studies indicate that lead detected in the aquatic environment has been primarily deposited by man's activities, either directly or as a result of atmospheric deposition. Atmospheric transport results in the distribution of lead to areas far removed from sources of release.

## 3. ENVIRONMENTAL DYNAMICS

The form and concentration of lead in surface waters depends on a number of factors such as pH, temperature, salinity, hardness, redox conditions and the presence of soluble complexes (1, 2).

Under acidic conditions lead sulfates, chlorides and ionic forms are prevalent, while in alkaline conditions precipitates such as carbonates and hydroxides are more common (3). Lead may also be bound to soluble organic material and suspended particulates as the pH increases. Organic matter such as fulvic and humic acids are important in transporting metals due to their mobility (1, 4).

Compounds present in the water column bind metals with varying efficiencies ($MnO_2$, humic acid, iron oxide, clay minerals). While hydrous oxides of iron and manganese effectively bind metals in oxidized systems, reducing conditions can result in their solubilization (1, 4, 5, 6).

Oxidized conditions and soft water systems favour the presence of the free ion, $Pb^{2+}$ which is considered to be the most toxic form.

As fresh water (pH usually 7.0-7.5) comes in contact with seawater (pH usually $\sim$ 8) more lead becomes complexed with carbonate, hydroxides and chlorides. The solubility of many of these complexed forms is reduced in seawater and much of the lead carbonate will precipitate to the bottom sediments. Most of the lead in open seawater is in dissolved form (1, 3, 7, 8).

Lead concentrations are highest in bottom sediments with small particle size and high organic carbon content. Organic matter and clay content are important in the retention of lead in sediments. As with other metals, the release of lead from sediments back to the water column is influenced by pH, oxidation state, organic matter content, iron content, particle size and sulfide levels.

When bottom sediments become anoxic or reduced due to burial or oxygen depletion, insoluble lead sulfide is formed and the lead becomes unavailable for release to the water column (5, 9, 10). However, one study of anoxic marine sediments has shown that metal sulfide is not necessarily the dominant form of metals in anaerobic sediments. Between 40-50% of the lead was associated with clay, 20-30% was associated with iron sulfide and 20% with humic acid (11).

Physical disturbance or tidal activity can result in oxygenation of sediments and overlying waters and remobilization of lead (12). Also, it has been shown that trivalent iron ($Fe^{3+}$), sulfur bacteria and organic compounds such as NTA can mobilize lead from insoluble lead sulphide (3).

Lead/zinc mine tailings discharged into a fjord in Greenland resulted in increased dissolved metal levels including lead. The increased dissolved metals were attributed to the formation of compounds in the tailings during milling and flotation, and the partial oxidation of metal sulphides in high pH tailings when contacting somewhat lower pH seawater (13). Also, the presence of $Fe^{3+}$ in tailings can promote the oxidation of metal sulphides and the release of metals including lead (3).

Although the methylation of lead in sediments has been demonstrated under certain conditions, the potential impacts of methylation in the natural environment is not well understood. It has been shown that temperature, pH and microbial activity in the sediment are important factors in determining methylation while the concentration of lead is less important (14, 15). Some researchers suggest that methylation does not significantly affect lead mobilization in anoxic marine sediments, but may be important in intertidal areas which experience periodic oxidation (16).

It is unlikely that the temporary release of lead during dredging significantly affects organisms at either the dredge site or the disposal site. Most of the metal released rapidly binds to particulates and settles out of solution. However, highly contaminated material should not be disposed of in estuarine or nearshore littoral environments as oxidation may result in the release of lead and other metals (8, 17, 18).

## 4. ENVIRONMENTAL LEVELS

### 4.1 Aquatic Systems

#### 4.1.1 Water.

General

Freshwater lead concentrations typically ranged from 0.6-120 ug/l (average 3-5 ug/l) (19). However, in the U.S., a survey of freshwater systems revealed a mean concentration of 23 ug/l dissolved lead and a mean of 120 ug/l suspended lead (20).

Lead levels in the upper levels of the ocean average 0.01-0.03 ug/l, while concentrations in estuaries or coastal areas receiving industrial wastes may exceed 0.100 ug/l (8, 9, 21).

Due to difficulties with analytical methods and contamination of samples during collection and/or analysis, it is likely that much of the pre-1975 data overestimates the concentration of lead in water (9).

British Columbia

Most of the water samples from the coastal B.C. areas sampled contained mean lead levels of close to or less than 1.0 ug/l (usually < 1.0-3 ug/l) (22). Concentrations rarely exceeded 3 ug/l. The detection limits ranged from < 0.5-< 1.0 ug/l.

Mean water concentrations in most freshwater systems were less than or close to 1.0 ug/l, however, concentrations near several mines and industrial areas were much higher. Elevated water concentrations were detected in the vicinity of several mines and smelters including: Northair; Dolly Varden; Scottie; Cominco smelter; Silvana; Cominco Sullivan; Noranda; and Western Mine. Average lead concentrations were elevated near mine discharge sites in the following water systems: Anomaly Creek, Kitsault River, Summit Lake, Columbia River, Trail Creek, Carpenter Creek, St. Mary River, James Creek, Mark Creek, Babine Lake, Buttle Lake and Myra Creek.

Elevated lead levels have also been detected in Lynn Creek near a landfill and in the highly industrialized Brunette River system.

4.1.2 Sediments.

General

The average lead concentration in the continental crust is approximately 12 mg/kg, while deep sea sediments and deep sea clays contain an average of 45 and 80 mg/kg, respectively. Sediments collected near richly mineralized or heavily industrialized areas may contain much higher concentrations. For example, sediments from a sludge sampling area in Great Britain contained 360 mg/kg lead, while sediments from a smelting area in Norway contained 30500 mg/kg (21, 23, 24).

It has been estimated that Canadian estuarine and coastal sediments contain an average of approximately 20 mg/kg (8).

British Columbia

Background concentrations of lead in most freshwater and coastal areas of B.C. ranged from < 10 to < 20 mg/kg. However, concentrations exceeded background in many of the areas sampled (22).

In marine areas elevated lead levels were detected at mining operations in Alice Arm, the Alcan smelter at Kitimat, several pulp mills in Victoria and Vancouver Harbours, certain ocean dump sites, False Creek, Comox, and the Esquimalt Harbour Armed Forces Base.

In freshwater systems, elevated lead levels were present in sediments near several mines, the Columbia River near the Pb/Zn smelter; the Brunette River system; and certain areas in the Fraser River.

The highest concentrations were detected at the following locations.

| LOCATIONS | MAXIMUM CONCENTRATION (mg/kg) |
|---|---|
| Marine: | |
| Esquimalt Harbour - Armed Forces Base | 7 to 5550 |
| Victoria Inner Harbour | 24 to 2000 |
| Burrard Inlet | 3 to 2570 |
| Coal Harbour | 5 to 4440 |
| False Creek | 2 to 778 |

Freshwater:

| | |
|---|---|
| Buttle Lake & associated creeks | < 1 to 840 |
| Brunette Riverbasin | 4 to 950 |
| Homestake Creek at mouth | 1150 |
| Columbia River d/s smelter | 48 to 25600 |
| Slocan Lake | 50 to 14600 |
| Mark Creek (near base metal mine) | 222 to 38900 |
| St. Mary's River (near base metal mine) | 70 to 3040 |

### 4.1.3 Aquatic Organisms.

4.1.3.1 Uptake. Factors affecting uptake of lead into aquatic organisms include salinity, temperature, pH, concentration and form of the metal, organic content, sulphide content, presence of iron oxides, redox conditions, and particle size of sediments. The age, size, weight, diet, species of the organism and the time of year are also important (1, 8, 9, 25, 26, 27, 28, 29).

Some researchers have reported that lead levels in aquatic invertebrates and fish do not vary with size (30, 31, 32). Others report that concentrations decrease with increasing size, possibly due to rapid growth rate and changes in dietary habits (33, 34, 35, 36, 37).

Lead accumulates most readily in the gills, digestive organs, kidneys, and also in the shell and exoskeleton of aquatic invertebrates (32, 34, 38, 39, 40, 41, 42). In fish, lead may concentrate in the bony parts such as the gills, backbone and tail, and also in the liver and kidney. Concentrations in the muscle tissue are usually low (28, 29, 33, 36, 43).

Laboratory studies have shown that organic forms of lead are more readily accumulated by aquatic biota than are inorganic forms. In some studies tetraalkyllead compounds have been detected in many species of aquatic organisms, but not in ambient waters or nearby sediments. The absence of these compounds in the environment may be explained by their low solubility and high volatility in water systems, but the possibility of in vivo production has not been discounted (44, 45).

4.1.3.2 Levels. Lead does not biomagnify in the food chain and concentrations in organisms at the lower levels of the food chain are usually greater than in organisms at the higher levels. For instance, insects and other aquatic invertebrates typically contain higher levels than do fish (46, 47, 48).

The highest body burdens of lead are usually found in organisms living in close association with bottom sediments. Benthic organisms and deposit feeders such as annelids and certain molluscs, including gastropods and pelecypods, commonly contain high lead concentrations (3, 7, 8, 50).

There are no clear trends for lead concentrations in fish species. Some researchers suggest that levels in grazers and detritus feeders are higher than in predators, while other researchers find no significant differences between species (50, 51).

Lead concentrations in the edible tissues of aquatic invertebrates usually reflect the levels in the environment, while concentrations in the flesh of fish are usually low regardless of environmental levels. However, lead concentrations may become elevated in livers of fish from contaminated areas (33).

Elevated lead levels are commonly detected in aquatic biota near shipbuilding and repair facilities, harbours and marinas (due to the use of lead-based paints) (39, 52); mining and smelting operations; storm sewers (47, 53, 54); and in the vicinity of roads with high vehicular traffic flow (27, 55).

British Columbia

Aquatic invertebrates from most areas of B.C. contain lead levels comparable with those found in other areas of the world. Typical concentrations in various species from British Columbia are listed below (22).

| SPECIES | CONCENTRATIONS (mg/kg wet weight) |
|---|---|
| Mussels | $\leq$ 0.2 |
| Oysters | $\leq$ 0.3 (with few exceeding 0.5) |
| Scallops | $\leq$ 0.3 (at all sites) |
| Crabs | < 0.5 |
| Shrimp and Prawns | < 0.2 |
| Snails | < 0.3 |

Higher concentrations were detected in these species when collected near mines, certain other industrial facilities and stormwater discharges.

High lead levels detected in Yoldia from Alice Arm area (up to 50 mg/kg dry weight (d.w.) or approximately 9 mg/kg wet weight (w.w.)) have been attributed to tailings releases from a now closed nearby mine.

Lead concentrations in mussels from Burrard Inlet commonly exceeded 3 mg/kg (wet weight) and levels of up to 86 mg/kg were detected. Contamination is probably associated with local industrial releases, marine traffic and stormwater discharges (53). Elevated lead levels have also been detected in crabs and Toredo worms collected near a shipbuilding/repair facility in Burrard Inlet.

Clams collected in the vicinity of a sewage treatment plant in the Fraser River estuary contained much higher lead concentrations (26 mg/kg d.w. or approximately 3.25 mg/kg w.w.) than clams from most other areas ($\leq$ 3.0 mg/kg d.w. or $\leq$ 0.5 mg/kg w.w.).

It has been shown that snails from various parts of the world accumulate particularly high levels of lead, however, concentrations in various species of snails collected from the B.C. coast are low.

Lead concentrations in muscle tissue of B.C. freshwater and marine fish were usually less than 0.3 mg/kg wet weight and did not often exceed 0.5 mg/kg. Information on lead concentrations in liver tissue is limited but available data indicate that levels are somewhat higher than in muscle.

Muscle tissue in rainbow trout from lakes in the highly mineralized Kamloops area contained lead at levels exceeding 1.0 mg/kg. Lead concentrations in some species of fish collected downstream from a smelter on the Columbia River appear to be higher than those in the same species collected upstream. Based on limited data, muscle and liver tissue contained mean lead levels of $< 0.2$ and 0.39 mg/kg respectively, in sucker and 0.08 and 0.10 mg/kg in whitefish, collected upstream. Muscle and liver tissue in these species collected downstream contained 0.78 and 2.45 mg/kg and 0.17 and 3.22 mg/kg, respectively.

High lead concentrations were also detected in both muscle and liver tissue from rainbow trout and Dolly varden in Buttle Lake in the mid-1970's. However, over the next few years concentrations decreased to normal levels.

4.1.3.3 Toxicity. Lead is not an essential element and has no known beneficial effect. The toxicity of lead increases with water softness, as the concentration of free $Pb^{2+}$ increases (3), but is generally somewhat lower than the toxicity of cadmium. Organic lead compounds are usually more toxic than inorganic forms (39).

At high concentrations lead precipitates on fish gills causing excessive mucous production and congestion, while lower levels inhibit enzyme activity (56).

The 96 hr $LC_{50}$ for rainbow trout in soft water is 1.17 mg/l lead, while the MATC (maximum acceptable toxicant concentration) for rainbow trout was 0.0072 to 0.0146 mg/l (57). Lethal concentrations to fathead minnows in soft water range from 5.6 to 7.3 mg/l, while in hard water the $LC_{50}$ is 482 mg/l (58).

Two to three month exposures to 0.10 mg/l resulted in detrimental effects on rainbow trout (59) and chronic exposure to 0.1 to 0.3 mg/l causes sublethal effects on stickleback (60). A concentration of 1.24 mg/l slows growth of guppies (61) and 0.07 mg/l affects the conditioned behaviour of goldfish (62). Levels of 0.134 to 0.525 mg/l interfere with alevin development in brook trout (63). Rainbow trout exposed to 0.05 mg/l of lead as a result of a mine tailings dam washout developed spinal curvatures and tail blackening. Chronic exposure of trout to levels as low as 0.0076 to 0.0120 mg/l lead in laboratory experiments has been shown to cause the same symptoms (56, 64, 65).

Certain invertebrate species are also very sensitive to lead. The 28 day $LC_{50}$ for Gammarus was 0.028 mg/l (66) and exposure of Daphnia to 0.030 mg/l lead for 3 weeks caused a 16% reproductive impairment (67).

Although available data is limited, acute and chronic toxic effects have been identified in marine species at concentrations as low as 668 ug/l and 25 ug/l, respectively (68).

## 4.2 Terrestrial Systems

### 4.2.1 Atmosphere.

General

Lead enters the atmosphere primarily in automobile emissions, but also as a result of primary and secondary lead smelting, fossil fuel combustion and waste incineration.

Due to the widespread transport of atmospheric lead, it is difficult to determine natural levels of lead in air as even very remote areas are influenced by anthropogenic releases (3). Levels of atmospheric lead reported for remote areas include; 0.0001-0.064 ug/m$^3$ (microgram per cubic metre) over the North Atlantic and < 0.00019-0.0012 ug/m$^3$ at the South Pole (69, 70).

The atmosphere in urban areas normally contains lead at levels of 0.3 to 2.5 ug/m$^3$ (3), but concentrations in heavy traffic in the downtown centres and in the vicinity of point sources, such as smelters, may be much higher. Average annual atmospheric lead levels in Toronto, and in La Jolla, San Diego and Los Angeles have been estimated to be 0.97, 0.42, 2.1 and 3.6 ug/m$^3$, respectively (71). A 1976 survey indicated that atmospheric levels in Canada ranged from ND to 5.3 ug/m$^3$ (56). Levels of 8.4, 8.2, 8.9 and 11.3 ug/m$^3$ have been detected in downtown heavy traffic areas in Toronto, Vancouver, New York and Los Angeles (3).

British Columbia and Yukon

Mean atmospheric lead concentrations in all areas of B.C. sampled between 1977 and 1981 were below 1 ug/m$^3$, with the exception of Trail, where concentrations commonly exceeded 2 ug/m$^3$ (22). The primary point source of lead release to the atmosphere in the Trail area is a lead/zinc smelter and fertilizer plant complex. Similarly monthly deposition of lead in dustfall in the Trail area (93-10928 ug/m$^2$) was higher than in other areas of B.C. sampled: Castelgar, < 11.68-443 ug/m$^2$; Genelle, 19-980 ug/m$^2$; and Kimberley, < 11.68-2054 ug/m$^2$ (22).

In general, atmospheric lead concentrations have decreased since the 1970's but are higher in densely populated urban areas such as Vancouver and Victoria than in small towns and rural areas.

Information on atmospheric levels of lead in Yukon is limited to the City of Whitehorse (22). Samples collected between 1977 and 1981 contained mean values of 0.32 ug/m$^3$ or less.

Precipitation samples recently collected in southwestern B.C. by the Atmospheric Environment Service contained 1-9 ug/l of lead (72).

No information was available on lead levels in wet precipitation (rain and snow) Yukon.

4.2.2 Soil and Vegetation.

General

The average lead content in the earth's crust has been estimated to be less than 20 mg/kg (56). However, lead levels in soils vary significantly with natural mineralization, local automobile traffic and proximity to industrial point sources.

It has been reported that Canadian soils contain an average of 12 mg/kg with levels in urban areas ranging from 40 to 2600 mg/kg (72). Concentrations of several thousand milligrams per kilogram have been detected in soils near lead deposits, heavy traffic areas, and lead smelters.

The mobility of lead in soils is very limited. Mobility in soils and availability to vegetation is influenced by a number of factors including; soil composition, metal content, pH, cation exchange capacity, organic matter content and the presence of phophorus. Lead is most mobile and, therefore, most available to plants in acidic, sandy soils with low phosphorus and organic matter content (3, 71).

Given soil conditions favouring uptake, plants located in highly mineralized areas, near busy highways and in close proximity to point sources (especially smelters) can accumulate high concentrations of lead. For example, vegetation collected near a battery smelter and a battery manufacturer in Ontario contained up to 2740 and 387 mg/kg (dry weight), respectively (73).

Plants obtain lead through the roots and the foliage and, although some translocation may occur in the plants, it is limited (3, 71). Plants exposed to atmospheric lead deposition often contain the highest levels in the foliage, while plants grown on contaminated soils usually concentrate lead in the roots. The edible parts of plants normally do not concentrate high levels of lead with the exception of some leafy vegetables, such as lettuce (56, 75, 76, 77).

As most of the lead in contaminated soils is located in the surface layer, shallow rooted plants often contain higher lead concentrations than do deeper rooted species (74). However, mosses and lichens concentrate higher levels of lead than do other plants and are often used as indicators of atmospheric pollution (78).

## British Columbia

Agricultural soils collected throughout B.C. contained an average of 10.4 mg/kg (dry weight nitric acid extractable lead). Soils from areas near Vancouver contained the highest concentration of lead, probably due to input from automobile exhausts. In all areas the highest concentrations were in the surface soil layer (79).

Soil samples obtained from downtown Vancouver contained up to 490 mg/kg total lead, while samples from downtown Victoria contained much lower levels of lead (13 to 35 mg/kg) (22).

Lead contamination was detected in soils in the vicinity of the lead/zinc smelter at Trail in 1972. Concentrations of up to 12000 mg/kg (nitric acid extractable lead) were detected in soils near the smelter, but levels decreased with increasing distance from the source (80, 81). Smelters are recognized as important point sources of lead to the atmosphere and similar contamination has been identified near smelters from other areas of the world (82, 83, 84).

No recent data was available for soils in the Trail area but lead emissions from the smelter have been reduced significantly since the early 1970's.

Elevated lead concentrations (up to 1200 mg/kg) were also detected in some soil samples collected near a phosphate fertilizer plant in Kimberley in 1976 (22).

The highest levels of contamination were detected in soils collected near a battery smelter in Richmond in 1971. A concentration of 59600 mg/kg (nitric acid soluble lead) was detected in surface soils 15 metres from the stack, but at a distance of 300 metres the lead levels in the soil had decreased to 106 mg/kg (79).

Most of the information on lead concentrations in terrestrial vegetation in B.C. was collected from highly mineralized mine exploration sites in the 1960's (22). For this reason, these concentrations are not typical of B.C. vegetation. The various species of deciduous and coniferous species sampled commonly contained 20-50 mg/kg (dry weight) lead while levels exceeding 100 mg/kg were detected in vegetation from some areas.

Vegetation collected in the vicinity of a copper smelter in the Kamloops area contained much lower levels of lead and did not exceed 16 mg/kg. Levels of lead in soils from this area were not elevated ($\bar{x}$ = 16 mg/kg).

Moss collected in the vicinity of Trail contained 1.03 to 4.65 mg/kg.

4.2.3 Wildlife.

General

Lead concentrations in birds are determined by species, age, tissue, location, diet and migratory habits.

Lead levels in song birds, pigeons and doves in large cities are usually much higher than in rural areas (85, 86, 87). This has been attributed to lead emissions in automobile exhausts. High lead levels have also been detected in birds from industrial areas. For instance, birds from the Mersey Estuary in England accumulated high, sometimes lethal, levels of alkyl lead compounds discharged in petrochemical plant effluents (88, 89).

Game birds and waterfowl in more rural areas obtain lead from the ingestion of spent lead shot. Birds ingest spent shot both accidentally during feeding and intentionally for use as grit in digestive processes. Lead fishing weights have also been identified as a source of lead poisoning in birds (90, 91, 92).

Little information was available on lead levels in terrestrial mammalian wildlife species.

Small mammals living near busy roadways and in urban areas often contain elevated lead levels due to the lead contamination from automobile exhausts (93, 94). Elevated levels of lead in wild mammalian species have been reported (95), but lead contamination is more common in domestic species, particularly in livestock foraging near highways and smelters (96, 97).

British Columbia and Yukon

Information on lead levels in B.C. wildlife species is very limited (22). The lead concentrations in the few eggs and tissue samples analyzed to date are not elevated in comparison to other areas and do not approach toxic levels.

However, in the early 1970's, elevated lead concentrations were detected in horses suffering from lead poisoning as a result of smelter emissions in the Trail area (97). Releases of lead from the smelter and atmospheric levels of lead in the Trail area have decreased significantly since the early 1970's.

No information on Yukon wildlife species was available.

4.2.3.1 Toxicity. Ingestion of spent lead shot is the most common cause of lead poisoning in wildfowl and has been the cause of significant die-offs in some water bird populations in past years (3, 92, 93).

Species at highest risk include diving and dabbling ducks, whistling swans and Canada geese (3, 92). Lead shot has also been detected in the gizzards of game birds such as grouse (90). Ingested lead shot is absorbed by the gut and may cause various physiological disturbances of the digestive, circulatory and nervous systems and, in some cases, may result in death. As few as 5 to 6 lead shot pellets may be lethal to mallards (90, 91, 92, 98).

Alkyl lead contamination from petrochemical plant effluents were responsible for high mortality among waterfowl in the Mersey estuary in England between 1979 and 1981. Wading birds collected in the area contained up to 35 mg/kg (wet weight) lead in the liver. Internal morphological alterations were noted in birds containing more than 0.5 mg/kg trialkyl lead in the liver (88, 89).

Lead levels exceeding 100 mg/kg (wet weight) are common in the bone of waterfowl dying of lead poisoning. Lead levels in other tissues which are indicative of lead poisoning in waterfowl include the following: 6 to 20 mg/kg in liver, > 20 mg/kg in kidney and > 3 mg/kg in the brain (99, 100, 101).

In comparison, a wild raccoon suffering from lead poisoning contained approximately 35 mg/kg lead in liver and kidney tissue and abnormalities were noted in the lungs, liver, kidney and brain (95).

Although incidents of lead poisoning in wild mammalian species have been reported, most lead associated deaths involve domestic species.

Livestock poisonings have resulted from the ingestion of lead contaminated materials (paints, batteries, etc.) dumped on pasture land. Also, the ingestion of lead contaminated forage near major industrial emission sources, such as smelters, has resulted in deaths. Horses are particularly sensitive (3, 56, 97).

The toxicity of lead to wildlife varies significantly with species, age, reproductive state, ability to absorb lead, form of lead, route of entry, and the general health of the animal. Diet, particularly calcium intake, also plays an important role. Adequate levels of dietary calcium and aquatic vegetation are important in minimizing the effects of lead poisoning (101, 102).

Lead is a cumulative poison and many of the effects are irreversible. Characteristic effects of lead poisoning include: impairment of learning ability; loss of motor function and muscular strength; seizures; behavioural changes; weight loss; anemia; enzyme inhibition; suppression of antibody production; respiratory problems; decreased fertility; abortion; and morphological abnormalities in tissues, particularly the brain, kidney and liver. In birds, paralysis of the gizzard can ultimately lead to starvation. Decreased survival of offspring occurs due to the ability of lead to penetrate the placental barrier in mammals and to pass into the eggs in birds (56, 59, 87, 103, 104).

## 5. REGULATIONS AND GUIDELINES

Current regulations and guidelines pertaining to lead in the environment are summarized following.

### 5.1 Water Quality

At present there are no Canadian (or U.S.) water quality guidelines for acceptable levels of lead in marine waters. The Inland Waters

Directorate recommended water quality criteria for total lead in Canadian freshwater systems depends on water hardness (56):

| | |
|---|---|
| soft water (< 95 mg/l $CaCO_3$) | 5 ug/l |
| hard water (> 95 mg/l $CaCO_3$) | 10 ug/l |
| in the absence of sensitive species (eg. rainbow trout) | 30 ug/l |

The 1978 Canada/U.S. Great Lakes Water Quality Agreement specifies that lead levels in unfiltered water not exceed 10 ug/l in Lake Superior, 20 ug/l in Lake Huron, and 25 ug/l in the remaining lakes.

## 5.2 Human Health

There are presently no guidelines on acceptable levels of lead in fish and shellfish for human consumption. Incidents of elevated lead levels in commercially important species are reviewed on a case by case basis.

## 5.3 Ocean Disposal

Federal and provincial legislation control the release of lead into the aquatic environment.

The ocean disposal of wastes and other materials off the Canadian coast is controlled under the Federal Ocean Dumping Control Act. Lead is a 'restricted' compound under this Act. Although there is no set criteria for maximum levels of lead in materials to be ocean disposed, applications for the disposal of materials containing lead are reviewed on a case by case basis.

The Quebec and Ontario provincial criteria for ocean disposed material specify maximum lead concentrations of 20 mg/kg and 50 mg/kg, respectively.

## 5.4 Industrial Effluents and Emissions

The level of lead in specific industrial effluents and atmospheric emissions is regulated under provisions contained in the British

Columbia Waste Management Act as well as regulations issued according to the federal Fisheries Act. Lead content in gasoline and emissions from secondary lead smelters are controlled by regulations under the federal Clean Air Act.

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