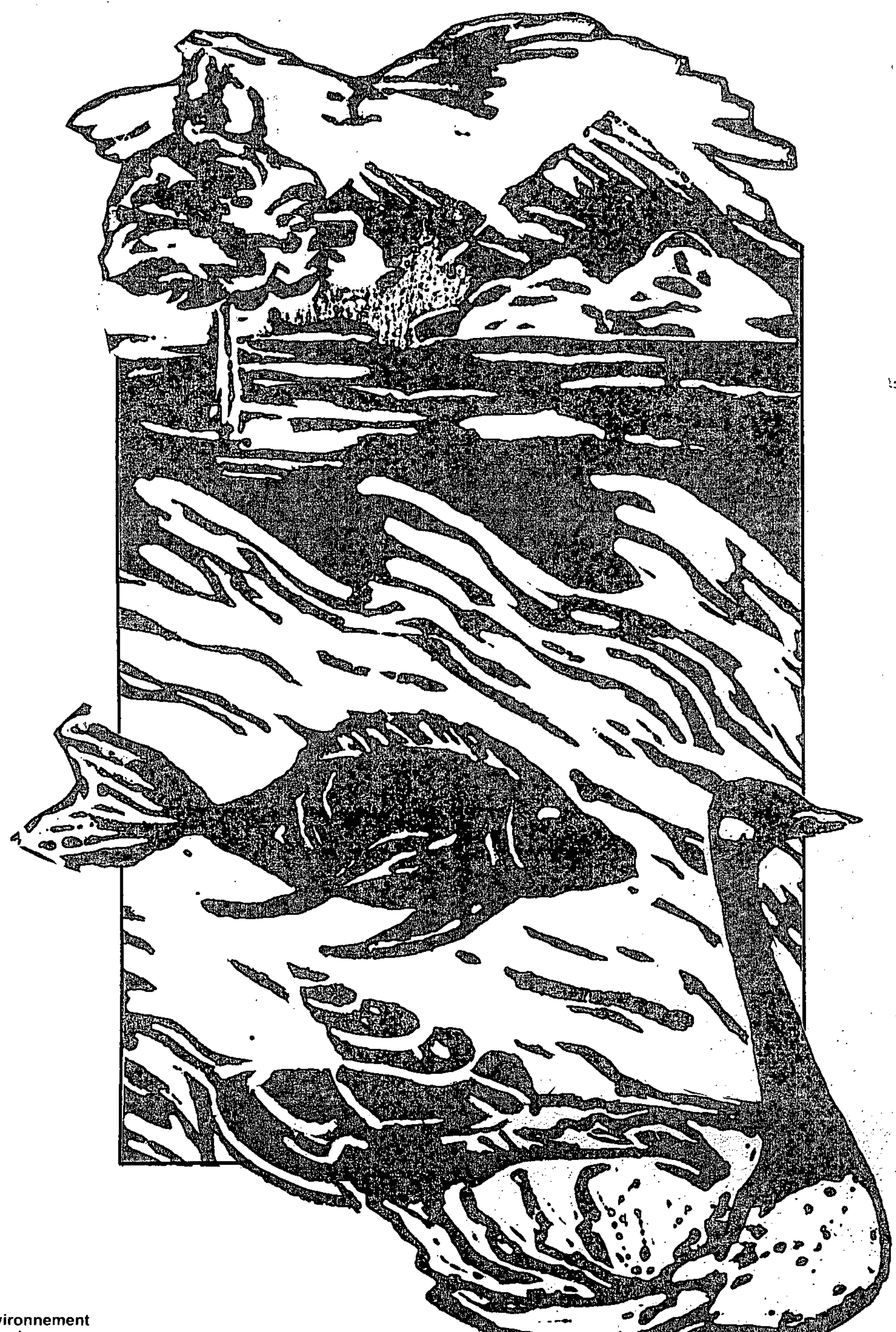
SUMMARY REPORT

CHEMICALS IN THE ENVIRONMENT

# CADMIUM



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Canada

PACIFIC & YUKON REGION

DEPARTMENT OF THE ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC AND YUKON REGION

# CHEMICALS IN THE ENVIRONMENT
# PACIFIC AND YUKON REGION

## II. CADMIUM

By

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## 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 Cadmium 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

Cadmium is a silver-white metal which occurs naturally in the earth's crust in association with lead, copper and, especially zinc sulfide deposits. Cadmium metal is obtained primarily as a by-product of zinc metal production. Canada is one of the world's major cadmium producing countries.

The major use of cadmium is for the electroplating and coating of metal products and parts, but large quantities are also used as pigments in paints. Smaller amounts of cadmium compounds are used as stabilizers in plastics; in pesticides; as catalysts; and in the production of nickel-cadmium batteries. Releases to the environment occur as a result of these uses. Cadmium is also a common contaminant of phosphate fertilizers. This can result in uptake into plants and animals used for human consumption. Significant amounts also enter the environment as a result of zinc mining and smelting, sewage discharges and fossil fuel combustion.

## 3. ENVIRONMENTAL DYNAMICS

The form of metals in surface waters depends on a number of factors including pH, salinity, redox conditions, hardness, temperature and the presence of soluble complexes (1, 2, 3, 4, 5).

Cadmium in freshwater systems exists largely in free ionic form, particularly in systems where the pH is low. However, a significant proportion of the cadmium may be bound to particulates in neutral or alkaline pH conditions (6, 7).

In marine waters cadmium is predominantly associated with chloride complexes. Cadmium chloride complexes tend to remain in solution and, therefore, most of the cadmium detected in seawater is in dissolved rather than particulate form (6, 8, 9, 10).

In estuaries the behaviour of cadmium and other metals is complex. The continually changing physicochemical conditions result in fluctuations in the concentrations and forms of metals present in the water column (11).

The majority of the cadmium entering aquatic systems precipitates or is bound to particulates and is ultimately deposited in the bottom sediments. Even in polluted areas, where cadmium concentrations in sediments are high, levels in the water column are often low.

Very little of the cadmium in sediments is available for immediate release to the water column. However, in the event of changes in the physicochemical conditions of the water system, all forms, except the residual fraction, are potentially available for remobilization (9, 12). The conditions which promote the adsorption of metals to sediments and decrease their potential for remobilization include high pH (1, 4, 13, 14), high organic matter content (7, 15), reducing conditions (low dissolved oxygen) (16, 17, 18), fine sediment grain size (19), absence of organic chelators in the water, and lack of microbial activity (1). Redox, pH and salinity conditions appear to have the most significant effect on metal remobilization (9). There is evidence that increased salinity can result in the mobilization of cadmium from oxidized sediments (2, 20, 21, 22, 23). Cadmium and other metals are less likely to be mobilized in a reducing environment than in an oxidizing environment. The large concentrations of sulphide normally present in reduced sediments results in the formation of insoluble metal sulphides which precipitate out of solution and back into the sediment. However, any change in the redox potential of the sediments will have marked effects on the mobilization of metals from the sediments (17, 18, 19, 24).

The disturbance of sediments caused by dredging operations can result in the remobilization of metals by changing redox conditions. A study of dredging activities in San Francisco Bay demonstrated that cadmium releases from sediments increased with oxygenation and with salinity (under oxidized conditions) (9, 16, 17, 19).

# 4. ENVIRONMENTAL LEVELS

## 4.1 Aquatic Systems

### 4.1.1 Water.

General

It is reported that the normal background concentration of cadmium in seawater is $\leq$ 0.11 ug/l (25, 26). The mean (geometric) cadmium content in water collected from the Atlantic Ocean off the east coast of Canada was 0.04 ug/l but 50% of the samples contained concentrations below the detection limit of 0.03 ug/l (27). Levels in estuaries and coastal areas are often higher due to inputs from both natural and man-related sources. Cadmium concentrations in estuaries and coastal areas are also more variable than in the open sea due to changing physicochemical conditions and fluctuations in inputs by runoff, fluvial transport, and industrial and municipal discharges (11, 24, 28).

Increasing cadmium concentrations with water depth have also been reported for several marine waters, and it has been shown that cadmium in ocean waters is correlated to the levels of nutrients ($PO_4$ and $NO_3$) at all depths (29, 30, 31, 32).

At present there are no Canadian guidelines or criteria for cadmium in marine waters. However, the U.S. Environmental Protection Agency guideline for marine waters specifies a concentration of not more than 4.5 ug/l as a 24 hour average and 59 ug/l as a maximum (41).

The cadmium content of surface waters from freshwater systems is often higher than in marine waters. It has been reported that the cadmium concentrations in most unpolluted freshwaters are typically 0.01 to 0.1 ug/l (33) and usually less than 1 ug/l (34, 35). Elevated cadmium concentrations have been detected in surface waters near sewage treatment plants, mining and smelting activities, and electroplating operations (36, 37, 38, 39).

The Canadian Inland Waters Directorate (IWD) recommended a water quality criteria for freshwater systems of 0.2 ug/l total cadmium (40). U.S. Environmental Protection Agency freshwater guidelines vary with water hardness ($CaCO_3$ content) and recommended 24 hour averages range from < 0.051-0.12 ug/l (refer to Section 5).

British Columbia

The mean concentrations of cadmium in coastal waters off British Columbia are less than the detection limits (< 0.10 to < 0.50 ug/l) at most sites. At the few stations where mean values slightly exceed the detection limits, the elevated mean is usually attributable to one unusually high value (42).

Mean cadmium concentrations in most freshwater systems in B.C. and Yukon, sampled to date, did not exceed 1 ug/l. Higher concentrations have been detected at several sites, however, particularly in the vicinity of mining and smelting activities.

In B.C. elevated surface water concentrations have been detected in Anomaly Creek; Columbia River near Trail; Carpenter Creek in the Slocan area; the St. Mary River and various creeks near Kimberley; and in Myra Creek near Buttle Lake (42).

It should be noted that the reliability and comparability of data on cadmium levels in surface water is the subject of much concern. In past years inconsistencies in techniques for the collection and analysis of surface water data has cast doubt on the reliability of much of the available data.

4.1.2 Sediments.

General

In addition to industrial inputs and natural mineralization, sediment grain size and composition are important factors in determining cadmium concentrations in bottom sediments. The highest cadmium levels are usually detected in fine-grained sediments with a high organic content, while sandy or gravelly sediments contain low concentrations (7, 15, 19). For this reason, variations in sediment cadmium concentrations between different sites may be a reflection of differences in grain size and/or organic content, rather than an indication of local sources of contamination.

It is reported that the cadmium concentration in deep sea clay averages approximately 0.4 mg/kg but levels in coastal and harbour areas are often much higher (43).

Coastal regions often receive large inputs of cadmium from both industrial and municipal discharges. For example, surface sediments in the vicinity of a sewage outfall in Southern California contained up to 66 mg/kg (44). Concentrations of up to 392 mg/kg were detected in Narragansett Bay off Rhode Island in the early 1970's and were attributed to discharges from electroplating operations (45).

Elevated cadmium concentrations are also commonly detected in active harbours. Concentrations of up to 654 mg/kg (average 6.3-6.6 mg/kg) have been detected in Baltimore Harbour. Cadmium concentrations in Los Angeles Harbour sediments ranged from 0.66 to 22 mg/kg (12, 46).

Cadmium concentrations in freshwater sediments vary greatly with proximity to industrial discharges and natural mineralization. Sediments from unpolluted lakes in South America, Asia, Africa and Australia contained an average concentration of 0.35 mg/kg (19).

Cadmium levels of between 1 and 10 mg/kg are not uncommon in the vicinity of sewage discharges and even higher concentrations (in some cases > 1000 mg/kg) have been detected near industrial activities, particularly mines, metal finishing plants and battery plants (36, 47, 48, 49, 50, 51, 52, 53).

## British Columbia

Elevated cadmium concentrations were detected in sediments from many coastal locations of British Columbia (42). However, most of the areas for which information was available receive discharges from industrial plants or waste treatment facilities. For this reason, many of the samples contained 1-2 mg/kg of cadmium or more. Elevated cadmium concentrations were detected most commonly in the vicinity of mines, pulp mills and active harbours.

| LOCATION | CONCENTRATION (mg/kg) |
|---|---|
| <u>Mines</u> | |
| Alice Arm - site of past and present mining activities | < 1 to 43 |
| Observatory Inlet - near site of an abandoned smelter | < 1 to 29.4 |
| Tasu Sound - near mine | x = 1.33 |
| <u>Pulp Mills</u> | |
| Port Mellon | < 0.25 to 64 |
| Powell River | 0.2 to 10.5 |
| Alberni Inlet | < 0.5 to 13.2 |
| Crofton | < 0.05 to 3.46 |
| Howe Sound | < 0.5 to 2.6 |
| Zeballos Inlet | < 0.5 to 7 |
| <u>Harbour Areas</u> | |
| Vancouver Harbour/Burrard Inlet | |
| - near docks and ship repair facilities | < 0.01 to 12 |
| - near ore concentrate loading facility | 0.43 to 57 |
| Coal Harbour | < 0.10 to 4.32 |
| False Creek | < 0.10 to 7.87 |
| <u>Ocean Dump Sites</u> | |
| Watts Point | < 0.55 to 5.0 |
| Eliza Passage | 0.49 to 1.82 |
| Muchalet Inlet | 0.15 to 3.2 |
| Alberni Inlet | < 0.56 to 4.4 |
| Point Grey | 0.4 to 2.9 |

Mean cadmium concentrations in most freshwater sediments sampled in B.C. did not exceed 1 mg/kg but higher concentrations have been detected at several sites, particularly in the vicinity of mining and smelting activities:

| LOCATION | CONCENTRATION (mg/kg) |
|---|---|
| Columbia River - d/s from smelter | < 0.5 to 178 |
| Slocan Lake area | 5 to 235 |
| St. Mary River and creeks | < 0.25 to 21 |
| Water bodies near Stewart | 1.2 to 20 |
| Buttle Lake | < 1.0 to 42 |
| Myra Creek | < 0.10 to 1100 |
| Price Creek | < 0.10 to 58 |
| Thelwood Creek | < 0.10 to 76 |

Very little information on cadmium levels in bottom sediments from the Yukon Territory was available. High cadmium concentrations (up to 149 mg/kg) were detected near an abandoned mine tailings pond on Tagish Lake at Windy Arm.

4.1.3 Aquatic Organisms.

4.1.3.1 Uptake. The biological availability and rate of metal uptake into aquatic organisms is influenced by a number of environmental factors including: the concentration and chemical form of the metal; sediment characteristics such as particle size, organic content, sulphide content, redox conditions and physical disturbance; and water characteristics such as pH, hardness, temperature, salinity and DO (17, 54, 55, 56, 57, 58).

Characteristics of the organism such as species, sex, size, age, feeding habits and general physiology have also been shown to be important (54, 59, 60, 61).

Unlike mercury, cadmium concentrations in fish muscle tissue generally do not increase with increasing size or age. In fact, higher cadmium levels are often detected in the smaller individuals (59, 60, 62). In contrast, several researchers have noted a positive correlation between the age or size of an organism and the cadmium concentration in liver tissue and, in some cases, whole body. Positive correlations between size and cadmium level are more commonly reported for certain species of aquatic invertebrates. However, the effects of size are not consistent (63, 64, 65, 66, 67).

The cadmium content in aquatic organisms at the lower trophic levels are generally higher than those at the higher trophic levels. For instance, aquatic insects and other invertebrates typically contain higher levels than do fish. Also, fish species utilizing crustaceans and plant material for food often contain more cadmium than do piscivorous species (54, 60, 68).

4.1.3.2 Levels.

General

Bivalve molluscs, especially scallops, limpets, and oysters, have been shown to be particularly effective accumulators of cadmium and can attain significant concentrations even in areas free from known sources of contamination (69, 70). However, tissue concentrations are generally highest near sources of industrial contamination and municipal discharges (71, 72, 73, 74, 75, 76, 77).

The highest concentrations of cadmium are normally detected in the digestive organs of invertebrates and levels of over 100 mg/kg have been reported by several researchers (71, 78).

Significant concentrations of cadmium have also been detected in the edible tissue (meat) of bivalves, whereas the edible tissue of crustaceans normally contains low cadmium levels (71, 79, 80, 81, 82).

This is probably due, at least in part, to the fact that filter feeding bivalves obtain cadmium associated with contaminated supsended particulates. Cadmium levels in the edible portion of fish are normally much lower than those reported for various species of invertebrates. It has been reported that muscle tissue of most freshwater fish contains 0.1 mg/kg cadmium or less (25). Even in water systems receiving large cadmium inputs, the levels in muscle tissue of fish often remain low.

Liver tissue is a more reliable indicator of environmental contamination than is muscle. Most of the cadmium accumulated by fish is deposited in the liver. Cadmium levels in fish liver reflect the environmental availability of cadmium and tend to increase with increasing concentrations in the water. Levels in the liver also increase with length of exposure and unlike muscle, have often been positively correlated with the age, length and weight of the organism (63, 64).

Cadmium levels in marine and estuarine fish are generally lower than those detected in fish from many freshwater systems. However, elevated levels may occur in coastal areas of high pollution.

<u>British Columbia</u>

Cadmium levels in invertebrates from most areas of British Columbia are comparable to those found in other areas of the world. Typical concentrations for various invertebrate species in British Columbia are listed below (42).

| SPECIES | CONCENTRATIONS (mg/kg wet weight) |
|---|---|
| Oysters | > 0.5 in all areas; commonly 1-2 mg/kg |
| Scallops | 1.87 to 3.6 |
| Chiton | 0.6 to 3.7 |
| Limpets | 0.75 to 8.2 |
| Mussels | ≤ 1 (most areas) |
| Clams and Cockles | ≤ 0.5 (most areas) |
| Shrimp - tail | ≤ 0.05-0.51 |
| - whole body | 0.10-2.7 |
| Crab - muscle | 0.01 to 0.10 (most areas) |
| - viscera | up to 25.0 |
| Zooplankton | < 0.5 (most areas) |

Somewhat elevated cadmium levels were detected in oysters from Howe Sound; mussels, clams and Yoldia from Alice Arm; zooplankton from the Campbell River system; and aquatic insects from the Columbia River downstream from Trail.

Cadmium concentrations in muscle tissue of freshwater fish generally ranged from < 0.01 to 0.10 mg/kg (wet weight). Although cadmium concentrations in liver tissue from freshwater fish were much higher than those in muscle tissue, levels were below 1.0 mg/kg (wet weight) in most locations.

Cadmium levels in muscle tissue of marine fish from coastal British Columbia were similar to those in freshwater species (< 0.01 to 0.1 mg/kg in most cases). Very few samples contained levels of greater than 0.2 mg/kg and only one specimen contained more than 0.3 mg/kg.

4.1.3.3 Toxicity. Cadmium is one of the most toxic metals to aquatic organisms. The toxicity of cadmium is dependent on many factors including exposure time, chemical concentration and form, species of organism, life stage and the presence of other toxicants (83, 84, 85, 86, 87). Ambient water conditions such as temperature, dissolved oxygen content, hardness, pH, salinity and the presence of calcium humic acids and other complexans also affect the susceptability of aquatic organisms to environmental contaminants including cadmium (88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99). Due to the many factors influencing cadmium toxicity it is difficult to compare species' sensitivities based on laboratory bioassays. However, it has been demonstrated with cadmium, as with many other chemical pollutants, that salmonids are particularly sensitive (100). Larval and juvenile stages of aquatic invertebrates are usually more susceptible to the toxic effects of cadmium than are adult organisms (83, 101, 102).

Acute toxicities of cadmium to fish and aquatic invertebrates are summarized in Table 1.

Laboratory exposure to very low concentrations of cadmium has caused population declines in some aquatic species due to sublethal

TABLE 1 TOXICITY OF CADMIUM TO FISH AND AQUATIC INVERTEBRATES AS DETERMINED BY $LC_{50}$ VALUES

i) Fish

| SPECIES | EXPOSURE | CONCENTRATION (ug/l) | COMMENTS | REFERENCE |
|---|---|---|---|---|
| Chinook salmon | 96 hr. | 3.5 | parr | 100 |
| | | > 26 | alevin | 100 |
| | | 1.8 | swim-up | 100 |
| | | 2.9 | smolt | 100 |
| Coho salmon | 9 days | 3.7 | adult | 103 |
| Steelhead trout | 96 hr. | 1.0 | parr | 100 |
| | | > 27 | alevin | 100 |
| | | 1.3 | swim-up | 100 |
| | 17 days | 5.2 | adult | 103 |
| Rainbow trout | 96 hr. | 0.95 | juvenile | 104 |
| | 7 days | 10 | (hardwater) | 105 |
| Striped killifish | 96 hr. | 21000 | | 88 |
| Sheepshead minnow | 96 hr. | 50000 | | 88 |
| Northern squawfish | 96 hr. | 1104 | juvenile | 106 |
| Atlantic silverside | 11-19 days | < 150-1120 | larvae ($LC_{50}$ varies with salinity) | 107 |
| Largemouth bass | 56 days | 850 | fry | 108 |
| Flounder | 96 hr. | 24.4 | | 109 |
| Mummichog | 96 hr. | 55000 | | 88 |
| Sucker | | 107.2 | $LC_{100}$ | 110 |

TABLE 1 TOXICITY OF CADMIUM TO FISH AND AQUATIC INVERTEBRATES AS DETERMINED BY $LC_{50}$ VALUES

ii) Aquatic Invertebrates

| SPECIES | EXPOSURE | CONCENTRATION (ug/l) | COMMENTS | REFERENCE |
|---|---|---|---|---|
| Daphnia hyalina | 96 hr. | 55-65 | | 111 |
| A. Serrulaus | 96 hr. | 7 | | 112 |
| Amphipod | 96 hr. | 40 | | 113 |
| Sand shrimp | 96 hr. | 320 | | 88 |
| Grass shrimp | 96 hr. | 420 | | 88 |
| Pink shrimp | 96 hr. | 3500 | juvenile | 114 |
| Hermit crab | 96 hr. | 320 | | 88 |
| Green crab | 96 hr. | 4100 | | 88 |
| Blue crab | 96 hr. | 4700 | juvenile | 115 |
| Cancer magister | 96 hr. | 247 | zooe | 116 |
| Lobster | 96 hr. | 78 | larva | 117 |
| Oyster | 48 hr. | 3800 | embryo | 118 |
| Mussel | 96 hr. | 1620 | | 84 |
| Starfish | 96 hr. | 7100 | | 119 |
| Softshell clam | 96 hr. | 2200 | | 88 |
| Scallop | 96 hr. | 1480 | juvenile | 120 |
| Eastern mud snail | 96 hr. | 10500 | | 88 |
| Polychaetes (4 species) | 96 hr. | 4200-20000 | | 121 |

effects such as reproductive impairment, reduced production of young and reduced survival of young (122).

Concentrations of 5 ug/l or more reduced productivity in mysids, Daphnia and other zooplankton species (123, 124, 125). Freshwater snails were rendered infertile by 0.1 mg/l cadmium in water (126). Chronic exposure to 57 ug/l in hardwater reduced hatchability and caused larval deformities in fathead minnows, and concentrations as low as 8.1 ug/l inhibited reproduction in flagfish (127).

Exposure to cadmium can cause morphological alterations and organ damage in aquatic organisms. Tissue damage in the kidney, liver, intestine, testes and gills are the most commonly detected pathological changes. Vertebral damage and deformities have been observed in fish exposed to cadmium concentrations of 10 ug/l or more (128, 129).

Other effects of cadmium exposure to aquatic invertebrates and fish include: reduction of antibody levels (130); increased susceptability to disease (131); interference with red blood cell production and hemoglobin synthesis (132); retardation of fin regeneration (and also limb regeneration in amphibians) (133, 134, 135); inhibition of shell growth (136); loss of colour and markings definition (90); and behavioural abnormalities (108).

## 4.2 Terrestrial Systems

### 4.2.1 Atmosphere.

General

The release of cadmium to the atmosphere from metal mining, smelting and refining, waste incineration and fossil fuel combustion, are important routes of entry into the environment (137). Atmospheric transport can distribute cadmium to areas far removed from original sources of release.

Atmospheric cadmium concentrations in rural areas are usually less than 0.001 ug/m$^3$ (microgram per cubic metre); while average levels in urban areas are often between 0.001 and 0.050 ug/m$^3$. Much higher levels are often present in the immediate vicinity of point sources, especially smelters (137, 138, 139, 140, 141).

Similarly, cadmium levels in both wet and dry precipitation (snow, rain, dustfall) are highest near emission sources (142, 143, 144, 145).

British Columbia and Yukon

Atmospheric cadmium concentrations in B.C. were less than the detection limit of 0.01 ug/m$^3$ in all areas sampled, with the exception of Trail. Similarly, cadmium deposition by dustfall in most areas of the province was less than or close to the detection limit of 11.68 ug/m$^2$ (micrograms per square metre). Significantly higher deposition rates were measured in Trail (up to 584 ug/m$^3$). The primary source of cadmium release to the atmosphere in the Trail area is a lead/zinc smelter and fertilizer plant complex (42).

Information on cadmium levels in wet precipitation (rain and snow) in B.C. was limited. Recent monitoring in southwestern B.C. conducted by the Atmospheric Environment Service revealed cadmium concentrations of 0.2-0.8 ug/l in precipitation (146).

No information was available for Yukon.

### 4.2.2 Soil and Vegetation.

General

Cadmium is present in low concentrations (0.1 to 0.5 mg/kg) in the earth's crust (147). Cadmium levels in soils reflect those of their parent rocks and are usually low. Uncontaminated soils normally contain less than 1 mg/kg with an average of 0.4 mg/kg (148). Much higher concentrations have been found in mineralized regions and in areas of localized pollution, particularly in the vicinity of base metal smelters (149).

Agricultural soils may receive cadmium input from sewage sludge and phosphate fertilizer applications, as these materials often contain high cadmium levels.

The mobility of cadmium in soils is generally less than that of any other metal with the exception of lead. Availability for uptake into vegetation is influenced by various soil characteristics including; composition, metal content, pH, temperature, cation exchange capacity, moisture content, organic matter content and the presence of phosphorus, zinc and other elements and cations (150, 151, 152, 153, 154, 155, 156). These factors determine the capacity of soil to adsorb and bind cadmium and also the uptake and accumulation of cadmium in overlying plants. It is reported that pH is the most important factor, with the availability of cadmium to plants increasing with decreasing pH (155).

The cadmium content of plants varies widely but the mean natural level in most terrestrial plants is < 0.6 mg/kg (dry weight) (157). Leafy plants (lettuce, spinach, etc.) are particularly effective at accumulating cadmium, whereas cereal grain crops are much less effective (147, 158). Fungi, mosses and lichen are good indicators of cadmium contamination and have the potential to accumulate especially high concentrations (159, 160, 161).

Atmospheric deposition of cadmium can also result in uptake into plants (162). Very high cadmium levels (over 50 mg/kg) have been detected in the foliage of trees in the vicinity of smelters and it has been shown that cadmium tends to penetrate the leaf more readily than do certain other metals (163, 164).

British Columbia and Yukon

Information on cadmium concentrations in B.C. and Yukon soils is limited.

Elevated cadmium levels (up to 36 mg/kg) were detected in surface soils near the lead/zinc smelter in Trail in the early 1970's (165, 166). High concentrations of cadmium (up to 95 mg/kg) were also detected in soils collected near a battery smelter in Richmond in 1971 (167).

Agricultural soils collected in Delta contained an average of 0.9 mg/kg cadmium with the highest levels occurring at the sites nearest Vancouver (167).

Very little information was available for cadmium levels in the terrestrial vegetation of B.C. Samples of grass, sagebrush and Douglas fir collected near a smelter in Kamloops contained no detectable cadmium, with the exception of one grass sample which contained 2.0 mg/kg. Moss samples collected near the smelter at Trail contained very low levels of cadmium (0.02 to 0.04 mg/kg) (42).

No information was available for Yukon vegetation.

### 4.2.2 Wildlife

General

Elevated cadmium levels in birds can usually be correlated with proximity to industrial development, however, significant concentrations have been detected in relatively uncontaminated areas (168, 169).

Cadmium levels in birds are influenced by such factors as species, age, tissue, location, diet and migratory habits.

Particularly high concentrations have been detected in the kidney of various species of pelagic seabirds (over 100 mg/kg) (170). Eggs are not good indicators of cadmium contamination in wild bird populations as very little cadmium is transported to the eggs even after high exposures (171, 172, 173).

Very little information is available on cadmium levels in terrestrial mammalian wildlife species. However, it has been shown that cadmium levels in small rodents correlate with the levels in the their environment, with higher levels being found in rodents urban or industrial areas than in those from rural areas (174, 175, 176).

Cadmium concentrations are usually higher in marine mammals than in terrestrial species. As with birds, the highest cadmium levels are present in the kidney (177, 178). Positive correlations between age of the animal and cadmium concentrations in the kidneys have been reported for some species including squirrel, deer and antelope although this relationship was not evident in the liver tissue of these species (175, 179). A positive correlation between age and cadmium levels in both liver and kidney has been noted in seals (177, 178, 181).

The fact that foetal tissues normally contain very low cadmium concentrations has led to conclusions that transport across the placenta was minimal. This has been confirmed in laboratory experiments (180, 181).

British Columbia and Yukon

Information on cadmium levels in B.C. wildlife species is very limited, however, available data indicate that concentrations are not elevated in comparison to other areas (42).

No information on Yukon wildlife species was available.

4.2.3.1 Toxicity. Cadmium levels in wild bird and mammal populations do not normally reach sufficient magnitude to cause toxic effects. Although high levels of cadmium in the tissues of sea birds and mammals have been documented, deleterious effects are rarely evident.

Most of the toxic effects of cadmium have been identified in experimental animals at much higher exposure levels than would normally occur in the natural environment. Animal species and method of administration are important factors in determining the toxic effects of cadmium. However, the two main critical organs identified as a result of experimental cadmium poisoning are the testes, following a high acute exposure, and the kidney, following a lower level chronic exposure (183).

Sterility resulting from vascular damage and circulatory failure has been observed in many species of birds and mammals following acute exposure to Cd (184, 185, 186).

Cadmium accumulates in the kidney until a critical level of approximately 200 mg/kg (wet weight) (183) is reached in the renal cortex, at which time cadmium accumulation in the kidney ceases and urinary cadmium excretion increases. This is the level at which renal dysfunction occurs (183, 187).

Other reported symptoms of cadmium toxicity include anemia (188), immunosuppression (189, 190), hypertension (191), bone abnormalities (when calcium deficiency is also present) (192, 193), tumor formation (194, 195, 196) and respiratory ailments (197, 198).

Reproductive, fetotoxic and teratogenic effects have also been demonstrated in laboratory animals exposed to cadmium but the occurrence and intensity of these effects vary between species and even strains of animals (199, 200, 201).

Exposure to even low levels of cadmium stimulates the liver (202), the kidney (203) and possibly other organs to synthesize a low molecular weight protein called metallothionein. Metallothionein binds cadmium in the tissues and is thought to play an important role in reducing toxic effects.

In the event of very high or sudden exposure, the rate of intake may exceed the rate of metallothionein synthesis. The excess of cadmium ions bind with higher molecular weight proteins such as enzymes, thus disrupting important enzyme systems and physiological processes (204).

It has also been suggested that once the threshold values of cadmium in the tissues are reached, the protective effect of the metallothionein no longer exists (205).

The simultaneous administration of certain elements, including zinc, selenium, cobalt, thiols, and iron, during cadmium exposure may also protect against certain of the toxic effects of cadmium (188, 206, 207, 208, 209).

## 5. REGULATIONS AND GUIDELINES

Current regulations and guidelines pertaining to cadmium in the receiving environment are summarized below.

5.1 Water Quality

At present there are no Canadian water quality guidelines for acceptable levels of cadmium in marine waters. However, the U.S. Environmental Protection Agency (EPA) guidelines specify a concentration of 4.5 ug/l as a 24 hour average and 59 ug/l total recoverable cadmium as a maximum (41).

The Canadian Inland Waters Directorate (IWD) recommended water quality objective for Canadian freshwater systems is 0.2 ug/l total cadmium (40). The 1978 Canada/U.S. Great Lakes Water Quality Agreement specifies that the cadmium level in unfiltered water from the Great Lakes must not exceed 0.2 ug/l.

The U.S. EPA freshwater quality guidelines vary with water hardness ($CaCO_3$ content) as follows (41):

| HARDNESS | CRITERIA (total recoverable Cd) | |
|---|---|---|
| | 24 hour Average | Not to Exceed |
| 50 mg/l $CaCO_3$ | 0.12 ug/l | 1.5 ug/l |
| 100 mg/l $CaCO_3$ | 0.025 ug/l | 3.0 ug/l |
| 200 mg/l $CaCO_3$ | 0.051 ug/l | 6.3 ug/l |

5.2 Human Health

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

5.3 Ocean Disposal

The ocean disposal of wastes and other materials off the Canadian coast is controlled under the federal Ocean Dumping Control Act. The regulations under this Act specify that the solid phase of materials disposed of at sea must contain a maximum of 0.6 mg/kg of total cadmium and the liquid phase must contain no more than 3.0 mg/kg.

Quebec provincial criteria specify a maximum level of 5 mg/kg cadmium in ocean disposed material, while Ontario provincial criteria specify a level of 0.1 mg/kg.

## 5.4 Industrial Effluents and Emissions

The level of cadmium in specific industrial effluents and atmospheric emissions is controlled under provisions contained in the British Columbia Waste Management Act as well as regulations issued pursuant to the federal Fisheries Act and Clean Air Act.

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