Recovering Resident Killer Whales: A Guide to Contaminant Sources, Mitigation, and Regulations in British Columbia

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RECOVERING RESIDENT KILLER WHALES:
A GUIDE TO CONTAMINANT SOURCES, MITIGATION, AND REGULATIONS IN BRITISH COLUMBIA

by

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List of Acronyms

Acronym/Abbreviation	Meaning
μg/L	micrograms per litre
μg/m^3	micrograms per cubic metre
ABS	acrylonitrile-butadiene-styrene
ACA	ammoniacal copper arsenate
ACQ	alkaline copper quaternary
ACZA	ammoniacal copper zinc arsenate
AET	apparent effects threshold
Ag	silver
ARD	acid rock drainage
AMPA	aminomethylphosphonic acid
AOX	adsorbable organic halides
AP	alkylphenol
APF	Agricultural Policy Framework
APnEOs	alkylphenol polyethoxylates
BBP	butylbenzyl phthalate
BC	British Columbia
BCF	bioconcentration factor
BC MAL	BC Ministry of Agriculture and Lands
BC MOE	BC Ministry of Environment
BCTWG	British Columbia Toxics Work Group (of the PS/GB ITF)
BC MOH	BC Ministry of Health
BCWQC	BC Water Quality Criteria
BDE	brominated diphenyl ether
BIEAP	Burrard Inlet Environmental Action Plan
B-IBI	benthic index of biotic integrity
BMPs	Best Management Practices
BOD	biological oxygen demand
CABIN	Canadian Aquatic Biomonitoring Network
CCA	copper chromium arsenate
CCME	Canadian Council of Ministers of the Environment
Cd	cadmium
CDPEs	chlorinated diphenyl ethers
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
CFIA	Canadian Food Inspection Agency
CMN	Community Mapping Network
COTF	British Columbia-Washington Coastal and Ocean Task Force
CPPA	Canadian Pulp and Paper Association
Cr	chromium
CRD	Capital Regional District
CSMWG	Contaminated Sites Management Working Group
CSO	combined sewer overflow

Acronym/Abbreviation	Meaning
CWS	Canadian Wildlife Service
CWSs	Canada-Wide Standards
DAP	diallyl phthalate
DBDE	decabromodiphenyl ether (commercial PBDE mixture)
DBP	di-n-butyl phthalate
DBT	dibutyltin
DDAC	didecyldimethylammonium chloride
DDD	2,2-bis(p-chlorophenyl)-1,1dichloroethane
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DEHP	bis(2-ethylhexyl)phthalate or di(2-ethylhexyl)phthalate
DEP	diethyl phthalate
DHAA	dehydroabietic acid
DIBP	diisobutyl phthalate
DIDP	diisodecyl phthalate
DFO	Department of Fisheries and Oceans (or Fisheries and
DMP	dimethyl phthalate
DnOP	di-n-octyl phthalate
DW	dry weight
EC	Environment Canada
EC_{50}	median effect concentration (concentration at which 50% of the exposed organisms show a specific effect)
ECC	Environmental Cooperation Council
EDCs	endocrine-disrupting compounds
EEM	Environmental Effects Monitoring
EFP	Environmental Farm Planning
EMA	*Environmental Management Act*
EMPs	Environmental Management Plans
ENGOs	Environmental Non-Government Organizations
EPA	Environmental Protection Agency (United States)
EROD	ethoxyresorufin O-deethylase
FA	*Fisheries Act*
FCSAAP	Federal Contaminated Sites Accelerated Action Plan
FCSAP	Federal Contaminated Sites Action Plan
FCSI	Federal Contaminated Sites Inventory
FOCs	fluorinated organic compounds
FPTCC	Federal/Provincial Toxic Chemicals Committee
FRAP	Fraser River Action Plan
FREMP	Fraser River Estuary Management Program
G	gram
GB	Georgia Basin
GAP	Georgia Basin Action Plan
GBEI	Georgia Basin Ecosystem Initiative
GIS	geographic information system

Acronym/Abbreviation	Meaning
GPP	Groundwater Protection Program
GVRD	Greater Vancouver Regional District (now Metro Vancouver)
HC	Health Canada
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
Hg	mercury
HMW	high molecular weight
HpCDD	heptachlorodibenzodioxin
HxCDD	hexachlorodibenzodioxin
IMO	International Maritime Organization
IOS	Institute of Ocean Sciences (of DFO)
IPBC	3-iodo-2-propynyl butyl carbamate
IPM	Integrated Pest Management
IPMA	*Integrated Pest Management Act*
ISMPs	Integrated Stormwater Management Plans
ISQG	Interim Sediment Quality Guideline
Kg	kilograms
Km	kilometres
K_{ow}	octanol/water partition coefficient
L	litre
LC_{50}	the lowest concentration of a contaminant that will kill 50% of the test organisms (median lethal concentration)
LMW	Low molecular weight
LOEC	lowest-observed-effects-concentration
LOEL	lowest-observed-effect-level
LWMPs	Liquid Waste Management Plans
M	metres
MATC	maximum-acceptable-toxicant-concentration
MBT	monobutyltin
MFO	mixed function oxidases
mg/L	milligrams per litre
MMT	methylcyclopentadienyl manganese tricarbonyl
Mn	manganese
MOU	Memorandum of Understanding
MTBE	methyl tertiary-butyl ether
N	nitrogen
ND	non-detectable or not detected
ng/L	nanograms per litre
Ni	nickel
NOAA	National Oceanic and Atmospheric Administration
NOEC	No-observed-effect-concentration
NP	nonylphenol
NPnEO	nonylphenol ethoxylates

Acronym/Abbreviation	**Meaning**
NPRI	National Pollutant Release Inventory
NPS	non-point source
NWRI	National Water Research Institute (of EC)
OBDE	octabromodiphenyl ether (commercial PBDE mixture)
OC	organochlorine
OCDD	octachlorodibenzodioxin
OCP	Official Community Plan
P2	pollution prevention
PAHs	polycyclic aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers
P-B-T	persistent-bioaccumulative-toxic
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
PCNs	polychlorinated naphthalenes
PCP	pentachlorophenol
PCPA	*Pest Control Products Act*
PeBDE	pentabromodiphenyl ether (commercial PBDE mixture)
PEL	probable effects level
PESC	Pacific Environmental Science Centre (EC laboratory)
PFAs	perfluorinated acids
PFOA	perfluoroalkyl sulfonic acid
PFOS	perfluorooctane sulfonate
pg/L	picograms per litre
pg/m^3	picograms per cubic metre
PMRA	Pest Management Regulatory Agency
POPs	persistent organic pollutants
PPCPs	pharmaceuticals and personal care products
PPER	*Pulp and Paper Effluent Regulations* (under the *Fisheries Act)*
Ppq	parts per quadrillion
PS/GB ITF	Puget Sound/Georgia Basin International Task Force
PSL	Priority Substances List (CEPA)
PVC	polyvinyl chloride
QACs	quaternary ammonium compounds
QA/QC	quality assurance/quality control
RSCP	Regional Source Control Program (of CRD)
SETAC	Society of Environmental Toxicology and Chemistry
SFU	Simon Fraser University
SHWP	Stormwater, Harbours and Watersheds Program (of CRD)
SLRAs	Screening Level Risk Assessments (CEPA)
SOP	Strategic Options Process (CEPA)
SORs	Strategic Options Reports (CEPA)

Acronym/Abbreviation	Meaning
SPMDs	semi-permeable membrane devices
SPMEs	solid phase microextraction fibres
STP	sewage treatment plant
T	tonnes
t/yr	tonnes per year
TBT	tributyltin
TCDD	tetrachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
TCMTB	2-(thiocyanomethylthio)benzothiazole
TEL	threshold effects level
TEQ	toxic equivalence; toxic equivalency; or toxic equivalents
TIA	total impervious area
TOC	total organic carbon
TRD	Technical Recommendations Document
TSMP	Toxic Substances Management Policy
TSS	total suspended solids
UBC	University of British Columbia
UK	United Kingdom
UV	ultraviolet
US	United States
VEHEAP	Victoria and Esquimalt Harbours Environmental Action Plan
Ww	wet weight
WMA	*Waste Management Act*
WWTP	wastewater treatment plant

Abstract

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British Columbia's killer whales comprise several distinct populations with unique ecological needs. The two resident killer whale populations (southern and northern resident) consume only fish, notably Chinook salmon. The southern resident killer whales are listed as 'endangered' under the Species at Risk Act (SARA), and the northern residents are listed as 'threatened'. Both populations face conservation-level risks including reduced prey abundance, noise and disturbance, and very high levels of contaminants in their tissues. As some of the most contaminated marine mammals in the world, there exists a need to better understand the source, transport and fate features of contaminants in their environment. Contaminant-mediated risks for killer whales basically comprise i) those associated with ingestion via their prey, notably those with persistent, bioaccumulative and toxic properties; ii) those that reduce the abundance or quality of their preferred prey, such as currently used pesticides; and iii) toxic spills that form a film on the surface and may be inhaled or ingested, such as oil spills. Resident killer whale populations are vulnerable to accumulating high levels of contaminants because of their high position in the coastal food web, their long lifespans, and their inability to metabolize persistent contaminants. This document provides an overview of the types and sources of contaminants of concern in British Columbia, and identifies the legislation and agencies responsible for their oversight. While not all-inclusive, this review is intended to assist in the design of a SARA-based Action Plan, and to guide stakeholders in efforts to conserve killer whales for future generations.

Résumé

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Les orques de Colombie-Britannique forment plusieurs populations distinctes ayant chacune des besoins écologiques originaux. Les deux populations d’orques résidentes (du Sud et du Nord) se nourrissent uniquement de poisson, notamment de saumon quinnat. Les orques résidentes du Sud sont inscrites dans la liste des espèces en voie de disparition en vertu de la Loi sur les espèces en péril (LEP) tandis que les orques résidentes du Nord font partie des espèces menacées. Ces deux populations sont confrontées à des risques en matière de préservation dont la diminution de l’abondance de leurs proies, le bruit, les perturbations ainsi que de très hauts niveaux de contaminants dans leurs tissus. Comme elles font partie des mammifères marins les plus contaminés de la planète, il est nécessaire de mieux comprendre les éléments des sources, du transport et du devenir des contaminants dans leur environnement. Pour les orques, les risques liés aux contaminants comprennent essentiellement: i) ceux qu’elles ingèrent par le biais de leurs proies, notamment ceux qui possèdent des propriétés persistantes, bioaccumulatives et toxiques; ii) ceux qui réduisent l’abondance ou la qualité de leurs proies préférées, tels que les pesticides utilisés de nos jours; et, iii) les déversements toxiques qui forment une pellicule à la surface de l’eau et qui peuvent être inhalés ou ingérés, comme les déversements d'hydrocarbures. Les populations d’orques résidentes sont vulnérables à l’accumulation de hauts taux de contaminants du fait de leur position élevée dans le réseau trophique des eaux côtières, de leur longue durée de vie et de l’incapacité qu’elles ont de métaboliser les contaminants persistants. Ce document vise à présenter un survol des types et des sources de contaminants d’intérêt spécial pour la Colombie-Britannique et à cerner les lois et les organismes chargés de leur surveillance. Bien qu’il ne soit pas exhaustif, cet examen a pour but de faciliter l’élaboration d’un plan d’action axé sur la LEP et d’orienter les efforts de divers intervenants cherchant à préserver les populations d’orques pour les générations futures.

1 Introduction

In accordance with the *Species at Risk Act* (SARA), the federal government is responsible for the development of recovery strategies and action plans for species at risk. In 2001, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the southern resident killer whale population of the west coast of Canada as ‘endangered’ and the northern resident killer whale population as ‘threatened’ (www.cosewic.gc.ca). As the responsible agency for aquatic species under SARA, Fisheries and Oceans Canada (DFO) initiated the development of a recovery strategy for the both the northern and southern killer whale populations, now posted on the SARA Registry (Fisheries and Oceans Canada 2008). The goal of the recovery strategy is:

> *“to ensure the long-term viability of resident killer whale populations and sustain their genetic diversity and cultural continuity by reducing human threats, including noise and pollutants, and protecting their habitat and prey”.*

The process for the development of the recovery strategy for killer whales brings together the scientific expertise of the Killer Whale Recovery Team and a core group of technical experts, with input from First Nations, stakeholders, and the public.

While the impacts of each individual threat are not well understood, nor the way in which they interact, three major threats facing resident killer whales were identified as (Fisheries and Oceans Canada 2008):

- high concentrations of environmental contaminants;
- reduced prey availability; and
- noise and disturbance.

This document was prepared for the Killer Whale Recovery Team as a guidance document on contaminant issues which may directly or indirectly impact resident killer whales. The objective of this document is to provide a scoping of contaminant types, sources, and trends as these relate to possible risks to resident killer whales, and to list relevant developments, pieces of legislation, and responsible agencies in order to guide the development of a Recovery Strategy and Action Plan. For the purposes of this working group, we attempt to provide a simplified guidance document based on an assessment of existing information. Information contained in this document is by no means all-inclusive, nor is it meant to represent the views of any one person or agency.

2 Potential Impacts of Environmental Contaminants on Killer Whales and Their Prey

2.1 Potential contaminant sources of concern to killer whales

Marine mammals are particularly vulnerable to the effects of environmental contaminants, reflecting their aquatic or semi-aquatic lifestyle, their heavy reliance on the air-water boundary, their often large habitat needs, their long lifespan, and their feeding ecology. Given the plethora of contaminants that end up in the world's oceans, and the multiple effects that take place, an understanding of the ways in which contaminants may lead to population-level effects can provide some basic guidance as to the risks involved with environmental pollution.

In basic terms, contaminants that present a potential risk to killer whales may be categorized into the following functional groupings (Figure 1):

1) those contaminants that are ingested via prey and accumulate in killer whales (e.g. bioaccumulative substances);
2) those that impact on the quality or quantity of killer whale prey such as salmonids (e.g. effects of pesticides on salmon in their freshwater habitat); and
3) those that form a film on the surface of the ocean and may cause direct effects on killer whales (e.g. oil spill).

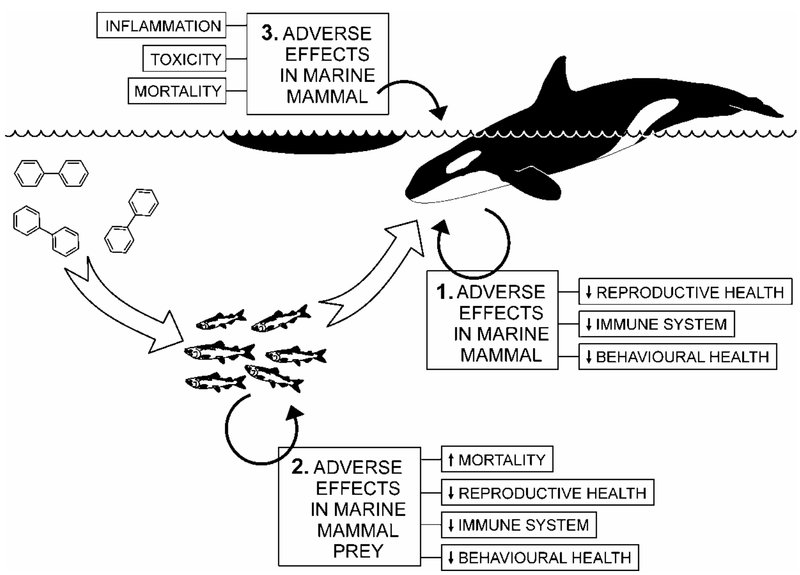

Figure 1. The large number of chemicals found in killer whale habitat creates a challenge to conservationists and managers. Since the physical and chemical properties of each pollutant are unique, an initial grouping of contaminants on the basis of their behaviour in the marine environment forms a basis for an initial risk assessment. Killer whales are vulnerable to the effects of environmental contaminants via 1) the consumption of contaminated prey, 2) impacts on the quality or quantity of their preferred prey, and/or 3) a direct impact associated with exposure to a toxic spill on the ocean's surface (e.g. oil).

2.1.1 Persistent, bioaccumulative and toxic chemicals

Marine mammals are considered vulnerable to the accumulation of high concentrations of Persistent Organic Pollutants (POPs), as a result of their often high position in aquatic food chains, their long lifespan, and their relative inability to eliminate these contaminants (Ross 2000). While these chemicals have widely varying applications, they share three key features: they are persistent, bioaccumulative, and toxic (P-B-T). Since POPs are oily (lipophilic), they are easily incorporated into organic matter and the fatty cell membranes of bacteria, phytoplankton, and invertebrates at the bottom of aquatic food webs. As these components are grazed upon by small fishes and other organisms at low trophic levels, both the lipids and the POPs are consumed. In turn, these small fishes are consumed by larger fishes, seabirds, and marine mammals that occupy higher positions in aquatic food chains. This step-by-step, food chain-based process delivers both nutrients and contaminants into high trophic level wildlife. However, lipids are burned off at each trophic level and are utilized for metabolism, growth, and development, while the POPs are left largely intact. This leads to a process known as biomagnification, with higher and higher concentrations of POPs being found at each trophic level (Fisk *et al.* 2001;Hoekstra *et al.* 2003). In this way, fish-eating mammals and birds are often exposed to high levels of POPs, even in remote areas of the world.

An icon of the northeastern Pacific Ocean, the killer whale (*Orcinus orca*) is actually one of the most widely distributed mammals on the planet. Although elusive and poorly studied in many parts of the world, these large dolphins have been the subject of ongoing study in the coastal waters of British Columbia (BC) and Washington State in the United States (US). A long-standing photo-identification catalogue based on unique markings has facilitated the study of killer whale populations in this region of the world (Ford *et al.* 2000). Several communities, or ecotypes, frequent these coastal waters, including the salmon-eating resident killer whales, the marine mammal-eating transient killer whales, and the poorly characterized offshore killer whales. The two resident communities of killer whales are the northern residents that ply the waters of northern BC, and the southern residents that straddle the international boundary between BC and Washington (Figure 2).

The discovery that these and adjacent communities of killer whales are among the most contaminated marine mammals in the world highlights concerns about the relative ease with which POPs move great distances around our planet (Krahn *et al.* 2007;Ross 2006;Ross *et al.* 2000a;Ylitalo *et al.* 2001). Several studies have characterized a number of POPs of concern in these animals. Initial reports identified PCBs as a dominant concern in southern residents, with the concentrations of these industrial chemicals readily exceeding the concentration of dioxins (PCDDs) and furans (PCDFs)(Ross et al. 2000a). A subsequent study found that levels of the flame retardant PBDEs exceeded those of the PBBs and PCBs in the same southern resident samples, though at levels much lower than PCBs (Rayne *et al.* 2004). A subsequent study of southern residents in 2004-06 found that the organochlorine pesticide DDT dominated males, as follows: DDT > PCBs > Chlordane > PBDEs > HCH > HCB (Krahn et al. 2007). These studies collective underscore concerns about legacy PCBs and DDT in killer whales, and also identify a number of potentially emerging contaminants concerns, such as the largely current us PBDEs.

As high trophic level marine mammals, resident killer whales are exposed to POPs through the ingestion of prey. Salmon, and especially chinook salmon, represent the preferred prey for resident killer whales (Ford *et al.* 1998;Ford and Ellis 2006). Research on numerous species indicates that salmon return from the Pacific carrying POPs, effectively delivering these contaminants to coastal ecosystems and to wildlife including resident killer whales (Christensen *et al.* 2005;Cullon *et al.* 2009;Ewald *et al.* 1998;Krümmel *et al.* 2003;Missildine *et al.* 2005;Ross *et al.* 2000a).

Recent work has suggested that as much as 97-99% of POPs in adult Chinook salmon are acquired during their time ‘at sea’ (Cullon et al. 2009), although this includes time spent in coastal waters. PCbs represent the top POP when evaluated in four sets of samples (Lower Fraser, Johnstone Strait, Duwamish and Deschutes) against DDT, PBDEs, PCDDs, PCDFs, and HCH. For the Lower Fraser stocks, POPs were ranked as follows: PCBs > PBDEs > DDT > PCDF > PCDD > HCH. This study clearly reveals a continuing concern about legacy PCBs, but also the emergence of the PBDEs as a contaminant of concern in the Pacific Ocean.

In addition to ‘ocean-derived’ POPs, killer whales likely consume local (non-migratory) fishes that are exposed to POPs from sources in British Columbia and Washington State. Research has identified a number of local POP concerns in resident killer whale habitat, including high levels of legacy polychlorinated biphenyls (PCBs) in Puget Sound food webs (Cullon *et al.* 2005;Malins *et al.* 1984;Ross *et al.* 2004), and continued dioxin and furan contamination around some pulp mills in British Columbia (Hagen *et al.* 1997). Such research highlights the persistence of the POPs in killer whale habitat, as PCBs were banned in the 1970s in Canada and the USA, and dioxins and furans were dramatically reduced from pulp and paper mills effluent in 1989.

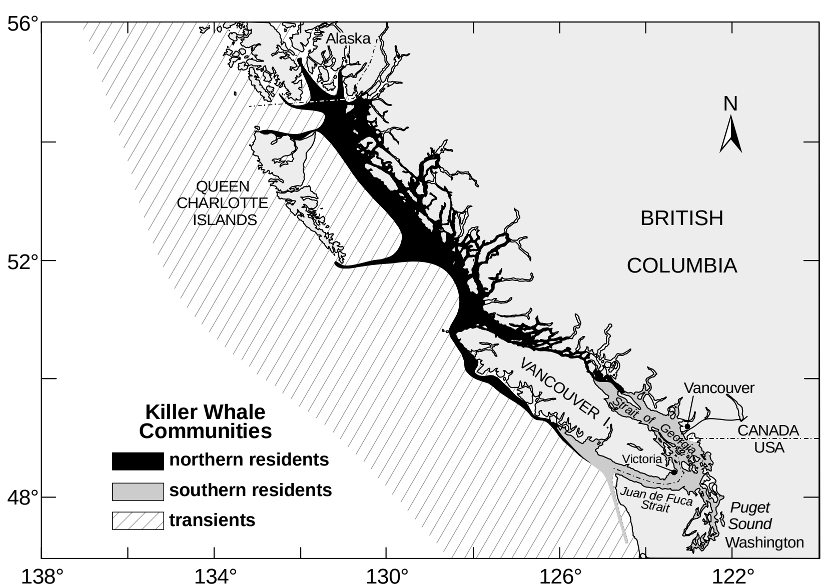

Figure 2. During the summer feeding period (May~October), resident killer whales frequent the coastal waters of British Columbia and Washington State, where they feed on salmon, particularly chinook salmon. While the northern residents ply the waters of northern Vancouver Island up to the Alaska border, the southern residents can be found in the more industrialized waters of the Strait of Georgia, Juan de Fuca Strait and Puget Sound (From Ford *et al.* 1994;Ross *et al.* 2000a).

The POPs are of considerable concern because many of its members (including PCBs and the pesticide DDT) are highly toxic. Laboratory animal studies have conclusively demonstrated that such chemicals are endocrine disrupting, with effects observed on reproduction, the immune system, and growth and development. Studies of wildlife are more challenging, since free-ranging populations are exposed to thousands of different chemicals, in addition to many other stressors in their natural environment. Studies of wild populations provide clues about the impact of POPs on marine mammals. However, as is the case with humans, a combined 'weight of evidence' from numerous lines of experimental and observational evidence in different species provides the most robust means of assessing health risks in such animals as killer whales (Ross 2000;Ross 2002). This weight of evidence is based on critical inter-species extrapolation, and depends upon the conserved nature of many organ, endocrine, and immunological systems among vertebrates.

In British Columbia and Washington State, research has revealed that free-ranging harbour seals are being affected by exposure to POPs. These include disruption of vitamin A and thyroid hormone physiology, and immune function (Levin *et al.* 2005;Mos *et al.* 2006;Mos *et al.* 2007;Tabuchi *et al.* 2006). While the association between contaminants and these endpoints does not specifically identify the causative agent(s), the dominant contribution of PCBs to the total POP burden, coupled with the demonstrated toxicity of this contaminant to the vitamin A, thyroid, and immune system, underscores the important role that this contaminant likely plays in the observed effects. A recent study that draws on the collective results of field-based studies on the effects of POPs on the health of non-migratory harbour seals reveals two major points of interest (Mos *et al.* 2010). Firstly, a risk-based characterization which combined concentration (in harbour seals) and toxicity (in laboratory animals) ranked the individual POPs according to their potential health effects in harbour seals as follows: PCBs > Dieldrin > DDT > Chlordane > Endrin > Heptachlor > HCH > Endosulfan > HCB > Aldrin > Octachlorostyrene > Methoxychlor > Mirex. Secondly, a new and more protective Toxicity Reference Value (TRV) of 1.3 mg/kg PCBs would be considered protective of harbour seals in terms of endocrine disruption and immunotoxocity.

Whether the resident killer whales are affected by exposure to high concentrations of POPs is unclear. However, based on the very high PCB levels in these killer whales, a 'weight of evidence' from multiple lines of research would suggest that they are at significant risk for the endocrine-disrupting effects of POPs, including reproductive impairment, immunotoxicity, and developmental abnormalities (Ross *et al.* 2000a;Ross 2006). A modelling-based study reveals that all members of the southern resident community exceed the 17 mg/kg threshold established for endocrine disruption and immunotoxicity in harbour seals, (Hickie *et al.* 2007). While direct toxicological research using killer whales is fraught with legal, ethical and logistical constraints, a 'weight of evidence' approach offers a means to evaluate POP-related health risks, in a manner akin to that used for assessing drug safety in humans (Ross 2000;Ross *et al.* 2000b;Ross and Birnbaum 2003).

While regulations have resulted in decreased environmental concentrations of certain POPs, new chemicals are introduced to the environment each year. For example, possible impacts associated with newer generation flame retardants may represent emerging priorities for conservationists and managers (Grant and Ross 2002;Rayne *et al.*

2004;Ross 2006). Concerns about the impact of three classes of PBDEs on the aquatic environment led to a PBDE ban in Canada in 2008 (Ross *et al.* 2008;Ross *et al.* 2009).

While persistence, bioaccumulative nature, and toxicity represent chemical features of concern for high trophic level wildlife, the high trophic level and long lifespan provide for an added conservation level of concern with killer whales (Ross 2006). Recent research predicts that southern resident killer whales will not be safe from the effects of PCBs until 2063-2089 for 95% of the population to fall below this threshold (Hickie et al. 2007).

2.1.2 Contaminant impacts on killer whale prey

While high concentrations of endocrine-disrupting contaminants in killer whales represent a threat to the health of these cetaceans, indirect effects as a consequence of reduced health or abundance of their prey may represent another way in which contaminants may impact killer whale populations (Figure 3). While such linkages are exceedingly difficult to establish, there are tangible examples of contaminant impacts on salmon health and abundance. Reduced marine returns of Atlantic salmon were associated with pesticide applications to natal streams during their early life (Fairchild *et al.* 1999). Dioxin-like contaminants in the Great Lakes were implicated in a complete failure of lake trout reproduction during the period 1945-1985 (Cook *et al.* 2003).

Reduced immunological fitness has been related to contaminants in urban developments (Arkoosh *et al.* 1991). Salmonids are particularly sensitive to the effects of copper from urban runoff or net-pens (Borufsen Solberg *et al.* 2002;Sandahl *et al.* 2006). Agricultural pesticides can impair olfaction and disrupt homing behaviour in salmon (Tierney *et al.* 2007a;Tierney *et al.* 2007b;Tierney *et al.* 2008) which, in turn, can negatively impact important behaviours such as prey avoidance, reproduction, and migration.

Tierney *et al.* (2008) reported that environmentally realistic concentrations of pesticide mixtures caused damage to olfactory tissue in rainbow trout (after a 96 hour exposure), and concluded that the pesticide concentrations currently found in the environment could threaten the viability of some salmon stocks. Many of the effects of contaminants on salmon relate to a disruption of endocrine processes and alteration of metabolic, neurological, growth, development, immunological, and behavioural processes. Symptoms may include increased incidence of disease, developmental abnormalities, stress, and behavioural aberrations (Collier *et al.* 1995;Reichert *et al.* 1998;Tierney *et al.* 2007b).

While not well studied, the detrimental effects on salmon chronically exposed to low-levels of multiple contaminants are recognized and several studies have reported the presence of complex mixtures of pesticides and other contaminants in salmon habitat in BC. In addition, many BC salmon stocks are impacted by other stressors, such as habitat loss and degradation. Salmon stocks in BC are declining and, therefore, the availability of prey for resident killer whales is also declining. While declining salmon stocks likely have a multitude of causes, the potential impacts of the combined effects of chemical and physical stresses on BC salmon requires further consideration.

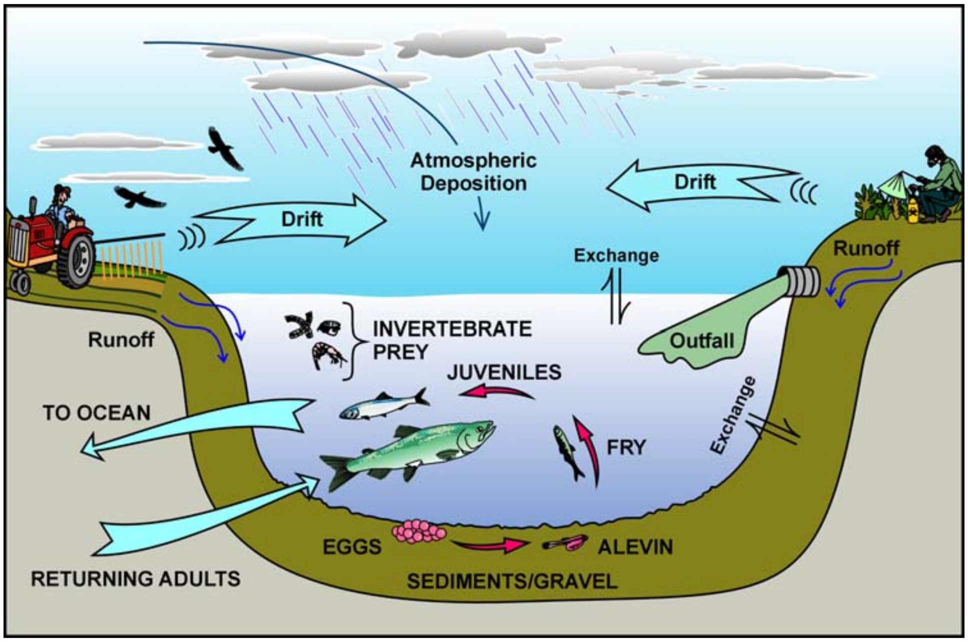

Figure 3. Contaminants may adversely affect the health and/or abundance of resident killer whale prey: salmonids are vulnerable to contaminant impacts at various points during their complex life histories. They are particularly vulnerable when young (eggs, alevins, fry and smolts), as they face multiple contaminant exposures in their habitat: urban runoff, agricultural, forestry and cosmetic pesticides, sewage effluent, and fertilizers.

2.1.3 Toxic spills

Catastrophic oil spills represent highly visible threats to marine biota, and killer whales may be vulnerable when such spills take place in their habitat. After the Exxon Valdez spilled 40,000 tonnes (t) of crude oil into Prince William Sound in 1989, 13 killer whales were lost and presumed dead (Helm 1995;Matkin *et al.* 1999). The 1985 ARCO Anchorage tanker spill of 905,000 litres (L) of crude oil and the 1988 Nestucca spill of 875,000 L of bunker C oil in Washington State released large amounts of oil into the environment and impacted biota (Harding and Englar 1989;Waldichuk 1989). A rash of smaller more recent spills in British Columbia, including one inside the boundaries of the Robson Bight Ecological Reserve in August 2007, deemed Critical Habitat for Northern Resident killer whales, has raised concerns about the potential risk of spills to marine mammals. Increased vessel traffic, pipeline ruptures, oil refinery releases, and accidental releases from small craft operations all contribute to a heightened risk of exposure of killer whales to oil and related products.

Oil and related products may cause immediate injury to eyes, airway passages (blowhole, trachea, lungs), mouth and skin (St Aubin 1990). Uptake via oral – gastric and/or via pulmonary routes can lead to systemic toxicity, including such adverse effects as stomach or intestinal irritation or lesions, hepatic injury, neurotoxicity, and death (Hall *et al.* 1996;Jenssen 1996;St Aubin 1990).

3 Environmental Contaminants of Concern to Killer Whales and Their Prey in the South Coastal Environment of BC

Through direct (contact) and indirect (via prey) means, resident killer whales are exposed to a multitude of both chemical and biological contaminants in their habitat (Figure 4). However, certain contaminants have been identified to be of primary concern to killer whales and their prey (Grant and Ross 2002;Johannessen and Ross 2002). These include conventional or legacy POPs such as PCBs, polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs and PCDFs), organochlorine pesticides (OCs), and polycyclic aromatic hydrocarbons (PAHs); new or emerging POPs such as polybrominated diphenyl ethers (PBDEs), alkylphenol and its ethoxylates (AP and APnEOs), chlorinated paraffins, polychlorinated naphthalenes (PCNs), and fluorinated organic compounds (FOCs); current-use pesticides including those used in forestry, agriculture and industry; metals; pharmaceuticals and personal care products (PPCPs); and biological contaminants.

These same substances have recently been identified as contaminants of concern in the Georgia Basin by the BC Toxics Work Group of the Puget Sound/Georgia Basin International Task Force (Garrett 2004;Garrett 2009). Some of these contaminants have been well studied, both in Canada and worldwide, while many others, including some of the emerging POPs, pharmaceuticals and personal care products, and biological contaminants, have not been extensively studied. Information on their sources and loadings to the environment, environmental persistence and fate, and potential to cause adverse biological impacts is limited. However, many of these contaminants have the potential to cause serious biological effects, including the disruption of endocrine systems and immune systems, and thus further threaten the viability of populations of a variety of species which are already affected by other stressors.

Many of these contaminants are controlled under existing legislation and regulations. For example, under federal legislation, the *Canadian Environment Protection Act*, 1999 (or CEPA 1999) (Government of Canada 1999), substances which are determined to be toxic as defined by the Act (CEPA-toxic) are added to the CEPA Schedule 1 List of Toxic Substances. For these substances, the federal government must develop management strategies within a specified timeframe. In addition, CEPA-toxic substances which are also bioaccumulative, persistent, and anthropogenic are targeted for virtual elimination from the environment and CEPA 1999 mandates that they be added to the Virtual Elimination List. For more information refer to http://www.ec.gc.ca/CEPARegistry/subs_list/.

This section summarizes available information on contaminants of concern to killer whales and their prey in the south coastal BC environment. Where possible, information on the sources, loadings, potential impacts, and environmental levels of these contaminants has been included. Where regulations or other management tools have been developed for specific contaminants, these have been noted. However, additional information on jurisdictional responsibilities, existing legislation and regulations, and other management actions implemented to eliminate or reduce the release of contaminants to the BC environment is provided in Sections 4 and 5.

Much of the content of this section was taken from the summaries on contaminants in the Georgia Basin contained in Garrett (2004) and Garrett (2009).

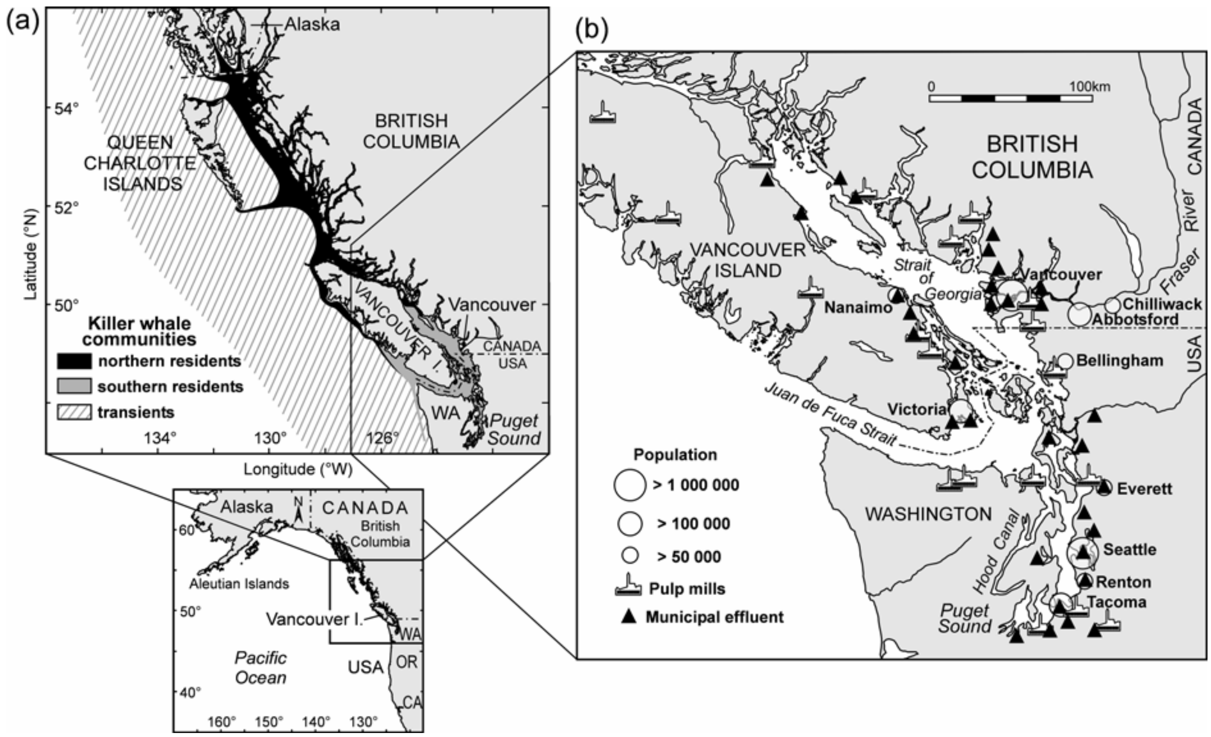

Figure 4. British Columbia's reproductively isolated killer whale (*Orcinus orca*) communities include the marine mammal-eating transients (threatened), and the fish-eating northern (threatened) and southern residents (endangered) (Ford et al. 1998). The Georgia Basin (BC)-Puget Sound (USA) waters represent summer feeding habitat for the ~ 85 southern resident killer whale individuals, who must share this coastal region with approximately 8 million humans (From Ross 2006).

3.1 Conventional or Legacy POPs

Conventional POPs are anthropogenically-produced chlorinated substances, many of which have been shown to be persistent, bioaccumulative, and toxic (PBT). Some of these substances came into use several decades ago and were produced for a variety of pesticidal and industrial applications (e.g., DDT and PCBs). Others have never been produced intentionally, but are formed as by-products of combustion and specific industrial processes (e.g., PCDDs and PCDFs). The environmental concerns associated with the presence of conventional POPs in the environment have long been recognized worldwide. In many countries, including Canada, the use and release of most of these substances have been eliminated or severely restricted; however, despite this they remain of global concern. The continued presence of environmental hotspots provides a source for their recycling and re-entry to the environment, while their ability to be transported long distances via atmospheric and ocean currents results in their redistribution from areas of current use to other areas of the world.

A number of conventional POPs are of potential concern in south coastal areas of BC. These include PCBs, PCDDs/PCDFs, PAHs, hexachlorobenzene (HCB), and several organochlorine pesticides (DDT, toxaphene, and hexachlorocyclohexane).

3.1.1 Sources and Loadings of Conventional or Legacy POPs to the South Coastal BC Environment

Limited information is available on sources and loadings of POPs to the south coastal environment of BC. However, a study has been initiated to assess the sources and fate of POPs (using available information for PCBs and PBDEs) in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin. This will involve the use of mass balance and exchange process modeling, combined with focused sampling to fill critical gaps identified by the modeling exercise (Macdonald *et al.* 2007;Shaw 2009). While no overall loading estimates are available, atmospheric deposition is thought to be an important source of POPs to the south coastal area of BC (Noël *et al.* 2007). The presence of these substances in fish, marmots, and snowmelt from remote and/or high altitude areas in BC has been attributed to atmospheric deposition (Demers *et al.* 2007;Lichota *et al.* 2004;Morrissey *et al.* 2005;Shaw and Gray 2004). Several POPs have been identified in atmospheric deposition to some areas of the Georgia Basin. Other possible sources include municipal wastewater treatment plant (WWTP) discharges, combined sewer overflows (CSOs), runoff from urban and agricultural areas, and landfill leachate.

Many of the legacy POPs have been deemed CEPA-toxic and are on the CEPA 1999 Schedule 1 List of Toxic Substances. Twelve of these POPs were targeted for virtual elimination before CEPA 1999 came into force. These include hexachlorobenzene, PCBs, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, as well as the pesticides aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, and toxaphene. Since these twelve POPs were targeted for virtual elimination before CEPA 1999 came into force, they have not been added to the CEPA Virtual Elimination List (http://www.ec.gc.ca/ceparegistry/subs_list/VirtualEliminationList.cfm). However, the pesticides aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene are not registered for use under the *Pest Control Products Act* (PCPA) (http://laws.justice.gc.ca/en/P-9.01/) and, therefore, cannot be used in Canada. For the non-pesticidal substances, a series of regulations to virtually eliminate their release to the Canadian environment have been developed and these are discussed in the following sections.

3.1.1.1 Polychlorinated Biphenyls (PCBs)

PCBs have been used worldwide as dielectric fluids in electrical equipment, heat exchanger fluids, investment casting waxes, and in a variety of other products including paints, pesticides, plastics, and carbonless copy paper. Commercial formulations of PCBs have been sold in North America since 1929 under the trade name Aroclor. These chemicals were never manufactured in Canada but were imported, almost exclusively, from the US. The manufacture of PCBs in the US was voluntarily discontinued in 1977 and formally banned in 1979. In Canada, regulations under CEPA (1999) prohibit the use of PCBs in new products and equipment; however, the continued use of older closed electrical equipment containing PCB fluids, such as transformers, is permitted until the end of their service life. Environment Canada prepares annual summaries of the national PCB inventory, which is a compilation of reported PCBs in use and in storage in Canada http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=C2AAAA7F-4F1B-453F-

91CB-5896B1A1B7F1. Releases from these sources are minor in comparison to the losses which occurred before the introduction of regulations; however, occasional spills from older in-use electrical equipment do occur and PCB-contaminated oil is sometimes found at abandoned contaminated sites (Garrett and Goyette 2001). However, since the continued limited use and long-term storage of PCBs in Canada are potentially significant sources of release to the environment, Environment Canada has revised the PCB regulations to address these potential sources.

Regulations under CEPA 1999 prohibit the use of these chemicals for other purposes, their import into Canada, and also control the storage and destruction of PCBs in Canada. Federal regulations controlling PCBs in Canada include: the *Federal Mobile PCB Treatment and Destruction Regulations*; the *Chlorobiphenyl Regulations*; the *Storage of PCB Material Regulations*; the *PCB Waste Export Regulations, 1996*; the *Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations*; and the *Export of Substances Under the Rotterdam Convention Regulations* (which ensure that pesticides and other chemicals (including PCBs) that are subject to the Prior Informed Consent procedure are not exported to other Parties to the Convention, unless the importing Party has provided its "prior informed consent"). For more information on federal actions to control PCBs and the CEPA 1999 regulations pertaining to PCBs, refer to the Environment Canada websites: http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-0&xml=444EED1B-F1C6-424B-8AA3-B3A04DB44193 and http://www.ec.gc.ca/bpc-pcb/default.asp?lang=En&n=663E7488-1.

While municipal WWTP discharges, contaminated sites, landfill leachate, and incineration are still potential sources of PCBs to the environment, major releases from these and other point sources have been virtually eliminated through the introduction of controls in most western countries. But the large repositories of PCBs in soils and bottom sediments are available for recycling in the environment and volatilization from soils and surface waters results in the atmospheric transport and redistribution of these chemicals to other areas.

Another potential source of PCBs to some ecosystems was reported by Krümmel *et al.* (2003), who found that significant amounts of PCBs were deposited to some lakes in Alaska by spawning sockeye salmon. Sockeye salmon accumulate significant amounts of PCBs during their lifetime at sea and, when the salmon return to their natal lakes to spawn and die, these PCBs are deposited to the lake sediments. PCB concentrations in surface sediments of lakes where sockeye returned to spawn were much higher than in sediments from lakes with no returning spawners. The authors concluded that PCB loadings from this source were likely greater than loadings from atmospheric deposition.

PCB loadings to south coastal BC have not been calculated. However, a report prepared for Environment Canada estimated that PCB loadings to the Georgia Basin from municipal WWTPs were 4.11 kilograms/year (kg/yr) (based on available information collected between 1990 and 1998). Information was insufficient to estimate PCB loadings from other wastewater discharges (ENKON Environmental Ltd. 2002). In addition, a study was initiated under the Georgia Basin Action Plan (GBAP) to assess the sources and fate of PCBs (and PBDEs) in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin by using mass balance and exchange process modeling (Macdonald *et al.* 2007;Shaw 2009).

3.1.1.2 Polychlorinated Dibenzo-*p*-dioxins and Polychlorinated Dibenzofurans (PCDDs and PCDFs)

PCDDs and PCDFs have never been manufactured intentionally. They are formed as by-products of chemical manufacture and incomplete combustion and have also been identified as micro-contaminants in commercial formulations of PCBs, chlorophenols, and some pesticides.

The chlorinated bleaching process used at pulp and paper mills was identified as an important source of dioxins and furans to the environment in the 1980s. The introduction of stringent federal regulations on dioxins and furans in the 1980s has significantly reduced the concentration of these chemicals in pulp and paper effluents discharged to the environment. In the 1980s, the estimated annual input of PCDDs into the Canadian environment was 1.5 t; however, this has now been reduced by more than 90% (Canadian Council of Ministers of the Environment (CCME) 1992). Since 1992, loadings of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) from BC mills have decreased 98.8% (from 17 milligrams/day (mg/day) to 0.2 mg/day) and loadings of 2,3,7,8-tetrachlorodibenzofuran (TCDF) have decreased 98.8% (from 163 mg/day to 1.8 mg/day). A report prepared for Environment Canada estimated that dioxin and furan loadings to the Georgia Basin from pulp and paper effluents were 0.0010 kg/yr (based on 1998 data) (ENKON Environmental Ltd. 2002). Pulp and paper mill effluent is no longer considered a major source of these contaminants to the BC environment. For more information on CEPA 1999 regulations controlling dioxin and furan releases from pulp and paper mills, refer to Environment Canada websites
http://www.ec.gc.ca/CEPARegistry/regulations/detailReg.cfm?intReg=20 and
http://www.ec.gc.ca/CEPARegistry/regulations/detailReg.cfm?intReg=21.

Currently, the major source of dioxins/furans to the environment from BC pulp and paper mills is their atmospheric release during the combustion of salt-laden wood. Hogged fuel, which includes bark and similar wood wastes, is a by-product of sawmills and is burned by pulp and paper plants to produce steam. At coastal mills, the wood adsorbs chlorine (in the form of salt) from marine water during transport in log booms. Under certain conditions, the burning of wood containing chlorine can result in the production of dioxins and furans. In 1995 and 1997, dioxin emissions from coastal power burners burning salt-laden hog fuel were estimated to be 10.5 grams/year (g/yr) and 7.9 g/yr (based on toxic equivalents (TEQ)), respectively. To address this issue, the Canadian Council of Ministers of the Environment (CCME) developed a Canada-Wide Standard (CWS) for pulp and paper boilers burning salt-laden wood, the majority of which are located in BC. Since 1995, mill closures and voluntary industry initiatives have substantially decreased dioxin releases. In both 2001 and 2002, estimated releases from this source were 3.3 to 3.4 g/yr (Uloth *et al.* 2004). For information on the Canada-Wide Standard for pulp and paper boilers burning salt laden wood refer to the CCME website http://www.ccme.ca/ourwork/air.html?category_id=97.

The widespread use of chlorophenol-based chemicals for wood treatment in BC was also a major past source of dioxins and furans to the Georgia Basin. PCDDs/Fs (mainly the hexa-, hepta-, and octa- forms) were present as impurities in the chlorophenol- and chlorophenate-based formulations used for wood treatment. These products, which were used extensively in Canada for sapstain control (the short-term protection of wood), were banned for this use in 1990. Oil-based mixtures of chlorophenols are still registered for use in heavy-duty wood preservation (long-term protection of wood); however, the use of these products is declining. In 2003, approximately 148 t of pentachlorophenol (PCP) were sold for use in BC, compared to 789 t in 1991. In 2003, approximately 80 t of the total amount sold was for use in the Lower Mainland area (ENKON Environmental Ltd. 2005). The main use of PCP-based wood preservatives was for the treatment of utility poles. However, BC Hydro, the main user of utility poles in BC, no longer uses PCP-treated poles. In addition, the introduction of more stringent pollution control measures at wood treatment facilities in BC has significantly reduced the amount of wood treatment chemicals entering the aquatic environment. Since the 1980s, a combination of industry actions, the development of codes of practice, and the implementation of federal government inspection and enforcement programs have decreased stormwater releases by approximately 90% (Environment Canada 1998a).

Other potential sources of dioxins and furans to the environment include domestic and industrial wastewater and stormwater discharges, landfill leachate, municipal and industrial incineration, diesel emissions, coal combustion, chimney soot from home heating, black liquor recovery furnace flue gas, and scrap and car incineration. Occasional accidental spills or fires in older electrical equipment containing PCB fluids is a possible source of release to the environment, although the commercial PCB formulations used contained primarily furans, rather than dioxins. In addition, the use of specific pesticides may contribute dioxins and furans to both agricultural and urban runoff. Some commercial pesticide formulations are contaminated with low concentrations of dioxins and furans which are formed as inadvertent by-products during the manufacturing process. Pesticides which have been reported to contain dioxins, included dactal, 2,4-D, dichlorophenoxyl-phenol, dicamba, 2,4-DP, hexaconazole, MCPA, mecoprop, and quintozene (Mittelstaedt 2003). Dioxin and furan contaminants in pesticides released to land and air can enter the aquatic environment through surface runoff, groundwater infiltration, atmospheric transport, and precipitation events. Although loadings of dioxins and furans to the BC south coastal environment from most of these potential sources have not been estimated, a report prepared for Environment Canada estimated that CSOs contributed 0.00014 kg/yr to the Georgia Basin (based on available data between 1990 and 1998) (ENKON Environmental Ltd. 2002).

PCDDs and PCDFs are considered to be CEPA-toxic and have been added to the List of Toxic Substances in Schedule 1 of CEPA 1999. In addition, they have been targeted for virtual elimination of releases to the Canadian environment under the federal Toxic Substances Management Policy. For more information on these substances and the management strategies developed for these substances refer to Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.1.1.3 Polycyclic Aromatic Hydrocarbons (PAHs)

While most PAHs are not intentionally produced or released to the environment, there are numerous natural and anthropogenic sources. Direct releases to the aquatic environment occur through the use and spillage of petroleum products, coal, and creosote, which contain high levels of PAHs. In particular, the release of PAHs from creosote-treated wood products has been identified as a significant source. Municipal WWTP discharges, urban runoff, and some industrial discharges also release PAHs, but atmospheric deposition is considered to be the major source of PAHs to most aquatic systems. PAHs enter the atmosphere via both natural (e.g., forest and grass fires and volcanic eruptions) and anthropogenic sources. Major anthropogenic sources include residential heating (especially the use of wood as fuel), transportation, aluminum smelters, steel and coking plants, municipal incinerators, agricultural and forest slash burning, wood waste combustion, and other open-air burning (National Research Council of Canada (NRC) 1983). A 1990 survey by Environment Canada identified forest fires and aluminum smelters as the major sources of PAHs to the atmosphere, accounting for 47% and 21% of the total, respectively (Environment Canada/Health Canada 1994f;Lalonde 1993).

Pulp mills, municipal WWTPs, oil refineries, historic coal gasification plants, historic coal-use, leaching from creosote-treated wood structures, boat traffic, fuel spillage, CSO and stormwater discharges, and atmospheric deposition have been identified as likely sources of PAHs to the south coastal BC environment; however, information on loadings to the environment from these sources is limited (Garrett and Shrimpton 2000). Recently, the use of parking lot sealcoats has been identified in the US as an important source of PAHs to urban runoff. Sealcoats, which are commonly used on parking lots and driveways to protect and enhance the appearance of pavement, are made from a coal-tar pitch-based emulsion or an asphalt-based emulsion (Mahler *et al.* 2005). These authors reported that, in some urban areas, the contribution of PAHs from sealcoats can exceed contributions from other sources. The potential contribution of sealcoats to PAH loadings to urban waterways in BC has not been investigated.

In the past, the widespread use of creosote for wood preservation in BC was an important source of PAHs to the environment. The release of large quantities of creosote-contaminated stormwater from some wood preservation facilities in BC resulted in the entry of large amounts of PAHs to the aquatic environment. While annual usage of creosote at BC facilities has decreased from the 5,387,761 kg used in 1999, very large quantities are still in use (2,163,142 kg in 2003) (ENKON Environmental Ltd. 2001). However, the introduction of more stringent pollution control measures in the 1980s substantially reduced releases of creosote and other wood treatment chemicals to the BC environment (Environment Canada 1998a).

Both low molecular weight[1] and high molecular weight[2] PAHs have been detected in municipal WWTP effluents discharged to the Georgia Basin (Bertold 2000). Alkylated PAHs, whose presence indicates a petroleum-related source, were also consistently detected in effluents (Bertold 2000). A report prepared for Environment Canada examined wastewater releases of select contaminants to the Georgia Basin between 1990 and 1998 and estimated that average PAH annual loadings from refined petroleum and coal products discharges, municipal WWTP discharges (based on plants for which data was available), and stormwater discharges (based on information from the Lower Mainland/Fraser Valley, Capital Regional District (CRD), and Nanaimo) were 4.98 kg, 149 kg, and 667 kg, respectively (ENKON Environmental Ltd. 2002). Another study estimated annual PAH loadings from urban runoff to be 0.50 t in the Fraser Basin and 0.44 t in the Lower Fraser River (McGreer and Belzer 1998).

1 low molecular weight (LMW) PAHs have a molecular structure consisting of two or three rings
2 high molecular weight (HMW) PAHs have a molecular structure consisting of four or more rings

Both Metro Vancouver (formerly Greater Vancouver Regional District) and the CRD have introduced more stringent measures to prevent the entry of contaminants to sewer systems by controlling releases at the source. Through municipal bylaws, Metro Vancouver and CRD limit the allowable concentrations of specific contaminants which can be discharged to sewer systems in wastewater (Capital Regional District (CRD) 2009b;Lewis 2002;Metro Vancouver 2009).

PAH loading to the Georgia Basin from atmospheric deposition is thought to be a major source, but available information is limited. Studies in the Brunette River area of Burnaby estimated that the mean atmospheric deposition of PAHs to this area was 924 nanograms/square metres/day ($ng/m^2/d$) for LMW PAHs and 204 $ng/m^2/d$ for HMW PAHs (Hall *et al*. 1998).

Environment Canada and Health Canada assessed PAHs and creosote-contaminated wastes and found them to be toxic as defined by CEPA 1988 (an earlier version of CEPA 1999). These substances were added to the CEPA Schedule 1 List of Toxic Substances (Environment Canada/Health Canada 1994c;Environment Canada/Health Canada 1994f).

For more information on the federal management strategies developed for PAHs and creosote-impregnated waste materials, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.1.1.4 Hexachlorobenzene (HCB)

While HCB has not been manufactured in Canada, it was imported for use in dye manufacturing, porosity control in electrode manufacture, wood preservatives, fungicides, and pyrotechnic applications. HCB is no longer used as a commercial product in Canada, nor is it registered for use as a pesticide under the federal *Pest Control Products Act* (PCPA). The use of HCB as a fungicide to control wheat bunt and smut on seed grains was terminated in Canada in the 1970s, and the major use of HCB since that time has been in chemical synthesis. In the early 1990s, it was estimated that HCB releases to the Canadian environment were more than 1000 kg/yr (Canadian Council of Ministers of the Environment (CCME) 1992;Canadian Council of Ministers of the Environment (CCME) 1999). In addition, since commercial formulations of HCB contained toxic impurities, including dioxins and furans (Schmitt *et al.* 1999), releases of HCB were a source of these contaminants to the environment as well.

Small amounts of HCB continue to enter the environment as a result of the manufacture and use of chlorinated solvents and pesticides, incineration and combustion, some industrial processes, and long-range transport. HCB can be produced unintentionally as a by-product or impurity in some chemical processes (Canadian Council of Ministers of the Environment (CCME) 1992). At one time, HCB was formed as a process residue by the chlor-alkali industry and elevated concentrations of HCB were detected in the process sludges of a, now closed, BC chlor-alkali plant located in Howe Sound. However, process changes made by the chlor-alkali industry now preclude HCB formation (Wilson and Wan 1982). HCB has also been detected in commercial PCP wood preservative formulations; however, the use of PCP-based wood preservatives has decreased significantly in BC in recent years. The Pest Management Regulatory Agency (PMRA) of Health Canada has recently re-evaluated the registration of PCP and other heavy-duty wood preservatives in Canada (PMRA (Pest Management Regulatory Agency) 2009b).

Information on current sources of HCB to the south coastal BC environment is limited;

however, a report prepared for Environment Canada estimated annual loadings of HCB to the Georgia Basin from municipal treatment plants to be 0.171 kg (based on available data from 1990 to 1998) (ENKON Environmental Ltd. 2002).

HCB is considered toxic, as defined by CEPA 1999, and is targeted for virtual elimination under the federal Toxic Substances Management Policy. The federal government has taken measures to minimize the release of HCB to the Canadian environment from current sources. HCB is an inadvertent contaminant of chlorinated solvents and ferric/ferrous chloride. Actions have been taken to control pollution issues associated with the use of chlorinated solvents in the drycleaning and degreasing sectors, and also those associated with the ferric/ferrous chloride sector. Many of the other potential sources of HCB to the environment are similar to those of dioxins and furans (e.g., municipal waste and sewage sludge incineration, chemical production, cement kilns, coal combustion, etc.). Actions implemented under CEPA 1999 to minimize releases of dioxins and furans from these facilities will also reduce or eliminate releases of HCB. As well, in 2003, a regulation was introduced to ban the intentional production, use, import, and export of HCB in Canada. This regulation has now been replaced by the *Prohibition of Certain Toxic Substances Regulations*, 2005 (http://www.ec.gc.ca/CEPARegistry/regulations/DetailReg.cfm?intReg=62). For additional information on HCB and the status of federal actions to eliminate or minimize HCB releases to the environment, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.1.1.5 Organochlorine (OC) Pesticides (DDT, Toxaphene, and Hexachlorocyclohexane (HCH))

DDT is a broad spectrum pesticide which was imported into Canada for widespread use in controlling insect pests on crops. It was also used in both domestic and industrial applications. While most pesticidal uses of DDT were phased out in the early to mid-1970s, DDT was still registered in Canada for very restricted purposes (mainly for killing bats and rodents) until 1985, when the registration for all uses was phased out. The sale and use of existing pesticide stocks was permitted until the end of 1990. Since DDT is no longer registered in Canada, the PCPA prohibits its use or import into Canada for pesticidal use. However, in many tropical countries DDT is still used for the control of malaria. To ensure that there are no future non-pesticidal uses of this pesticide in Canada, DDT was added to the *Prohibition of Certain Toxic Substances Regulations, 2005*. These regulations prohibit the manufacture, use, sale, offer for sale and import of DDT for any non-pesticidal purposes. For additional information on the status of federal actions to control DDT, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Toxaphene is an organochlorine pesticide containing a mixture of polychlorinated bornanes and camphenes. Toxaphene was used widely as an agricultural insecticide to replace DDT and was the most heavily used insecticide worldwide, prior to the introduction of bans and restrictions on its use in several countries. Toxaphene was used extensively in the US until 1982, primarily for insect control on cotton and other crops in the southern states (Oehme *et al.* 1996). Toxaphene has also been used to remove unwanted fish from lakes. There are historical records indicating that some BC lakes were treated with toxaphene to remove competing fish species prior to stocking with rainbow trout (Stringer and McMynn 1960). Most uses of toxaphene were de-registered in Canada in 1982 and its use has been banned under the PCPA since 1985.

HCH has been used in Canada since the 1950s for insect control in domestic, agricultural, and silvicultural applications. HCH is made up of a mixture of five isomers. Recently, lindane, which is the purified gamma (γ) isomer of HCH, has been registered under the PCPA for restricted uses including moth sprays, seed treatment, and the control of domestic insects (Canadian Council of Ministers of the Environment (CCME) 1992;Canadian Council of Ministers of the Environment (CCME) 1999). Because lindane appears on internationally recognized lists of POPs, a special review of this pesticide was undertaken by PMRA. This review was completed in 2001 and the PMRA announced that all uses of lindane, for which alternatives were available, would be phased out by 2002 and all other uses would be phased out by the end of 2004. This decision was based on the potential health risks associated with occupational exposure. All but one of the registrants of this pesticide requested voluntary discontinuation of sales for the remaining uses of lindane. At the request of this one remaining registrant, a Board of Review was established by the Minister of Health to review the PMRA decisions. As a result, the PMRA initiated a new review and considered new information and data and risk mitigation proposals from registrants of lindane products and other interested parties. As a result of this new review, the PMRA Re-evaluation Note REV2009-08 was prepared and posted on the Health Canada website for public comment. The public comment period is from August 27, 2009 to October 26, 2009. For more information, or to review this document, refer to http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_rev2009-08/lindane-eng.php.

Inventories of pesticide sales in BC indicate that the use of lindane has been relatively stable over the years for which information is available; 326 kg in 1995, 272 kg in 1997, 239 kg in 1999, and 249 kg in 2003 (ENKON Environmental Ltd. 2005).

Very little information is available on loadings of OC pesticides to the south coastal BC environment. A report prepared for Environment Canada estimated that loadings of lindane and total HCH to the Georgia Basin from municipal WWTPs were 9.45 and 9.38 kg/yr, respectively (based on available data from 1990 to 1998). No information was available on loadings of DDT or toxaphene (ENKON Environmental Ltd. 2002). Some POPs have been identified in atmospheric deposition in the Agassiz and Abbotsford areas (McGreer and Belzer 1998) and the long-range atmospheric transport of OC pesticides is considered to be a current source to south coastal BC.

3.1.2 Presence of Conventional or Legacy POPs in the South Coastal BC Environment

A variety of POPs have been detected in ambient fresh and marine surface water, groundwater, marine and freshwater sediments, aquatic organisms, birds, and marine mammals in the south coastal areas of BC. The most commonly detected POPs are industrial pollutants such as PCBs, dioxins/furans, and PAHs, and the OC pesticides, DDT, toxaphene and HCB. Much of the information from the following summary is summarized elsewhere (Garrett 2004;Garrett 2009).

Many studies have reported the presence of PCBs in the south coastal region of BC, with the highest concentrations being detected in Vancouver, Victoria, and Esquimalt harbours, likely due to historic releases from the past industrial activity in these areas (Bertold 2000;Boyd *et al.* 1998;Boyd *et al.* 1997;Bright *et al.* 1996;Garrett 1985a;Garrett 1995;Garrett 2004;Gordon 1997;Goyette and Boyd 1989;Greater Vancouver Regional

District (GVRD) 2000;McPherson *et al.* 2001;Paine and Chapman 2000;Sekela *et al.* 1995;Transport Canada 2000;Yunker 2000).

Very high concentrations of PAHs have also been detected in these harbours and in the vicinity of wood treatment facilities using creosote for the long-term preservation of wood. At many locations, concentrations in the sediments exceeded Canadian environmental quality guidelines (Canadian Council of Ministers of the Environment (CCME) 1992). At some sites, concentrations were in the range considered high enough to cause adverse environmental impacts, depending on local environmental conditions (Boyd and Goyette 1993;Bright *et al.* 1996;Garrett and Shrimpton 2000;Goyette and Boyd 1989;Goyette and Wagenaar 1995).

A variety of PAHs were detected in sediments from the vicinity of the Iona Island WWTP discharge. Input from the Fraser River, rather than WWTP effluents, is thought to be the major source of PAHs to this area (Paine and Chapman 2000;Yunker 2000).

Many of the facilities that were historic sources of PAHs and other contaminants to these areas have now been closed and are undergoing redevelopment (Boyd and Goyette 1993;Bright *et al.* 1996;Garrett and Shrimpton 2000;Goyette and Boyd 1989;Goyette and Wagenaar 1995). In some cases, the redevelopment of industrial areas results in actions to reduce the concentrations of contaminants in shoreline areas. Much of the shoreline along the Fraser River, False Creek, and Vancouver, Victoria, and Esquimalt harbours is currently being redeveloped or is under consideration for redevelopment. As a requirement of redevelopment, site assessment reports are prepared for many of the sites where high levels of PAHs and other contaminants have been found. The site assessment reports are reviewed by regulatory agencies and, where required, remedial action is taken.

Prior to the introduction of controls on dioxins and furans, these contaminants were detected at elevated concentrations in several areas of the Georgia Basin, particularly in the vicinity of pulp and paper mills, wood preservation facilities, and Vancouver and Victoria harbours (Garrett 1995;Harding 1990;Harding and Pomeroy 1990;Macdonald *et al.* 1992).

POPs have also been detected in a wide range of biota from the BC south coast. Due to the ability of many POPs to be transported atmospherically to areas far removed from sources, these contaminants have even been detected in remote and high altitude areas (Demers *et al.* 2007;Lichota *et al.* 2004;Morrissey *et al.* 2005;Shaw and Gray 2004). However, as was the case with sediments, the concentrations are highest in urban and industrial areas. Generally, the highest concentrations have been detected in mussels and in the hepatopancreas tissue of crab, while concentrations in fish muscle were much lower. In the late 1980s, high concentrations of dioxins and furans were detected in local shellfish species collected in the vicinity of kraft pulp and paper mills and wood treatment facilities. These contaminants were being released to the environment as a result of their formation during the chlorine-bleaching process at pulp mills and as a result of their presence as contaminants in the pentachlorophenol-based chemicals used for the treatment of wood. The concentrations of dioxins and furans in some species made them unsuitable for human consumption. As a result, the federal government introduced closures, restrictions, and consumption advisories on various crab, prawn, shrimp, oyster, and clam fisheries on the BC coast, mainly in the vicinity of pulp and paper mills. By February 1995, approximately 1200 km^2 of BC coastal waters were affected by restrictions on shellfish harvesting due to dioxin/furan concentrations

(Environment Canada 2000a;Hagen *et al.* 1997;Karau and Pierce 2000).

POPs have been detected in many fish species from south coastal BC. Although concentrations are typically low, their tendency to be biomagnified in the food chain means that their presence, even at low concentrations, is a potential concern to higher trophic level species. Elevated POPs concentrations have been detected in fish-eating species of birds and mammals in BC including cormorants (Elliott *et al.* 2003;Harris *et al.* 2003b), seaducks (Wilson and Elliott 2004), eagles (Elliott and Norstrom 1998;Elliott *et al.* 1996a), osprey (Elliott *et al.* 1998;Elliott *et al.* 2007b), herons (Elliott *et al.* 2001;Elliott *et al.* 2003;Harris *et al.* 2003a), seabirds (Elliott 2005), grizzly bears (Christensen et al. 2005), otters (Elliott *et al.* 2008;Harding *et al.* 1999), marmots (Lichota et al. 2004), killer whales (Addison and Ross 2000;Ross 2000), harbour porpoises (Jarman *et al.* 1996), and seals (Addison *et al.* 1996;Addison and Ross 2000).

Pacific herring from Puget Sound and the Strait of Georgia, an important food source for chinook and coho salmon, harbour seals, and many fish-eating bird species, contain a number of POPs including PCBs, DDT (and isomers), and hexachlorobenzene (HCB) (West *et al.* 2008). However, segregation of herring populations was observed and the concentrations of these substances varied between herring populations. Puget Sound herring contained much higher concentrations of PCB and DDT than did herring from the Georgia Strait, while HCB concentrations were low in herring from all areas. Similarly, Ross *et al.* (2004) reported that harbour seals from Puget Sound also contained much higher PCB concentrations than did harbour seals from the Strait of Georgia. However, harbour seals from the Strait of Georgia contained higher concentrations of PCDDs and PCDFs than did the Puget Sound harbour seals.

POPs have also been detected in wild salmon, and salmon have been identified as an important source of POPs to resident killer whales (Ross et al. 2000a) and grizzly bears (Christensen et al. 2005) in BC. Christensen *et al.* (2005) estimated that salmon contribute 70% of the OC pesticides and 90% of the PCBs in grizzly bears feeding on salmon. While the contribution that salmon make to POPs in killer whales has not been determined, chinook salmon are the primary food source of the south resident killer whale population (Ford and Ellis 2006).

Salmon can accumulate POPs during their time in freshwater, estuarine and coastal environments, which often receive contaminants from urban and agricultural sources and from long-range transport. Some authors have reported that juvenile salmon experience health effects as a result of inhabiting contaminated waterways during their outmigration, and concentrations of POPs in juvenile salmon in some waterways were comparable to concentrations which have previously been associated with adverse biological effects (Collier *et al.* 2000;Stehr *et al.* 2000).

However, anadromous salmon spend the majority of their lives at sea and significant accumulations of POPs occur over this time (Cullon *et al.* 2009;O'Neill *et al.* 1998). Cullon *et al.* (2009) studied four stocks of chinook salmon from BC and Washington and estimated that 97 to 99% of the PCBs, PCDD/Fs, DDT and HCH in returning adult chinook salmon were acquired during their time at sea. These authors also observed differences in POPs concentrations in different chinook stocks; however, PCBs were the dominant POP detected in adult salmon and smolts. PCB concentrations were much higher in salmon collected from the more southerly locations, the lower Fraser River and Washington State rivers (approximately 35 to 56 ng/g (ww)), than from Johnstone Strait, BC (approximately 9 ng/g (ww)). PCDDs and PCDFs were also present at lower concentrations in Johnstone Strait salmon. A comparison of Washington and BC smolts reflected regional differences in inputs from sources. While PCBs accounted for 100% of the TEQs in Puget Sound smolts, PCDDs and PCDFs made greater contributions to the TEQs in smolts from the Strait of Georgia. DDT and HCH were the OCs detected at the highest concentrations in all adult stocks; however, while DDT dominated in Fraser River and Washington salmon, HCH dominated in salmon from Johnstone Strait. Since metabolites made up the majority of the DDT contributions, it was concluded that fresh DDT input was minimal (Cullon et al. 2009).

Salmon have also been identified as a major vector in the transport of POPs to natal lakes and streams. Krümmel *et al.* (2003) reported that the PCBs that accumulate in sockeye salmon during their lifetime at sea were deposited to natal lakes when the salmon died following spawning. PCB concentrations in surface sediments of lakes where sockeye salmon returned to spawn were much higher than the PCB concentrations in sediments from lakes with no returning spawners.

A number of studies have also reported the presence of some POPs in farmed BC salmon (Easton *et al.* 2002;Hites *et al.* 2004a;Kelly *et al.* 2008a). Higher concentrations of POPs were detected in farmed salmon than in wild Pacific salmon, likely due to the presence of these substances in commercial fish food (Easton *et al.* 2002;Hites *et al.* 2004a).

Information is not sufficient to determine temporal trends for most POPs in south coastal areas of BC; however, it is evident that PCB and DDT concentrations increased from the 1940s until the 1970s, and then began to decline as a result of the introduction of controls on the use and release of these chemicals. For example, studies in the Fraser River indicate that the concentrations of some POPs, such as PCBs and HCB, have declined in bed sediments, fish, and/or wildlife in the estuary and in some other areas since the 1970s and 1980s (Elliott *et al.* 1989a;Elliott *et al.* 1989b;Elliott *et al.* 2001;Elliott and Norstrom 1998;Elliott *et al.* 2003;Gray and Tuominen 1998;Harris *et al.* 2003a;Harris *et al.* 2003b;Karau and Pierce 2000;Macdonald *et al.* 1992;Macdonald *et al.* 1998;Raymond *et al.* 1998a;Raymond *et al.* 1998b).

In addition, the unacceptably high concentrations of dioxins and furans, which were detected in local shellfish species near pulp and paper plants, decreased as a result of voluntary actions by the pulp and paper industry and the introduction of federal government regulations limiting the concentrations of dioxins and furans in pulp mill effluents. Dioxin and furan concentrations in the hepatopancreas of crab collected in the vicinity of nine coastal mills decreased by more than 90% and, since 1996, have remained below or near the Health Canada guideline. As a result, fishing areas have been reopened to recreational and commercial use (Environment Canada 2000a;Hagen *et al.* 1997;Karau and Pierce 2000).

Environment Canada studies also identified dramatic decreases in the dioxin and furan levels in eggs from cormorant colonies in the Strait of Georgia in the early 1990s, and attributed these declines to the reduced releases of these contaminants from BC pulp mills. Declining trends were also observed in dioxin/furan concentrations in bald eagles and great blue herons in the Georgia Basin, in grebes and seaducks from the BC coast, and in osprey nesting downstream of pulp mill sites on the Fraser and Columbia rivers. Similarly, the concentrations of PCBs and OC pesticides also began to decrease in some species in the 1980s; however, concentrations have levelled off in recent years (Elliott *et* *al.* 2001;Elliott and Martin 1998;Elliott and Norstrom 1998;Elliott *et al.* 1996b;Elliott *et al.* 2003;Harris *et al.* 2003b). For more information on Environment Canada monitoring of POPs in BC birds, refer to the Environment Canada website http://www.ecoinfo.ec.gc.ca/env_ind/indicators_e.cfm.

Recent information on environmental concentrations of PAHs is not available for many areas of south coastal BC, including many of the areas where high concentrations were previously detected. However, the introduction of more stringent pollution control measures has reduced PAHs releases to the environment. For example, the introduction of pollution control measures by the wood treatment industry, combined with the decreased use of creosote for wood preservation in BC, have decreased the release of PAHs to the environment from these facilities and have likely resulted in decreased environmental concentrations in the vicinity of wood treatment facilities (Environment Canada 1998a;Garrett 2004).

The introduction of bans and restrictions on the use and release of POPs has been successful in reducing environmental concentrations of these substances. However, elevated levels persist and, in some areas, sediment concentrations still exceed Canadian sediment quality guidelines (Canadian Council of Ministers of the Environment (CCME) 2006). A 1998 summary of environmental studies conducted under FRAP reported that total DDT (sum of DDT and its breakdown products) was the most prevalent pesticide measured in biota and sediments in the Fraser Basin, despite the fact that this pesticide has been banned in Canada for many years (Gray and Tuominen 1998). Current environmental levels of some POPs present a continued risk to aquatic species, especially to some populations of marine mammals. Resident and transient populations of killer whales, which frequent coastal BC, are among the most contaminated in the world (Ross *et al.* 2000a;Ylitalo *et al.* 2001). Studies to date indicate that a combination of local and offshore contaminant sources contribute to the levels of contaminants in these whales (refer to Section 2.1.1 for more information).

While Canadian regulatory controls for POPs have been successful in eliminating or severely restricting local sources, many POPs are deposited in the south coastal environment as a result of long-range atmospheric transport from other areas of the world (Noël *et al.* 2007;Noël *et al.* 2009). In addition, there is evidence that, while regulatory controls resulted in a relatively rapid and steady decline in the environmental concentrations of several POPs, the rate at which their concentrations are declining has now slowed significantly. Future declines in environmental concentrations for some POPs will likely be slower and much less evident.

3.1.3 Environmental Concerns and Potential Biological Impacts of Conventional or Legacy POPs

Several conventional POPs substances are on the CEPA 1999 Schedule 1 List of Toxic Substances including PCBs, HCB, dioxins and furans, PAHs, and DDT. Substances are designated as toxic under CEPA 1999 and added to the list if assessments conducted by Environment Canada and Health Canada find that they present a potential risk to either human or environmental health in Canada. The CEPA 1999 Schedule 1 List of Toxic Substances can be viewed at http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm.

Local, as well as global, atmospheric and oceanographic processes contribute to the distribution and transport of these chemicals. They are semi-volatile and, as a result, can travel long distances in the atmosphere and then re-enter biogeochemical cycles in other areas. Several researchers have noted that a variety of POPs (including PCBs, dioxins, furans, DDT, HCB, toxaphene, and HCH) can be transported great distances in the atmosphere. This results in the presence of POPs in areas far removed from sources, such as in northern regions and remote lakes (Atuma *et al.* 2000;Grant and Ross 2002;Macdonald *et al.* 2000a;Macdonald and Crecelius 1994;Macdonald *et al.* 2000b).

POPs are resistant to degradation and their persistence in the environment allows them to accumulate to high concentrations. Most POPs are soluble in lipids and accumulate in the fatty tissues of organisms. High bioconcentration factors (BCFs) have been observed in organisms exposed to POPs. For example, BCFs reported for aquatic species were as high as 10^6 for PCBs and DDT, 10^2 to 10^4 for HCB and toxaphene, and up to 10^4 for 2,3,7,8-substituted dioxins and furans (those which have chlorine atoms located in the 2,3,7, and 8 positions on the molecule). Dioxin and furan congeners lacking the 2,3,7,8-substitution pattern are generally metabolized by fish, birds, and mammals; however, the accumulation of some non-2,3,7,8-TCDD-substituted dioxins has been observed in crustaceans (Canadian Council of Ministers of the Environment (CCME) 1992;Environment Canada/Health Canada 1990).

Similar BCF ranges have been observed for some PAHs; however, the hydrophobic HMW PAH compounds are less likely to concentrate in aquatic organisms than are the more soluble LMW compounds. Since fish have a greater ability to metabolize PAHs than do aquatic invertebrates, these compounds generally do not accumulate to high concentrations in fish tissue (Lawrence and Weber 1984;Veith *et al.* 1979).

The toxicity of POPs to aquatic organisms is manifested in a variety of sublethal and acute toxicological effects that interfere with organ function and metabolism. Both lab studies and observations in the field show that chronic exposure to some POPs, at concentrations comparable to those in the natural environment, can result in a broad range of potentially serious effects in fish, birds, and mammals. These effects include metabolic, neurological, growth, development (vitamin A deficiencies), and behavioural abnormalities; suppression of immune function, leading to increased immunological dysfunction and susceptibility to viral infections; increased levels of cancer; hypothalmo-pituitary-adrenal, thymus, and liver damage; birth defects; endocrine disruption; and long-term reproductive and intergenerational effects (Borrell *et al.* 1999;Goksøyr and Husoy 1998;Harris *et al.* 2007;Lorenzen *et al.* 1999;Ross *et al.* 1997;Simms *et al.* 2000;Van Loveren *et al.* 2000).

POPs (such as PCBs, PAHs, DDT and its metabolites, toxaphene, and lindane) are acutely toxic to a wide range of aquatic species at concentrations in the low micrograms/litre (µg/L) range and can adversely affect growth, physiology, ionoregulation, endocrine systems, behaviour, and immunocompetence and can impact both reproduction and survival. The 2,3,7,8-substituted dioxins and furans are particularly toxic, with 2,3,7,8-TCDD being the most toxic isomer (Arkoosh *et al.* 2001;Hansson and Hahn 2008;Lerner *et al.* 2007b;Misumi *et al.* 2005;Mortensen and Arukwe 2008). Concentrations of less than 38 picograms/litre (pg/L) were reported to effect the growth, survival, and behaviour of rainbow trout (Environment Canada/Health Canada 1990).

Juvenile salmon can accumulate POPs by ingesting prey (benthic invertebrates) during their residence in contaminated estuaries and streams (or hatchery food in fish originating from hatcheries). These contaminants can adversely impact the growth rate and immune function of juvenile salmon and, therefore, have the potential to negatively impact salmon populations (Arkoosh *et al.* 1998a;Arkoosh *et al.* 1998b;Arkoosh *et al.* 1994;Arkoosh and Collier 2002). Wilson *et al.* (2000) measured biological responses to contaminants in juvenile chinook salmon in three BC rivers, prior to their downstream migration. Significant enhancement of EROD activity, CYP 1A concentrations, and DNA adduct concentrations were observed in Fraser River fish, compared to fish from the reference sites. Several POPs, including PCDDs, PCDFs, and PCBs, were detected in the fish, but there was no correlation between the observed biological responses and the POPs concentrations in fish tissues. Johnson *et al.* (2007) detected high concentrations of PCBs and DDT in outmigrant juvenile chinook salmon in the Lower Columbia River in Washington State in 2001 to 2002. In some cases, the concentrations of PCBs were higher than the estimated threshold for adverse effects in salmonids (2400 ng/g (lipid)). The average concentrations in salmon (whole body samples) from the various sites ranged from 1300 to 14,000 ng/g (lipid) for PCBs and from 1800 to 27,000 ng/g (lipid) for DDTs. Collier *et al*. (2000) concluded that both field and laboratory studies indicate that juvenile Pacific salmon migrating through contaminated estuaries suffer impaired health.

Studies on migrating Pacific salmon stocks in BC have shown that, with increasing migration distance towards spawning areas, the lipid reserves in these fish decreased and the concentrations of PCBs and PCDD/Fs increased (DeBruyn *et al.* 2004;Kelly *et al.* 2007). In addition, TEQ levels in eggs of the spawning sockeye approached or exceeded 0.3 pg/g (ww), which has been reported as a threshold level associated with a mortality rate of 30% in salmonid eggs. The authors concluded that historic concentrations of PCBs and PCDD/Fs may have contributed to the decline of certain Pacific salmon stocks and may still pose a threat to ecosystem health in coastal BC.

The presence of POPs in salmon habitat can also reduce the availability of prey to juvenile salmon, as these contaminants are toxic to prey species such as benthic organisms. Numerous studies have demonstrated the ability of POPs to alter the community structure of benthic organisms by decreasing both diversity and abundance (Kemble *et al.* 2000;Long *et al.* 1995;Swartz *et al.* 1989).

Adverse effects have also been observed in aquatic organisms exposed to elevated concentrations of POPs, such as PCBs, PAHs, lindane, and DDT, in the bottom sediments. For example, high incidences of liver lesions have been observed in fish from several PAH-contaminated aquatic systems (Bowser and Martineau 1990;Goyette and Boyd 1989;Goyette *et al.* 1988;Krahn *et al.* 1986;Landahl *et al.* 1990;Malins *et al.* 1985;Malins *et al.* 1984;Myers *et al.* 1991;Simpson 1997;Varanasi and Stein 1991). In the late 1980s, a high incidence of liver neoplasms (up to 75%) was observed in English sole (greater than 20 centimetres in length) collected in the vicinity of a petroleum refinery in the Port Moody area of Burrard Inlet. However, in the early 1990s, a much lower incidence of liver lesions was observed (30-45%) and was attributed to the fact that the refinery process effluent no longer discharged to the Inlet (Goyette 1991;Goyette 1994;Goyette and Boyd 1989).

POPs can also cause a number of health effects in mammals and birds. DDT and its metabolites generally have low to moderate acute toxicities to birds and mammals. However, long term exposure can result in a variety of adverse effects including impairment of reproduction, growth, liver function, and immunocompetence; mutagenicity; carcinogenicity; neurotoxicity; and estrogenicity. Many of these effects have also been observed in mammalian species chronically exposed to PCBs. In addition, it has been suggested that both DDE and PCBs may be associated with premature deaths and reproductive problems in sea lions (Anderson and Hickey 1972;Canadian Council of Ministers of the Environment (CCME) 1992;Canadian Council of Ministers of the Environment (CCME) 1999;Colborn and Smolen 1996;Henshel *et al.* 1997;Kolaja 1977;Lincer 1975;Reijnders 1986;Thompson and Hamer 2000).

High concentrations of DDT, which is highly toxic to bird embryos and can impair egg-shell quality, have been detected in some BC birds, including bald eagles. Although the reproductive success of eagles began to improve following the banning of DDT in Canada in 1970, sampling conducted twenty years later (1990 to 1992) found that 31% of the bald eagle eggs sampled from the Fraser Valley in BC still contained DDT at concentrations which could impair the production of offspring (Elliott et al. 1996b). In addition, it has been suggested that bill deformities observed in cormorants from the Strait of Georgia, in the late 1980s, may have been due to the combined effects of PCBs and dioxin. PCB (and dioxin) levels have declined since this time and are below concentrations normally associated with health effects in birds (http://www.ecoinfo.ec.gc.ca/env_ind/region/cormorant/pcbs_e.cfm).

Increased mortality, reduced growth, reproduction impairment, fetal abnormalities, immune system suppression, and cancer have been observed in mammals exposed to 2,3,7,8-TCDD. In general, birds and fish are more sensitive to acute exposures than are mammals. Studies on fish-eating birds indicate that the presence of elevated TCDD and related chemicals in the BC south coastal environment may have caused adverse biological effects. Eagle chicks from nests located near pulp mills in coastal BC contained significantly elevated levels of liver enzyme activity, compared to chicks from reference sites. Similarly, cormorant eggs contained total TEQs greater than or equal to TEQs which have been linked to adverse effects. The researchers concluded that cormorants may have exhibited significantly elevated liver enzyme and/or brain asymmetries at all BC colonies between 1973 and 1989, and from some colonies during the 1990s (Canadian Council of Ministers of the Environment (CCME) 1999;Elliott *et al.* 1996a;Harris *et al.* 2003b;Henshel *et al.* 1997;Sanderson *et al.* 1994). In addition, evidence of toxicity was observed in herons in southern BC and was attributed to TCDD and related chemicals (Bellward *et al.* 1995). Elliott *et al.* (2001) reported on concentrations of dioxins in great blue heron from rookeries along the coast of BC from 1983 to 1998. They noted that TEQs in eggs from some colonies between 1985 and 1991 were high enough to cause embryotoxicity.

Elliott *et al.* (2008) detected the presence of a number of POPs in the scat (feces) of river otters collected on the south coast of BC in 1998 and 2004. PCB concentrations in otter scat from Victoria Harbour latrines and TCDD-toxic equivalent concentrations in scat from some Victoria and Esquimalt Harbour latrines were above the concentrations thought to be related to health effects, such as reproductive impairment.

Canadian environmental quality guidelines have been developed for some conventional POPs. Water and sediment quality guidelines are presented in Table 1. Tissue residue guidelines have also been developed for DDT, PCBs, PCDDs and PCDFs, and toxaphene for the protection of wildlife consumers of aquatic biota. The guideline for total DDT is

14 ng/g (ww) in the diet. There are separate guidelines for avian and mammalian consumers for both PCBs and PCDDs/PCDFs. These are 2.4 and 0.79 pgTEQ/g, respectively for PCBs and 4.75 and 0.71 pgTEQ/g, respectively, for PCDDs/PCDFs (Canadian Council of Ministers of the Environment (CCME) 2006). For additional information on Canadian environmental quality guidelines, refer to the CCME website http://ceqg-rcqe.ccme.ca/.

Table 1 Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment (CCME) 2006)

Chemical	Water Quality Guidelines		Sediment Quality Guidelines (ng/g (dw) except where noted)			
	Freshwater	Marine	Freshwater		Marine	
			ISQG	PEL	ISQG	PEL
PCBs						
- Aroclor 1254	NG	NG	60.0*	340*	63.3	709
- Total PCBs	NG	NG	34.1	277	21.5	189
PCDDs/PCDFs	NG	NG	0.85 pg/g TEQ	21.5 pg/g TEQ	0.85 pg/g TEQ*	21.5 pg/g TEQ*
PAHs						
LMW Compounds:						
- Acenaphthene	5.8	NG	6.71	88.9	6.71*	88.9*
- Acenaphthylene	NG	NG	5.87	128	5.87*	128*
- Acridine	4.4	NG	NG	NG	NG	NG
- Anthracene	0.012	NG	46.9	245	46.9*	245*
- Fluorene	3.0	NG	21.2	144	21.2*	144*
- 3-Methylnaphthalene	NG	NG	20.2	201	20.2*	201*
- Naphthalene	1.1	NG	34.6	391	34.6*	391*
- Phenanthrene	0.4	NG	86.7	544	41.9	515
- Quinoline	3.4	NG	NG	NG	NG	NG
HMW Compounds:						
- Benz[a]anthracene	0.018	NG	74.8	693	31.7	385
- Benzo[a]pyrene	0.015	NG	88.8	769	31.9	782
- Dibenzo[a,h]anthracene	NG	NG	6.22	135	6.22*	135*
- Fluoranthene	0.04	NG	113	1494	111	2355
- Pyrene	0.025	NG	153	1398	53.0	875
DDT	NG	NG	1.19*	4.77*	1.19	4.77
DDD	NG	NG	3.54	8.51	1.22	7.81
DDE	NG	NG	1.42	6.75	2.07	374.0
Lindane (HCH)	0.01	NG	0.94	1.38	0.32	0.99
Toxaphene	NG	NG	0.1*	NG	0.1*	NG

* interim or provisional guidelines

NG no guideline

3.2 New or Emerging POPs

In addition to the conventional or legacy POPs, whose environmental concerns have long been recognized, a number of other PBT substances with similar properties have more recently been identified as potential threats to environmental and human health. Although some of these compounds have been in use for many years, they are often referred to as "new or emerging" POPs since they have only recently been identified as persistent and widespread environmental toxicants. Regulations on their use and release to the environment have not yet been widely developed. Several new and emerging POPs are of potential concern to killer whales and their prey in the south coastal area of BC. These include alkylphenol and alkylphenol ethoxylates (APs and APnEOs), halogenated diphenyl ethers (PBDEs and chlorinated diphenyl ethers (CDPEs)), phthalate esters, chlorinated paraffins, chlorinated naphthalenes (PCNs), and fluorinated organic compounds (FOCs).

3.2.1 Sources and Loadings of New or Emerging POPs to the South Coastal BC Environment

3.2.1.1 Alkylphenols and Alkylphenol Ethoxylates (AP and APnEOs)

APnEOs (also called alkylphenol ethoxylates (APEOs)) enter the environment as a result of their widespread use in industrial and consumer products. Many forms of APnEOs are produced commercially; however, nonylphenol polyethoxylates account for approximately 80% of the global usage and octylphenol polyethoxylates account for most of the remainder. These substances are used as detergents, degreasers, emulsifiers, wetting agents and dispersing agents by the textile, pulp and paper, metal processing, petroleum refining, oil and gas recovery, power generation, food and beverage processing, plastics manufacture, building and construction, and the paints and coatings industries. They have also been used in a variety of pesticide products (Bennie *et al.* 1997;Renner 1997).

A survey conducted by Environment Canada in 1997 found that 189 Canadian companies used or handled quantities of over 1,000 kg per year of nonylphenol (NP) or nonylphenol ethoxylates (NPnEOs). Major Canadian industrial sources were the formulators and distributors of surfactants and the industrial users of cleaning products, degreasers, and detergents. Between 25 and 60 t of NP and NPnEOs were released as a result of each of these uses. Significant amounts (5 to 10 t) were also released by the paint, coating, resin, and adhesive manufacturers. Formulators of cleaning products, degreasers and detergents; pulp and paper mills; formulators/distributors of products for the pulp and paper industry; oil and gas recovery; wastewater treatment product manufacturers; and miscellaneous other industries released 0.1 to 5.0 t per industry. The total Canadian release of NP and NPnEOs from their manufacture and industrial use in 1996 was approximately 96.5 t. NPnEO releases from Canadian pulp mills have likely decreased since this time as a result of initiatives to reduce the use of these compounds at pulp and paper mills (Environment Canada 1993). Canadian households and institutions likely contribute NP and NPnEO loadings to wastewater treatment facilities (Environment Canada/Health Canada 2001;Metcalfe *et al.* 1996). The efficiency with which municipal WWTPs degrade APnEOs prior to the release of effluents to the environment varies between plants. Various degradation and transformation products of APnEOs are formed during treatment and, in some cases, these substances are more persistent, lipophilic, toxic, and/or estrogenic than the parent compounds (Ahel *et al.* 1994a;Maguire 1999;Reinhard and Goodman 1982;Stephanou 1985).

NP and NPnEOs have been detected in WWTP effluents discharged to south coastal area of BC. A Metro Vancouver study found that, along with phthalate esters, 4-NP and its ethoxylates were the dominant organic contaminants in raw WWTP influents, treated effluents, and effluent suspended sediments. APnEOs have also been detected in CSO discharges and in urban runoff to the Georgia Basin area; however, existing information was insufficient to determine loadings. In particular, information on APnEOs in agricultural runoff is lacking (Bertold 2000;Bertold and Stock 1999;ENKON Environmental Ltd. 1999).

According to inventories of pesticide sales in BC, sales of nonylphenoxypolyethoxyethanol as an active ingredient in pesticides were 5,585 kg in 1991, 8,929 kg in 1995, 9,245 kg in 1999, and 8,791 kg in 2003 (a 57% increase in sales between 1991 and 2003). Sales of this chemical were primarily in the Lower Mainland region of the province (5,823 kg in 2003). Smaller amounts of octylphenoxypolyethoxyethanol as an active ingredient in pesticides were sold in BC over this time period; 2,563 kg in 1991, 5,957 kg in 1995, 4,680 kg in 1999, and 3,133 kg in 2003 (ENKON Environmental Ltd. 2005).

Assessments by Environment Canada and Health Canada have determined that NP and NPnEOs are toxic, as defined by CEPA 1999, and these substances have been added to the CEPA Schedule 1 List of Toxic Substances. Under the federal Toxic Substances Management Policy, Environment Canada has initiated a risk management strategy for these substances. This strategy includes pollution planning requirements for effluents from wet-process-type textile mills, for NP and NPnEOs used at these mills, and also for NP and NPnEOs contained in products. For more information on these substances and actions being taken to minimize their release to the Canadian environment, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.2.1.2 Halogenated Diphenyl Ethers (Polybrominated Diphenyl Ethers (PBDEs) and Polychlorinated Diphenyl Ethers (CDPEs or PCDEs))

The release of CDPEs to the environment has been associated primarily with their presence as impurities in chlorophenol-based wood treatment formulations. Less significant sources include flyash from incinerators, the chlorination of discharges containing diphenyl ether at WWTPs and industrial facilities, past spills of transformer fluid oils containing CDPEs as contaminants, leaks from improperly disposed of transformers, and the use of nitro-substituted CDPE-based herbicides. In addition, derivatives of CDPEs have been widely used as antimicrobials. Triclosan (also called Irgasan) has been used widely as an antimicrobial agent in cosmetics, sanitizing products, fabric softeners and also as an industrial bacteriostat in textiles, leather, plastic, and rubber (Environment Canada 1988;Willis *et al.* 1978).

The major source of CDPEs to the Georgia Basin was likely associated with their presence as impurities in chlorophenol-based wood treatment formulations (Garrett and Ikonomou 2002). Past surveys on pesticide use in BC indicate that the use of PCP for wood preservation in BC is declining (148 t in 2003 compared to 789 t in 1991) (ENKON Environmental Ltd. 2005). The main use of PCP-based wood preservatives has been for the treatment of utility poles. However, BC Hydro, the major past user in the south coastal area, no longer uses PCP-treated poles. Historically, large quantities of stormwater contaminated with wood treatment chemicals (including PCP) were released to the aquatic environment in south coastal BC. However, industry initiatives, the development of environmental codes of practice, and the implementation of extensive federal inspections and enforcement programs in the 1980s have reduced discharges of contaminated stormwater by more than 90% (Environment Canada 1998a).

PBDEs are not manufactured in Canada, but are imported in a wide variety of finished products, and also for the purpose of manufacturing into finished articles. These compounds are used extensively as flame retardants in polymer resins and plastics, sealants, adhesives and coatings and are present in a variety of consumer products including furniture, stereos, televisions, computers, carpets, and curtains. Commercial mixtures, including pentabromodiphenyl ether (PeBDE), octabromodiphenyl ether (OBDE), and decabromodiphenyl ether (DBDE), contain a variety of congeners. For example, the PeBDE commercial mixture, which is used mainly in polyurethane foam in furniture and automobile upholstery, contains mainly penta-BDE, tetra-BDE, and hexa-BDE. The OBDE commercial mixture, which is used primarily in acrylonitrile-butadiene-styrene (ABS) in computers and other electronic equipment, contains mainly hepta-BDE, octa-BDE, and hexa-BDE. The DBDE commercial product contains deca-BDE, almost exclusively, and is used in high-impact polystyrene and other polymers used in manufacturing computer and television cabinets, electrical and electronic components, cables and textile coatings. PBDEs may enter the environment from manufacturing and processing operations and also as a result of the use and ultimate disposal of articles containing these compounds (Environment Canada 2006b).

PBDE loadings to the BC environment have not been estimated, but PBDEs have been detected in municipal WWTP discharges (De Boer *et al.* 2003), and the source is assumed to be the widespread use of consumer products containing these compounds. PBDEs have been detected in WWTP discharges in the Okanagan area of BC and the overall removal efficiency of PBDEs at this facility was 93%, due to sorption onto sludges. PBDE concentrations in sludges were high (approximately 2.4 µg/g (dw)) (Rayne and Ikonomou 2005). In addition, elevated concentrations of PBDEs have been detected in sediments collected off the Iona Island municipal wastewater treatment plant discharge, further indicating that wastewater effluents are a significant source of PBDEs to the BC aquatic environment (Johannessen *et al.* 2007).

Similarly, septic field inputs are thought to be a major source of PBDEs to the Columbia River, where concentrations have increased substantially in recent years. PBDE concentrations in the Columbia River are much higher than in a nearby pristine watershed, which is affected only by atmospheric deposition (Rayne *et al.* 2003).

Also, a GBAP-funded project is underway to assess sources and fate of PBDEs (and PCBs) in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin. This study involves a combination of mass balance and exchange process modeling, combined with focused sampling, to address critical data gaps identified in the modeling. Preliminary information from this study indicates that PBDEs loadings are greater than PCB loadings to the Strait of Georgia and approximately 30% of the BDE-209 loading is from municipal wastewater discharges (Macdonald et al. 2007). BDE-209 is the main ingredient of deca-BDE and is the dominant PBDE detected in the water, sediments, and air samples (Ross et al. 2008).

Over a one year period, Noël *et al.* (2007) collected air samples to determine local and background sources of PCBs and PBDEs to a remote site (Ucluelet) on western Vancouver Island and at a near-urban site (Saturna Island) in the Strait of Georgia. The deposition of PBDEs was much lower at the remote location than at the near-urban site (42%), likely due to the contribution of local sources of PBDEs to the near-urban site. It was estimated that total atmospheric inputs of PBDEs to the Strait of Georgia were 17.1 $\pm$ 6.5 kg/year (based on the values recorded at Saturna Island) compared to an estimated PCB deposition of 3.5 $\pm$ 0.7 kg/year. The authors concluded that this study supports the theory that non-North American sources make significant contributions of PBDEs to coastal BC air. They also noted that the concentrations of PBDEs in air masses moving across the Pacific Ocean could increase in the future, due to the extensive recycling and scrapping of the electronic waste which is exported to Asia from North America.

Actions initiated in other countries helped to reduce the use and release of PBDEs in Canada over the last few years. In late 2004, the only US manufacturer of PeBDE and OBDE stopped the production of these products. In addition, the European Union prohibited the marketing and use of PeBDE and OBDE in products as of August 15, 2004 (Environment Canada 2006b).

In July 2006, Environment Canada and Health Canada released the final Screening Assessment Reports (SARs) for Polybrominated Diphenyl Ethers (PBDEs; http://www.chemicalsubstanceschimiques.gc.ca/about-apropos/assess-eval/projet-pilot-project/index-eng.php). It was concluded that PBDEs (i.e., tetrabromodiphenyl ether (tetraBDE), pentabromodiphenyl ether (pentaBDE), hexabromodiphenyl ether (hexaBDE), heptabromodiphenyl ether (heptaBDE), octabromodiphenyl ether (octaBDE), nonabromodiphenyl ether (nonaBDE) and decabromodiphenyl ether (decaBDE) -- which are found in commercial PentaBDE, OctaBDE and DecaBDE technical formulations, are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity, and thus meet the criteria under paragraph 64(a) of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

In addition, it was concluded that all seven PBDE homologue groups met criteria for persistence, but only tetraBDE, pentaBDE and hexaBDE met the criteria for bioaccumulation as defined in the *Persistence and Bioaccumulation Regulations* under CEPA 1999. TetraBDE, pentaBDE and hexaBDE and were identified for virtual elimination. Since the publication of the final SARs on the PBDEs, a large amount of new information was and continues to be published on the accumulation of decaBDE in wildlife and its potential to transform to persistent bioaccumulative substances. In order to evaluate the new science on decaBDE, the Government of Canada prepared a State of Science Report on the Bioaccumulation and Transformation of DecaBDE. This report found that decaBDE may contribute to the formation of bioaccumulative, and/or potentially bioaccumulative transformation products such as lower brominated BDEs in organisms and in the environment; and found that decaBDE is available for uptake in organisms and may accumulate to high and potentially problematic levels in certain species. This State of Science Report was published for a 60 day public comment period in March 2009 (http://www.chemicalsubstanceschimiques.gc.ca/fact-fait/glance-bref/decabde-eng.php).

Following the release of the SAR in 2006, a Risk Management Strategy was published in December 2006 which consisted of the following main elements: the final Polybrominated Diphenyl Ether Regulations (PBDE Regulations), published in *Canada Gazette*, Part II, on July 9, 2008 (and came into force on June 19, 2008) which prohibit the manufacture of all seven PBDEs assessed under CEPA (tetraBDE, pentaBDE, hexaBDE, heptaBDE, octaBDE, nonaBDE and decaBDE); and the use, sale, and import of raw materials tetraBDE, pentaBDE and hexaBDE; a proposed Performance Agreement with industry, which aims to manage and reduce releases of DecaBDE from its use in plastic and textile manufacturing facilities; the development of a regulation to control PBDEs (tetraBDE, pentaBDE, hexaBDE, heptaBDE, and octaBDE) in domestic and imported manufactured products, the development of a management strategy for PBDE-containing products at end-of-life; and monitoring of Canadians' exposure to PBDEs and concentrations in the environment. Based on the draft conclusions in the State of Science report on decaBDE, a revised Risk Management Strategy for PBDEs is being proposed which incorporates controls on decaBDE in domestic and imported manufactured products.

3.2.1.3 Phthalate Esters

Phthalate esters are used extensively as plasticizers in a wide range of products including polyvinyl chloride resins, adhesives, and cellulose film coatings. Products such as food wraps, plastic tubing, floor tiles, plastic furniture, upholstery, toys, shower curtains and medical equipment obtain their flexibility from phthalate esters. These substances are also used in cosmetics, insect repellents, insecticide carriers, lacquers, propellants, and defoaming agents in paper manufacturing. While a variety of phthalate esters are used commercially, di(2-ethylhexyl) phthalate or bis(2-ethylhexyl)phthalate (DEHP) has the most extensive usage and accounts for 40 to 50% of the global use (Environment Canada/Health Canada 1993b;Environment Canada/Health Canada 1993d;Environment Canada/Health Canada 1993e;Giam *et al.* 1984;Pierce *et al.* 1980). DEHP is manufactured in eastern Canada, but a variety of phthalate esters are imported into Canada as commercial chemicals. Phthalate esters are also imported into Canada in association with manufactured products. The manufacture of phthalate esters and the manufacture, use, and disposal of products containing these chemicals can result in the entry of these substances to the environment. Other potential sources of phthalate esters to the environment include effluents from a variety of industries, WWTP discharges, CSOs, urban stormwater, stack emissions from coal-fired power plants and hazardous waste combustion, and flyash from municipal incinerators (Environment Canada/Health Canada 1993b;Environment Canada/Health Canada 1993d;Environment Canada/Health Canada 1993e;Garrett 2004).

An Environment Canada survey found that phthalate esters are used by the paints, coatings, rubber, and resin industries in BC. While the BC plastics industry did not report the use of phthalate esters as raw materials, it was assumed that this industry sector imports resin bases containing phthalate ester plasticizers (Krahn 1985a;Krahn 1985b;Sigma Resource Consultants 1985). Little information is available on sources or loadings of phthalate esters to the south coastal BC environment; however, these compounds have been identified in WWTP effluents, CSOs, and urban runoff in the

Metro Vancouver area and in WWTP discharges in the CRD. Atmospheric deposition is thought to be an important source of phthalate esters to the aquatic environment (Garrett 2002;Garrett 2004).

Four phthalate ester compounds (DBP, DEHP, DnOP, and BBP) were assessed by Environment Canada and Health Canada; however, only DEHP was found to be toxic as defined by CEPA 1999. Under the requirements of the Act, a risk management strategy must be developed for all CEPA-toxic substances. However, it was recommended that no further risk management actions be pursued for DEHP, since an identifiable link has not been established between human exposure and the manufacture/use of this substance (Environment Canada/Health Canada 1993b;Environment Canada/Health Canada 1993d;Environment Canada/Health Canada 1993e;Environment Canada/Health Canada 2000). For more information on the federal review of DEHP, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.2.1.4 Chlorinated Paraffins, Chlorinated Naphthalenes (PCNs), and Fluorinated Organic Compounds (FOCs)

Chlorinated Paraffins:

Chlorinated paraffins (or polychlorinated-n-alkanes) are chlorinated derivatives of n-alkanes with carbon chain lengths ranging from 10 to 38 carbons. Chlorinated paraffins with chain lengths of 1- to 13 carbons are termed short-chain, those with carbon chain lengths of 14 to 17 are medium-chain, and those with carbon chain lengths of 18 or more are long-chain. Short, medium, and long-chain chlorinated paraffins are imported into Canada, and one plant in Ontario produces medium and long-chain chlorinated paraffins. These substances are used primarily as plasticizers and flame retardants in plastics and in extreme-pressure lubricants (Environment Canada/Health Canada 1993c). The annual use of chlorinated paraffins in Canada was approximately 3000 t in 2000 and 2001, with most of this being used in plastics, lubricants, and metalworking.

Chlorinated paraffins enter the environment as a result of the manufacture, use, and disposal of these substances and the products containing them. The manufacture, use, and disposal of products containing chlorinated paraffins, such as polyvinyl chloride (PVC) plastics and metalworking and metal cutting fluids, can result in releases to the environment either directly or indirectly as a result of their discharge to sewer systems. Short-chain chlorinated paraffins have been detected in municipal WWTP effluents, while medium-chain compounds have been detected in sewage sludge (Alcock *et al.* 1999;Campbell and McConnell 1980;Environment Canada 2004;Iino *et al.* 2001). Medium-chain chlorinated paraffins have also been detected in effluents from a chlorinated paraffin manufacturing plant in Canada and in sediments collected downstream from the effluent discharge (Metcalfe-Smith *et al.* 1995;Muir *et al.* 1999).

Chlorinated paraffins were assessed by Environment Canada and Health Canada under the provisions of CEPA 1999 and the first assessment report on these substances was published in 1993. This report concluded that short-chain chlorinated paraffins are toxic to human health. However, the information available at that time was not sufficient to conclude whether medium- or long-chain chlorinated paraffins are toxic to human health, or whether any short-, medium- and/or long-chain chlorinated paraffins are harmful to the environment. A subsequent follow-up assessment was conducted by Environment Canada and Health Canada. As a result of this re-assessment, the Ministers of Environment and

Health announced in the Canada Gazette, on June 11, 2005, their intention to recommend that short, medium, and long chain chlorinated paraffins be added to the List of Toxic Substances in Schedule 1 of CEPA 1999 and to propose these substances for virtual elimination. Final reports and decisions relating to the toxicity of these substances are now being finalized (Environment Canada 2000b). For more information on chlorinated paraffins, refer to Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Chlorinated Naphthalenes (PCNs):

Chlorinated naphthalenes (also called polychlorinated naphthalenes or PCNs) are structurally similar to PCBs, PCDDs, and PCDFs. They are used primarily in electroplating, insulation for cables, impregnators for condensers and capacitors, refractive index testing oils, dye carriers and feedstocks for dye production, and as additives to engine oil. In the 1940s and 1950s, they were also used for wood preservation. Production of PCNs was discontinued in the US and Europe in the 1980s, due to concerns over their toxicity and environmental persistence. At that time their main use in the US was in refractive index testing oils and as dielectric fluids in capacitors. Technical formulations of PCNs may contain trace concentrations of PCBs, dioxins, and furans. PCNs may also enter the environment as a result of PCB releases, as PCNs have also been detected as micro-contaminants in commercial PCB formulations (Haglund *et al.* 1993;Kodavanti *et al.* 2001;Yamashita *et al.* 2000). While an inventory of PCBs currently in use in electrical equipment and in storage is maintained by Environment Canada, there is no similar information on the volume of PCNs contained in electrical equipment in Canada (Mendoza 2005).

Other potential sources of PCNs to the environment include effluents from municipal WWTPs and some industrial facilities (including chlor-alkali plants and mills utilizing chlorine bleaching) (Kannan *et al.* 1998a;Kannan *et al.* 2000); the chlorination of drinking water supplies (Shiraishi *et al.* 1985); waste incineration and the landfill disposal of products containing PCNs (Howe *et al.* 2001;Jarnberg *et al.* 1997); flue gas and fly ash from municipal incinerators; emissions from the incineration of chlorinated phenols, HCB and PCBs (Abad *et al.* 1999;Helm and Bidleman 2003;Iino *et al.* 2001;Imagawa and Takeuchi 1995;Kim and Mulholland 2005;Oehme *et al.* 1987); percolating water at a city dump (Jarnberg et al. 1997); and (in minor amounts) emissions from the domestic burning of coal and wood as fuel (Lee *et al.* 2005).

PCNs have not been assessed under CEPA 1999 and there are currently no regulations specifically addressing these substances.

Fluorinated organic compounds (FOCs):

FOCs are used as refrigerants, insecticides, stain repellents, paper coatings, chemical catalysts, lubricants, surfactants, pharmaceuticals, and fire-fighting foams. Polyfluorinated alkyl substances, especially the perfluorinated alkyl substances, are now receiving worldwide attention due to their widespread presence and persistence in the environment. Perfluorinated alkyl substances are those substances whose carbon atoms have been completely saturated with fluorine. The strength of the carbon-fluorine bond results in their extreme persistence in the environment. These substances do not occur naturally, but can enter the environment as a result of their manufacture and use. In addition, commercially produced substances can be transformed to other perfluorinated alkyl substances in the environment (Environment Canada 2006d;Houde *et al.* 2006;Tomy *et al.* 2004b).

Some FOCs, most commonly the perfluoroalkyl sulfonic acid, perfluorooctane sulfonate (PFOS), and the perfluoroalkyl carboxylate, perfluorooctanoic acid (PFOA), have been identified in air, water and biota worldwide and are of global concern. A use pattern survey conducted by Environment Canada in 2000 indicated that PFOS, its salts, and precursors are not manufactured in Canada, but are imported as raw chemicals and in products and manufactured items. Between 1997 and 2000, approximately 318 t of these compounds were used in Canada, primarily as stain repellents for fabric, leather, packaging, rugs, and carpets; additives in fire-fighting foams; additives in paints and coatings; and in chemical formulations. The primary North American supplier, 3M, voluntarily phased out the production and import of all perfluorooctanyl chemicals, and products containing PFOS, as of the end of 2002. However, these substances are still produced in other countries and could continue to be imported into Canada from non-US sources (Environment Canada 2006d).

Use pattern information is not currently available for PFOA. However, at EPA's request, Dupont and several other US companies agreed to take action to reduce manufacturing emissions of PFOA, to reduce by 95% the presence of this compound in consumer products by 2010, and to virtually eliminate them by 2015. Although Dupont will continue to use PFOA in the manufacture of Teflon®, they will make changes to the manufacturing methods to prevent PFOA exposure from their products (US Environmental Protection Agency (USEPA) 2009).

Environment Canada and Health Canada recently completed an ecological and human health screening assessment of PFOS, its salts and precursors under the provisions of CEPA 1999. These substances were found to be toxic as defined under CEPA 1999 (Environment Canada 2006d;Health Canada 2006b). PFOS, its salts and precursors were added to the CEPA 1999 Schedule 1 List of Toxics Substances and options for the control of these substances in Canada are now being considered. For more information on PFOS refer to Environment Canada websites http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1 and http://www.ec.gc.ca/CEPARegistry/documents/part/PFOS/s1.cfm.

In addition, four fluorotelomer-based substances were also assessed by Environment Canada and Health Canada. As a result of this assessment, Environment Canada and Health Canada announced that these substances were suspected to be toxic as defined under CEPA 1999. As a precautionary measure, Environment Canada introduced a two-year prohibition on these substances, which include PFOA, to allow new scientific data to be reviewed. These substances have now been recommended for addition to CEPA 1999 Schedule 1 List of Toxic Substances. For more information refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.2.2 Presence of New or Emerging POPs in the South Coastal BC Environment

Although limited information is available, many new and emerging POPs have been detected in both sediments and biota in the south coastal area of BC.

Alkylphenol and Alkylphenol Ethoxylates:

Available information on alkylphenol and its ethoxylates in the BC environment pertains to NP and NPnOEs. Limited sampling indicates that concentrations of these substances in sediments in south coastal BC are highest near urban centres, downstream of pulp mills, and near WWTP discharges. In the Main Stem of the Fraser River 4-NP, concentrations in suspended and bed sediments were highest downstream of the Annacis Island WWTP (mean of 0.062 µg/g (dw)). Overall, the highest concentrations were detected in the highly industrialized North Arm of the Fraser River (up to 0.064 µg/g (dw)). Stormwater runoff is thought to be an important source of NP loadings to the North Arm, and high NP concentrations were detected in creeks receiving large amounts of stormwater in urban areas of the Fraser Basin (Bennie *et al.* 1997;Brewer *et al.* 1998a;Brewer *et al.* 1998b;Sylvestre *et al.* 1998). Elevated concentrations of NPnEOs were also detected in sediment samples collected in the Sturgeon Bank area, in the vicinity of the Iona Island WWTP outfall (average concentration of 1.5 µg/g (dw). The concentration contours indicated that the WWTP was the major source of NPnEOs to this area (Shang *et al.* 1999). Other studies have also detected elevated concentrations of 4-NP in the vicinity of the Iona Island WWTP discharge and it was concluded this substance was one of the best chemical indicators of the outfall influence (Hodgins and Hodgins 2000;Paine and Chapman 2000). Dods *et al.* (2005) studied the exposure of insectivorous tree swallows breeding at the Iona Island WWTP to 4-nonylphenol (4-NP). They detected elevated concentrations of 4-NP in lagoon sediment and in insects compared to a reference site.

Halogenated Diphenyl Ethers:

Elevated concentrations of CDPEs and PBDEs have been detected in some areas of the south coastal BC environment. Concentrations of CDPEs in the thousands of pg/g range were detected in sediments, fish, and aquatic invertebrates from Vancouver, Victoria, and Esquimalt harbours. However, CDPEs were not detected in sediments and rock sole collected from coastal reference sites. Since, CDPEs were common micro-contaminants of the chlorophenol-based wood treatment chemicals, which were once very widely used in the south coastal area of BC, it is likely that elevated CDPE concentrations occurred in past high-use areas. In agreement with findings for other areas, the higher chlorinated CDPE isomers predominated in BC sediments and biota. No information on CDPE concentrations in BC birds or aquatic mammals was available (Garrett and Ikonomou 2002).

PBDEs have been detected in water, sediment, biota, air, and precipitation samples collected in the Strait of Georgia (Christensen *et al.* 2005;Dangerfield *et al.* 2007;Elliott *et al.* 2005;Hale *et al.* 2006;Ikonomou and Addison 2008;Ikonomou *et al.* 2002;Johannessen *et al.* 2007;Noël *et al.* 2007;Rayne *et al.* 2004). In general, concentrations were highest in harbour areas and near municipal WWTP discharges. Johannessen *et al.* (2008) reported that the PBDE concentrations near the Iona Island wastewater outfall (12,647 pg/g) were much higher than concentrations detected elsewhere in the Strait of Georgia (270 to 1800 pg/g). At other locations in the Strait of Georgia, the ranges of concentrations for PCBs (507 to 2910 pg/g) and PBDEs (271 to 1793 pg/g) in surface sediments were similar. However, the authors predicted that PBDEs will dominate in the next decade, due to the slowly decreasing concentrations of PCBs and the increasing concentrations of PBDEs. PBDE concentrations in biota were also higher in urban areas than in reference sites. For example, PBDE levels in the hepatopancreas tissue from Dungeness crab collected near industrialized and urban locations on the BC coast were 200 to 480 ng/g lipid weight (lw) compared to 4.2 ng/g (lw) in crabs from a reference site (Ikonomou et al. 2002). Similarly, PBDE concentrations were much higher in mussels and sediments collected near the Capital Regional District's Clover Point municipal wastewater outfall than in mussels collected from a reference area (DeBruyn *et al.* 2009).

PBDEs have also been detected in several fish species in BC including whitefish from the Columbia River (Rayne et al. 2003), Pacific herring from the Georgia Basin (Cullon et al. 2005), wild Pacific salmon and farmed salmon (Christensen *et al.* 2005;Hites *et al.* 2004b), and sole from the west and east coasts of Vancouver Island (Ikonomou et al. 2002).

Hites *et al*. (2004b) tested farmed salmon from several areas of the world and several species of Pacific salmon for PBDEs. They reported that, in general, farmed salmon contained higher PBDE concentrations than did wild Pacific salmon and BDE 47 was the dominant isomer. However, the highest concentrations (average concentration >4 ng/g (ww)) were detected in wild BC chinook salmon. BC chinook contained higher PBDE levels than did wild chinook salmon from Oregon or any other species of Pacific salmon tested. Based on limited sampling, total PBDE concentrations in Fraser River chinook (approximately 17 ng/g (ww)) were higher than in chinook from the Duwamish River in Washington State (6.43 ng/g (ww)) (Cullon et al. 2009). However, other studies found that PBDE concentrations were higher in chinook salmon and Pacific herring from Puget Sound than from the Strait of Georgia (Puget Sound Action Team (PSAT) 2007).

Christensen *et al.* (2005) reported that grizzly bears on the BC coast contained 1.12 to 53.47 ng/g (lw) PBDEs. Bears living on the coast, and consuming primarily salmon, were dominated by the more bioaccumulative lower chlorinated BDE-47 isomer, while bears living inland, and consuming a higher proportion of vegetation, were dominated by the heavier PBDE isomers such as BDE-209. The authors estimated that salmon contributed 85% of the lower brominated PBDEs in the grizzly bears feeding on salmon.

The fish-based diet of marine mammals is also thought to contribute significantly to the high concentrations of many POPs, including PBDEs, which have been detected in BC marine mammals including killer whales (several hundred ng/g (lw)) (Rayne et al. 2004), harbour porpoises (350 to 2300 ng/g (lw)) (Ikonomou et al. 2002), and harbour seals (>300 ng/g (lw) in the Strait of Georgia and <20ng/g (lw) in Quatsino Sound) (Ikonomou and Addison 2008).

Similarly, PBDEs and other POPs have been detected in many species of fish-eating birds in BC. Environment Canada analyzed POPs concentrations in great blue heron eggs from the Fraser River estuary, double-crested cormorant eggs from the Strait of Georgia, osprey eggs from the lower Fraser River, and Leach's storm petrel eggs from the Queen Charlotte Islands for the purpose of analyzing trends over the last twenty to thirty years. Heron eggs collected in the Fraser River estuary in 2002 contained the highest concentrations of PBDEs. Concentrations in cormorant and osprey eggs were approximately half the level in heron eggs (mean of 455 ng/g (ww)). Very low concentrations were detected in storm petrel eggs. Over the time period examined, the concentrations of PBDEs in heron and cormorant eggs increased substantially, while the concentrations of PCBs and DDE remained stable or decreased (Elliott et al. 2005). PBDEs have also been detected in the blood of nestling BC bald eagles collected from nests at freshwater lake sites in the Northern Interior, coastal freshwater sites in the Fraser Valley, inshore marine sites in the Strait of Georgia, marine sites from western Vancouver Island, and northern offshore marine sites at Johnstone Strait and Haida Gwaii (Elliott *et al.* 2009).

Phthalate Esters:

Due to their widespread use, phthalate esters are ubiquitous in the environment. However, environmental samples can also become contaminated during collection and/or analysis as phthalate esters can also occur as contaminants in laboratory air and reagents as well as in analytical and sampling equipment. In recent years, greater emphasis has been placed on ensuring that samples are not contaminated during collection or analysis and recent information on phthalate ester concentrations in the environment is considered to be more reliable. However, care must be taken in the interpretation of all analytical results for phthalate esters (Hites and Budde 1991;Ishida *et al.* 1980;Kohli *et al.* 1989;Pierce *et al.* 1980). Problems associated with sample contamination have been documented in surveys conducted in BC (Swain and Walton 1990); however, blank-corrected data revealed the presence of several phthalate ester compounds in the south coastal environment. Phthalate esters were detected in sediment and aquatic biota collected from the Fraser River, False Creek, and Vancouver, Victoria, Esquimalt, and Ladysmith harbours.

Phthalate esters were also detected in surf scoters from Burrard Inlet (Wilson and Elliott 2004). However, no information was available on the presence of phthalate esters in marine mammals or in wild salmon.

Canadian sediment quality guidelines have not yet been developed for phthalate esters. However, the concentrations of select phthalate ester compounds in some sediment samples from the south coast of BC exceeded the non-regulatory apparent effects threshold (AET) values for Puget Sound and also the Puget Sound Dredged Disposal Analysis Sediment Quality screening levels (Garrett 2002;Mackintosh *et al.* 2004;Paine and Chapman 2000).

Chlorinated Naphthalenes (PCNs) and Chlorinated Paraffins:

PCNs have been detected in sediments, fish, birds, and marine mammals in several countries (Asplund *et al.* 1990;Cooke *et al.* 1980;Corsolini *et al.* 2002;Falandysz *et al.* 1996;Helm *et al.* 2002;Herbert *et al.* 2005;Ishaq *et al.* 2000;Jarnberg *et al.* 1993;Jarnberg *et al.* 1999;Kannan *et al.* 2000;Koistinen *et al.* 1989;Lundgren *et al.* 2002;World Health Organization (WHO) 2001). Locally, these substances have been detected in Vancouver Island marmots and in southern resident, northern resident, and transient killer whales frequenting coastal BC (Lichota *et al.* 2004;Rayne *et al.* 2004). Information on current levels of PCNs in BC coastal sediments, fish, and aquatic invertebrates is lacking.

Short-, medium, and/or long-chain chlorinated paraffins have been detected in surface waters, sediments, fish, invertebrates, and marine mammals in Canada and in other areas of the world. Concentrations of these substances are typically highest in urban areas and in the vicinity of facilities manufacturing these substances (Bennie *et al.* 2000;Campbell and McConnell 1980;Drouillard *et al.* 1997a;Drouillard *et al.* 1997b;Jansson *et al.* 1993;Marvin *et al.* 2003;Metcalfe-Smith *et al.* 1995;Muir *et al.* 2001;Muir *et al.* 1999;Reth *et al.* 2005;Tomy *et al.* 1998;Tomy *et al.* 1999;Tomy *et al.* 1997). No information is available on the presence of chlorinated paraffins in the BC environment.

Fluorinated organic compounds (FOCs)

Fluorinated organic compounds have been detected in water, sediments, biota, and humans throughout the world, including the Great Lakes and Arctic regions of Canada. Of particular concern are the perfluorinated alkyl substances, including the perfluoroalkyl sulfonate acids (PFSAs) and the perfluorocarboxylates (PFCAs). PFOS is the most commonly detected substance in biota; however long-chain PFCAs (containing more than 8 carbons) and PFSAs, with 4 to 10 carbons, have also been detected. In some species, such as northern fulmars, beluga whales, and dolphins, the proportions of some PFCAs were similar to, or greater than, those of PFOS. Some substances, including PFOS and PFCAs with 8 to 12 carbons, biomagnify through food webs and reach elevated concentrations in species at the higher trophic levels. Environmental concentrations of perfluorinated alkyl substances are highest in urban areas.

Temporal trend studies indicate that concentrations of PFOS, PFSAs, and/or PFCAs have increased over time in biota from many regions of the world including lake trout in Lake Ontario, guillemot eggs from the Baltic Sea, thick-billed murres and northern fulmars from the Canadian Arctic, polar bears from North Baffin Bay, ringed seals from Greenland, and the livers of ringed seals and beluga whales from the Canadian Arctic (Bossi *et al.* 2005;Butt *et al.* 2005;Holmstrom *et al.* 2005;Houde *et al.* 2006;Kannan *et al.* 2001a;Kannan *et al.* 2001b;Smithwick *et al.* 2006;Solomon and Muir 2006;Tomy *et al.* 2005).

No information is available on the environmental levels of fluorinated organic compounds (FOCs) in the BC environment.

3.2.3 Environmental Concerns and Potential Biological Impacts of New or Emerging POPs

Like the conventional or legacy POPs, several of the new and emerging POPs are persistent in the environment, have the potential to bioaccumulate, and are toxic to a wide variety of organisms. Some of these substances have been assessed under the mandate of CEPA 1999 and have been found to be toxic, as defined by the Act. New or emerging POPs which have been added, or are in the process of being added, to the CEPA 1999 Schedule 1 List of Toxic Substances include NP and NPnEOs, PBDEs, DEHP, chlorinated paraffins, PFOS, and four fluorotelomer-based substances. The Schedule 1 List of Toxic Substances can be viewed at http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm.

Alkylphenol and Alkylphenol Ethoxylates:

Alkylphenol (AP) compounds have a wide range of physical and chemical properties which determine their environmental fate, and relatively few of these compounds have been well studied. While some APs are water soluble and tend to remain in the aqueous phase, others bind to particulates and accumulate in the sediments. Biodegradation in the environment can result in the formation of degradation products which are more persistent than the parent compounds. For example, while the biodegradation of NPnEOs occurred quite rapidly in the environment, NP and some of the ethoxylated and carboxylated degradation products were more persistent than the parent compounds, particularly under anaerobic conditions (Ahel *et al.* 1994b;Environment Canada/Health Canada 2001;Maguire 1999;Maki *et al.* 1994).

Several studies have demonstrated the rapid uptake and elimination of NP and its ethoxylates in aquatic organisms. Bioconcentration factors ranging from 3 to more than 3,000 have been reported (Ahel *et al.* 1993;Brooke 1993;Ekelund *et al.* 1990;Grammo *et al.* 1991;McLeese *et al.* 1981;Wahlberg *et al.* 1990;Ward and Boeri 1991). Acute toxicity has been observed in fish and aquatic invertebrates exposed to NP in the 17 to 3,000 µg/L range. Impairment of reproduction, growth, fecundity, and photosynthesis has been observed in aquatic organisms exposed to concentrations below the acutely toxic range (Environment Canada/Health Canada 2001). APs and APnEOs bind to estrogen receptors and cause estrogenic responses in aquatic organisms at exposure concentrations comparable to those causing other chronic effects (Environment Canada/Health Canada 2001;Jobling *et al.* 1996;Nimrod and Benson 1996). Lerner *et al.* (2007a) reported that exposure of juvenile Atlantic salmon to 4-NP and other environmental estrogens can increase sensitivity to stress, impair ion regulation, and disrupt endocrine pathways which are critical for smolt development.

Dods *et al.* (2005) studied the exposure of insectivorous tree swallows breeding at the Iona Island WWTP to 4-NP. The authors detected higher concentrations of 4-NP in insects and lagoon sediments at the WWTP compared to a reference site. In addition, clutch size and fledgling success were lower in the swallows from the WWTP compared to a reference site; however, the authors noted that further work is needed to determine whether there is a link between 4-NP exposure and effects on riparian insectivorous birds.

Canadian environmental quality guidelines for NP and its ethoxylates, for the protection of freshwater and marine aquatic life, have been developed for water and interim guidelines have been developed for sediment (Canadian Council of Ministers of the Environment (CCME) 2006). The guidelines for fresh and marine waters are 1.0 and 0.7 µg/L, respectively. Interim guidelines for fresh and marine sediments are 1.4 and 1.0 µg/g (dw) (at total organic carbon (TOC) of 1%), respectively. For more information on Canadian environmental quality guidelines, refer to the CCME website http://ceqg-rcqe.ccme.ca/.

Halogenated Diphenyl Ethers:

The environmental persistence of CDPEs has not been well studied; however, they are similar in both physical and chemical properties to some of the highly persistent chlorinated organic compounds. They can also be thermally and photochemically converted to dioxin and furan compounds. CDPEs have low water solubilities and tend to accumulate in bottom sediments; however, they are readily taken up by, and slowly eliminated from, aquatic organisms. BCFs of several hundred to 1,000 have been reported for some species. CDPEs are considered to be moderately to highly persistent in fish (more persistent than dioxins and furans, but less persistent than PCBs). This has led to speculation that biomagnification through the food chain may occur (Choudhry *et al.* 1977a;Choudhry *et al.* 1977b;Choudhry *et al.* 1982;Kanetoshi *et al.* 1988a;Kanetoshi *et al.* 1988b;Lindahl and Rappe 1980;Nilsson *et al.* 1974;Norstrom *et al.* 1977).

PBDEs have been detected in the environment worldwide and have received considerable attention in recent years. This interest was triggered by the discovery that the concentrations of these substances have increased markedly in recent decades and are continuing to increase. The increasing concentrations of PBDEs in Arctic regions indicate that they are capable of long-range transport. PBDEs are resistant to biodegradation in the environment and decaBDE can persist in anaerobic sediments for up to two years. Tetrato hexaBDEs have BCFs of up to several thousand and elevated concentrations of tetra- and pentaBDEs have been detected in marine mammals in Canada. The large molecular size of the more highly brominated compounds (hepta- decaBDE) likely limits their bioconcentration potential. However, the presence of these substances in fish, mammals, and bird eggs indicates that uptake of some of the more highly brominated PBDEs is occurring (Environment Canada 2006b).

There are currently no Canadian environmental quality guidelines for CDPEs or PBDEs.

Phthalate Esters:

The fate of phthalate esters in the environment is determined largely by the length of the carbon (alkyl) chain in the molecule. In general, phthalate esters have low water solubility and tend to adsorb to particulate matter in aquatic systems. Photolysis and hydrolysis are ineffective degradation processes; however, microbial degradation occurs under both aerobic and anaerobic conditions. Lower molecular weight phthalate esters degrade more quickly than the higher molecular weight compounds. Although accumulation of phthalate esters has been observed in a variety of aquatic organisms worldwide, it has been reported that some laboratory studies may have overestimated the potential of these substances to bioaccumulate. In general, BCFs are higher for species at the lower end of the food chain, since their ability to metabolize these substances is less than that of the higher trophic level species. BCFs are typically higher for algae, intermediate for invertebrates, and lower for fish. For this reason, it has been suggested that biomagnification through the food chain is unlikely, but studies to confirm this are lacking (Al-Omran and Preston 1987;Brown and Thompson 1982;Carr *et al.* 1997;Staples *et al.* 1997b;Tarr *et al.* 1990;Wofford *et al.* 1980;Wolfe *et al.* 1980a;Wolfe *et al.* 1980b;Yan *et al.* 1995).

The more soluble low molecular weight phthalate esters are more toxic to aquatic organisms than are the higher molecular weight compounds. Low molecular weight substances such as dimethyl phthalate (DMP), diethyl phthalate (DEP), di-n-butyl phthalate (DBP), and butylbenzylphthalate (BBP) are acutely toxic to aquatic organisms at concentrations in the µg/L to mg/L range, while the higher molecular weight substances, such as DEHP and diisodecyl phthalate (DiDP), are not toxic at concentrations that approach their solubility in water. Chronic exposure of aquatic organisms to phthalate esters can cause decreased growth and development, reduced locomotor activity, impaired reproduction and fertility, and alterations in steroid metabolism. Some phthalate ester compounds have also demonstrated weak estrogenic activity (Adams *et al.* 1995;Defoe *et al.* 1990;Parkerton and Konkel 2000;Rhodes *et al.* 1995;Staples *et al.* 1997a;Staples *et al.* 1997b).

Canadian interim water quality guidelines for the protection of freshwater aquatic life are 16 µg/L for DEHP and 19 µg/L for DBP. Guidelines have not yet been developed for marine waters or for sediments (Canadian Council of Ministers of the Environment (CCME) 2006). For more information on Canadian environmental quality guidelines, refer to the CCME website http://ceqg-rcqe.ccme.ca/.

Chlorinated Paraffins:

The environmental fate of chlorinated paraffins has not been well studied; however, these substances have been detected in the environment worldwide. Although chlorinated paraffins do not readily volatilize to the atmosphere, the presence of short-chain chlorinated paraffins in Arctic regions indicates that they are capable of long-range transport (Tomy *et al.* 2000). Chlorinated paraffins are not readily biodegradable in the environment and degradation is influenced by the acclimatization of the microbes, the chain length of the compound, and the degree of chlorination. The rate of degradation is slower for highly chlorinated compounds and for medium and long-chain compounds. It has been estimated that both short- and medium-chain chlorinated paraffins have a half-life of more than one year in lake sediments. Studies on long-chain forms are lacking; however, their physical and chemical properties indicate that they would also persist in bottom sediments.

Chlorinated paraffins readily accumulate in aquatic organisms, with short-chain and lower chlorinated compounds being accumulated to a greater extent than the higher chlorinated and medium to long-chain compounds. BCFs of several thousand have been reported for both fish and invertebrates exposed to short-chain compounds. In addition, it has been suggested that chlorinated paraffins may have the potential to biomagnify in the aquatic food chain (Fisk *et al.* 1996;Fisk *et al.* 1998;Marvin *et al.* 2003).

The short-chain compounds are more toxic to aquatic species than are the medium and long-chain compounds and adverse effects have been observed in fish and invertebrates exposed to concentrations of less than 1 µg/L. In addition, cancer has been observed in experimental animals exposed to short-chain chlorinated paraffins (Environment Canada 2000b;Environment Canada 2004;Environment Canada/Health Canada 1993c;Health Canada 2003;World Health Organization (WHO) 1996).

Canadian environmental quality guidelines have not yet been developed for chlorinated paraffins.

Chlorinated Naphthalenes:

PCNs are also widespread and persistent environmental contaminants. These substances, especially the more highly chlorinated congeners, bind to particulates and accumulate in the bottom sediments. Although information on the atmospheric transport and deposition of PCNs is lacking, there is evidence that these substances reach Arctic and Antarctic regions through long-range transport. Lower chlorinated congeners have a greater potential for volatilization and atmospheric transport than do the higher chlorinated congeners (Corsolini *et al.* 2002;Harner *et al.* 1998;Helm *et al.* 2004).

BCFs of PCNs range from moderate to high, depending on the degree of chlorination of the molecule. BCFs of several thousand to tens of thousands have been reported for some of the lower chlorinated PCNs (Oliver and Niimi 1984;Oliver and Niimi 1985;Opperhuizen *et al.* 1985). Tetra- and pentachloronaphthalenes are among the dominant congeners detected in species from all trophic levels. However, organisms at the higher levels of the food chain tend to concentrate the more highly chlorinated homologues. While several individual PCN congeners are accumulated to a lesser extent by higher trophic level species, there is evidence that some congeners are biomagnified. The bioaccumulation of hepta- or octo-chlorinated congeners is impeded by the large size of these highly chlorinated molecules, which makes it more difficult for them to permeate biological membranes. However, hepta-congeners have been detected in some fish (Falandysz *et al.* 1996;Ishaq *et al.* 2000;Lundgren and Tysklind 2002;World Health Organization (WHO) 2001).

Some PCN congeners can cause toxic effects similar to those of dioxins. In addition, enzyme induction tests indicate that some of the more highly chlorinated PCN congeners (especially the 2,3,6,7- chlorine substituted compounds) have relative potencies comparable to, or higher than, many of the non- and mono-ortho substituted PCBs (Blankenship *et al.* 2000). Acute toxicity has been observed in aquatic organisms exposed to µg/L to low mg/L concentrations of PCNs (Abernethy *et al.* 1986;Buccafusco *et al.* 1981;Green and Neff 1977;Heitmuller *et al.* 1981;United States Environmental Protection Agency (USEPA) 1980;Ward *et al.* 1981). In general, the tri- to hexachlorinated naphthalenes are more toxic than octochlorinated naphthalene, which is not readily bioaccumulated.

Laboratory tests have shown that PCNs are toxic to salmon. Baltic salmon fed PCN-contaminated food exhibited hepatotoxicity, induction of EROD activity, delayed development, and impaired ovaries (Akerblom *et al.* 2000).

Canadian environmental quality guidelines have not yet been developed for PCNs.

Fluorinated Organic Compounds:

Fluorinated organic compounds, including perfluorinated alkyl substances, have been detected in a variety of environmental media throughout the world. The environmental fate, distribution, and transport of these substances are not well understood (Houde et al. 2006), but the available information indicates potential environmental concerns. This has led to global attention and has prompted some governments to take action to limit the use and/or release of these substances. To date, the FOCs which have received the most attention are the perfluoroalkyl substances, PFOS and PFOA. The strength of the carbon-fluorine bonds of perfluorinated alkyl substances make these substances extremely persistent in the environment, since they resist both metabolism and degradation (Martin *et al.* 2003a;Martin *et al.* 2003b). Most of the available information on environmental fate pertains to PFOS and studies on other perfluorinated alkyl substances are limited. PFOS persists for more than 285 days in water microcosms under natural environmental conditions (Boudreau *et al.* 2003). The estimated half-life for PFOS is more than 41 years; however, the actual half-life may be much longer (Hekster *et al.* 2003).

These substances have been detected in Arctic regions (Smithwick *et al.* 2005;Tomy *et al.* 2004a); however, their presence was unexpected since the chemical and physical properties of these substances indicate that they would not be readily transported by long-range atmospheric transport (Hurley *et al.* 2003;Tomy *et al.* 2004b). It has been suggested that the more volatile and environmentally mobile precursors of these substances are transported to Arctic regions, where they are then transformed to PFOS and PFOA (Smithwick *et al.* 2005;Tomy *et al.* 2004b). PFOS is detected more frequently in the environment, and at higher concentrations, than are other FOCs (Bossi *et al.* 2005;Giesy and Kannan 2001;Kannan *et al.* 2002a;Kannan *et al.* 2001a;Kannan *et al.* 2002b;Kannan *et al.* 2001b;Smithwick *et al.* 2005;Van de Vijver *et al.* 2004;Verreault *et al.* 2005). Biomagnification in the Arctic food chain has been reported (Martin *et al.* 2004;Tomy *et al.* 2004a;Van de Vijver *et al.* 2003a;Van de Vijver *et al.* 2003b).

Although, unlike other POPs, this substance does not accumulate in the fat tissue of aquatic species, elevated concentrations have been detected in the blood and liver of many species, particularly fish-eating species at higher trophic levels (Giesy and Kannan 2001;Martin *et al.* 2003a;Martin *et al.* 2003b;Martin *et al.* 2004;Smithwick *et al.* 2005;Tomy *et al.* 2004a). Perfluoroalkyl substances with chain lengths of more than six carbons can bioconcentrate in fish. However, since perfluoroalkyl substances do not accumulate in lipids, it has been suggested that K_{ow} is not an appropriate predictor for bioaccumulation potential. BCFs of up to several thousand have been reported for PFOS in fish (Martin *et al.* 2003a;Taniyasu *et al.* 2003).

Information on the toxicity of FOCs is limited and most of the available information relates to PFOS. PFOS causes a variety of adverse effects in both aquatic and terrestrial species including inhibition of growth, thymus atrophy, histopathological effects, and increased mortality. The lowest reported no-observed-effect concentration (NOEC) for aquatic species was 0.086 mg/L, based on a study with bluegill (*Lepomis macrochirus*) (Environment Canada 2006d). NOEC values for other aquatic species, based on a variety of endpoints, were in the low mg/L range (Boudreau *et al.* 2002;Boudreau *et al.* 2003). Sublethal effects, such as reduced growth and reproduction and embryo teratogenesis, were also observed in fish and aquatic invertebrates exposed to low mg/L concentrations of PFOS (Environment Canada 2006d). NOEC values in the low mg/L or µg/g range were reported for birds and mammals, based on dietary studies (Environment Canada 2006d). Available information indicates that the PFOS precursors cause toxic effects at concentrations similar to PFOS (Health Canada 2006b). Although information is limited, birds and mammals likely have a greater ability to biotransform PFOS precursors to PFOS than do organisms at lower trophic levels. The potential effects of long-term exposure to FOCs have not been studied; however, it has been suggested that both PFOS and PFOA may function as hepatocarcinogens. In addition, the US Environmental Protection Agency has expressed concern that human fetuses may be exposed to PFOA concentrations high enough to cause adverse effects (Renner 2005).

Canadian environmental quality guidelines have not yet been developed for perfluorinated alkyl substances or other FOCs.

3.3 Current-Use Pesticides

3.3.1 Sources and Usage of Current-Use Pesticides in the South Coastal BC Environment

The mild climate and fertile soils of BC's south coast make this region suitable for growing a wide range of crops. The diverse agriculture industry, combined with an extensive forestry sector and widespread urbanization, result in the use of a wide range of pesticides to control crop-specific diseases, insect problems, and the growth of unwanted vegetation.

In some situations, pesticides are intentionally applied directly to aquatic systems for the control of mosquito larvae or unwanted aquatic vegetation. In areas adjacent to water bodies, overspraying during aerial application of both forestry and agricultural pest control products can also result in the direct entry of pesticides to aquatic systems. However, a wider variety of pest control products reach surface waters indirectly as a result of surface runoff from treated areas, stormwater discharges, groundwater infiltration, and atmospheric deposition. Several current-use pesticides (CUPs) have been detected in both agricultural and urban streams in the south coastal region of BC.

Surveys of pesticide sales and use in BC were conducted under contract to Environment Canada and BC Ministry of Environment (MOE) in 1991, 1995, 1999, and 2003

(ENKON Environmental Ltd. 2001;ENKON Environmental Ltd. 2005;Norecol 1993;Norecol, Dames and Moore Ltd. 1997). These surveys help to identify the trends in pesticide use in BC. Based on the most recent inventory (2003), the top twenty pesticides sold or used in BC are presented in Table 2.

Table 2 The Top Twenty Pesticides Sold or Used in BC in 2003 (from ENKON Environmental Ltd. 2005)[1]

Pesticide Active Ingredient	Pesticide Type	Quantity (kg)
Creosote	Anti-microbial	2,163,142
CCA	Anti-microbial	824,100
Mineral Oil	Insecticidal or adjuvant	317,108
Didecyl dimethyl ammonium chloride	Anti-microbial	174,606
Pentachlorophenol	Anti-microbial	147,684
Glyphosate - Trimethylsulfonium salt	Herbicide	120,724 5,545
Bacillus thuringiensis Berliner ssp.*kurstaki*	Insecticide	85,765
ACQ	Anti-microbial	74,448
Sulphur	Fungicide	73,408
Bacillus thuringiensis, Serotype H-14	Insecticide	39,153
Mancozeb	Fungicide	34,888
Chlorothalonil	Fungicide	33,505
Metam	Fumigant	28,582
Diazinon	Insecticide	27,074
Captan	Fungicide	25,500
Disodium octaborate tetrahydrate	Anti-microbial	24,679
MCPA a) amine salts b) esters c) potassium or sodium salt	Herbicide	23,598 (total) 9,125 12,810 1,663
Mineral oil	Herbicide	23,575
Formaldehyde	Anti-microbial	21,822
Lime sulphur	Fungicide	20,524
Copper oxychloride (as Cu)	Fungicide	19,562

[1] This list does not include domestic-use pesticides

Information on the quantities of various pesticide types sold in 2003, and their contribution to total pesticide sales in BC, is summarized in Table 3. By far, the greatest volume of pesticides sold in BC (approximately 72%) is used as anti-microbials for wood preservation and antisapstain treatment of cut lumber.

Table 3 Pesticide Types used in BC in 2003 (from Brimble *et al.* 2005;ENKON Environmental Ltd. 2005)

Pesticide Type	Quantity Sold (kg)*	Proportion of Total Pesticide Sales (%)
Anti-microbials	3,344,531	71.67
Insecticides	408,662	8.76
Fungicides	304,682	6.53
Herbicides	286,423	6.14
Other**	322,411	6.91

* Based on active ingredient
** Includes fumigants, growth regulators, soil fumigants, molluscicides, vertebrate control products, adjuvants and surfactants

Under the BC *Integrated Pest Management Act*, pesticides are divided into five classes:

i.) Permit-restricted – pesticides requiring a permit for purchase and/or application

ii.) Restricted – pesticides requiring a pesticide applicator licence for purchase and/or use

iii.) Commercial – pesticides with a Commercial Product classification on the label

iv.) Domestic – pesticides intended for use by non-professionals in private homes and gardens

v.) Excluded – pesticides whose use and/or sale does not require any licence, certification, or permit because the exclusion of these products from registration is not considered to increase the risk of unreasonable adverse effects

Pesticides classified as Restricted are those with high toxicity, or other characteristic, which makes them of concern to human and/or environmental health. Restricted and Commercial use label products are considered to be Reportable pesticides. These pesticides are used for both agricultural and industrial applications.

The top 20 Reportable pesticides, and the quantities of these pesticides used in BC in reporting years 1991, 1995, 1999, and 2003, are listed in Table 4 (ENKON Environmental Ltd. 2005). Mineral oil (insecticidal or adjuvant), glyphosate, sulphur, and mancozeb were among the top five active ingredients sold in BC in all four survey periods. Glyphosate and metam were among the top three pesticides used by nursery growers in 2003 (ENKON Environmental Ltd. 2005).

Of the pesticides listed in Table 4, only one, methyl bromide, is classified as a Restricted pesticide. Methyl bromide is used as a structural fumigant. According to information collected during the BC pesticide sales survey, this pesticide is used to treat grain terminals in Vancouver Harbour, and possibly rail cars. However, information obtained by surveys on the quantity of methyl bromide used/sold in BC is considered to be inaccurate as a significant quantity of this pesticide is purchased outside BC (ENKON Environmental Ltd. 2005).

Table 4 Top 20 Reportable Pesticides (and Other Selected Reportable Pesticides) Sold in BC in 1991, 1995, 1999, and 2003 (from ENKON Environmental Ltd. 2005)

Active Ingredient	Total Sales (kg)			
	2003	1999	1995	1991
Mineral Oil (insecticidal or adjuvant)	317,108	261,845	206,440	162,245
Glyphosate	120,724	135,573	124,698	110,157
Sulphur	73,408	36,393	26,319	28,101
Bacillus thuringiensis, Serotype H-14	39,153	21,875	11,270	3,188
Mancozeb	34,888	44,682	41,907	29,511
Chlorothalonil	33,505	26,640	15,871	3,721
Metam	25,582	30,855	20,422	27,437
Diazinon	27,074	24,563	22,552	19,643
Captan	25,500	27,498	29,160	28,451
Mineral oil (herbicidal or plant growth regulator	23,575	35,260	25,215	38,540
Formaldehyde	21,822	25,495	14,342	3,007
Lime sulphur or calcium polysulphide	20,524	10,851	20,565	8,835
Copper oxychloride (as Cu)	19,562	14,699	16,316	10,202
Bacillus thuringiensis Berliner ssp. *kurstaki*	17,608	17,895	12,283	3,095
Metiram	15,293	23,890	20,874	27,618
2,4-D Amine	14,756	13,903	12,340	12,327
MCPA esters	12,810	10,847	7,697	4,973
Carbaryl	12,363	9,271	8,984	7,274
Atrazine	11,535	9,991	10,928	22,898
Methyl bromide*	9,948	9,353	21,888	21,958
Soap (insecticidal)	6,846	3,599	2,405	1,033
Malathion	4,658	6,691	6,523	12,094
Triallate	2,248	3,289	5,958	20,584
Ethalfluralin	1,546	2,289	5,033	26,917
Sodium metaborate tetrahydrate	37.5	8,773	29,020	14,259
Metolachlor	29.9	5,621	6,807	10,727

* Information for methyl bromide is not considered to be accurate due to the fact that significant quantities of this pesticide are purchased outside BC.

Survey results indicate that the sales of Restricted pesticides decreased in BC by 63% between 1991 and 2003 (ENKON Environmental Ltd. 2005). Federally-labelled Restricted pesticides sold in BC between 1991 and 2003 are listed in Table 5.

Table 5 Sales of Restricted Pesticides in BC from 1991 to 2003 (from ENKON Environmental Ltd. 2005)

Active Ingredient	Pesticide Type	Sales in kg			
		1991	1995	1999	2003
4-Aminopyridine	Rodenticide	0.07	0.21	0.47	0.011
Aluminum phosphide	Insecticide	200	736	151	196
Amitraz	Insecticide	0	69.3	32.7	14.6
Azinphos-methyl	Insecticide	17,820	21,804	10,595	6,499
Bendiocarb	Insecticide	346	216	118	60.7
Capsaicin/Oleoresin capsicum	Rodenticide	0	0.73	0.51	0.088
Carbofuran	Insecticide	1,021	997	478	484
Copper triethanolamine complex	Fungicide	276	96.5	24	0
Dinoseb		7,233	6	48	0
Disulfoton	Insecticide	702	556	343	0
Fensulfothion		211	0	0	0
Fonofos	Insecticide				12
Formetanate hydrochloride		14.7	59.3	55.2	0
Methamidophos	Insecticide	2,947	1,910	1,500	984
Methyl bromide*	Fumigant	21,958	21,888	9,353	9,948
Oxamyl	Insecticide	141	2,027	658	698
Oxyfluorfen	Herbicide	184	234	180	209
Parathion	Insecticide	4,054	4,125	3,792	203
Phorate		878	0	0	0
Propetamphos	Insecticide	16.3	7.59	4.18	31.2
Pyrazophos		12	9	0	0
Strychnine	Rodenticide	61.1	49.2	30.01	47
Sulfotep		2,131	3,665	1,593	0
Terbufos	Insecticide	143	585	2,405	3,210
Triadimefon		13.5	0	0	0
Water soluble dyes	Herbicide	149	48.6	25.2	18.7

* Information for methyl bromide is not considered to be accurate due to the fact that significant quantities of this pesticide are purchased outside BC.

A number of recent initiatives within the Georgia Basin and Puget Sound have resulted in the development of lists of chemical contaminants, including pesticides, which are of potential concern when released to these shared waters. These lists include:

i.) the “Substances of Interest List for the Lower Fraser River and the Georgia Basin”, which was based on a list of substances developed by member agencies of the British Columbia Toxics Work Group reporting to the Puget Sound/Georgia Basin Task Force (Garrett 2004;Garrett 2009). The first draft of this list was originally prepared in 1998 under the Georgia Basin Ecosystem Initiative;

ii.) a list of contaminants of concern in the Puget Sound, which was prepared under contract for the US National Oceanic and Atmospheric Administration (NOAA), for consideration by the Puget Sound/Georgia Basin International Task Force (ENKON Environmental Ltd. 2005);

iii.) a list of contaminants whose presence in the environment could pose a health risk to southern resident killer whales, prepared by (Grant and Ross 2002;Johannessen and Ross 2002); and

iv.) a list of contaminants whose presence in the environment may pose a risk to late-run sockeye salmon, prepared by (Grant and Ross 2002;Johannessen and Ross 2002).

Past pesticide sales surveys for BC indicate that forty of the pesticide active ingredients on the Reportable pesticides list (Table 4), appear on one or more of the above lists (ENKON Environmental Ltd. 2005). These active ingredients (listed in Table 6) account for 17.8% of the total pesticides sold in the Georgia Basin in 2003. Eight of these active ingredients (atrazine, simazine, chlorpyrifos, malathion, metolachlor, endosulfan, trifluralin, and lindane) were found on two or more of the above lists, and accounted for 5.7% of the total pesticides sold in the Georgia Basin in 2003. Four of these active ingredients (diazinon, atrazine, 2,4-D, and nonylphenoxypolyethoxyethanol) were on the overall top 20 list of pesticides sold in the Georgia Basin. The use of atrazine, endosulfan, malathion, and metolachlor decreased substantially between 1991 and 2003; however, the downward trend was significant only for metolachlor. Sales of atrazine decreased between 1991 and 1995, and then increased again after this time. Chlorpyrifos, lindane, and simazine sales were not significantly changed over the study period (ENKON Environmental Ltd. 2005).

Table 6 Pesticide Active Ingredients of Environmental Concern Sold in the Georgia Basin Region in 2003 (ENKON Environmental Ltd. 2005)

A.) Pesticide Active Ingredients on Two or More Lists of Chemicals Concern	Quantity Sold (kg)
Atrazine	10,340
Simazine	6,179
Chlorpyrifos	4,252
Malathion	3,444
S-Metolachlor	3,445
Endosulfan	1,533
Trifluralin	1,135
Lindane (Gamma-BHC)	152

B.) Other Pesticide Active Ingredients of Concern	Quantity Sold (kg)
Diazinon	17,085
2,4-D	6,756
Nonylphenoxypolyethoxyethanol	6,291
Quintozene	5,426
Napropamide	5,125
Linuron	4,585
MCPA amine salts	4,018
MCPA esters	3,694
Octylphenoxypolyethoxyethanol	2,210
Dicamba	1,769
Carbaryl	1,646
2,4-D LV esters	777
Diuron	757
Oxamyl	698
Permethrin	666
EPTC	584
Oxadiazon	580
Pendimethalin	566
Carbofuran	480
Terbacil	294
Dicofol	202
Parathion	198
MCPA potassium or sodium salt	198
Metribuzin	161
Fenbutatin oxide	90.4

3.3.1.1 Agricultural Pesticides

In BC, the crops on which pesticides are most commonly applied include oats, barley, canola, corn, mixed grains, potatoes, apples, blueberries, grapes, raspberries, cranberries, cherries, ginseng, green or waxed beans, and spring wheat. In the Lower Mainland and on Vancouver Island the major crops include hay and fodder crops, alfalfa, oats, barley, corn, blueberries, potatoes, raspberries, cranberries, and green or wax beans (ENKON Environmental Ltd. 2005).

Past surveys of pesticide use in BC indicated that the amount of pesticides used by the agricultural sector in BC doubled between 1991 and 1999 (42,083 kg to 86,565 kg, respectively). The most recent information on the types and quantities of pesticides used on specific agricultural crops in various regions of BC is included in the use survey report for 2003 (ENKON Environmental Ltd. 2005).

Most of the top twenty Reportable pesticides applied for agricultural purposes in BC in 2003 were used on fruits, berries, and potatoes. Those used on other crops include formaldehyde (used as fumigant by mushroom growers and as a fumigant/disinfectant in poultry production); MCPA esters (used as a selective herbicide primarily on grain crops); and atrazine (a selective herbicide used primarily on corn with some use on canola) (ENKON Environmental Ltd. 2005).

Licensed pest control services for agriculture applied 11,338 kg of pesticides, containing 83 different active ingredients, in the Lower Mainland in 2003. However, only five active ingredients accounted for 60% of the total pesticides applied by pest control services: the fumigant methyl bromide (2026 kg); the herbicide atrazine (1,810 kg); the fungicides chlorothalonil (1,096 kg) and mancozeb (941 kg); and the fungicide/insecticide chloropicrin (998 kg) (ENKON Environmental Ltd. 2005).

Pesticides applied to crops can enter nearby waterways and can also contaminate groundwaters and drinking water wells. Surface runoff, groundwater infiltration, and atmospheric deposition of pesticides are important routes of pesticide entry to the aquatic environment. Pesticides volatilize in agricultural areas of BC and are deposited again in rainfall and dry deposition. A wide range of pesticides have been detected in rainfall and air samples. In the agricultural areas of Agassiz and Abbotsford, the pesticides which were detected most frequently and at the highest concentrations were 2,4-D, 2,4,5-trichlorphenoxypropionic acid (TP), atrazine, captan, diazinon, dicamba, dichlorvas, dieldrin, dinoseb, heptachlor, malathion, mevinphos, and terbufos (Belzer *et al.* 1998a;Belzer *et al.* 1998b).

3.3.1.2 Forest Products Industry Pesticides

The forest products industry in BC utilizes pesticides for the treatment of standing timber to control disease, infestation, and unwanted vegetation and also for the treatment of harvested timber for short-term protection against sapstain or for long-term preservation.

3.3.1.2.1 Pesticides Applied to Standing Timber

BC MOE approves permits or pest management plans for the forest products industry to utilize pesticides on standing timber. Reasons for use include the control of vegetation on rights-of-way, the protection of forest health, the management of unwanted vegetation in timber and planting areas, range management, and the control of noxious weeds.

In the Lower Mainland of BC and on Vancouver Island, the major use of pest control products by the forest industry between 1990 and 1999 was for vegetation management (99.6% and 89.1%, respectively) (Verrin *et al.* 2004). Glyphosate, which was applied by either aerial or ground-based treatment to control vegetation in planting sites, was the main herbicide used in forestry and accounted for over 90% of forest pesticide use. However, a recent increase was observed for the use of trichlopyr, which is applied on the ground by basal bark treatment. Aerial application of this product is not permitted and, due to the high toxicity of the ester forms of trichlopyr to fish, buffer zones must be incorporated during application (Verrin et al. 2004).

Between 1990 and 1999, other pesticides were used in smaller amounts on standing timber in the Lower Mainland and on Vancouver Island. These included 2,4,-D, dicamba, and 1,3-dichlorpropene. The use of herbicides such as picloram and 2,4-D by the forestry industry has declined in recent years. Picloram was not used in the Lower Mainland or on Vancouver Island between 1990 and 1999, and the use of 2,4-D has decreased in the Vancouver Island region (988 kg in 1990, 1.2 kg in 1997, and none in 1999) (Verrin et al. 2004). Verrin *et al.* (2004) also identified the use of the pesticide MSMA (monosodium methan arsonate) for both herbicidal and insecticidal purposes; however, information on the volume used was not available. MSMA has been used for commercial thinning of conifer stands and for controlling mountain pine and spruce beetle by the forest industry. The registration of this product expired in 2005 and this product is no longer used in BC. Information on this product and its past use in BC can be found on the BC Ministry of Forests and Range website
http://www.for.gov.bc.ca/hfp/health/MSMA.htm#links.

Licensed pest control services for the forestry industry applied 102,804 kg of five pesticide active ingredients in the Lower Mainland in 2003. *Bacillus thuringiensis ssp. kurstaki* (BTK), an insecticide used to control gypsy moth and spruce budworm, accounted for approximately 84% (85,765 kg) of the total active ingredients applied. Other active ingredients applied in 2003 included glyphosate (14,970 kg), triclopyr (2,249 kg), dried blood (0.12 kg), and denatonium benzoate (0.00024 kg) (ENKON Environmental Ltd. 2005). A comparison of information on trichlopyr use from the 1991 and 2003 pesticide use surveys confirms a large increase in the use of this product. While more than 2,000 kg of trichlopyr were used in the Lower Mainland in 2003 for forestry application, less than 100 kg were used in 1991 (ENKON Environmental Ltd. 2005).

Loadings of pesticides to the aquatic environment of the south coast of BC as a result of the treatment of standing timber have not been estimated.

3.3.1.2.2 Wood Treatment Chemicals (Antisapstain Chemicals and Wood Preservatives)

Two types of wood treatment chemicals are used in BC. Antisapstains are used by the lumber industry, in moist coastal areas of the province to prevent staining caused by the growth of fungus and molds on freshly cut softwood lumber for export. Wood preservatives are used to provide long-term protection of wood to be used in exposed conditions such as railway ties, patio decks, fence posts, and utility poles. The use of antisapstain chemicals and wood preservatives on harvested timber accounts for the vast majority of pesticide use in BC (approximately 72% in 2003). According to the 2003 pesticide use survey, three of the top five pesticides sold in BC were wood preservatives (creosote, CCA (copper chromium arsenate) and PCP) and one was an antisapstain chemical (didecyl dimethyl ammonium chloride or DDAC). Creosote, CCA, and PCP accounted for 47%, 18%, and 3% of the total pesticide use in BC, while the antisapstain chemical, DDAC, accounted for 4% (ENKON Environmental Ltd. 2005).

Despite the continued heavy use of these types of chemicals in BC, the use of both antisapstain chemicals and wood preservatives has decreased since the 1990s (ENKON Environmental Ltd.

2005). The use of antisapstain chemicals in BC declined by more than 79% between 1994 and 2003. A variety of chemicals have been used for antisapstain treatment of cut lumber in BC since the first inventory of pesticide use was conducted in 1991; however, the use of most of these chemicals has now been discontinued. Chlorophenate-based antisapstain formulations were used extensively in BC in the 1980s; however, their use was banned in Canada on December 31, 1990. The use of copper 8-quinolinolate and TCMTB (2-(thiocyanomethylthio)benzothiazole) for antisapstain purposes was virtually eliminated by 1992; however, one BC mill reported the use of small amounts of TCMTB in 1999. This mill did not report to the inventory in 2003 and it is not known if TCMTB is still in use at this facility. Sodium carbonate, a component of borax-based antisapstains, has not been used since 1998. The 2003 pesticide use inventory identified only two antisapstain chemicals in use at BC facilities. These include DDAC and IPBC (3-iodo-2-propynyl butylcarbamate or iodocarb) (ENKON Environmental Ltd. 2005).

DDAC is a quaternary ammonium compound (QAC). QACs are frequently used for their germicidal, fungicidal, and algicidal properties. DDAC is registered for use in Canada as a molluscicide and as an industrial disinfectant. IPBC, a carbamate compound, is registered for use as a preservative in paints, adhesives, and caulking. In 1991, DDAC and IPBC both received temporary registration under the PCPA for use as antisapstain chemicals. The temporary registration of DDAC and IPBC is reviewed annually. While both DDAC and IPBC have other minor uses, the major source of these chemicals to the aquatic environment in BC is associated with their use as antisapstain chemicals. Although its use has declined in recent years, DDAC is still one of the most heavily used pesticides in the province. Approximately 310 t of DDAC were used in antisapstain treatments at 46 BC facilities in 1999 (primarily in the Lower Mainland and on Vancouver Island), compared to approximately 175 t in 2003. In 2003, the use of DDAC accounted for 85% of the total antisapstain chemical usage in the province. The use of IPBC in antisapstain treatment at BC facilities has also declined; 42 t in 1993, 26.5 t in 1999, and 11.8 t in 2003 (ENKON Environmental Ltd. 2005).

Losses of DDAC and IPBC to the BC environment as a result of their use for antisapstain treatment have not been estimated. In the past, the uncovered storage of treated lumber resulted in the generation of a large amount of contaminated surface runoff. Best management practices introduced at BC mills, including covered storage and catchment basins, have greatly reduced releases of wood treatment chemicals in stormwater runoff from lumber yards (Garrett 2004). Allowable concentrations of wood treatment chemicals, including DDAC and IPBC, in stormwater runoff from lumber mills are regulated by the BC MOE under the provincial *Environmental Management Act* (EMA) (http://www.canlii.org/en/bc/laws/regu/bc-reg-300-90/latest/bc-reg-300-90.html).

Pesticide use surveys show that the majority of pesticide use in BC is for the long-term preservation of wood intended for use in exposed conditions such as railway ties, patio decks, fence posts, and utility poles. Six heavy-duty wood preservatives were used in BC in 2003 including creosote, PCP, CCA, alkaline copper quaternary (ACQ), disodium octaborate tetrahydrate, and ammoniacal copper zinc arsenate (ACZA). While most facilities used only CCA, three used creosote, one used ACZA, and three used ACQ. ACQ is used as a replacement for CCA, which has been phased out for use on lumber products intended for consumer use due to potential health concerns associated with arsenic (ENKON Environmental Ltd. 2005).

Although creosote use was reported by only three facilities in BC, the amounts being applied at these facilities were very high and creosote accounted for 47% of the total pesticide usage in BC. In 1999, approximately 5.4 t of creosote were sold in BC compared to 2.2 t in 2003. In 2003, of the 2.2 t of total creosote sold in BC, 1.3 t were sold in the Lower Mainland and the rest was sold in the Southern Interior and Cariboo regions of the province. No creosote was sold on Vancouver Island (ENKON Environmental Ltd. 2005).

CCA is the second most commonly used pesticide in BC. Sales of CCA in BC in 2003 were 824 t, and the majority of this (542 t) was sold in the Lower Mainland. Most of the wood preservation facilities in BC are using CCA, and some use other chemicals as well (ENKON Environmental Ltd. 2005).

PCP is still used for heavy-duty wood preservation in BC; however, the amounts being used are declining. The pesticide use inventories for BC indicated that approximately 148 t of PCP were used in BC in 2003, compared to 789 t in 1991. In 2003, approximately 80 t, of the total 148 t sold in BC, were sold in the Lower Mainland area (ENKON Environmental Ltd. 2005). The main use of PCP wood preservatives in BC was for the treatment of utility poles; however, the major past user of these poles, BC Hydro, no longer uses PCP-treated poles.

In 2003, usage of ACQ, disodium octaborate tetrahydrate, and ACZA for wood preservation in BC was 74.5 t, 24.7 t, and 2.2 t, respectively (ENKON Environmental Ltd. 2005).

In the past, high concentrations of wood preservative chemicals were released to the BC environment in association with contaminated stormwater from heavy-duty wood preservation facilities. These contaminated stormwaters also contained a number of chemicals which are present as impurities in commercial wood preservative formulations. For example, commercial PCP formulations contained pentachlorobenzene, HCB, CDPEs, PCDDs and PCDFs, while creosote contains high concentrations of PAHs. Contaminated stormwater discharges have been reduced by more than 90%, compared to the early 1990s, through the implementation of codes of practice, inspection and enforcement programs by the federal government, and a heightened awareness of environmental concerns within the industry sector (Environment Canada 1998a).

Heavy duty wood preservatives (including CCA, creosote, and pentachlorophenol) are being jointly re-evaluated by Health Canada's PMRA and the United States Environmental Protection Agency (USEPA). For more information on this re-evaluation, refer to http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php.

In addition, PMRA reached an agreement with the industry to move away from the use of CCA on lumber for residential use by December 31, 2003. This agreement was implemented due to concerns over the presence of arsenic in this compound and does not affect the application of CCA on wood for use on industrial sites. For more information, refer to http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_fact-fiche/cca-acc/index-eng.php.

3.3.1.3 Antifouling Chemicals

Organotin compounds are synthetic organometallic substances whose toxic properties have contributed to their diverse and widespread use. They are not manufactured in Canada, but have been imported for use. Organotins have been used as industrial cooling water slimicides and agricultural biocides, wood preservatives, and as antifouling agents in marine paints applied to ship hulls, marine structures, and net pens in aquaculture.

Tributyltin, an organotin compound, was once widely used in BC as an antifoulant. The use of tributyltin compounds in antifouling paints applied to boat hulls has resulted in widespread environmental contamination and adverse effects in marine organisms. Many countries have taken action to restrict their use and release to the environment. The International Maritime Organization (IMO), a United Nations body, adopted a convention calling for a global ban on the application of organotin-based antifouling paints on ships. PMRA terminated the registration of organotin-based antifouling paints in Canada on October 31, 2002. Although some restrictions on the use of organotin-based antifoulants had been introduced in Canada previously, this action, which is consistent with the IMO Convention, was taken due to continued potential risks to the Canadian environment. While the sale and distribution of organotin-based antifoulants ended in Canada as of September 1, 2002, their continued use on some foreign vessels entering Canadian waters and harbours is a current source of tributyltin compounds to the aquatic environment (Garrett 2004).

Copper-based antifouling paints have been used more extensively in recent years to replace the organotin-based paints. As with organotin-based antifouling paints, the copper contained in the hull paints leaches directly into surrounding waters. Also, the application and removal of copper-containing paint from boat hulls can result in the release of copper to the environment. No information is available on the quantity of copper- and organotin-based antifoulants used in BC, or their loadings to the south coastal environment as a result of this use.

3.3.1.4 Rights-of-Way Pesticide Use

The use of pesticides to remove unwanted vegetation from industrial rights-of-way is common in BC. Permits for such pesticide use are obtained from BC MOE. The major electrical company in BC, BC Hydro, uses pest control products for vegetation control in electrical facilities and on rights-of-way. BC Hydro treats a very small proportion of its rights-of-way each year and utilizes herbicides which are target-specific and highly selective. The most commonly used active ingredients were triclopyr, glyphosate, diuron, and simazine (Verrin et al. 2004).

Several railway companies also use pest control products to control vegetation on railroad rights-of-way. (Verrin et al. 2004) summarized available information on pesticide use on BC railway rights-of-way and noted that herbicide use by BC Rail fluctuates substantially. For example, 2 kg were used for this purpose in 1991, compared to 6,164 kg in 1999. Information on pesticide use by the Canadian Pacific Railway indicates that diuron, picloram, and 2,4-D were used in 2001, with an increasing usage of trichlopyr. In 2003, BC MOE issued permits for the use of glyphosate, chlorsulfuron, dicamba, imazapyr, diuron, and bromacil/diuron. Where pesticides are applied to industrial rights-of-way in close proximity to waterways, the possible entry of pesticides to aquatic systems is of concern.

3.3.1.5 Urban Pesticide Use

The use of pesticides in urban areas contributes to the contamination of urban streams and watersheds through stormwater/urban runoff, CSOs, groundwater infiltration, and atmospheric deposition. Accurate information on urban pesticide use is not available for the south coastal area of BC. The reporting of domestic label pesticide sales has not previously been required under Canadian legislation and this type of information has not been consistently collected or recorded. However, recent revisions to the federal PCPA require all registrants of pest control products, including Domestic label pesticides, to record and report information on the sales of their products. Registrants are required to provide PMRA with annual reports on sales information for each product within each province and territory (PMRA (Pest Management Regulatory Agency) 2009a).

Studies in the Puget Sound area of Washington State indicated that the urban use of pesticides exceeds the agricultural use of pesticides (Bortelson and Davis 1997). Although the use of urban pesticides varies between cities, it is thought that the use of pesticides in most Canadian cities is approximately equal to, or higher than, the use in nearby agricultural areas. It has been estimated that pesticide use in Canadian cities ranges from 0.97 to 3.65 times the use in agricultural areas (Brimble et al. 2005).

A 2003 survey of BC pesticide use obtained limited information on the sales of domestic pesticides from some vendors. While this information is not adequate to provide estimates of overall sales, it does provide some useful information on the types of products sold for home use. Although the list is considered incomplete, the report identified a total of 56 active ingredients sold for home use in BC in 2003 (ENKON Environmental Ltd. 2005). A study conducted in the Toronto area indicated that the most commonly used pesticides for home use include the herbicides 2,4-D, dicamba, mecoprop, MCPA, and glyphosate; the insecticides malathion and carbaryl; and the fungicides chlorothalonil, benomyl, quintozene, and bendiocarb. Many of these chemicals have demonstrated a potential to cause adverse environmental effects and several have been detected in surface and groundwaters (Verrin et al. 2004).

The 1999 BC pesticide use inventory reported that a telephone survey of Victoria residents, conducted by the Georgia Strait Alliance, found that 34% of the homeowners surveyed had used pesticides. The most commonly reported pesticides used were weed and feed type products containing active ingredients such as 2,4-D, dicamba, and mecoprop amine. Homeowners also frequently reported the use of glyphosate isopropylamine, metaldehyde, insecticidal soap, diazinon, ferric phosphate, and a sulphur/zineb/methoxychlor/rotenone combination (ENKON Environmental Ltd. 2001).

The 2003 BC pesticide use survey includes information on the use of pest control products by licensed landscaping services and golf courses, as well as the use of flea control products by veterinarians (ENKON Environmental Ltd. 2005). In 2003, licensed landscape services in the Lower Mainland applied more than 7,500 kg of pesticides containing 77 different active ingredients. The most extensively used active ingredients were insecticidal mineral oil (1,171 kg), glyphosate (969 kg), and 2,4-D amine (899 kg). Other commonly applied active ingredients included the herbicides mecoprop amine salts and dichlobenil; the insecticide diazinon; and the fungicides quintozene, lime sulphur, and chlorothalonil. A comparison of 2003 information with that obtained from earlier surveys indicates that there has been a 50% decrease in the use of pesticides by landscape services in the Lower Mainland since 1991 (ENKON Environmental Ltd. 2005).

Based on information reported by the 53 golf courses in the Lower Mainland which responded to the 2003 survey (54% of those surveyed), it was estimated that 14,000 kg of ten different pesticide active ingredients were used by all golf courses in the Lower Mainland. The fungicides quintozene and chlorothalonil accounted for 68% of the total pesticide use on golf courses. Other commonly used pesticides included the fungicides iprodione, mancozeb, thiophanate-methyl, fosetyl-al, and propiconazole; the insecticide carbaryl; and the herbicides 2,4-D amine and mecoprop amine (ENKON Environmental Ltd. 2005).

Veterinarians in BC sold approximately 122 kg of flea control pesticide active ingredients in 2003. Imidacloprid accounted for approximately 84% of the pesticides sold by veterinarians to homeowners for flea control. Other active ingredients in products sold for this use include permethrin, piperonyl butoxide, methoprene, pyrethrins, and pyriproxyfen. The results of the BC pesticide use surveys indicate that veterinary sales of flea control pesticides have decreased by 83% since 1991. This decrease is primarily due to the introduction of new products which are registered as drugs and are applied to the skin or administered orally or by injection (ENKON Environmental Ltd. 2005).

3.3.2 Presence of Current-Use Pesticides in the South Coastal BC Environment

Agricultural, Forestry, and Urban-Use Pesticides:

Several agricultural, forestry, and urban-use pesticides have been detected in the aquatic environment in both the south coastal area of BC and in the Puget Sound area. In the Puget Sound area, more pesticides are present in streams in urban areas than in agricultural areas. This was attributed to the much higher domestic use than agricultural use of pesticides in the Puget Sound area (Bortelson and Davis 1997). Sampling conducted between 1996 and 1998 found that insecticides (including diazinon, carbaryl, and malathion) were the most commonly detected pest control products in urban streams; while herbicides (atrazine, prometon, simazine, and tebuthiuron) were the most commonly detected products in agricultural stream waters (Bortelson and Davis 1997). Verrin *et al.* (2004) summarized studies conducted by the Washington State Department of Ecology in the Puget Sound area. In 1994 and 1996, surface water sampling programs in orchards, agricultural, urban, and forestry areas in Washington State detected the presence of a wide range of pesticides and their breakdown products. The concentrations of several pesticides exceeded US recommended levels for the protection of aquatic life. These included azinphosmethyl, carbaryl, chlorpyrifos, diazinon, DDT, DDE, and malathion. Samples from cranberry bogs contained an especially wide range of pesticides at high concentrations.

A variety of current-use pesticides (CUPs) have also been detected in agricultural areas in the lower Fraser Valley area of BC. Environment Canada studies detected more than 60 current-use pesticides and/or their transformation products in surface waters, sediments, field runoff, wellwater, and/or precipitation. Some of the pesticides detected include azinphosmethyl, diazinon, dinoseb, dimethoate, endosulfan, fensulfothion, lindane, malathion, metalochlorparathion, methoxychlor, parathion, simazine, atrazine, and trifluralin (Cox and Liebscher 1999;Tuominen 2004;Wan 1989;Wan *et al.* 2005;Wan *et al.* 1994;Wan *et al.* 1995).

In 2003, 2004, and 2005, Environment Canada sampled CUPs in surface waters, groundwaters, field run-off, and rainwater in high pesticide use areas of the Lower Fraser Valley (Tuominen 2004). A wide range of pesticides were detected and all samples contained multiple pesticides. The most commonly detected pesticides were the fungicides quintozene and chlorothalonil; the insecticide endosulfan; and desethylatrazine, a breakdown product of the herbicide atrazine. The highest concentrations of pesticides were detected in field runoff samples. Pesticides detected at the highest concentrations included:

- in field runoff samples- the fungicide metalaxyl, the herbicide glyphosate, and AMPA (aminomethylphosphonic acid), which is a transformation product of atrazine;
- in surface water samples- the insecticide diazinon and the herbicides 2,4-D and linuron;
- in groundwater samples- atrazine, simazine, and MCPP (mecoprop); and
- in precipitation samples- chlorothalonil, diazinon, and diazinon-oxon (a breakdown product of diazinon) (Tuominen 2004).

Several pesticides were detected in surface waters, groundwater, and rainwater at pg/L to ng/L concentrations. Some run-off and surface water samples contained concentrations in the µg/L range. Pesticides were detected more frequently, and at higher concentrations, at sites close to agricultural activity. In general, pesticide concentrations were higher in surface water samples than in groundwater samples, although the concentrations of pesticides, with the exception of diazinon and chlorpyriphos, were well below guidelines for the protection of aquatic life (Tuominen 2004).

A recent study by Harris *et al.* (2008) showed that complex mixtures of pesticides are present in urban and agricultural environments, as well as in remote areas of BC. A mixture of legacy and CUPs were detected at all sites, although total pesticide concentrations were lowest at the remote location. While some CUPs were detected in biota, legacy pesticides dominated in biota samples from all sites. CUPs dominated in water samples, but did not exceed CCME water quality guidelines at any site. The results of both Harris *et al.* (2008) and Tuominen (2004) indicate that aquatic organisms in agricultural and urban regions of the Lower Fraser Valley are exposed to low concentrations of several pesticides and that many of these pesticides (both CUPs and legacy) can also be found in remote areas of the province. The possible effects of this chronic low-level exposure to complex pesticide mixtures are not known. However, some studies suggest that adverse effects experienced by salmon exposed to pesticide mixtures could contribute to loss of viability of some salmon stocks.

Verrin *et al.* (2004) reviewed information on pesticides used in BC (Table 6) and identified a list of CUPs of concern in the various land use sectors. The pesticides contained in this list were selected based on their environmental concerns and their level of use.

Table 7 Current-Use Pesticides (CUPs) of Concern in BC According to Land-Use Sectors (Verrin et al. 2004)

CUPs of Concern in Urban Areas	CUPs of Concern in Forestry Areas	CUPs of Concern in Agricultural Areas
2,4-D	Carbaryl	2,4,-D
Carbaryl	CCA	Atrazine
Chlorothalonil	Creosote	Captan
Diazinon	Fenitrothion	Chlorothalonil
Diuron	Glyphosate	Chlorpyrifos
Glyphosate	PCP	Diazinon
Malathion	Surfactants in *Bacillus thuringiensis*	Endosulfan
MCPA	Triclopyr	Ethalfluralin
Quintozene		Glyphosate
Triclopyr		Pendimethalin
		Simazine
		Trifluralin

A wide range of pesticides have also been detected in air samples collected in some areas of BC. In the agricultural areas of Agassiz and Abbotsford, pesticides commonly detected included 2,4-D, 2,4,5-trichlorphenoxypropionic acid (2,4,5-TP), atrazine, captan, diazinon, dicamba, dichlorvos, dieldrin, dinoseb, endosulfan, fonofos, heptachlor, malathion, mevinphos, and terbufos. Fewer pesticides were detected in precipitation samples than in air samples. The deposition rates were highest for captan and 2,4-D, followed by dichlorvos and diazinon (Belzer *et al.* 1998a;Belzer *et al.* 1998b;McGreer and Belzer 1998). These studies indicate that the presence of some CUPs is, in part, due to atmospheric transport from other areas. For example, the presence of high concentrations of 2,4-D in the atmosphere of the Fraser Valley, at a time when this product was not being applied, was attributed to long-range transport from California.

A study on the atmospheric distribution of OC pesticides in North America found that endosulfan concentrations in air samples from the Okanagan Valley in BC were among the highest detected in North America (Shen *et al.* 2005).

Wood Treatment Chemicals

The antisapstain chemicals, DDAC and IPBC, which are used for the short-term protection of wood for export, entered the BC environment primarily as a result of spills and discharges from facilities using these products. However, there have been numerous improvements to the pollution control measures used at these facilities and the concentrations of these chemicals in stormwater releases from these facilities are controlled by regulations under the BC EMA. Information on the presence of DDAC and IPBC in the aquatic environment of south coastal BC is very limited; however, these chemicals have been detected in Fraser River sediment and water samples collected in the vicinity of lumber mills (Szenasy *et al.* 1998b). No information was available on current concentrations of these chemicals in the environment.

The majority of pesticide use in BC is for wood preservation, with creosote having the highest use (47% of total pesticide use in BC). Other commonly used wood preservatives in BC are CCA and PCP. In the past, large quantities of wood preservative chemicals were released to the south coastal BC environment as a result of contaminated stormwater discharges from heavy-duty wood preservation facilities. Stormwater discharges also released a variety of other chemicals due to their presence as impurities in wood preservative chemical formulations. For example, creosote contains high concentrations of various PAH compounds, while PCP formulations can contain pentachlorobenzene, HCB, CDPEs, PCDDs, and PCDFs. These chemicals were also released to the environment in association with wood preservatives, and elevated concentrations of several of these substances have been detected in the vicinity of south coastal wood treatment facilities. The implementation of more stringent pollution control measures in the 1980s substantially reduced releases of wood preservatives to the environment. While the success of these measures in reducing the environmental concentrations of these substances has not been well studied, decreased concentrations of chlorinated phenols and chlorinated anisoles (degradation products of chlorophenols), PCDDs, and PCDFs have been observed in BC (Garrett 1995;Garrett and Shrimpton 1988). Additional information on environmental levels of PAHs, HCB, PCDDs, and PCDFs in the south coastal BC environment is summarized in Section 3.1.3 on conventional or legacy POPs; information on CDPEs is found in Section 3.2.2 on new and emerging POPs; and information on chromium and copper is found in Section 3.4.2 on metals.

Antifouling Chemicals

The past use of tributyltin-based antifouling chemicals on boat hulls, net pens at aquaculture facilities, and marine structures has resulted in elevated concentrations of butyltin compounds in the BC environment. Elevated concentrations have been detected in the surface waters, bottom sediments, fish, aquatic invertebrates, and fish-eating birds in the vicinity of some south coastal BC marinas, harbours, shipyards, recreational boating areas, and salmon farms (Garrett and Shrimpton 1997). In the late 1980s and early 1990s, the concentrations of butyltins in some areas exceeded Canadian water quality guidelines for the protection of marine life. Surveys conducted in 1995 indicated that concentrations decreased in BC coastal marinas following the introduction of controls on the use of butyltin-based antifoulants; however, concentrations in harbour areas remained elevated (Garrett and Shrimpton 1997). Sediments collected from Vancouver, Victoria and Esquimalt harbours in 2003 also contained elevated concentrations of butyltin compounds (Thompson *et al.* 2005). Although it is expected that butyltin concentrations in the vicinity of salmon farms and recreational boating areas have decreased since the introduction of controls, environmental surveys have not been conducted to confirm this (Garrett and Shrimpton 1997).

Kannan *et al.* (1998b) detected elevated concentrations of butyltins in the liver tissue of seaducks collected from harbour and marinas areas on the BC coast between 1989 and 1992. They reported that seaducks feeding on molluscs accumulated greater concentrations of butyltins than did predatory birds feeding on other prey, such as fish, other birds and small mammals. Elliott *et al.* (2007a) collected surf scoters from the Georgia Basin between 1998 and 2001 and found that hepatic concentrations of butyltins were significantly higher in scoters from Vancouver and Victoria harbours than in scoters from reference sites.

The use of copper-based antifoulants in BC increased following the de-registration of organotin-based products. Information on the effects of this use on the south coastal BC environment is lacking; however, some studies have detected elevated concentrations of copper at salmon farms using net pens treated with copper-based antifoulants. For more information, refer to the discussion on the presence of copper in the BC environment in Section 3.4.2.

3.3.3 Environmental Concerns and Potential Biological Impacts of Current-Use Pesticides

Agricultural, Forestry and Urban-Use Pesticides

Most pesticides currently used in Canada are much less persistent and present fewer environmental concerns than did those used in the past; however, some CUPs have moderate toxicity, persistence, and bioaccumulative abilities. While these chemicals do not persist in the environment for long periods, in some agricultural areas, it is possible for them to reach concentrations high enough to cause biological impacts.

Aquatic systems such as streams and estuaries serve as critical habitat for fish, shellfish, amphibians, and birds and are commonly present in agricultural and urban areas of south coastal BC. Several CUPs have the potential to impact fish, aquatic invertebrates, and non-target species of terrestrial and aquatic plants if they enter aquatic systems in high enough concentrations. Some, such as endosulfan, are toxic to birds and mammals. The proximity of agricultural, urban, and forestry areas to marine and estuarine waters means that surface runoff, groundwater, and stormwater containing pest control products can also affect critical marine and estuarine habitats and sensitive species. While little information is available on the effects of pesticides used in forestry, a variety of potential impacts have been identified as a result of pesticides used in agriculture and urban areas.

A wide range of adverse effects have been observed in salmon and other aquatic species exposed to pesticides. These include developmental effects, immunosuppression, renal function alteration, olfactory effects, reduced hatching success, larval mortality, reduced numbers of spawning adults, acetylcholinesterase inhibition, and endocrine disruption (Eder *et al.* 2009;Moore *et al.* 2008;Moore and Waring 2001;Nieves-Puigdoller *et al.* 2007;Tierney *et al.* 2007a;Tierney *et al.* 2007b). Environmentally realistic concentrations of pesticide mixtures (similar to those found in the Nicomekl River in the Lower Mainland of BC) disrupted olfaction in rainbow trout after a 96 hour exposure. The authors suggested that pesticide mixtures present in some BC freshwater salmon habitats could contribute to a decline in the viability in some salmon stocks (Tierney et al. 2008).

Pesticide poisoning of fish and birds have been reported in BC; however, these have not been methodically recorded. In 2001, 82 carp were killed in the Lower Mainland as a result of endosulfan poisoning (Kuo 2006). Several bird kills in BC have also been attributed to pesticide poisoning. Although the recovery and testing of birds is not done with consistency from year to year, CWS noted that approximately 12% of the dead eagles recovered between 1991 and 1997 had been poisoned by anti-cholinesterase pesticides (organophosphate and carbamate insecticides). However, the number of bald eagle pesticide poisonings in the Fraser River delta region decreased over this time period and fewer incidents of pesticide poisoning were also observed for other raptor species (http://www.ecoinfo.ec.gc.ca/env_ind/region/bepesticide/bepesticide_e.cfm).

Some pesticides have also been shown to alter both the functional and structural aspects of the food web. For example, atrazine can alter the estuarine microbial food web by inhibiting phytoplankton production. This can result in increased bacterial abundance and productivity (DeLorenzo *et al.* 1999). Atrazine can also cause shifts in community composition in aquatic vegetation (Solomon *et al.* 1996).

The presence of pesticides in agricultural streams is also suspected as a contributing factor in global decreases in amphibian populations (Hayes *et al.* 2002). Research conducted by Environment Canada indicated that some amphibian populations in agricultural areas of BC had lower hatching success compared to reference sites. These results suggest that agricultural runoff may be contributing to lower reproductive success and viability in some amphibian populations in the Lower Fraser Valley. However, other agricultural contaminants, such as ammonia and nitrate, have also been shown to affect amphibian reproduction. The relative effects of these contaminants and pesticides, both alone and in combination, on the viability of amphibian populations in the Fraser Valley is not known and requires further investigation (De Solla *et al.* 2002;Schreier *et al.* 1998).

It is important to note that pesticide toxicities vary substantially with their formulation. The toxicity of the transformation products and metabolites of some pesticides can be higher than the toxicities of the parent compounds. For example, while the trichlopyr parent compound and the amine salt formulation have a very low toxicity to fish, the ester form of trichlopyr, which is found in the commercial formulations of Garlon™ and Release™, has a much higher toxicity. In addition, the most common degradation product of trichlopyr, 3,5,6-trichloro-2-pyridinol, is of concern due to its toxicity (Wan *et al.* 1987). Similarly, while metam sodium and dazomet are not highly toxic to aquatic organisms, these products break down in the environment to methyl isothiocyanate, which is both toxic to fish and persistent in the environment (California Environmental Protection Agency 2003).

A variety of so-called “inert” ingredients (also called formulants or adjuvants) are added to pest control products as carriers and to improve their performance, application, efficacy, and shelf life. The potential adverse effects of these substances are not well understood; however, since these substances can constitute up to 90% of the commercial pesticide formulation, their entry into aquatic systems is of concern. These substances can be added as spreaders, defoamers, and pH adjusters prior to pesticide application or they can be added to the pesticide during formulation. The fact that these additives are not used for their pesticidal properties does not mean that they are not toxic in their own right. In fact, some of the substances added to pesticides as “inert” ingredients are toxic and are known to cause endocrine disruption. Pesticide manufacturers consider information on the addition of adjuvants in the commercial formulation of pest control products to be proprietary. Since these substances are not added to commercial formulations as pesticidal active ingredients, pesticide manufacturers have not been legally required to report the use of these substances or to list them on the product label. However, recent revisions to the PCPA require pesticide manufacturers to remove from the formulation any additive identified to be of toxicological concern, or to identity these substances on the product label. PMRA developed a list of substances which were to have been removed from commercial pesticide formulations by January 2005, as well as a list of substances which were required to be identified on pesticide labels by January 2006. For more information refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/reg2007-04/index-eng.php. Very little information is available on the "inert" ingredients in pest control products sold in BC. While the 2003 survey of pesticide use in BC includes some information, this information is not considered to be complete (ENKON Environmental Ltd. 2005).

CCME environmental quality guidelines have been developed for a number of pesticides and can be viewed at http://ceqg-rcqe.ccme.ca/.

Wood Treatment Chemicals

Antisapstain chemicals:

Many of the chemicals which were widely used as antisapstain chemicals and wood preservatives in BC are toxic to aquatic organisms and their use has been discontinued or restricted due to environmental concerns. At present, the most widely used antisapstain chemicals in BC are DDAC, a quaternary ammonium compound, and IPBC, a carbamate compound (ENKON Environmental Ltd. 2005).

While bioaccumulation of DDAC and IPBC in aquatic species is not expected to be significant, both of these chemicals are toxic to aquatic organisms at concentrations which can occur in the natural environment in the vicinity of sources. DDAC is acutely toxic to freshwater fish in the µg/L range; however, the sensitivity of fish varies significantly with life stage, with the early life stages being the most sensitive (Farrell and Kennedy 1999;Farrell *et al.* 1998;Henderson 1992;Teh 2001;Wood *et al.* 1996). Adverse effects observed in fish exposed to sublethal concentrations of DDAC include reduced growth, cellular damage to gills and digestive tract, increased biochemical indicators of stress, and reduced swimming performance (Farrell and Kennedy 1998;Farrell and Kennedy 1999;Johnston *et al.* 1998;Szenasy *et al.* 1998a;Szenasy *et al.* 1998b;Wood *et al.* 1996). Information on the toxicity of DDAC to marine species is limited; however, acutely toxic concentrations ranged from 39 µg/L to 972 µg/L for marine and estuarine invertebrates tested (Farrell and Kennedy 1998).

Concentrations of IPBC in the µg/L range have also been found to be toxic to fish (Canadian Council of Ministers of the Environment (CCME) 1999;Farrell and Kennedy 1998;Farrell and Kennedy 1999;Springborn Laboratories Inc. 1992). The lowest observable effect concentration (LOEC) reported was 19 µg/L, based on reduced weight gain and growth in fathead minnow embryos over a 35-day exposure period (Springborn Laboratories Inc. 1992). IPBC is also toxic to aquatic invertebrates in the µg/L range, but was found to be slightly less toxic to invertebrates and slightly more toxic to fish than is DDAC (Farrell and Kennedy 1998;Farrell and Kennedy 1999). Simultaneous exposure to IPBC and DDAC produced additive toxicity in fish, but variable toxicity results in invertebrates (Farrell and Kennedy 1998;Farrell and Kennedy 1999). Since these substances are sometimes used at the same facilities, it is likely that they co-occur in the aquatic environment and, in some areas, they may be present at combined concentrations high enough to be toxic to some aquatic organisms. In addition, DDAC and IPBC may interact with other chemical contaminants in the environment and adversely impact aquatic biota.

These substances can also be toxic to aquatic organisms when present in sediments. Preliminary information indicates that IPBC in sediments may be toxic at lower concentrations than DDAC.

DDAC was toxic to *Hyalella azteca* at a concentration of 1100 µg/g (dw) (over a 14-day exposure period), while IPBC was toxic to *Hyalella* at a concentration of 1.94 µg/g (dw) (Raymond *et al.* 2000;Szenasy *et al.* 1998a;Szenasy *et al.* 1998b).

The Canadian interim water quality objectives for DDAC and IPBC, for the protection of freshwater aquatic life, are 1.5 µg/L and 1.9 µg/L, respectively. There are currently no guidelines for marine water or for sediments due to the lack of relevant toxicity data (Canadian Council of Ministers of the Environment (CCME) 1999;Canadian Council of Ministers of the Environment (CCME) 2006).

The existing BC provincial stormwater discharge guideline under the EMA specifies a maximum concentration of 700 µg/L DDAC in stormwater discharges from wood treatment facilities. However, since the development of this guideline, some additional toxicity information has become available which indicates a higher sensitivity of some species to DDAC than previously reported. Because of this new information, it has been suggested that the provincial stormwater discharge guideline may not adequately protect juvenile rainbow trout or white sturgeon. In addition, some researchers have concluded that, while the existing provincial guideline for IPBC in stormwater discharges (120 µg/L) would likely protect the more tolerant species, more sensitive organisms, such as juvenile coho salmon, may not be adequately protected. It has been suggested that the existing provincial guidelines for DDAC and IPBC in stormwater discharges should be reviewed based on the most recent toxicity data (Garrett 2009).

Wood Preservatives:

The most commonly used wood preservatives in BC are creosote, CCA, and PCP. Prior to the introduction of stringent pollution control measures at wood preservation facilities in the 1990s, large amounts of wood preservation chemicals were released to the south coast BC environment in stormwater discharges. In addition, other toxic substances which were present as impurities in commercial formulations of wood preservatives, including PAHs, pentachlorobenzene, HCB, CDPEs, PCDDs and PCDFs, were also released to the environment.

Chlorophenols, including PCP, are less persistent than are many other organic chemicals due to the fact that they can be readily degraded by exposure to light and by microorganisms in the natural environment. Aquatic organisms readily accumulate chlorophenols even at low environmental concentrations; however, they also rapidly eliminate these substances when exposure has been terminated. Although chlorophenols can be present in the environment at high concentrations in areas receiving continuous loadings, environmental concentrations decline quite rapidly when the source is removed. The half-life in fish ranges from one day to approximately one week and there is no evidence of biomagnification in higher trophic levels. Pentachloroanisole (PCA), a degradation product of PCP, is also rapidly accumulated by aquatic organism, but has a longer half-life in fish than does PCP (as summarized from Garrett and Shrimpton 1988).

Chlorophenols can adversely affect the survival, growth, metabolism, and reproduction of aquatic organisms at very low environmental concentrations. Acutely toxic concentrations of PCP for various fish species ranged from 0.05 to 1 mg/L, while sublethal effects on growth, reproduction, and metabolism were observed at much lower concentrations. Molluscs and salmonids, particularly the early life stages, are very sensitive to chlorophenols. In addition, there is evidence that the presence of micro-contaminants found in technical chlorophenol formulations can contribute significantly to their toxicity (as summarized from Garrett and Shrimpton 1988).

Information on the potential biological effects of PAHs, HCB, PCDDs, and PCDFs in the aquatic environment is summarized in Section 3.1.3 on conventional or legacy POPs; information on CDPEs is found in Section 3.2.3 on new and emerging POPs; and information on arsenic, chromium and copper is found in Section 3.4.3 on metals.

Canadian environmental quality guidelines have been developed for chlorophenols and for several of the chemicals which have been found as impurities in wood preservative formulations (Canadian Council of Ministers of the Environment (CCME) 1999;Canadian Council of Ministers of the Environment (CCME) 2006). For more information on Canadian environmental quality guidelines, refer to the CCME website http://ceqg-rcqe.ccme.ca/.

Antifouling Chemicals

Antifouling paints have been used extensively in the south coastal region of BC on boat hulls, net pens at aquaculture facilities, and marine structures. In the past, tributyltin (TBT), an organotin compound, was a widely used additive in marine antifouling paints; however, the use of organotin-based antifoulants was terminated in Canada in 2002. Copper-based antifoulants are now commonly used as replacements for the organotin-based products. Information on the potential adverse biological effects of copper in the aquatic environment is presented in Section 3.4.3.

Organotin compounds are readily accumulated by aquatic organisms and BCFs of several thousand have been observed (Blair *et al.* 1982;Laughlin *et al.* 1986). The elevated concentrations of butyltin compounds detected in fish-eating birds and marine mammals suggest that higher trophic level organisms may accumulate these chemicals more efficiently than do fish and other lower trophic level organisms (Iwata *et al.* 1994;Iwata *et al.* 1995;Kannan and Falandysz 1997).

TBT is toxic to a wide range of aquatic organisms at low concentrations. TBT and other butyltin compounds disrupt endocrine systems and affect energy production, survival, growth, metabolism, and reproduction in aquatic organisms at ng/L to μg/L concentrations. Early life stages of aquatic species are often more susceptible to the effects of organotin compounds than are adults. Molluscs are particularly sensitive and TBT concentrations of less than 1 μg/L cause mortality in larval stages, abnormal shell and gonad development, and reduced larval settlement and growth. In the 1980s, the presence of elevated environmental concentrations of TBT caused the depletion of commercial oyster growing areas in several countries. In addition, a condition known as 'imposex' (the development of male sex organs in females) diminished gastropod populations in coastal areas worldwide and has been attributed to TBT contamination (as summarized in Garrett 2004).

Commercial oyster stocks and gastropod populations in south coastal areas of BC were also affected in the 1980s (Harding and Kay 1988). Following the introduction of controls on the use of butyltin-based antifoulants, a recovery of gastropod populations was observed in south coastal harbours with small boat traffic, but not in industrial harbours such as Vancouver Harbour where environmental concentrations of butyltin compounds remained elevated (Tester *et al.* 1996). Horiguchi *et al.* (2003) collected neogastropods from 15 sites at Vancouver and Victoria in 1999 and observed recovery from imposex in neogastropod populations from three sites in Victoria. However, populations in Vancouver Harbour had not recovered and no neogastropods were found at the Vancouver sites. Reitsema *et al*. (2002) conducted additional sampling in 2000 at 14 sites on the southern and western coasts of Vancouver Island and in the Strait of Georgia and noted that recovery of neogastropod populations was slower at sites with high boat traffic compared to sites with moderate or low boat traffic.

Canadian environmental quality guidelines have been developed for some organotin compounds. Interim guidelines for the protection of freshwater aquatic life are 8 ng/L (3 ng Sn/L) for tributyltin and 20 ng/L (7 ng Sn/L) for triphenyltin. The interim guideline for tributyltin in marine and estuarine water is 1 ng/L (0.4 ng Sn/L). Guidelines have not been developed for other organotin compounds due to the lack of adequate toxicity information (Canadian Council of Ministers of the Environment (CCME) 1999;Canadian Council of Ministers of the Environment (CCME) 2006).

3.4 Metals

3.4.1 Sources and Loadings to the South Coastal BC Environment

Metals enter the environment from both natural and anthropogenic sources. The most important natural source is the weathering and erosion of metal-bearing rocks; however, some metals are also released as a result of forest fires and volcanic emissions. The major anthropogenic sources vary; however, urban stormwater discharges have been identified as a major source of some metals to the south coastal BC environment.

Arsenic

Sources of arsenic to the environment include the mining and processing of gold and base-metal ores, releases from coal-fired power generation, the use of pesticides containing arsenic, and the release and disposal of domestic and industrial wastes (Environment Canada/Health Canada 1993a).

Limited information is available on sources and loadings of arsenic to the south coast of BC. A report prepared for Environment Canada estimated loadings of various contaminants from wastewater discharged to the Georgia Basin (based on data collected between 1990 and 1998). This study reported that, on average, more than 8.6 t (8,669 kg) of arsenic were released to the Georgia Basin from stormwater discharges annually (based on stormwater discharge information for the Lower Mainland Fraser Valley (7,400 kg)) (from Stanley Associates 1992), the CRD (956 kg), and the City of Nanaimo (314 kg)). In addition, the average annual loading was estimated to be 385 kg from municipal WWTPs (based on plants for which data was available). Insufficient information was available to estimate arsenic loadings from other wastewater discharges (ENKON Environmental Ltd. 2002).

Surveys of pesticide sales and use in BC were conducted in 1991, 1995, 1999, and 2003 (ENKON Environmental Ltd. 2001;ENKON Environmental Ltd. 2005;Norecol 1993;Norecol, Dames and Moore Ltd. 1997). The heavy duty wood preservative, CCA, which contains arsenic, was the second most commonly used pesticide in BC, accounting for 18% of the total pesticide sales in BC in 2003. Sales of CCA were 923,987 kg (924 t) in 1999 and 824,100 kg (824 t) in 2003. The majority of this product is sold in the Lower Mainland (542,438 kg or 542 t in 2003). While most of the wood preservation facilities in BC use CCA exclusively, some also use other chemicals (ENKON Environmental Ltd. 2005). Small amounts of other compounds containing arsenic have also been used for wood preservation in BC. ACA was sold in BC in 1991 and 1995 (500 and 909 kg, respectively). This compound has now been replaced with ACZA; however, only one wood preservation plant in the Lower Mainland reported using ACZA (16,488 kg in 1999 and 2,214 kg in 2003) (ENKON Environmental Ltd. 2005). The pesticide MSMA (monosodium methanearsonate) has been used for commercial thinning of conifer stands and for controlling mountain pine and spruce beetle by the forest industry (Verrin et al. 2004). The registration of this product expired in 2005 and this product is no longer used in BC. Information on this product and its past use in BC can be found on the BC Ministry of Forests and Range website http://www.for.gov.bc.ca/hfp/health/MSMA.htm#links.

In the past, contaminated stormwater from BC wood preservation facilities released unacceptable loadings of wood preservative chemicals, including CCA, to the environment. However, the implementation of environmental codes of practice, combined with inspection and enforcement programs, has reduced the release of contaminated stormwater from these facilities by more than 90% (Environment Canada 1998a).

Based on information collected in the Brunette River area of Burnaby in 1995, (Brewer *et al.* 2000) estimated that the atmospheric deposition rate for arsenic ranged from less than the limits of detection to 950 μm^2/day. The total estimated annual deposition rate to the entire Brunette River watershed was 2 t.

Inorganic arsenic compounds were assessed by Environment Canada and Health Canada under the authority of CEPA 1988 and were determined to be toxic as defined under the Act (Environment Canada/Health Canada 1993a). Risk management options for reducing releases of arsenic to the Canadian environment were developed under the federal Toxic Substances Management Policy. They include recommendations for actions to reduce arsenic releases from the base metal smelting, steel manufacturing, and wood preservation sectors and from fossil fuel power generation. For more information on inorganic arsenic compounds and actions being implemented to minimize the release of these compounds to the Canadian environment, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Cadmium

Cadmium is released from a variety of anthropogenic sources including metal mines (zinc, lead, copper) and smelters; industries manufacturing alloys, paints, batteries; plastics; agricultural application of sludges, fertilizers; pesticides and fungicides containing cadmium; urban runoff; marine disposal of sewage sludges; fossil fuel combustion; and the deterioration of galvanized materials and sacrificial anodes (Canadian Council of Ministers of the Environment (CCME) 1987).

It was estimated that 159 t of cadmium were released to the Canadian environment annually in association with metal production (82% from base metal smelters and refineries), stationary fuel combustion, transportation, solid waste disposal, agriculture, and other select sources in Ontario (for which data were available). Most of this cadmium, approximately 92% of the total (147 t), was released to the atmosphere; while 12 t were released to the aquatic environment. Major sources to the atmosphere were the iron and steel industries (blast furnace), primary zinc production (especially the roasting phase), and primary copper and nickel production (Environment Canada/Health Canada 1994a;Environment Canada/Health Canada 1994b). While the use of cadmium in electroplating (metal finishing) was a significant source of cadmium to the environment in the past, this usage has decreased substantially in recent years and now accounts for only 4.3% of the total Canadian consumption of cadmium (Environment Canada 1999).

Loadings of cadmium to the south coastal BC environment have not been estimated; however, a report prepared for Environment Canada estimated loadings to the Georgia Basin from various wastewater discharges. Stormwater was identified as the main source of cadmium, contributing, on average, more than 5.4 t (5,421 kg) annually (based on stormwater information for the Lower

Mainland Fraser Valley (4,600 kg) (from Stanley Associates 1992), the CRD (618 kg), and the City of Nanaimo (203 kg)). Average annual loadings from other sources were 144 to 175 kg from municipal WWTPs (based on plants for which data was available); 13.2 kg from CSOs; and 14.6 kg from metal mines (Westmin Myra Creek Mines) (ENKON Environmental Ltd. 2002). The, now closed, Britannia Mines on Howe Sound, was one of the largest identified metal pollution sources in North America. For many years this mine released significant amounts of cadmium and other metals to Howe Sound as a result of acid rock drainage (ARD) and, to a lesser extent, from waste rock disposal, concentrate spills, and tailings disposal. ARD from the mine contributed an estimated 430.8 kg of cadmium per day to Howe Sound (Government of British Columbia (BC) 2009). Pollution prevention measures have now been implemented and, in 2005, the province completed the construction of a treatment plant for this drainage. For more information, refer to http://www.agf.gov.bc.ca/clad/britannia/index.html.

Limited information is available on cadmium loading from atmospheric deposition. A 1995 study estimated the mean wet deposition rate to be 1.39 $\mu g/m^2$/day in Burnaby Lake/Still Creek/Brunette Basin area (Belzer and Petrov 1997). The atmospheric deposition of particulates contributed approximately 24 kg/yr of cadmium to the Brunette River watershed (Brewer *et al.* 2000;Brewer *et al.* 1998a). A 1996 study identified a decreasing trend in the atmospheric deposition of cadmium in the Lower Fraser Valley by examining the concentrations of cadmium in moss (Pott and Turpin 1996).

In 1994, inorganic cadmium compounds were assessed by Environment Canada and Health Canada under the authority of CEPA 1988, and were determined to be toxic as defined under the Act (Environment Canada/Health Canada 1994a). Under the federal government Toxic Substances Management Policy, risk management options were developed for base metal smelting, steel manufacturing, fossil fuel power generation, and metal finishing sectors. These include recommendations for specific actions to decrease the release of cadmium and other CEPA-toxic substances to the environment. The metal finishing industry is no longer considered to be a significant source of cadmium to the Canadian environment and no additional actions for this industry sector were recommended. For additional information on inorganic cadmium compounds and actions to minimize the release of these compounds to the Canadian environment, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Chromium

The metallurgical and chemical industries are the major users of chromium. Chromium is used for corrosion inhibition and decoration by the metal-plating industry; the production of stainless and heat-resistant steels; the manufacture of consumer goods such as cutlery and decorative trims; electrical applications requiring strength and good conductivity; and corrosion resistance in marine equipment. Chromium alloys are used in the automobile industry, while chromium oxide, chromium chloride, and chromium sulfate are used in pigments, leather tanning, and wood preservatives (Canadian Council of Ministers of the Environment (CCME) 1999;Environment Canada/Health Canada 1994d;Outridge and Scheuhammer 1993).

Loadings to the atmosphere, water, and land in Canada were 84 t, 27 t, and 5,000 t, respectively (Environment Canada/Health Canada 1994d). Major contributors of chromium to the atmosphere were fossil fuel combustion (51%), industrial processes such as iron and steel production and refractory and chemical processing (29%), and transportation-related sources such as motor vehicles (12%). Base metal mine smelters and refineries, iron and steel plants, metal finishing plants, and petroleum refineries were identified as sources to the aquatic environment. Since many of the industries utilizing chromium in their processes discharge to sewer systems, municipal WWTPs are also a source of chromium to the aquatic environment. The improper storage and handling of CCA-preserved wood can also release chromium to the environment (Environment Canada/Health Canada 1994d).

Information on chromium loadings to the south coastal BC environment is limited; however, a report prepared for Environment Canada estimated loadings of select chemicals, including chromium, to the Georgia Basin from major wastewater discharges (based on available data from 1990 to 1998). Average annual chromium loadings were estimated to be 6.7 t (6,723 kg) from stormwater (based on stormwater information for the Lower Mainland Fraser Valley (Stanley Associates 1992), the CRD, and the City of Nanaimo); 4.2 t (4,245 kg) from municipal WWTP discharges; 289 kg from CSOs; 9.8 kg from metal fabricators; and 45 kg from metal mines (ENKON Environmental Ltd. 2002). Pulp mills have also been identified as possible sources of chromium to the Fraser Basin and chromium was detected in all but one of the samples of pulp mill effluents analyzed. Chromium loadings from the mills included in the study ranged from 0.2 to 100 kg/day (Environment Canada 1998b).

Large amounts of the heavy duty wood preservative, CCA, are used in BC (ENKON Environmental Ltd. 2005). In the past, the release of contaminated stormwater from wood preservation facilities was a significant source of wood preservative chemicals, including CCA, to the BC environment. However, the implementation of pollution control measures and federal government inspection and enforcement programs have reduced the release of contaminated stormwater by more than 90% (Environment Canada 1998a).

Chromium loadings to the BC environment from atmospheric deposition have not been estimated; however, limited information is available for some areas of the south coast. The mean wet deposition rate for chromium in the Brunette Basin was approximately 8.92 $\mu g/m^2/day$, which was similar to that in Sudbury Ontario (Belzer and Petrov 1997), and the rate of chromium deposition in the Brunette River watershed was estimated to be 180 kg/yr (Brewer et al. 2000). A significant decrease in the atmospheric deposition of chromium in the Fraser Valley was observed between 1966 and 1993 (Pott and Turpin 1996).

Chromium was assessed by Environment Canada and Health Canada under the authority of CEPA 1988 (an earlier version of CEPA 1999). While hexavalent chromium was determined to be toxic as defined by the Act, there was insufficient information to determine whether trivalent chromium compounds should also be considered toxic (Environment Canada/Health Canada 1994d). Risk management options developed under the federal Toxic Substances Management Policy made recommendations for actions to reduce chromium releases from the base metal smelting, steel manufacturing, and metal finishing sectors and from fossil fuel power generation. For more information on hexavalent chromium compounds and actions to minimize the release of these compounds to the Canadian environment, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Copper

Anthropogenic sources of copper include municipal WWTP effluents, urban stormwater runoff, copper-based aquatic algicides and antifoulant products, surface runoff and groundwater containing copper-based fungicides and pesticides or CCA wood preservatives, and industrial effluents and emissions. The major industrial sources of copper include mining, smelting and refining industries; copper wire mills; coal-burning industries; and iron and steel-producing industries. In addition, acidic water can lead to the corrosion of brass and copper pipes and release copper (Canadian Council of Ministers of the Environment (CCME) 1987).

Large quantities of wood preservative chemicals containing copper are sold and used in BC. CCA is the second most commonly used pesticide in BC with over 824 t being sold in BC in 2003 (for more information on the sales of CCA in BC, refer to Section 3.4.1.1). While most wood preservation facilities in BC use only CCA, several other chemicals are used for wood preservation by a small number of facilities. ACQ is being used at three plants in BC as a replacement for CCA. Small amounts of another copper-based compound, ACA, were sold in BC in 1991 and 1995 (500 and 909 kg, respectively); however, this compound has now been replaced with ACZA. Only one wood preservation plant in the Lower Mainland reported using ACZA (16,488 kg in 1999 and 2,214 kg in 2003) (ENKON Environmental Ltd. 2002).

In the past, contaminated stormwater from wood preservation facilities contributed unacceptable amounts of wood preservative chemicals (including CCA) to the south coast environment of BC. However, the implementation of environmental codes of practice, combined with inspection and enforcement programs, has been effective in reducing contaminated stormwater discharges from these facilities by more than 90% (Environment Canada 1998a).

Copper is also contained in some non-wood preservative pesticides used in BC. Copper oxychloride was among the top 20 reportable active ingredients in pesticides used in BC in 1999 and 2003. Sales of copper oxychloride (on an as copper basis) in BC were 19,562 kg (19.6 t) (with 13,815 kg (13.9 t) sold in the Lower Mainland), compared to 14,699 kg (14.7 t) in 1999, 16,316 kg (16.3 t) in 1995, and 10,202 kg (10.2 t) in 1991. Cupric hydroxide (a fungicide) is also sold in BC. Sales in 1999 were 6,907 kg (6.9 t) compared to 3,524 kg (3.5 t) in 2003. The majority of this product was also sold in the Lower Mainland area (ENKON Environmental Ltd. 2002).

The use of copper-based antifouling paints has increased in recent years as these products have replaced tributyltin-based paints, whose use in Canada was discontinued in 2002. The use of copper in antifouling paints on boat hulls is a potentially significant source of copper to the BC coastal environment, due to the extensive boating activity along the south coast. In addition, some aquaculture facilities also use copper-based antifoulants to treat salmon net pens. Copper loading to the south coastal environment from the use of copper-based antifouling paints has not been estimated. However, a preliminary mass balance for Central Puget Sound estimated that copper loading was 4000 kg/yr and that 64% of this was attributed to copper leaching from boat and ship hulls (Crecelius *et al.* 2004).

Copper-based grits are used as blasting materials for the removal of paint from boat hulls and for cleaning boat hulls. When the use of these materials is uncontained, significant copper contamination can occur in the vicinity of tidal grids and boatyards (Liu 2006). BMPs for shipbuilding/repair facilities and marinas were originally prepared in 1995 and were distributed to local shipyards and marinas. The widespread implementation of these guidelines would help to decrease releases of antifouling chemicals to the environment. Inspections of ship and boatyards in 1998 by Environment Canada found that the implementation of the eight sections of the BMPs was variable and ranged from 2% for record keeping to 74% for waste fluids management. The average overall score was 42%. These BMPs have been updated and their implementation has been promoted widely among these facilities (refer to website http://www.pyr.ec.gc.ca/boatyards/index_e.htm).

Copper loadings to the south coastal BC environment have not been determined; however, a report prepared for Environment Canada estimated copper loadings to the Georgia Basin in select wastewaters. The major source of copper was stormwater discharges. Based on data collected between 1990 and 1998 for the Lower Mainland and Fraser Valley (Stanley Associates 1992), the CRD and the City of Nanaimo, it was estimated that stormwater contributes an average of 23.5 t of copper annually to the Georgia Basin. Average annual copper loadings from municipal WWTPs were 41 to 46 t, while those from pulp and paper facilities, marine cargo handling, metal mines, CSOs, chemical products industries, and metal fabricators were 1,109 kg, 383 kg, 382 kg, 1,765 kg, 11.4 kg, and 3.42 kg, respectively (ENKON Environmental Ltd. 2002).

Atmospheric deposition also contributes copper and other contaminants to the south coastal area, but loadings from this source have not been estimated. Copper has been detected in precipitation in the Georgia Basin and concentrations in rainfall collected in the Burnaby Lake area in 1995 (9 µg/L) were consistently higher than the CCME Water Quality Guidelines for copper for the protection of freshwater aquatic life (Belzer *et al.* 1998a;Belzer *et al.* 1996;Belzer and Petrov 1997).

The, now closed, Britannia Mines on Howe Sound was one of the largest identified metal pollution sources in North America. For many years this mine released cadmium and other metals to Howe Sound as a result of acid rock drainage (ARD) and, to a lesser extent, waste rock disposal, concentrate spills, and tailings disposal. Loadings of copper to Howe Sound from this source were more than 100 t/day (103,241 kg/day) (Government of British Columbia (BC) 2009). Pollution prevention measures have now been implemented and, in 2005, the province completed the construction of a treatment plant for this drainage. More information can be obtained at http://www.agf.gov.bc.ca/clad/britannia/index.html.

Copper compounds have not been assessed under CEPA 1999 and, therefore, a risk management strategy for copper has not been developed under the federal Toxic Substances Management Policy. However, it is expected that the implementation of recommendations to reduce the release of CEPA-toxic substances from the base metal smelting, fossil fuel power generation, metal finishing, and steel manufacturing sectors would also decrease copper loadings to the environment. For more information, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Lead

The main anthropogenic sources of lead to the environment are smelters, metal mines, ore and concentrate loading facilities, refineries, electric power plants, battery manufacture and disposal, municipal wastewater treatment plants, and various industrial facilities. Government and industry initiatives have been effective in reducing releases of lead to the environment. For example, information from Environment Canada's National Pollutant Release Inventory (NPRI) program indicate that total on-site releases of lead from Canadian smelters decreased from 512 t in 1998 to 367 t in 2002. In addition, according to the Mining Association of Canada (MAC), member smelters have reduced lead releases to the air by 83% since 1988 (The Mining Association of Canada (MAC) 2005). However, a report by the Commission for Environmental Cooperation (CEC) in 2006 warned that lead releases were still a threat to human and environmental health and estimated that more than 43,300 tonnes of lead were released to the environment in the US and Canada in 2002. According to the CEC report, Canada's performance in reducing atmospheric releases of lead has lagged behind that of the US. While only 5% of the total reporting facilities were Canadian, these facilities were responsible for 42% of the lead in air emissions. The report also noted that, while releases from large-scale facilities were decreasing, releases from the more numerous smaller-scale facilities had increased (Commission for Environmental Cooperation (CEC) 2006).

Previously, a major source of lead to the environment was its use as an anti-knock additive to gasoline. However, due to environmental and health concerns, actions were taken in the 1970s and 1980s to reduce this source. In 1990, the use of leaded gasoline in cars was banned in Canada. Releases to the Canadian environment have decreased substantially as a result of this action. In addition, the use of lead for soldering food cans was also identified as a potential human and environmental health concern and has now been phased out in Canada. Most interior and exterior paints manufactured before 1950 contained lead. The lead content in interior paints has been limited under regulations in Canada since 1976. Although the regulations did not apply to exterior paints, Canadian paint manufacturers voluntarily reduced lead additives in exterior paints also. In 2005, the *Surface Coating Materials Regulations* further restricted the use of lead in paints. Some specialty paints may still contain higher levels of lead; however, warning labels must be applied to the paint containers.

However, there are still many products sold and used in Canada which contain lead and the use and disposal of these products can release lead to the environment. For example, the continued use of lead shot and lead fishing tackle (sinkers and lures) has resulted in lead poisoning of waterfowl and other wildlife species in some areas. The use of lead sinkers and jigs weighing less than 50 grams has been prohibited in Canada's national parks and wildlife areas since 1997. As a result of the high number of related bird mortalities in Canada, additional regulations on the use of lead shot were introduced. As of September 1999, the use of lead shot was prohibited nationally for hunting migratory birds. American woodcock, band-tailed pigeons, and mourning doves were exempted from this requirement (Environment Canada 2006a;Environment Canada 2006e;Environment Canada 2006h;Environment Canada 2006i;Swan Society 2009). Regulations to prohibit the use of lead fishing tackle have been proposed and are now being pursued (Environment Canada 2006f;Environment Canada 2006g).

Other products which can contain lead include plumbing and solder products, lead-based glazes on some ceramics and glassware, leaded crystal, lead-pigmented glass used to prevent radiation exposure from television and computer screens, and lead acid batteries. While most of the used lead acid batteries in Canada are now recycled, some are still discarded improperly and ultimately release lead to the environment (Environment Canada 2006e;Health Canada 2006a). The Canadian National Plumbing Code, 2005 prohibits the use of lead solder in new plumbing or in repairs to plumbing for drinking water supplies. In addition, several provinces have passed legislation to limit the amount of lead in solder used for drinking water supply lines.

Information on loadings of lead to the south coast of BC is limited. A report prepared for Environment Canada estimated average annual loadings of various contaminants to the Georgia Basin from wastewater discharges (based on data collected between 1990 and 1998). The major source of lead identified by this report was stormwater discharges. The estimated average annual loading of lead to the Georgia Basin from stormwater discharges was 10,043 kg (10 t), (based on stormwater information for the Lower Mainland Fraser Valley (8,550 kg) (from Stanley Associates 1992), the CRD (1,124 kg), and the City of Nanaimo (369 kg)). Estimated average annual loadings of lead from other wastewater sources included 5,593 kg (5.6 t) from municipal WWTPs (based on plants for which data was available); 379 kg from metal mines (not including Britannia Mines); 247 kg from marine cargo handling; and 56.8 kg from metal fabricators (ENKON Environmental Ltd. 2002).

Based on information collected in the Brunette River area of Burnaby in 1995, Brewer *et al.* (2000) estimated that the atmospheric deposition rate for lead ranged from 1.7 to 288 $\mu g/m^2$/day. The total estimated annual deposition rate to the entire Brunette River watershed was 1.3 t.

Lead is on the CEPA 1999 Schedule 1 List of Toxic Substances and a number of regulations under CEPA 1999 control lead releases to the Canadian environment. These include the *Contaminated Fuel Regulations*; the *Fuels Information Regulations No. 1*, the *Gasoline Regulations*, and the *Secondary Lead Smelter Release Regulations.* For more information on lead, CEPA regulations, and other tools developed to minimize the release of lead to the Canadian environment, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Manganese

Anthropogenic sources of manganese include acid rock drainage from mines, emissions, and effluents from the iron and steel industry, municipal WWTP discharges, and emissions from gasoline-powered motor vehicles (Canadian Council of Ministers of the Environment (CCME) 1987). Methylcyclopentadienyl manganese tricarbonyl (MMT) has been used to replace lead as an anti-knock agent in gasoline. In 1992, it was estimated that MMT contributed 650 t of manganese per year to the Canadian environment and releases were reported to be increasing at a rate of about 10% annually (Loranger and Zayed 1994). In 2003, petroleum refiners began voluntarily phasing out the use of MMT and virtually all gasoline used in Canada is now MMT free.

Based on information collected between 1990 and 1998, it was estimated that municipal treatment plants and pulp and paper plants released, on average, 34 t (33,941 kg) and 26 t (26,173 kg) of manganese, respectively, to the Georgia Basin annually. Average annual loadings from other identified sources were estimated to be 1,196 kg from landfills, 1,111 kg from metal mines, 12 kg from fabricated metal products, and 3.49 kg from transportation service industries. Loadings to the environment from stormwater discharges were not estimated (ENKON Environmental Ltd. 2002).

Total manganese emissions to the atmosphere in BC in the late 1980s were estimated to be 31 t, with 27 t originating from gasoline-powered vehicles (Jaques 1987). In 2000, atmospheric deposition was identified as a significant source of the elevated manganese concentrations detected in Still Creek and the Brunette River. The deposition rate of manganese for the entire Brunette River watershed was estimated to be 6.4 tonnes/year (t/yr) (Brewer et al. 2000). Studies measuring metal concentrations in moss in the Lower Mainland in the 1990s indicated that the atmospheric deposition of manganese had increased significantly since MMT was first added to Canadian gasoline. The use of the gasoline additive MMT was assumed to be a major source of manganese to the environment; however, manganese concentrations in moss did not correlate with mobile emission sources (Pott 1995;Pott 1997;Pott and Turpin 1996). Similarly, (Hall *et al.* 1999) reported that while manganese concentrations in street and stream sediments in the Brunette River Basin have also increased since the introduction of MMT to gasoline, the increase was not correlated with traffic density.

Manganese compounds have not been assessed under CEPA 1999 and, therefore, a risk management strategy for manganese has not been developed under the federal Toxic Substances Management Policy.

Mercury

Anthropogenic releases of mercury are primarily to the atmosphere rather than directly to the aquatic environment. Sources include metal mining and smelting, municipal waste incineration, sewage and medical waste incineration, coal-fired power plants, cement manufacturing facilities, ore processing, steel manufacturing, petroleum refining, and fossil-fuel combustion. Until the 1980s, chlor-alkali plants were the largest anthropogenic source of mercury to the Canadian environment; however, the introduction of new processes by this industry sector reduced mercury releases. Mercury is also contained in a variety of consumer products such as fluorescent lamps, thermostats, thermometers, electrical switches, blood pressure reading devices, and dental amalgams. The ultimate disposal of these products can result in the release of mercury to the environment. While the use of mercury in the manufacture of many of these products has now been discontinued, older items containing mercury are still in use and continue to be discarded to landfills. In the past, mercury-based formulations were registered in Canada for use as fungicides and antimicrobials; however, such use has been discontinued and no mercury-containing pesticides are currently registered for use in Canada (British Columbia Ministry of Environment 2001;Environment Canada 2006j).

Information on mercury loadings to the south coastal BC environment is limited. A report prepared for Environment Canada estimated that, on average, 21.0 to 56.9 kg of mercury were released annually to the Georgia Basin from municipal WWTPs (based on information available between 1990 and 1998). The report also estimated that 3.30 kg of mercury were released annually from CSOs (ENKON Environmental Ltd. 2002).

Johannessen *et al.* (2005) reported that a preliminary mercury budget indicated that the Fraser River is the major source of mercury to the Strait of Georgia (2090 kg/yr). However, while the sediments in the Strait of Georgia are a major sink of mercury (1800 kg/yr), significant outflow of mercury through the Juan de Fuca Strait may occur.

Hall *et al*. (1999) reported that the mean deposition rate of mercury in precipitation in the Brunette River area was 0.01 $\mu g/m^2/d$. Estimates for other south coastal BC areas were not available.

Mercury is toxic, as defined by CEPA 1999, and has been added to the Schedule 1 List of Toxic Substances. Management strategies developed under the federal Toxic Substances Management Policy include initiatives under CEPA to reduce releases of mercury and other CEPA-toxic substances to the Canadian environment from base metal smelting, steel manufacturing, and fossil fuel power generation. In addition, the Canadian Council of Ministers of the Environment (CCME) developed Canada-wide standards (CWSs) for mercury-emitting industry sectors and also for certain products containing mercury. CWSs have been developed for emissions from base metal smelters and waste incinerators, dental amalgams, mercury-containing lamps, and coal-fired power plants. For more information on CWSs, refer to the CCME website http://www.ccme.ca/ourwork/environment.html?category_id=108. For more information on mercury and actions being taken to minimize mercury releases to the Canadian environment and to manage the risks associated with mercury, refer to Environment Canada websites http://www.ec.gc.ca/mercury/en/index.cfm and http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Nickel

Anthropogenic sources of nickel to the environment include nickel mining, smelting, and refining; nickel plating; gold mining; iron and steel processing; municipal WWTP discharges;

fossil fuel combustion; and cement manufacturing. The improper disposal of nickel-cadmium batteries can also release nickel to the environment. While nickel-cadmium batteries are not manufactured in Canada, they are imported for use (Environment Canada/Health Canada 1994e).

It was estimated that stormwater discharges contributed 16.7 t (16,664 kg) of nickel annually to the Georgia Basin (based on information for the Lower Mainland/Fraser Valley (from Stanley Associates 1992), the CRD, and the City of Nanaimo) and that municipal wastewater treatment plants (WWTP) contributed 6.4 t (6,429 kg) annually (based on information from the plants for which data was available between 1990 and 1998). Estimated loadings from smaller sources included 117 kg from combined sewer overflows, 45.4 kg from the chemical products industry, 11.2 kg from marine cargo handling, and 1.77 kg from metal fabricators (ENKON Environmental Ltd. 2002). Another study estimated annual nickel loading from urban runoff to the Fraser River to be 12.6 t (12,600 kg), with the majority of this entering the Lower Fraser River (approximately 11.3 t (11,300 kg)) (McGreer and Belzer 1998).

While atmospheric deposition is known to be a source of metals and other environmental contaminants to the south coastal area of BC, loading estimates from this source are available for select areas only. A study by Environment Canada indicated that dry deposition contributed 1.85 $\mu g/m^2$/yr of nickel to the Abbotsford area, but nickel was not detected in wet deposition (Belzer 2001). Atmospheric deposition of nickel to the Brunette River watershed ranged from 0.0001 to 11.6 mg/ m^2/day (Belzer and Petrov 1997). Analysis of trends in concentrations of various environmental contaminants in moss in the Lower Fraser Valley indicated a significant decrease in nickel deposition between 1960 and 1993 (Pott and Turpin 1996).

In 1994, oxidic, sulfidic, and soluble inorganic nickel compounds were assessed by Environment Canada and Health Canada and were found to be toxic, as defined by CEPA 1988 (an earlier version of CEPA 1999) (Environment Canada/Health Canada 1994e). In accordance with the requirements of the Act, risk management options for these compounds were developed under the federal Toxic Substances Management Policy. These included initiatives to reduce releases from the base metal smelting, steel manufacturing, and metal finishing sectors and also for fossil fuel power generation. For more information on inorganic nickel compounds and on actions to minimize their release to the Canadian environment, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

Silver

It has been estimated that 11,000 t of silver enter the world's oceans annually as a result of natural weathering processes, compared to 2,500 t from anthropogenic sources. Anthropogenic sources include the iron and steel industry, the cement industry, photoprocessing, electronics manufacturing, metal plating, coal combustion, crude oil production, cloud seeding for weather modification, municipal WWTP discharges, and runoff from landfills. Until recently, the main source of silver to the aquatic environment was the use of silver thiosulfate complexes in photoprocessing solutions for medical and dental x-rays and photographic development. Waste solutions were primarily discharged to municipal sewer systems, ultimately releasing silver to the aquatic environment. However, in recent years, measures have been implemented to reduce the release of silver to sewer systems from these sources (British Columbia Ministry of Environment 1996;Canadian Council of Ministers of the Environment (CCME) 1987;Environment Canada 1999).

Both Metro Vancouver and CRD sewer-use bylaws set maximum limits on the concentration of silver in wastewaters discharged to sewer systems. Metro Vancouver and CRD have introduced

Codes of Practice for Dental Operations. Adherence of dental operations to the Codes will decrease the release of silver to the environment through the proper handling and disposal of X-ray wastes and dental amalgams, which both contain silver. In addition, a Code of Practice for Photographic Imaging Operations is included under both the Metro Vancouver and CRD sewer use bylaws.

Information on the sources and loadings of silver to the south coastal BC environment is limited. Atmospheric deposition loading estimates are not available for silver; however, a 1995 study in the Brunette Basin revealed that the concentrations of silver and several other metals in precipitation sometimes exceeded the Canadian water quality guidelines for the protection of aquatic life (0.1 µg/L) (Brewer *et al.* 2000;Environment Canada 1998b).

A report prepared for Environment Canada estimated that annual loadings of silver from municipal WWTPs to the Georgia Basin ranged from 715 to 1901 kg (based on information from plants for which data was available between 1990 and 1998). While some information was available on the presence of silver in CSOs, urban runoff, and landfill leachate, it was not sufficient for estimating loadings from these sources. The report also noted that, while characterization studies conducted on the effluents of a variety of industries in the Georgia Basin had detected silver, loadings had not been calculated. It was concluded that more comprehensive information on the sources of silver to municipal sewers may be required in order to better control releases of silver to the Georgia Basin (ENKON Environmental Ltd. 2002).

Silver has not been assessed under CEPA 1999 and, therefore, a risk management strategy for silver has not been developed under the federal Toxic Substances Management Policy.

Zinc

Zinc is used in coatings for the protection of iron and steel; die casting alloys; brass production; dry batteries; roofing and exterior fittings in construction; some printing processes; and in the manufacture of a wide variety of products including cosmetics, ointments, medicinal products, tires, glass, electrical apparatus, cement and concrete, textiles, agricultural fertilizers, pesticides, linoleum, rubber, paints, varnishes, and wood preservatives. Zinc sacrificial anodes are used on vessels in the marine environment to prevent corrosion. Zinc enters the environment as a result of the application, use, and disposal of these products. Primary zinc production, iron and steel production, municipal WWTP discharges, wood combustion, and waste incineration are also sources of zinc to the environment (Bird *et al.* 1996;British Columbia Ministry of Environment 1999;Canadian Council of Ministers of the Environment (CCME) 1987;Environment Canada 1999).

Sources and loadings of zinc to the BC south coast have not been well studied; however, a report prepared for Environment Canada estimated loadings of zinc and several other environmental contaminants to the Georgia Basin from wastewater discharges (based on information available between 1990 and 1998). As with several other metals, stormwater discharges were identified as the largest source of zinc. It was estimated that more than 100 t (100,433 kg) of zinc enter the Georgia Basin annually in stormwater discharges (based on stormwater information for the Lower Mainland/Fraser Valley (from Stanley Associates 1992), the CRD and the City of Nanaimo). Average annual zinc loadings from other sources were estimated to be 37.2 to 38.7 t (37,244 to 38,676 kg) from municipal WWTPs (based on information from plants for which data was available), 2,717 kg from pulp and paper facilities, 2,330 kg from metal mines, 1,750 kg from CSOs, 509 kg from marine cargo handling, 110 kg from fabricated metal products, and 57 kg from chemical products industries (ENKON Environmental Ltd. 2002).

The, now closed, Britannia Mines on Howe Sound was one of the largest identified metal pollution sources in North America. For many years this mine released zinc and other metals to Howe Sound as a result of acid rock drainage (ARD) and, to a lesser extent, from waste rock disposal, concentrate spills, and tailings disposal. Loadings of zinc to Howe Sound from this source were more than 82.5 t/day (Government of British Columbia (BC) 2009). Pollution prevention measures have now been implemented and, in 2005, the province completed the construction of a treatment plant for this drainage. More information can be obtained at http://www.agf.gov.bc.ca/clad/britannia/index.html.

Atmospheric contributions of zinc to the BC south coast have not been estimated; however, it was reported that zinc deposition to the Brunette River watershed in Burnaby was approximately 14 t/yr (14,000 kg/yr). The presence of zinc in the atmosphere in this region was attributed primarily to transportation sources and tire wear (Belzer and Petrov 1997;Brewer *et al.* 2000).

Zinc has not been assessed under CEPA 1999 and, therefore, a risk management strategy for zinc has not been developed under the federal Toxic Substances Management Policy. However, it is expected that the implementation of recommendations to reduce the release of CEPA-toxic substances from the base metal smelting, fossil fuel power generation, metal finishing, and steel manufacturing sectors would also decrease zinc loadings to the environment. For more information, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.

3.4.2 Presence of Metals in the South Coastal BC Environment

Recent information on metal concentrations in the south coastal BC environment is lacking and most of the available information was collected in or before the early 1990s. However, some recent studies have reported on metal concentrations in sediment core samples collected in the Strait of Georgia (Burd *et al.* 2008;Johannessen *et al.* 2005;Macdonald *et al.* 2008). While metal concentrations in surface waters are generally low, elevated metal concentrations have been detected, primarily in the vicinity of mines with ARD. Elevated concentrations of some metals have also been detected in aquatic biota and sediments in the vicinity mines with ARD.

However, in general, the highest concentrations of metals in BC coastal sediments and aquatic biota occur nearshore in industrial regions, primarily in the vicinity of harbours, shipbuilding/repair facilities, bulk loading facilities, pulp mills, and wood treatment facilities. Concentrations of some metals exceed Canadian sediment quality guidelines at several locations including Vancouver, Victoria, and Esquimalt harbours; the Fraser River and estuary region; and Howe Sound, in the vicinity of the now closed Britannia Mine. However, in some areas of south coastal BC, high metal concentrations in sediments were attributed to natural enrichment rather than to anthropogenic sources.

The following is a summary of existing information on the presence of arsenic, cadmium, copper, chromium, lead, manganese, mercury, silver, and zinc in the south coastal BC environment.

Arsenic

Historic information indicates that arsenic concentrations in BC south coastal sediments are generally in the low µg/g range (typically less than 8 µg/g (dw)); however, recent information is lacking. In the late 1980s and 1990s, arsenic concentrations in sediments from several areas exceeded the Canadian interim sediment quality guideline (ISQG) for marine sediments (7.24 µg/g (dw)) and the probable effects level (PEL) of 41.6 µg/g (Canadian Council of Ministers of the Environment (CCME) 1999). Particularly high concentrations (in the hundreds of µg/g range) were detected in Vancouver Harbour off shipbuilding/repair and ore loading facilities and in the Constance Cove area of Esquimalt Harbour, near the Department of National Defence (DND) facility. In 1995, arsenic concentrations above the sediment ISQGs were detected at stations throughout Vancouver Harbour; however, no samples contained concentrations higher than the PEL value of 41.6 µg/g (dw). Arsenic concentrations in sediments from False Creek and the Fraser River were generally below 8 µg/g, but concentrations of 15 to 30 µg/g (dw) were detected at some sites (Boyd *et al.* 1998;Brewer *et al.* 1998a;Brewer *et al.* 1998b;Chapman *et al.* 1996;Garrett 1995;Garrett and Shrimpton 1988;Goyette and Boyd 1989;Harding and Kay 1988). Brewer *et al.* (1998a;1998b) reported that arsenic levels were approximately twice as high in sediments from the Lower Fraser River than in sediments from the Upper Fraser River or from the Thompson River. In some areas of the Lower Fraser, the elevated concentrations of arsenic may be associated with the use of arsenic-based wood preservatives at wood treatment facilities.

The GVRD Year 2000 Iona WWTP Deep-Sea Outfall Environmental Monitoring Program found that arsenic concentrations exceed the Canadian ISQG value at twelve stations; however, no samples contained concentrations exceeding the PEL value (Greater Vancouver Regional District (GVRD) 2000). The study concluded that arsenic concentrations were due to natural enrichment and the Iona discharge was not thought to be a significant source.

Marine aquatic organisms, particularly marine shellfish and bottom-feeding fish, often contain naturally elevated concentrations of arsenic. Arsenic concentrations in marine species from BC are similar to those detected in other areas of the world and, in most cases, are due to natural enrichment and not to anthropogenic contamination. Crab, shrimp, and prawns from the BC coast commonly contained higher arsenic concentrations (20 to 30 µg/g range) than did bivalves (typically less than 20 µg/g). Arsenic concentrations in marine fish were variable and, while levels in salmon were low, higher concentrations were often detected in bottom-dwelling species (Farrell and Nassichuk 1984;Garrett 1995;Harding *et al.* 1988;Harding and Thomas 1986). In Vancouver Harbour, where past industrial activity has resulted in elevated concentrations of many contaminants in sediments and biota, arsenic concentrations in biota were not unusually elevated. Goyette and Boyd (1989) reported that arsenic concentrations in biota collected from Vancouver Harbour in 1984 and 1985 were comparable to those detected in similar species from other areas: 5 to 64 µg/g and from 11 to 51 µg/g (dw) in Dungeness crab muscle and hepatopancreas, respectively; 14 to 50 µg/g and 13 to 67 µg/g (dw) in pandalid shrimp muscle and hepatopancreas, respectively; and 19 to 123 µg/g and 8 to 64 µg/g (dw) in English sole muscle and liver, respectively. Biota collected from the vicinity of the Iona WWTP Deep Sea Outfall in 1993 contained mean arsenic concentrations of 28.9 and 27.2 µg/g in Dungeness crab muscle and hepatopancreas, respectively; 49.2 µg/g in pink shrimp tail muscle; and 22.2 and 28.8 µg/g (dw) in English sole muscle and liver, respectively (Stewart and Bertold 1994).

Arsenic levels in whitefish and peamouth chub from the Fraser River were low, but higher concentrations were detected in starry flounder from the Fraser estuary. Raymond *et al.* (1998a;1998b) reported that arsenic concentrations were three to five times higher in starry flounder than in peamouth chub collected from the same areas of the river.

Foran *et al.* (2004) reported that, organic arsenic concentrations were significantly higher in commercially farmed Atlantic salmon than in wild Pacific salmon (chum and coho); however, concentrations in both farmed and wild salmon were low and did not exceed guidelines for human consumption. In contrast, Kelly *et al.* (2008b) found no significant differences in the concentration of arsenic in farmed versus wild Pacific salmon. Arsenic concentrations in all salmon were low and ranged from 0.3 to 1.9 µg/g (ww).

The past use of the arsenic-based pesticide MSMA to treat mountain pine beetle in BC has resulted in increased concentrations of arsenic in the environment. Studies conducted by Environment Canada (CWS) found elevated concentrations of arsenic in beetles and in the blood of insect-eating birds in treatment areas (Morrissey *et al.* 2007). For more information, refer to the Environment Canada website http://www.ec.gc.ca/EnviroZine/default.asp?lang=En&n=B9657723-1.

Grey whales stranded in the Strait of Juan de Fuca and the Strait of Georgia contained mean arsenic concentrations of 410, 230, and 6,200 ng/g (ww) in liver, kidney and stomach contents, respectively (Varanasi *et al.* 1994).

Cadmium

Elevated cadmium concentrations were detected in sediments from many south coastal locations in BC. Concentrations exceeding Canadian sediment quality guidelines (the ISQG value of 0.7 µg/g (dw) and sometimes the PEL value of 4.2 µg/g (dw)) were detected in the vicinity of industrial and waste treatment facilities, pulp mills, mines, wood treatment facilities, marinas, and active harbours in the south coastal area. However, naturally high background concentrations of cadmium occur in several areas of the coast and likely account for the unexpectedly high concentrations found in areas removed from the direct influence of anthropogenic sources (Colodey and Tyers 1987;Garrett 1985a;Garrett 1995;Goyette and Boyd 1989).

In the late 1980s, elevated cadmium concentrations were frequently detected in the highly industrialized areas of Vancouver, Victoria, and Esquimalt harbours, particularly in foreshore areas. Sediment concentrations exceeded the Canadian ISQG at many sites, and exceeded the PEL at several sites. Subsequent monitoring in Vancouver Harbour found that, although cadmium concentrations in sediments at some sites were still elevated in the 1990s, overall, concentrations were lower than in the 1980s. This may be due, in part, to the fact that several of the industrial sites, which were active in the 1980s, had been closed by the 1990s and large sections of the harbour shoreline were undergoing extensive redevelopment. Elevated concentrations of cadmium were also found in the Port Moody area of Burrard Inlet, but were attributed to natural cadmium enrichment (Boyd *et al.* 1998;Boyd *et al.* 1997;Bright *et al.* 1996;Garrett 1985a;Garrett 1995;Goyette and Boyd 1989).

Cadmium concentrations in the low µg/g range have been detected in a wide range of aquatic organisms in south coastal areas of BC. Organisms collected from harbour, urban, and industrial areas typically contained concentrations which were elevated in comparison to reference areas. Cadmium concentrations in several bivalve species were in the 1 to 6 µg/g (dw) range, and concentrations were highest in oysters (Bright *et al.* 1996;Garrett 1985a;Garrett 1995;Harbo *et al.* 1983;Stewart and Bertold 1994).

There are currently no Canadian guidelines on acceptable concentrations of cadmium in aquatic species for the protection of human and wildlife consumers, and incidents of elevated concentrations in shellfish would be reviewed by Health Canada and Canadian Food Inspection Agency (CFIA) on a case-by-case basis. However, in late 1999 and early 2000, shipments of BC farmed oysters were rejected for import into Hong Kong as cadmium concentrations exceeded the Hong Kong maximum allowable import limit of 2 µg/g (ww). Subsequent investigations by CFIA found that mean cadmium concentrations in oysters cultured over a broad geographic area with BC were 2.63 µg/g (ww), and that 60% of the oysters sampled contained cadmium concentrations in excess of 2 µg/g (ww). Although it is thought that natural enrichment is the primary source of the cadmium in oysters on the BC coast, these concentrations are of concern to the BC aquaculture industry as they make BC farmed oysters unacceptable for export to some international markets (Kruzynski 2001;Kruzynski 2004).

Kelly *et al.* (2008b) reported that the concentrations of all metals were low in both BC wild salmon and commercially farmed salmon. Cadmium concentrations did not exceed 0.001 µg/g (ww). Contrary to a previous study by Foran *et al.* (2004), Kelly *et al.* (2008b) did not find that cadmium was present at higher concentrations in wild salmon than in farmed salmon.

Elevated cadmium concentrations have also been detected in some seabirds from the BC coast. Environment Canada studies found that cadmium concentrations in seabirds from northern areas of coastal BC (Queen Charlotte Islands) are significantly higher than cadmium concentrations in seabirds from southern regions (Georgia Basin). The highest concentrations were detected in Leach's Storm Petrels. The reason for the difference in cadmium levels in seabirds from the north and south coasts of BC has not yet been determined (Barjaktarovic *et al.* 2002;Elliott and Scheuhammer 1997;Wilson and Elliott 2004).

Information on cadmium concentrations in the tissues of marine mammals is lacking; however, Varanasi *et al.* (1994) reported that cadmium concentrations in the very low µg/g range (0.29 to 4.4 µg/g (ww)) were detected in the liver, kidney, and stomach contents of grey whales found stranded in the south coastal region of BC.

Chromium

Elevated chromium concentrations have been detected in sediments from both freshwater systems and marine areas receiving discharges from municipal WWTPs or industrial facilities, such as pulp mills and wood treatment plants. However, natural enrichment of sediments in some areas has also resulted in the presence of chromium concentrations in excess of Canadian sediment quality guidelines. Concentrations exceeding the ISQGs for freshwater sediments (37.3 µg/g (dw)) and/or marine sediments (52.3 µg/g (dw)) were detected in several south coastal areas including Burrard Inlet, False Creek, Sturgeon Bank, the Fraser River and estuary, Victoria Harbour, Esquimalt Harbour, Howe Sound, Crofton, Harmac, Port Alberni, and Powell River. In most cases, concentrations were below the PEL values of 90 µg/g (dw) for freshwater sediments and 160 µg/g (dw) for marine sediments. However, particularly high concentrations were detected in sediments from Vancouver and Victoria harbours (up to 267 µg/g (dw) and 326 µg/g (dw), respectively). In Vancouver Harbour, the highest concentrations were detected near an oil refinery in Port Moody, which was reported to be the major source of chromium to the harbour. Background chromium levels in sediment from Vancouver Harbour, Loughborough Inlet, and the Fraser River estuary were approximately 50, 34 to 38, and 48 µg/g (dw), respectively. Background chromium concentrations from reference sites at Warn Bay, on the west coast of Vancouver Island, and in the Queen Charlotte Islands were 15 to 62 µg/g (dw) and 6.6 to 16 µg/g (dw), respectively (Boyd *et al.* 1998;Boyd *et al.* 1997;Garrett 1995;Goyette and Boyd 1989;Johnson 1991;Pedersen and Waters 1989). Chromium concentrations in excess of the Canadian ISQG for marine sediments have also been detected in sediments from Sturgeon Bank and from the Lower Fraser River. However, since the concentrations at reference sites were also higher than the ISQG value, it was concluded that natural enrichment was the primary source of elevated chromium concentrations in these areas (Brewer *et al.* 1998a;Brewer *et al.* 1998b;Garrett 1995;Greater Vancouver Regional District (GVRD) 2000).

Sediment and surface water samples collected at five golf courses in the Fraser Basin also contained elevated concentrations of chromium. While the source of the chromium was not identified, possible sources include fertilizers, pesticides, surface runoff from roads, metal pipes, and atmospheric deposition (Environment Canada 1996).

Chromium concentrations in fish and shellfish from south coastal BC were typically 1 to 2 μg/g (dw) or less. Higher concentrations were detected in biota from the vicinity of some pulp mills and wood treatment facilities in the 1980s and early 1990s, including wood preservation plants on the Fraser River (Garrett 1995). Wood preservation plants in BC utilize large amounts of CCA for the preservation of wood. In the past, large quantities of wood treatment chemicals, including CCA, were released to the environment in surface runoff and stormwater from wood preservation facilities. Since this time, the implementation of environmental codes of practice at these facilities has reduced contaminated stormwater discharges by more than 90% (Environment Canada 1998a).

Little information is available on chromium concentrations in wildlife species in BC; however, a study on mustelids collected from the Lower Fraser River between 1990 and 1994 concluded that these populations were not at risk from chromium discharges to the area (Harding *et al.* 1998). Chromium was detected in the tissues of stranded grey whales in the Straits of Georgia and Juan de Fuca. Liver, kidney, and stomach contents contained 150, 540, and 8200 ng/g (ww), respectively (Varanasi et al. 1994).

Copper

Elevated copper concentrations were detected in sediments from several south coastal areas of BC. Concentrations exceeding the Canadian ISQG for marine sediments (18.7 μg/g (dw)) and, in some cases, the PEL value (108 μg/g (dw)), were detected in Vancouver, Esquimalt, and Victoria harbours (Boyd *et al.* 1998;Boyd *et al.* 1997;Bright *et al.* 1996;Garrett 1995;Johnson 1991;Transport Canada 2000). The copper concentrations detected in aquatic organisms from Vancouver and Victoria harbours also reflected the industrial and urban influences in these areas. Hepatopancreas tissue of shrimp and crab from Burrard Inlet and Victoria Harbour contained particularly high copper levels (several hundred to more than 1000 μg/g (dw)), but much lower concentrations (less than 100 μg/g (dw)) were detected in the muscle tissue. The copper concentrations in mussels and crabs collected near the DND facility at Constance Cove, in Esquimalt Harbour, were higher than those in organisms collected from other areas of the harbour (Garrett 1995;Goyette and Boyd 1989;VEHEAP 1997).

Sediments collected near the Iona Island WWTP discharge also commonly contained copper concentrations in excess of the ISQG. However, since sediments from reference sites contained comparable copper concentrations, it was concluded that elevated copper levels in sediments from this area were natural and were not associated with the Iona Island WWTP discharges (Gordon 1997;Greater Vancouver Regional District (GVRD) 2000;Thomas and Bendell-Young 1998).

Copper concentrations in Fraser River sediments were higher in the more urbanized areas of the downstream reaches than at upstream locations (Swain *et al.* 1998). However, there were no noticeable differences in copper concentrations detected in the muscle or liver of fish collected upstream and downstream of Hope (Raymond et al. 1998b). Elevated copper concentrations were also detected in the Sumas River and were attributed to high natural background concentrations of copper and/or the presence of copper in livestock feed supplements (Schreier et al. 1998). In some areas, environmental concentrations of metals have decreased in recent decades; however, copper levels in sediments from Still Creek in Burnaby increased between 1973 and 1993 due to increased traffic density over this time period (Hall et al. 1999).

Recent information is limited; however, historic data indicated overall mean concentrations of 5, 10, and 1.92 μg/g (ww), respectively, for molluscs, crustaceans, and fish from the south coast of BC. Especially high copper concentrations were present in oysters (mean of 27.33 μg/g (ww)), compared to other mollusc species (Harbo et al. 1983).

Very high copper concentrations (14,000 μg/g (dw)) were detected in oysters collected near the Britannia Mine in 1975 and were attributed to ARD from this mine (Hagen 2001). Surface waters and sediments in the vicinity of Britannia Mine also contained elevated copper concentrations, primarily as a result of ARD, and adversely affected algal growth and impacted phytoplankton populations. It was reported that the surface waters in Britannia Creek estuary were toxic to juvenile salmon during spring migration and may also have caused sublethal effects in mature salmon (Barry *et al.* 2000;Grout and Levings 2001). Sediments near the mine contained elevated copper concentrations as a result of contamination with mine tailings (Drysdale 1990). ARD from the Mount Washington Mine on Vancouver Island also contributed copper to nearby aquatic systems and resulted in elevated copper concentrations in rainbow trout in Buttle Lake. However, concentrations have decreased since the ARD problem at this mine was resolved in 2003 (Deniseger and Erickson 1991;Deniseger *et al.* 1995;McCandless 2006).

The use of copper-based antifouling paints has increased in recent years as these products have replaced tributyltin-based paints, whose use in Canada was discontinued in 2002. The use of these paints on boat hulls is a potentially significant source of copper, due to the extensive boating activity along the south coast of BC. In addition, some aquaculture facilities use copper-based antifoulants to treat salmon net pens. Insufficient information is available to determine whether the use of copper-based antifoulants makes significant contributions to the environmental concentrations of copper in the BC south coast. However, several studies found that both zinc and copper concentrations are elevated in sediments collected within BC fish farms relative to sediments from reference areas (Brooks 2000;Brooks and Mahnken 2003;Brooks *et al.* 2003;Obee 2009;Sutherland *et al.* 2007).

In addition, some aquaculture facilities use copper-based antifoulants to treat salmon net pens. Insufficient information is available to determine whether the use of copper-based antifoulants makes significant contributions to the environmental concentrations of copper in the BC south coast. However, several studies found that both zinc and copper concentrations are elevated in sediments collected within BC fish farms relative to sediments from reference areas (Brooks 2000;Brooks and Mahnken 2003;Brooks *et al.* 2003;Obee 2009;Sutherland *et al.* 2007).

Brooks (2000) compared copper concentrations in sediments from salmon farms using copper-treated nets, farms not using copper-treated nets, and reference sites and concluded that there were no significant differences in mean copper concentrations. However, there were large variations in the copper concentrations in sediments from the farms using copper-treated nets. In some cases, concentrations exceeded the mean of the Canadian sediment quality TEL and the PEL values, which has been used as a screening benchmark in British Columbia. NOAA's Effects Range Median of 270 µg/g (dw), the Washington State sediment quality criterion of 390 µg/g (dw), and the mean of the Canadian sediment quality TEL and PEL were all exceeded in several samples. Elevated concentrations occurred at farms where net washing was conducted on barges, but lower concentrations were generally detected at farms where copper treated nets were in use, but were not being washed. Brooks (2000) also reported that copper levels in sediments from farms not using copper-treated nets were well below any recognized effects benchmarks, indicating that the small amount of copper micronutrients added to fish food did not pose an environmental risk. Lewis and Metaxas (1991) measured concentrations of copper inside and adjacent to treated net pens in Jervis Inlet, BC. Concentrations were not significantly different than concentrations in an area removed from the influence of the net pens. Lewis and Metaxas (1991) and Peterson *et al.* (1991) also reported that copper concentrations were similar in salmon raised in treated and non-treated pens. Kelly *et al.* (2008b) measured metal concentrations in commercially farmed and BC wild salmon and reported that the concentrations of all metals were low. Copper concentrations did not exceed 1.0 µg/g (wet wt). Contrary to a previous study by Foran *et al*. (2004), Kelly *et al.* (2008b) did not detect higher copper concentrations in wild salmon than in farmed salmon.

Information on copper concentrations in aquatic wildlife species in BC is very limited. The liver and kidney tissue of mink and river otter from the Lower Fraser River in 1990/91 contained low µg/g (dw) concentrations of copper (up to 32 µg/g (dw)) (Harding et al. 1998). Copper concentrations in the low µg/g (ww) range (3.1 to 37.0 µg/g (ww)) were detected in the liver, kidney, and stomach contents of stranded grey whales from the south coastal area (Varanasi et al. 1994).

Lead

Historic information indicates that lead concentrations in sediments from the BC coast are generally less than 20 µg/g (dw); however, much higher concentrations (in the hundreds to thousands of µg/g range) have been detected in the vicinity of industries such as smelters, base metal mines, pulp mills, and harbours. In many of these areas, concentrations exceeded the Canadian environmental quality guidelines for marine sediments (both the ISQG (7.24 µg/g (dw)) and the PEL (112 µg/g (dw))) (Canadian Council of Ministers of the Environment (CCME) 2006). In the late 1980s and early 1990s, concentrations in the thousands of µg/g (dw) range were detected in Vancouver and Victoria harbours and were attributed to the extensive industrial and urban influences in these harbours. The highest concentrations were detected in the vicinity of shipbuilding/repair and bulk loading facilities. Very high concentrations were also detected in Esquimalt Harbour, in the vicinity of the DND facility at Constance Cove. In 1995, sediments collected in Vancouver Harbour contained lead concentrations ranging from 10 to 140 µg/g. Elevated lead concentrations were also detected near some south coastal area marinas, docks, sawmills, and pulp mills (Boyd *et al.* 1998;Garrett 1985b;Garrett 1995;Goyette and Boyd 1989;Harding *et al.* 1998).

The GVRD Year 2000 Iona WWTP Deep-Sea Outfall Environmental Monitoring Program found that lead concentrations sediments in the vicinity of the outfall ranged from 8 to 14 µg/g (dw), and did not exceed Canadian sediment quality guidelines (Canadian Council of Ministers of the Environment (CCME) 2006) at any stations (Greater Vancouver Regional District (GVRD) 2000).

In the lower Fraser River sediments, lead concentrations were typically in the low µg/g (dw) range (<20 µg/g at most sites), and rarely exceeded 50 µg/g (dw) (Garrett 1995). Brewer *et al.* (1998a;1998b) reported that lead concentrations in sediments from the Fraser River, between 1994 and 1996, were generally higher in the North and Main arms of the river than in the upper regions of the river. Since concentrations were similar to those detected in the early 1990s, the authors speculated that lead levels may now be levelling off, following the significant decrease in environmental concentrations which followed the ban on leaded gasoline in 1990.

Lead concentrations in aquatic organisms in BC freshwater systems and coastal waters are generally low (typically not more than a few ng/g (dw)); however, recent information is very limited. Elevated lead concentrations have been detected in biota from areas receiving discharges from industry and/or storm sewers, including mussels and clams from Vancouver, Victoria, and Esquimalt harbours; False Creek; and some south coastal area marinas (Garrett 1985b;Garrett 1995). However, (Goyette and Boyd 1989) reported that lead concentrations in biota collected from Vancouver Harbour in 1984 and 1985 were not unusually elevated compared to biota from other areas. Lead concentrations were similar in BC farmed and wild salmon (approximately 0.01 µg/g (ww)) (Kelly *et al.* 2008b).

Seabirds from the BC coast in 1990 contained two to ten times higher concentrations of lead in their bones than did Atlantic seabirds; however, it was not known whether this was due to greater natural enrichment on the west coast or to dietary differences between Pacific and Atlantic seabird populations (Elliott and Scheuhammer 1997). Lead shot is also a source of lead in several bird species in BC. Birds are exposed by the ingestion of spent shot and the ingestion of other birds containing lead shot. Past studies reported a high incidence of lead shot in waterfowl gizzards in BC (Elliott *et al.* 1992).

Lead concentrations in the µg/g (ww) range (80 to 320 µg/g (ww)) were detected in the liver, kidney, and stomach contents of stranded grey whales from the south coastal area (Varanasi et al. 1994).

Manganese

High concentrations of manganese (> 900 µg/g (dw)) have been detected in sediments from harbours in Vancouver (average concentrations of 613 µg/g (dw)) (Johnson 1991) and Victoria (mean concentration of 251 µg/g (dw)) (Transport Canada 2000), and also in Sturgeon Bank (701 to 6222 µg/g (dw)). Although potential sources are present in these areas, naturally elevated levels of manganese have been detected in sediments from BC coastal regions which are removed from known pollution sources. For example, manganese concentrations in sediments from Loughborough Inlet, a natural inlet on the BC coast, were 546 to 2650 µg/g (Goyette and Boyd 1989). Manganese concentrations in Fraser River sediments collected between Hope and the estuary ranged from 328 to 802 µg/g and were also attributed to natural sources (Swain et al. 1998).

The use of the gasoline additive MMT (methylcyclopentadienyl manganese tricarbonyl), which was introduced in 1974 as a replacement for lead, is thought to be the cause of increased manganese concentrations in stream and street surface sediments in the Burnaby area. Unlike the concentrations of most metals, which have decreased in recent years, the concentrations of manganese were substantially higher in stream and street surface sediments collected in the Burnaby Lake/Still Creek/Brunette River area in 1993 than in sediments collected in this area in the 1970s. Sediments collected from one third of the sampling stations contained manganese concentrations above 1000 µg/g (dw), which is the severe-effects-criterion being used by the province of BC. However, while the concentrations of other metals associated with vehicular emissions were positively correlated with changes in traffic density, the concentrations of manganese did not appear to be correlated with traffic density (British Columbia Ministry of Environment 1998;Hall *et al.* 1998).

Recent information on manganese concentrations in BC aquatic species is limited. Surveys conducted in the Fraser River in the 1980s revealed that, in most cases, the manganese concentrations in fish below Hope were comparable to the concentrations in fish collected from uncontaminated BC lakes. However, red shiner and stickleback contained somewhat higher concentrations than did other species (Swain et al. 1998). An Environment Canada study conducted in 1994 and 1995 noted that there was no obvious difference between the manganese concentrations in fish collected upstream of Hope and those collected downstream (Raymond *et al.* 1998a;Raymond *et al.* 1998b).

Manganese was detected at concentrations of up to a few μg/g (dw) in a variety of fish and aquatic invertebrate species collected in the south coastal area of BC; however no obvious areas of manganese contamination were identified from the available data (Goyette and Boyd 1989;Harding *et al.* 1988;Swain and Walton 1994;VEHEAP 1997).

Mercury

Mercury concentrations in sediments from south coastal areas of BC were typically less than 0.10 μg/g (dw). Past studies detected mercury concentrations exceeding 1.0 μg/g (dw) in sediments from several locations including Howe Sound (in the vicinity of a now closed chlor-alkali plant); Vancouver, Victoria, and Esquimalt harbours; Point Grey; and Sturgeon Bank. Mercury concentrations in the 0.1 to 1.0 μg/g (dw) range were detected in sediments from False Creek; Coal Harbour; Roberts Bank; Ladysmith Harbour; Comox; in the vicinities of pulp mills at Harmac, Chemainus and Powell River; and at various coastal marinas and government docks (Garrett 1985c).

Environment Canada surveys conducted in Vancouver Harbour in the 1980s found that the highest mercury concentrations were present in sediments collected adjacent to CSOs and shipyards (Boyd *et al.* 1998;Boyd *et al.* 1997;Bright *et al.* 1996;Garrett 1985c;Garrett 1995;Goyette and Boyd 1989). The highest concentrations in Esquimalt Harbour sediments were detected in the vicinity of the DND facility at Constance Cove. In Victoria Harbour, mercury concentrations were highest in sediments collected in the Inner Harbour area (Bright *et al.* 1996;Garrett 1995;Transport Canada 2000).

Recent information on mercury concentrations was not available for most south coastal areas. However, samples collected from Vancouver Harbour, Sturgeon Bank, and Roberts Bank in the late 1990s indicated that, while concentrations were still elevated at some sites, overall mercury concentrations in sediments from these areas had decreased since the late 1980s. However, Johannessen *et al.* (2005) collected 17 sediment cores in the Strait of Georgia and noted that, while surface sediment concentrations will likely decrease at all sites in coming years, sediments from the industrialized Vancouver Harbour and Port Moody Arm will likely retain sufficient contamination to pose a threat to benthic organisms. In addition, these authors noted that despite the high mercury load contributed by the Fraser River to the Strait of Georgia, sediments at the mouth of the Fraser River are low due to dilution by other particles.

A review of available information conducted by Environment Canada in the 1980s indicated that BC fish and shellfish generally do not contain mercury concentrations in excess of those considered safe for human consumption (Garrett 1985c). Health Canada recommends that mercury concentrations in fish for human consumption not exceed 0.5 μg/g (ww) in the edible portion. Shark, swordfish, and tuna often contain concentrations somewhat higher than this level. In addition, elevated mercury concentrations were detected in large halibut (over 60 lbs), groundfish, and shark species caught in coastal BC waters. The elevated concentrations were attributed to natural enrichment and to the long life span of these species. Molluscs, crustaceans, salmon, and most ocean species of fish generally contained mercury concentrations of less than 0.5 μg/g. Mercury concentrations in some species of fish collected from the lower Fraser River in the 1980s exceeded the Health Canada recommended guideline; however, maximum concentrations in Fraser River fish collected in 1994 to 1995 were well below this value (Garrett 1985c).

Debruyn *et al.* (2006) reported elevated mercury concentrations in demersal rockfish collected near BC salmon farms. They attributed this finding to higher concentrations of mercury in prey near the salmon farms and a higher trophic position of rockfish near salmon farms, compared to other areas. However, a recent study found that concentrations of mercury and other trace elements were low (below human health consumption guidelines) in commercially farmed salmon and in wild salmon in BC. Mercury concentrations in wild BC salmon were higher than in farmed salmon, and higher in fish-eating chinook salmon than in smaller, shorter-lived species, such as chum and pink (which feed primarily on plankton). However, concentrations of methylmercury (the form in which most of the mercury in fish is present), ranged from 0.03 to 0.1 µg/g (ww), compared to the Health Canada guideline of 0.5 µg/g (ww) (Kelly *et al.* 2008b).

Elevated mercury concentrations have been detected in fish-eating species of birds in south coastal areas of BC. High concentrations of mercury were detected in eagles found dead or dying in the vicinity of pulp and paper mills in the Georgia Basin between 1987 and 1994, and one bird was determined to have died from mercury poisoning. Elevated mercury concentrations were also found in mergansers from the Squamish area in 2000 and in the feathers of dippers breeding in the Chilliwack watershed in 1999/2000. Possible sources of the mercury to these birds were not identified (Elliott *et al.* 1996b;Weech *et al.* 2003).

Grey whales that were stranded in the south coastal area of BC contained mercury concentrations of 120, 60, and 85 ng/g (ww) in the liver, kidney, and stomach contents (Varanasi et al. 1994).

Nickel

Nickel concentrations in the low µg/g range are commonly detected in sediments from the south coast of BC. Although there are currently no Canadian sediment quality guidelines for nickel, concentrations in some sediment samples, from areas such as Vancouver and Esquimalt harbours and Sturgeon Bank, exceeded the BC provincial working guideline values for marine sediments of 30 µg/g (dw) nickel (for effects-range-low) and 50 µg/g (dw) nickel (for effects-range-medium)(Boyd *et al.* 1997;Bright *et al.* 1996;Gordon 1997;Goyette and Boyd 1989;Greater Vancouver Regional District (GVRD) 2000;McPherson *et al.* 2001;Transport Canada 2000). However, in many instances, these nickel concentrations were considered to be within the range of natural enrichment. For example, nickel concentrations in sediments from Sturgeon Bank ranged from 40 to 55 µg/g (dw), but no pattern was observed in the distribution of enrichment. The authors concluded that the nickel concentrations were natural and not due to contamination from the Iona Island WWTP deep-sea outfall (Bertold 2000;Gordon 1997;Greater Vancouver Regional District (GVRD) 2000;McPherson *et al.* 2001). In the 1980s, nickel concentrations in Burrard Inlet sediments ranged from 7 to 296 µg/g (dw), with the highest concentrations occurring in the Inner Harbour area (Goyette and Boyd 1989). Boyd *et al.* (1997) reported that, while later sampling found somewhat lower concentrations of nickel in sediment core samples from Burrard Inlet, many samples contained concentrations which were still in excess of the provincial working guidelines value. However, natural nickel concentrations in Burrard Inlet are reported to range from 4.5 to130 µg/g (dw) (Johnson 1991).

High concentrations of nickel detected in the Sumas River sediments and fish have been attributed to the naturally elevated nickel concentrations in the soils in that area. A landslide to the headwaters of the river in the US contributed to the particularly high concentrations of nickel in sediments in this area (2000 µg/g (dw)), compared to concentrations in the sediments at the mouth (200 to 300 µg/g (dw)) (Schreier 2005). Sediments collected from several locations in the Fraser River also contained nickel concentrations in excess of the provincial working guideline of 16 µg/g (effects-range-low) for freshwater sediments (Swain et al. 1998).

Current information on nickel concentrations in biota from the south coastal region of BC is limited; however, historic information for molluscs, crustaceans, and fish indicated that nickel concentrations were 0.5 to 1.2 µg/g, <0.5 to <0.5 µg/g, and 0.10 to 0.43 µg/g (ww), respectively. Biota from Vancouver and Esquimalt harbours typically contained nickel concentrations below or close to the detection limit of 2 µg/g (dw); however, English sole from Esquimalt Harbour contained concentrations of up to 35 µg/g (dw) (Bright *et al.* 1996;Goyette and Boyd 1989;Harbo *et al.* 1983). In the Fraser River, the highest concentrations were generally detected in fish from the upper reaches of the river, but whitefish from the Fraser River contained lower nickel concentrations than did whitefish from uncontaminated BC lakes (Raymond *et al.* 1998a;Swain *et al.* 1998).

Stranded gray whales in the Strait of Georgia/Strait of Juan de Fuca contained nickel concentrations of 100, 210 and 900 ng/g (ww), respectively in liver, kidney, and stomach contents (Varanasi et al. 1994).

Silver

At most locations south coast locations sampled, silver concentrations in surface waters were less than the detection limit (0.10 µg/L) (Canadian Council of Ministers of the Environment (CCME) 1999). However, silver concentrations in sediments from some nearshore areas were elevated compared to sediments collected in the deeper waters of the Strait of Georgia. In Sturgeon Bank, the highest concentrations (more than 1,000 ng/g (dw)) were detected near the Iona Island WWTP discharge and the deposition pattern of silver was clearly related to the Iona discharge (Greater Vancouver Regional District (GVRD) 2000;Wilson 2000). Silver concentrations were also elevated in sediments from south coastal harbours. Concentrations of more than 3,000 ng/g (dw) were detected in Vancouver Harbour (Boyd *et al.* 1998;Hall *et al.* 1999); up to 6,200 ng/g (dw) in Victoria Harbour; and up to 2,800 ng/g (dw) in Esquimalt Harbour (Transport Canada 2000;VEHEAP 1997).Sediment samples collected within 1,000 meters of the major Victoria deepwater sewage discharge contained silver concentrations of up to 1,700 ng/g, compared to concentrations of 70 to 130 ng/g at a reference site (Chapman et al. 1996).

Information on silver concentrations in biota from the south coastal area is limited. Biota collected in the vicinity of the Iona Island WWTP discharge off Sturgeon Bank contained 790 and 1430 ng/g (ww) in crab muscle and hepatopancreas, respectively; 590 ng/g (ww) in shrimp muscle; and <50 and 510 ng/g (ww) in English sole muscle and liver, respectively (Wilson 2000).

Varanasi *et al.* (1994) reported that gray whales that were stranded along the west coast contained 20 ng/g (ww) in the liver, kidney and stomach contents.

Zinc

Macdonald *et al.* (1991) reported that ambient zinc concentrations in the Georgia Basin waters ranged from 1 to 88 µg/L; and concentrations in waters collected in the Sturgeon and Roberts Banks areas ranged from <5 to 13 µg/L (Swain et al. 1998). The highest concentrations were detected sediments near historic mines, shipyards, and in active harbours. Sediments from Vancouver, Victoria, and Esquimalt harbours, in the 1980s and early 1990s, ranged from approximately 100 to several thousand μg/g (dw). These elevated concentrations likely reflect the extensive historic industrial activity in these harbours (Bright *et al.* 1996;Garrett 1995;Goyette and Boyd 1989;Transport Canada 2000). Lower zinc concentrations were detected in sediments collected during subsequent sampling conducted in the 1990s, possibly due to the extensive redevelopment of much of the shoreline in Vancouver Harbour (Boyd *et al.* 1998;Boyd *et al.* 1997). Elevated zinc concentrations have also been detected in sediments off public port facilities in the Georgia Basin (Transport Canada 2000). Sediments from a coastal reference area, Jervis Inlet, contained a mean concentration of 161 μg/g (dw) (Brothers 1990).

Sediments and surface waters at some golf courses in the Fraser Basin contained elevated concentrations of zinc and some other metals. The source of the metals was not identified; however, possible sources included fertilizers, pesticides, road runoff, piping, and atmospheric deposition (Environment Canada 1996).

Elevated environmental concentrations of metals, including zinc, have also been detected in the vicinity of some BC mines as a result of ARD. High zinc concentrations in water, sediments, and biota in the vicinity of the Britannia Mine on Howe Sound are the result of the long-term release of metals-contaminated drainage (Hagen 2001). Pollution control measures have now being implemented to address pollution from this source. ARD was also identified as the source of elevated zinc concentrations in surface waters near a mine at Buttle Lake on Vancouver Island. More recent data indicate that concentrations in the surface waters have decreased and now meet provincial guidelines in most samples; however, similar decreases were not observed in muscle tissue of rainbow trout from Buttle Lake (Deniseger and Erickson 1991).

As with other metals, the recent information on zinc concentrations in aquatic species from the south coastal area is limited; however, historic information indicates that mean zinc concentrations in molluscs, crustaceans, and fish were 30, <60, and <15 μg/g (ww), respectively. In comparison, the mean concentration of zinc in oysters was very high (642 μg/g) (Harbo et al. 1983). Particularly high zinc concentrations (541 to 1821 μg/g (dw)) were detected in the digestive gland of oysters from the Crofton area (Colodey and Tyers 1987). Elevated zinc concentrations were also detected in some species of aquatic biota from Vancouver, Victoria, and Esquimalt harbours (Garrett 1995;Goyette and Boyd 1989;VEHEAP 1997).

Zinc is added to fish food at salmon farms for nutritional purposes and elevated concentrations of zinc have been detected in the sediments in some BC salmon farms (Brooks 2001;Brooks *et al.* 2003;Sutherland *et al.* 2007); however, Brooks *et al.* (2003) reported that zinc in sediments under net pens in the Broughton Archipelago in BC were not bioavailable due to high sulphide levels. Also, these authors reported that zinc concentrations declined after the salmon were harvested.

Kelly *et al.* (2008b) analyzed commercially farmed and BC wild salmon and reported that the concentrations of all metals were low, and zinc concentrations did not exceed 5.0 µg/g (ww). Similar concentrations were reported in previous studies by Foran *et al*. (2004) and Barber *et al.* (1988).

Environment Canada (Canadian Wildlife Service) monitored heavy metal concentrations in diving duck species along the BC coast and also in harbours in the Georgia Basin (Barjaktarovic *et al.* 2002;Wilson and Elliott 2004). Studies on mink and otter from the lower Fraser River concluded that current levels of zinc did not pose a risk to mustelid populations (Harding et al. 1998).

Samples of liver, kidney, and stomach contents from gray whales that were stranded along the west coast contained zinc concentrations of 120, 69, and 52 µg/g (ww), respectively (Varanasi et al. 1994).

3.4.3 Environmental Concerns and Potential Biological Impacts of Metals in the Aquatic Environment

While metals do not break down in the environment, they can exist in a variety of forms, depending on environmental variables. The form in which metals are present determines their bioavailability, toxicity, and distribution in environmental media. Hence, the mobility, bioavailability, and toxicity of metals in aquatic environments is determined, to a large extent, by environmental conditions such as pH, dissolved oxygen levels, water hardness, salinity, organic carbon levels, and the presence of suspended particulates.

Several metals and metal compounds are considered to be CEPA-toxic and have been added to the Schedule 1 List of Toxic Substances. These include lead, mercury, inorganic arsenic compounds, inorganic cadmium compounds, and hexavalent chromium compounds. The Schedule 1 List of Toxic Substances can be viewed at http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm.

The following is a summary of environmental concerns and potential biological impacts associated with the presence of elevated concentrations of metals in the aquatic environment. Where there have been indications of adverse biological effects related to the presence of metals in the BC environment, these have been noted.

Arsenic

Arsenic is present in the environment in both organic and inorganic forms and can be reduced or biomethylated in both freshwater and marine systems. While arsenic uptake occurs in aquatic organisms under most environmental conditions, the rate of uptake is influenced by environmental variables as well as the species and age of the organism. BCFs of up to several thousand have been observed for some species of aquatic organisms. Aquatic species at the lower end of the food chain usually accumulate higher concentrations of arsenic than do fish; however, some fish species, particularly bottom-feeders, can accumulate elevated arsenic concentrations. Arsenic does not appear to biomagnify and the concentrations of arsenic are typically lower in organisms from the top of the food chain (Canadian Council of Ministers of the Environment (CCME) 1999;Environment Canada/Health Canada 1993a).

Arsenic is toxic to many species of freshwater fish and invertebrates at concentrations of less than 1 mg/L, and toxicity to plants has been observed at even lower concentrations. A variety of marine invertebrates and plant species exhibited toxic effects when exposed to arsenic concentrations of a few hundred µg/L and lower. However, in general, marine fish are less sensitive to arsenic than are marine invertebrates and plants and concentrations causing toxicity to marine fish are typically in the low mg/L range. The greater tolerance of higher trophic level marine organisms to arsenic is thought to be due to the fact that these species accumulate arsenobetaine, an organic form of arsenic with a relatively low toxicity. Arsenic concentrations in the low µg/g range can cause toxic effects in some invertebrate species (Canadian Council of Ministers of the Environment (CCME) 1999;Environment Canada/Health Canada 1993a).

The past treatment of BC forests with the arsenic-based pesticide MSMA to control mountain pine beetle infestations has caused concern due to the potential for adverse effects on non-target biota. Environment Canada (CWS) conducted studies to evaluate the exposure of woodpeckers

and other birds to arsenic as a result of this MSMA use (Morrissey et al. 2007). The study found higher concentrations of arsenic in beetles from treated trees and moderate to widespread exposure of woodpeckers and other insect-eating birds. The researchers concluded that birds were being exposed to arsenic at levels which could result in significant health effects, including weight loss and increased mortality rates. For more information on this study, refer to the Environment Canada website
http://www.ec.gc.ca/EnviroZine/default.asp?lang=En&n=B9657723-1.

Canadian environmental quality guidelines have been developed for arsenic. Guidelines for arsenic in surface waters, for the protection of freshwater and marine life, are 5.0 and 12.5 (interim value) µg/L, respectively. Interim sediment quality guidelines (ISQGs are considered to be equivalent to a threshold effect level or TEL) and probable effects levels (PELs) have been developed for a variety of metals. The ISQGs for arsenic in freshwater and marine/estuarine sediments are 5.9 and 7.24 µg/g (dw), respectively, and the PEL values are 17.0 and 41.6 µg/g (dw), respectively (Canadian Council of Ministers of the Environment (CCME) 2006).

Cadmium

Toxicity tests indicate that the most sensitive aquatic organisms to cadmium are *Daphnia magna* (LOEL of 0.17 µg/L) and *Mysidopsis bahia* (LOEL of 1.2 µg/L), while salmonids are the most sensitive fish species. The LOEL for Atlantic salmon exposed to $CdCl_2$ over a 42-day period was 0.47 µg/L, while concentrations of 0.5 to 1.0 µg/L ($CdCl_2$) were acutely toxic to rainbow trout over 96 hours (Environment Canada/Health Canada 1994a). Sublethal exposure of aquatic species to cadmium can cause a variety of adverse biological effects including reproductive impairment; reduced production of young; reduced survival of young; morphological alterations and organ damage in the kidney, liver, intestine, testes, and gills; reduction of antibody levels; increased susceptibility to disease; interference with red blood cell production and hemoglobin synthesis; retardation of fin regeneration (and also limb regeneration in amphibians); inhibition of shell growth; loss of colour and markings definition; and behavioural abnormalities (Dethloff and Bailey 1998;Gerhardt 1993;Reddy *et al.* 1997;Romero *et al.* 1999;Selck *et al.* 1998).

Bioaccumulation of cadmium in aquatic organisms has been reported and bioconcentration factors (BCFs) for freshwater and marine biota ranged from one to several thousand. While most evidence suggests that little or no biomagnification occurs in either aquatic or terrestrial ecosystems, the fact that some researchers have observed higher cadmium concentrations in organisms from the higher trophic levels indicates that there is a the need for further studies on biomagnification (Canadian Council of Ministers of the Environment (CCME) 1999;Environment Canada 1993;Environment Canada/Health Canada 1994a;Environment Canada/Health Canada 1994b).

Interim Canadian environmental quality guidelines for cadmium have been developed by CCME. The interim guideline for cadmium, for the protection of aquatic life, in freshwater systems is 0.017 µg/L (in soft waters), but varies with water hardness. The guideline for the protection of marine and estuarine species is 0.12 µg/L. ISQGs for freshwater and marine/estuarine sediments are 0.6 and 0.7 µg/g (dw), respectively, while the PEL values are 3.5 and 4.2 µg/g (dw), respectively (Canadian Council of Ministers of the Environment (CCME) 2006).

Chromium

Chromium is present in natural surface waters primarily in the trivalent (Cr III) and hexavalent (Cr VI) forms, but many environmental variables can influence the proportion in which these forms are present. Cr (VI) is relatively soluble in water and is less likely to form stable complexes or to sorb to suspended particulates in the water column than is Cr (III). However, certain environmental conditions can cause Cr (VI) to be reduced to Cr (III) (Canadian Council of Ministers of the Environment (CCME) 1987;Environment Canada/Health Canada 1994d).

While mammals are more sensitive to Cr (VI) than to Cr (III), likely due to its greater water solubility, this is not always the case for aquatic biota. Some studies indicated that Cr (III) is more toxic to fish than is Cr (VI). In salmonid species, the mean 96-h LC_{50} for Cr (III) is approximately 4-fold lower than that of Cr (VI), and exposure of rainbow trout eggs and spermatozoa to 5 μg/L of Cr (III) caused a 60 to 70% reduction in fertilization. However, other studies have reported that Cr (III) was more toxic to fish than was Cr (VI) (Environment Canada/Health Canada 1994d). Cr (III) can be deposited in the fish gills, resulting in tissue damage and interference with osmoregulation and respiration. While Cr (VI) does not accumulate in the gills, it can affect other organs including the liver, kidney, and spleen (Environment Canada/Health Canada 1994d;Gendusa and Beitinger 1992;Outridge and Scheuhammer 1993).

BCFs of <100 to 1,000 have been reported for chromium in aquatic species; however, biomagnification through the food chain has not been observed. There is evidence that the presence of sediments can sequester chromium and other metals, making them unavailable for uptake into aquatic organisms (Environment Canada/Health Canada 1994d).

CCME has developed Canadian environmental quality guidelines for Cr (VI) and Cr (III). The guidelines for surface waters, for the protection of freshwater aquatic life, are 1.0 and 8.9 (interim value) μg/L, respectively, and guidelines for the protection of marine life are 1.5 and 56 (interim value) μg/L, respectively. ISQGs and PEL values for total chromium are 37.3 and 90 μg/g (dw), respectively, for freshwater sediments and 52.3 and 160 μg/g (dw), respectively, for marine and estuarine sediments (Canadian Council of Ministers of the Environment (CCME) 2006).

Copper

The behaviour of copper in the aquatic environment is complex and is not well understood. The form and distribution of copper in the environment is determined by a number of environmental factors and even small changes in environmental conditions can affect the transfer of copper between different environmental compartments. While dissolved forms of copper in surface waters are the most bioavailable forms, changes in ambient environmental conditions can cause unavailable forms (such as those adsorbed to bottom sediments) to become more bioavailable (Canadian Council of Ministers of the Environment (CCME) 1987;Canadian Council of Ministers of the Environment (CCME) 1999).

Copper is readily accumulated by aquatic organisms and BCFs ranging from 100 to 26,000 have been reported. However, in general, whole body concentrations of copper tend to decrease with increasing trophic level and there is no evidence of significant biomagnification of copper. This is likely due to the fact that copper is an essential element and organisms are able to metabolically regulate copper levels in the body (Canadian Council of Ministers of the Environment (CCME) 1987;Canadian Council of Ministers of the Environment (CCME) 1999).

Copper concentrations of greater than 5 μg/L in water can be acutely toxic to aquatic organisms, depending on the form in which it is present. A review of toxicity information revealed that, at a water hardness of 50 mg/L, acutely toxic copper concentrations for various aquatic species ranged from a few μg/L to more than 10,000 μg/L. Sublethal effects observed in aquatic species exposed to copper include abnormal development, inhibition of enzyme production, interference with immune response and metabolic processes in trout, and inhibited photosynthesis and growth in algae (Dethloff and Bailey 1998;Dickman 1998;Konasewich *et al.* 1982;Taylor *et al.* 1998). Adverse biological effects have also been observed in aquatic organisms exposed to elevated concentrations of copper in the bottom sediments (Canadian Council of Ministers of the Environment (CCME) 1999).

Short-term exposures of fish to copper concentrations representative of urban stormwater runoff have been shown to impair sensory structures which are important in orientation, schooling, and predator avoidance. This finding suggests that stormwater releases of copper could impair the health and survival of salmonids and other fish species in urban areas (Kao and Scholtz 2004).

Elevated surface water and sediment concentrations near the, now closed, Britannia Mines in Howe Sound, BC where attributed to ARD from the mine. It was reported that these elevated concentrations adversely affected algal growth and impacted phytoplankton populations. In addition, surface waters in Britannia Creek estuary were reported to be toxic to juvenile salmon during spring migration, and may also have caused sublethal effects in mature salmon (Barry *et al.* 2000;Grout and Levings 2001).

CCME has developed Canadian environmental quality guidelines for copper. Guidelines for copper for surface waters, for the protection of freshwater aquatic life, vary with local water hardness and range from 2 to 4 μg/L (total copper). There are currently no Canadian guidelines for copper in marine waters. ISQGs for copper are 35.7 μg/g for freshwater sediments and 18.7 μg/g for marine and estuarine sediments, and PELs are 197 μg/g for freshwater sediments and 108 μg/g for marine and estuarine sediments (Canadian Council of Ministers of the Environment (CCME) 2006). BC provincial water quality criteria for copper in freshwater systems also vary with water hardness. Criteria for marine/estuarine systems are $\leq$2 μg/L (as a 30-day average) and 3 μg/L (as a maximum). There are currently no approved BC provincial sediment quality guidelines for copper (BC MELP1998).

Lead

The form, behaviour, and distribution of lead in aquatic systems are determined largely by local environmental conditions. Dissolved concentrations of lead in surface waters are low. Lead entering aquatic systems commonly forms insoluble complexes, particularly under high pH conditions, and adheres to suspended particulates. This results in lead being removed from the water column and deposited in the bottom sediments. Sediments can be an important route of exposure to aquatic organisms; however, the bioavailability of lead and its ability to be released back to the water column from sediments is also determined by local environmental conditions. For example, insoluble lead sulphide is often formed in oxygen depleted bottom sediments. Lead in this form is not readily available for release back to the water column and, therefore, is not readily available for uptake by aquatic organisms (Canadian Council of Ministers of the Environment (CCME) 1999).

Aquatic organisms can accumulate lead. Reported BCFs for fish and aquatic invertebrates are in the 20 to 360 range, while much higher BCFs have been reported for phytoplankton. Lead does not biomagnify through the food chain and concentrations are usually higher in organisms at the lower trophic levels. For example, insects and invertebrates typically contain higher concentrations than do fish. Organisms living in close association with bottom sediments, such as worms, mussels, scallops, and snails, often accumulate the highest body burdens of lead. The muscle tissue of fish usually contains low lead concentrations (Canadian Council of Ministers of the Environment (CCME) 1999).

Many environmental factors affect the toxicity of lead to aquatic species. Toxic effects have been observed in aquatic organisms exposed to lead compounds in the µg/L range. Lead is more toxic in soft water than in hard water and organic forms, such as tetraethyl lead, are more toxic than inorganic forms (Canadian Council of Ministers of the Environment (CCME) 1999). Sublethal effects observed in aquatic organisms exposed to lead include decreased growth rate, behavioural changes, developmental abnormalities, spinal curvature, and reproductive impairment (Canadian Council of Ministers of the Environment (CCME) 1999).

Lead is also toxic to birds and other wildlife. The ingestion of lead shot and fishing tackle (sinkers and lures) has resulted in lead poisoning in several species of birds in Canada and other countries. Even when the level of exposure is not adequate to cause acute lethality, it is often sufficient to cause effects which reduce the birds' chances of long-term survival. For example sublethal exposure can result in behavioural changes, loss of balance, inability to fly, feeding difficulties, and the inability to successfully mate or care for offspring. Lead shot is ingested as "grit" by waterfowl in order to aid in food digestion. However, in some cases, the ingestion of only a few pieces of shot can result in poisoning. The use of lead shot has long been recognized as a threat to waterfowl. However, secondary lead poisoning in birds and other wildlife can occur when scavenger species, such as bald eagles, feed on poisoned birds. Elliott *et al*. (1992) reported that lead shot was responsible for 10 to15% of the mortalities of post-fledgling bald eagles between 1988 and 1991. There were also several reports of lead poisoning in swans in BC. As a result of the high number of related bird mortalities in Canada, regulations on the use of lead shot have been introduced. As of September 1999, the use of lead shot was prohibited nationally for hunting migratory birds. American woodcock, band-tailed pigeons, and mourning doves were exempted from this requirement (Environment Canada 2006a;Environment Canada 2006h;Environment Canada 2006i;Swan Society 2009).

The use of lead sinkers and jigs for fishing has been identified as a leading cause of death in common loons in Canada. The ingestion of just one lead sinker or jig will result in sufficient lead exposure to be lethal to loons and other fish-eating birds. It has been estimated that up to 30% of adult loon deaths during the breeding season in eastern Canada are due to lead poisoning. The use of lead sinkers and jigs weighing less than 50 grams has been prohibited in Canada's national parks and wildlife areas since 1997. Regulations to prohibit the use of lead fishing tackles have been proposed and are now been pursued (Environment Canada 2006f;Environment Canada 2006g).

Canadian water quality guidelines for lead, for the protection of freshwater aquatic life, are 1 to 7 µg/L. ISQGs and PEL values for lead in freshwater sediments are 35.0 and 91.3 µg/g (dw), respectively, and 30.2 and 112 µg/g (dw), respectively, in marine and estuarine sediments (Canadian Council of Ministers of the Environment (CCME) 2006).

Manganese

Manganese can be present in aquatic systems in a variety of forms, some of which are relatively soluble in water and some of which are not. However, the solubility of manganese in the environment can be greatly affected by changes in environmental variables such as pH; organic matter; redox potential; dissolved oxygen; and the presence of nitrates, sulfates, and chlorides. Factors which increase the solubility of manganese also increase its availability for uptake by aquatic organisms (Canadian Council of Ministers of the Environment (CCME) 1987). Marine organisms readily bioconcentrate manganese and BCFs of 10^3 to 10^4 were reported for shellfish, 10^4 for marine algae, 10^5 for marine plants, and 10^2 for fish (Canadian Council of Ministers of the Environment (CCME) 1987).

Manganese is an essential element for plants and animals and occurs naturally in most organisms. In some situations, the presence of manganese has been shown to reduce the toxicity of other metals (Sinha *et al.* 1993;Stauber and Florence 1987). However, concentrations as low as 0.005 mg/L have been shown to have toxic effects in some algae and a 96-h LC_{50} of 2.4 mg/L has been reported for coho salmon exposed to manganese in soft water (British Columbia Ministry of Environment 2001).

There are currently no Canadian environmental quality guidelines for manganese; however, BC MOE has developed provincial criteria for manganese in freshwater and in marine/estuarine environments. Water hardness is an important factor in determining the toxicity of manganese to aquatic life and the BC MOE provincial water quality criteria for manganese in freshwater systems are based on local levels of water hardness. For example, at a water hardness of 25 mg/L $CaCO_3$, the acute (maximum) guideline is 0.8 mg/L and the chronic (30-day mean) guideline is 0.7 mg/L, while at 300 mg/L $CaCO_3$, the acute guideline is 3.8 mg/L and the chronic guideline is 1.9 mg/L. Approved provincial water quality guidelines for manganese in marine systems have not been developed; however, BC MOE Compendium of Working Water Quality Guidelines recommend that manganese concentrations in marine systems not exceed 0.1 mg/L, for the protection of consumers of shellfish. This value is subject to review (British Columbia Ministry of Environment 1998;British Columbia Ministry of Environment 2001). Environmental quality guidelines for manganese in sediments have not yet been developed.

Mercury

The distribution of mercury in both freshwater and marine systems is controlled by sedimentation and sediments can serve as a sink for mercury. This is particularly true under anaerobic conditions, which results in the formation of insoluble mercuric sulphide, which settles out to the bottom sediments. Mercury in aquatic systems can be converted to the more toxic and biologically available monomethyl- and dimethylmercury forms by microbial activity. However, there are also microorganisms in the sediments that can demethylate monomethyl- and dimethylmercury.

Methylmercury is much more easily taken up into aquatic organisms than is inorganic mercury, and it can pass through cell membranes and cross blood-brain and placental barriers. This can result in direct effects on the brain and on the fetus. While monomethyl- and dimethylmercury are both readily accumulated by aquatic organisms, monomethylmercury is more easily transported across membranes. Biomagnification of mercury through the food chain can occur and organisms at the higher trophic levels can accumulate very high concentrations of mercury and exhibit high BCFs (approximately 10^4) (Environment Canada 2006j).

Inorganic and organic mercury compounds at concentrations in the μg to mg/L range are acutely toxic to various species of aquatic organisms. Exposure to inorganic and organic mercury in the μg/L range can also result in impaired growth, development, and reproduction; inhibition of limb regeneration in crabs; and impaired immune responses. Very low concentrations (ng/L to μg/L range) can decrease growth, reproduction, and survival of plankton and diatoms. In contaminated areas, mercury concentrations in fish-eating birds can reach concentrations which are high enough to cause reproductive impairment and abnormal behaviour (Canadian Council of Ministers of the Environment (CCME) 1999).

High concentrations of mercury in BC bald eagles are known to have caused the death of, at least, one bird. A total of 82 eagles were found dead or dying in the vicinity of pulp and paper mills in the Georgia Basin between 1987 and 1994. Of these, one was determined to have died from mercury poisoning. This was the first documented case of mercury poisoning of a bald eagle. Another 14 eagles had sub-clinical levels of mercury in their tissues. Elevated mercury concentrations were also found in mergansers collected in the Squamish area in 2000 and in the feathers of dippers breeding in the Chilliwack watershed in 1999/2000. The significance of these residues, and the possible sources of mercury to these birds, are being investigated (Elliott *et al.* 1996b;Weech *et al.* 2003).

CCME has developed Canadian environmental quality guidelines for mercury. The recommended guideline for inorganic mercury, for the protection of freshwater aquatic life, is 26 ng/L and the interim guideline for methylmercury is 4 ng/L. The interim guideline for inorganic mercury for the protection of marine aquatic life is 16 ng/L. There is currently no recommended guideline for methylmercury in marine waters. The Canadian ISQG for mercury in freshwater sediment is 0.174 μg/g (dw) and the PEL is 0.486 μg/g. The ISQG for marine sediments is 0.13 μg/g and the PEL is 0.70 μg/g (dw) (Canadian Council of Ministers of the Environment (CCME) 2006). The tissue residue guideline, for the protection of wildlife consumers of aquatic biota, recommends that methylmercury concentrations in fish and shellfish consumed by wildlife not exceed 33 ng/g (dw) (Canadian Council of Ministers of the Environment (CCME) 2006).

Nickel

Nickel is relatively mobile in the aquatic environment and is transported in both particulate and dissolved forms. The BCFs for nickel in aquatic organisms ranged from approximately 100 to 5,000. BCFs of greater than 10,000 have been observed in some species of acid-metal-tolerant flora. No evidence of biomagnification in food chains has been reported (Environment Canada/Health Canada 1994e).

Adverse acute and chronic effects have been observed in a variety of freshwater aquatic organisms exposed to dissolved nickel in the 24 to 10,000 μg/L range. The 96-h LC_{50} values for the mussel, *Anodonta imbecilis,* and the snail, *Juga plicifera,* were 190 μg/L (in soft water) and 102 μg/g (in very soft water), respectively. The avoidance threshold concentration for rainbow trout was 24 μg/L and LC_{50}s for most adult fish in soft water ranged from 4,000 to 14,000 μg/L. Other sublethal effects observed in aquatic organisms include reduced growth, decreased life span, reduced number of offspring, and reduced size (Environment Canada/Health Canada 1994e). In addition, studies with *Daphnia magna* suggest that some populations are more sensitive to nickel than are others (Munzinger and Monicelli 1991).

Interim Canadian environmental quality guidelines for nickel recommend that concentrations in freshwater systems do not exceed 25 to 150 μg/L, depending on local water hardness. There are currently no Canadian environmental quality guidelines for nickel in marine waters or in sediments (Canadian Council of Ministers of the Environment (CCME) 2006).

Silver

Aquatic organisms can accumulate silver from the water column and from bottom sediments. BCFs of greater than 10^5 have been reported for silver uptake by algae; however, much of this concentration has been attributed to the adsorption of silver to cell surfaces. BCFs of approximately 10^2 or lower have been reported for zooplankton and bivalves. The bioaccumulation of silver in fish has not been well studied; however, in general, fish bioaccumulate silver to a lesser extent than do aquatic invertebrates. This has been confirmed by observations in the natural environment that fish contain lower concentrations of silver than do invertebrate species. There is no evidence of silver biomagnification through the food chain (British Columbia Ministry of Environment 1996;Canadian Council of Ministers of the Environment (CCME) 1987;Ratte 1999;Wang *et al.* 1999).

There is considerable variation in the sensitivity of various species and life stages of aquatic organisms to silver. Among the most sensitive organisms are phytoplankton and the embryonic and larval stages of invertebrates and fish. Sensitive freshwater fish species exposed to silver nitrate have LC_{50} values of between 2.5 and 10 µg/L. The LC_{50}s for marine fish were generally from 1 to 2 orders of magnitude higher than those for freshwater fish. In general, silver is also less toxic to juvenile and adult stages of marine fish than to freshwater fish. However, the sensitivity of flounder embryos and larvae to silver was similar to the most sensitive marine invertebrates. Sublethal effects can occur at concentrations far below acutely lethal levels. For instance, egg production in cladocerans and copepods was adversely impacted at concentrations of 1/500 and 1/400, respectively, of the LC_{50} values (Ratte 1999;Wood *et al.* 1999).

The toxicity of silver to aquatic species is determined by the presence of active free Ag^+ ions in the water. In general, the toxicity of silver to aquatic organisms in the natural environment is lower than that observed in laboratory tests. This is due to the fact that, in the environment, silver is likely to bind with particulate matter or one of the many reactants and complexing agents which remove free Ag^+ from the water column. However, silver nitrate, which is one of the most commonly used forms of silver in laboratory tests, is highly toxic because it readily dissolves and releases free Ag^+. More information is needed on the toxicity of the forms of silver that exist in the natural environment, particularly with respect to the effects on early developmental stages of fish (Guadagnolo *et al.* 2001;Ratte 1999;Wood *et al.* 1999).

The Canadian water quality guideline for silver, for the protection of freshwater aquatic life, is 0.1 µg/L. There are currently no Canadian guidelines for silver in marine waters or in sediments. BC MOE provincial water quality criteria for silver in freshwater and marine/estuarine systems vary according to local levels of water hardness (British Columbia Ministry of Environment 1996;Canadian Council of Ministers of the Environment (CCME) 1987).

Elevated concentrations of silver have been detected in sediments, crab and other biota in the vicinity of the Iona Island WWTP discharge off Sturgeon Bank. Histopathological effects observed in Dungeness crab collected near the WWTP were positively correlated with silver concentrations (Wilson 2000).

Zinc

Zinc is found in many different forms in the environment and can be present in both dissolved and suspended forms; however, the factors affecting the transformation and distribution of zinc in the environment are not well understood. Zinc is readily bioaccumulated by aquatic organisms and reported BCFs are 10^3 for freshwater plants and fish and 10^4 for freshwater invertebrates. While zinc is an essential trace element and is important in biological systems, it can be toxic to aquatic biota when present at elevated concentrations in the environment. Exposure to high concentrations can result a variety of adverse biological effects in marine and freshwater biota including decreased diversity and abundance, increased mortality, and behavioural changes.

The presence of zinc in stormwater runoff released to the marine environment was associated with a significant reduction in taxa abundance and biomass. The acutely toxic concentrations of zinc to aquatic organisms vary widely and are influenced by both the species and life stage of the organism and by environmental conditions. Zinc concentrations found to be acutely toxic to aquatic organisms ranged from approximately 90 to 58,000 μg/L. Maximum acceptable tolerance concentrations (MATC) for rainbow trout in soft water (based on success of fry from unexposed eggs) ranged from 36 to 71 μg/L, and the MATC values for fathead minnow eggs in soft water ranged from 78 to 145 μg/L. Sublethal effects observed in aquatic species include decreased growth, decreased fecundity, inhibition of microbial activity, changes in cell morphology, reduced size of offspring, and delayed hatching. Exposure to high concentrations of zinc in the bottom sediments can also result in adverse effects in both freshwater and marine species, depending on local environmental conditions. In benthic invertebrates, these effects include decreased diversity and abundance, increased mortality, decreased growth, delayed emergence, impaired reproduction, and behavioural changes (Canadian Council of Ministers of the Environment (CCME) 1987;Canadian Council of Ministers of the Environment (CCME) 1999;Casper 1994).

Elevated concentrations of zinc have been detected in the sediments at fish farms in BC. However, the toxicity of zinc in sediments below fish farms is difficult to assess because the speciation of the metal, and hence the toxicity, varies with factors such as interactions with sulphides, dissolved oxygen and pH. Elevated zinc levels under net pens in the Broughton Archipelago were observed when farms were at maximum production levels, but the researchers noted that zinc was not bioavailable due to the concurrently high sulphide levels (Brooks et al. 2003). They also found that zinc levels dropped after harvesting and throughout the fallowing period. The authors concluded that as long as chemical remediation is reached (approximately 6 months) during one fallowing period before the next production period begins, zinc will not accumulate in sediments (Brooks et al. 2003). Cumulative effects of numerous pens in a localized area were not addressed in the study.

Bailey *et al.* (1999) tested stormwater from BC sawmills and found that most of the samples tested were acutely toxic to juvenile rainbow trout. The authors attributed the toxicity primarily to zinc. The authors noted that the very low hardness of the samples increased the toxicity of the metals present. The source of the zinc is thought to be the galvanized building materials at the site, rather than the wood treatment chemicals being used.

The Canadian water quality guideline for zinc for the protection of freshwater aquatic life is 30 μg/L. A guideline has not yet been developed for marine/estuarine systems. The ISQG and PEL for zinc in freshwater sediments are 123 and 124 μg/g (dw), respectively, and the ISQG and PEL for zinc in marine/estuarine sediments are 315 and 271 μg/g (dw), respectively (Canadian Council of Ministers of the Environment (CCME) 2006). The BC MOE provincial water quality guidelines for zinc in freshwater systems vary with local levels of water hardness. The freshwater guidelines were based on the LOEL of 15 μg/L for copepods and a 96-h LC_{50} value of 66 μg/L for rainbow trout. The BC provincial water quality guidelines for marine systems are 10 μg/L for chronic exposures (30-day averages) and 33 μg/L for acute exposures (maximum concentration at any time) (British Columbia Ministry of Environment 1999).

3.5 Pharmaceuticals and Personal Care Products (PPCPs)

3.5.1 Sources and Loadings of PPCPs to the South Coastal BC Environment

Pharmaceuticals and personal care products (PPCPs) have recently been identified as environmental contaminants of concern due to their widespread presence in the aquatic environment. PPCPs, which are purchased over-the-counter and by prescription, include the several thousand substances which are used for medicinal purposes worldwide as pain killers, anti-inflammatories, tranquilizers, antibiotics, natural and synthetic hormones, blood lipid regulators, beta-blockers, anti-epileptics, impotence drugs, and parasiticides, and the thousands of other chemicals which are added to personal care products such as soaps, hair products, sunscreens, fragrances, disinfectants, and dental care products. In addition, the increased popularity of natural products and food supplements has increased the entry of these substances into the environment in recent years (Servos *et al.* 2002).

PPCPs pose a potentially significant risk to the environment due to the very large volume and the extensive variety of products in use worldwide. PPCPs can enter the environment in discharges from facilities manufacturing these chemicals; however, loadings from these sources are typically localized and relatively easy to control. More difficult to address are WWTPs discharges, which are a much more significant and widespread source of PPCPs than are manufacturing facilities. It has been demonstrated that many PPCPs are not completely broken down by conventional wastewater treatment systems and can be released to the environment in WWTP effluents. A wide range of PPCPs have been detected in WWTP effluents throughout the world. In Canada, a survey of WWTPs effluents in 14 cities revealed the presence of a number of PPCPs including analgesic/anti-inflammatory drugs (Ibuprofen and Naxopren), a metabolite of acetylsalicylic acid, salicylic acid, and lipid-regulating drugs (Metcalfe *et al.* 2000). The extent to which conventional activated sludge treatment degrades pharmaceuticals varies between facilities but, while studies indicate that longer sludge retention times can improve degradation, few of the substances investigated were completely degraded using conventional treatment (Buser *et al.* 1999;Daughton and Ternes 1999;Gobel *et al.* 2005;Heberer 2002;Hignite and Azarnoff 1977;Lee *et al.* 2003;McArdell *et al.* 2003;Snyder *et al.* 2003;Stumpf *et al.* 1999;Ternes 1998;Ternes *et al.* 2004;Ternes *et al.* 2003;Ternes *et al.* 1999). WWTP effluents contain PPCPs as both parent compounds and as the metabolites which are present urine and feces. Recent studies indicate that the use of ozonation for the treatment of both municipal wastewaters and drinking water can successfully reduce the presence of many pharmaceuticals (including many antibiotics and synthetic and natural estrogens) through oxidation (Boreen *et al.* 2003;Huber *et al.* 2005;Huber *et al.* 2004;Latch *et al.* 2003;McDowell *et al.* 2005;Ternes *et al.* 2002;Ternes *et al.* 2003;Westerhoff *et al.* 2005).

A recent study by Ikonomou *et al.* (2008) detected a wide range of estrogenic endocrine-disrupting chemicals (EDCs) and related compounds in the influent and effluent of Canadian wastewater treatment plants. They found that, while di(2-ethylhexyl)phthalate, cholesterol, cholestanol, and other cholesterol derivatives were reduced substantially by the waste treatment process, steroidal compounds (particularly estrone, 17β-estrodiol, and estriol, as well as most plant sterols) were higher in treated municipal wastewater versus untreated effluent.

The disposal of unused or expired PPCPs by consumers, medical clinics, and other facilities can also result in their entry into the environment. Unused and expired medications flushed down the toilet ultimately enter municipal wastewater treatment facilities, while those disposed of with household garbage enter landfills and can potentially contaminate landfill leachate (Servos et al. 2002).

Another major source of pharmaceuticals to the environment is the use of veterinary drugs to treat livestock and domestic animals. These products are used for eliminating parasites, for the prevention and treatment of bacterially transmitted diseases in livestock and domestic animals, and to accelerate livestock growth and production. Veterinary pharmaceuticals are typically administered in feed, by injection, or by external application. These pharmaceuticals are excreted by the animals as parent compounds and/or metabolites and subsequently enter soils and surface runoff. In urban areas, the feces and urine of domestic animals can be sources of pharmaceuticals to municipal storm sewers, which may ultimately discharge, untreated, to aquatic systems. In agricultural areas, the large volumes of urine and manure generated in livestock dense areas undoubtedly contribute significantly to the loading of pharmaceuticals to local surface waters and groundwater systems. The use of manure and digested WWTP sludge (which can contain significant concentrations of some PPCPs) for fertilizing crops is another potential source of pharmaceuticals to soils, surface water, and groundwaters in agricultural areas (Topp 2002;Xia *et al.* 2005).

Information on the types and volumes of PPCPs entering the south coastal BC environment from WWTP discharges and in urban or agricultural runoff is lacking. However, studies relating to PPCPs in WWTPs have recently been initiated by both Metro Vancouver and CRD and Environment Canada and Fisheries and Oceans Canada have also initiated studies on these substances.

Pharmaceuticals are also used at aquaculture facilities as crowded conditions and poor water quality can contribute to stress and lower resistance to disease. Chemical therapeutants, pesticides, and disinfectants are sometimes used in salmon farms to treat and prevent the spread of conditions such as sea lice and infectious salmon anemia. In Canada emamectin benzoate is used to combat sea lice. Laboratory studies indicate that these chemicals can be lethal to crustaceans; however, their effect on the natural invertebrate populations which are located in close proximity to salmon farms is not known. A variety of antibiotics and antimicrobials are also used to treat farmed salmon (Burridge *et al.* 2008;Haya *et al.* 2002). Oxytetracycline, trimethoprim80%/sulphadiazine20%, sulfadimethoxine80%/ormetoprim20%, and florfenicol are registered for use as antibiotics in aquaculture. However, the total use of these antibiotics in BC has declined from 2004 to 2006 (18,530 kg in 2004, 12,103 kg, in 2005, and 7,956 kg in 2006). The use of these products at aquaculture facilities has led to concerns over the potential development of drug-resistant bacteria (Burridge 2003;Burridge *et al.* 2008). In addition, these substances are administered in the feed or directly into the water, raising concerns over the release of these substances into the environment and with respect to their potential presence in fish and invertebrates farmed for human consumption. For example, the import of shrimp and prawns from China was banned in both Europe and the US due to the extensive treatment of these organisms with antibiotics (Chao 2003). A number of pesticides have been considered for use as parasiticides at aquaculture facilities, but they are not currently permitted for this use in Canada. These include cypermethrin, deltamethrin, dichlorvos, ivermectin, and azamethiphos; however, deltamethrin and azamethiphos (the active ingredients in AlphaMax and Salmosan) had temporary approval for use in select areas in New Brunswick (Burridge et al. 2008).

BC is one of the leading worldwide producers of farmed salmon. While some information is available on the types of chemicals in use at BC facilities, more specific information on types and volume of chemicals used is needed.

3.5.2 Presence of PPCPs in the South Coastal BC Environment

While the presence of some pharmacologically active substances (such as caffeine, nicotine, and aspirin) in the environment has been acknowledged for many years, a much wider range of pharmaceuticals, and also substances used in personal care products, have more recently been detected. These include numerous antibiotics, other prescription and non-prescription drugs, natural and synthetic hormones, fragrances, antimicrobials, and UV blockers. A wide range of PPCPs have been detected in the aquatic environment in Canada, US, Japan, Europe, and in the North Sea (Balmer *et al.* 2004;Boyd *et al.* 2003;Calamari *et al.* 2003;Hirsch *et al.* 1999;Koplin *et al.* 2002;Metcalfe *et al.* 2002;Thomas and Hilton 2004;Weigel *et al.* 2002;Yamagishi *et al.* 1983). In some areas, pharmaceuticals are present in surface waters and groundwaters in concentrations similar to those of pesticides (up to the µg/L range) (Daughton and Ternes 1999;Heberer 2002;Ternes 1998). Although the studies are limited, some PPCPs have been observed to accumulate in some aquatic organisms including mussels and plants. In addition, some antidepressant drugs (selective serotonin reuptake inhibitors (SSRIs)) and metabolites have been detected in fish collected from a US stream receiving wastes from a WWTP (Brooks *et al.* 2005). PPCPs have also been detected in manure-treated soils, as a result of the use of veterinary drugs to treat livestock. For example, tetracycline, which is widely used as a veterinary antibiotic, has been detected in the soils of manure-treated fields in the US at a concentration of approximately 10 ng/g (Hamscher *et al.* 2000).

In Germany, surface waters receiving effluents from WWTPs contained beta-blockers and anti-epileptic drugs in excess of 1 µg/L (Ternes 1998). A US study conducted in 1999 and 2000 analyzed surface waters for a wide range of substances including pharmaceuticals, antioxidants, phytosteroids, biocides, and flame retardants. Of the 95 compounds targeted, 82 were detected in at least one stream sample. While concentrations of individual substances were low, and typically did not exceed 1 µg/L, samples contained a median of seven (and up to 38) different chemicals. The potential additive effects resulting from exposure to multiple contaminants simultaneously, even at low concentrations, could be significant. As well, many of the substances detected have the potential to disrupt normal hormone activity. Detergent metabolites, plasticizers, and hormones contributed approximately 80% of the total measured concentration. Antibiotics, other prescription drugs, non-prescription drugs, and reproductive hormones were also detected. Of these, non-prescription drugs were detected most frequently, likely due to their greater volume of use. The authors suggested that the environmental presence of many substances may have been underestimated; however, due to a tendency of these substances to accumulate in the particulate matter and sediments, rather than remaining in the water column. According to the authors, the low concentrations of the reproductive hormones may present a greater environmental health risk than do the higher concentrations of many other PPCPs due to the ability of these hormones to cause deleterious effects in aquatic organisms at very low concentrations (Koplin et al. 2002).

The PPCPs which have been detected in the environment, to date, represent only a small fraction of those currently in use. Analytical methods are still under development and the majority of PPCPs have not yet been investigated.

Information on the presence of PPCPs in the south coastal BC environment is lacking; however, studies are underway by CRD, Metro Vancouver, Environment Canada, and Fisheries and Oceans Canada. As well, analytical methods are currently being developed for the purpose of identifying the presence and stability of these chemicals in the environment. Information is also needed on the presence of chemotherapeutants, used by the aquaculture industry, in the sediments and aquatic organisms in close proximity to aquaculture facilities.

3.5.3 Environmental Concerns and Potential Biological Impacts of PPCPs in the Aquatic Environment

While PPCPs have been detected in the aquatic environment worldwide, little is known about the fate of these substances in the environment. Some of the substances have been shown to be both persistent in the environment and bioaccumulative in aquatic organisms (Daughton and Ternes 1999). However, even PPCPs with a short environmental half-life can exhibit "pseudo-persistence" in the environment due to the fact that they are continually being released to receiving waters from sources such as municipal WWTPs and agricultural runoff. This results in a low but continuous exposure of non-target organisms in some areas (Daughton 2003a).

Photochemical processes have been shown to contribute to the transformation and degradation of some pharmaceuticals in the environment (Latch et al. 2003). Some PPCPs, especially some of the chemicals in personal care products (for example musks), have been shown to be quite volatile; however, most PPCPs have low volatilities. For this reason, atmospheric long-range transport, such as that observed for many POPs, is not expected to occur for most of these substances. It is likely that the distribution of these substances in the environment would occur primarily through aqueous transport and through the food chain (Daughton and Ternes 1999).

Although PPCPs are tested to ensure their safety, when used for the purposes for which they were designed, their potential effects on non-target organisms in the environment are not known. Concentrations of individual substances in the environment are typically low; however, even low concentrations of some PPCPs have been shown to have adverse effects on aquatic species. According to Daughton and Ternes (1999), the effects of PPCPs on non-target organisms in the environment may be so subtle that they are virtually undetectable. However, due to the continuous release of these substances to the environment, these subtle effects will be cumulative over an extended period of time. In many cases, by the time the effects become noticeable, they will be irreversible and will not easily be linked back to exposure to these substances. In addition, some pharmaceuticals exhibit a delayed-onset toxicity and so effects on non-target organisms may not appear until long after exposure (Daughton 2003b). The continuous low dose exposure of non-target organisms in aquatic systems receiving significant loadings of PPCPs could result in adverse effects on development and reproduction over multiple generations. Adverse effects on non-target organisms reported following laboratory exposure to pharmaceuticals include endocrine disruption and estrogen receptor antagonism in fish, inhibition of cytochrome P450 and P4501A in fish, toxicity and disruption of community structure in algae, and alterations in sex-ratios in amphipod populations (Halling-Sorensen *et al.* 2000;Jobling *et al.* 1996;Levine *et al.* 1997;Thomas and Smith 1993;Watts *et al.* 2002). Lerner *et al.* (2007b) reported that exposure of juvenile Atlantic salmon to environmental estrogens can increase sensitivity to stress, impair ion regulation, and disrupt endocrine pathways critical for smolt development.

Pharmaceuticals thought to be of special concern in the environment are antineoplastics, endocrine disruptors, and antibiotics (Huber et al. 2005). Antineoplastics are primarily used for chemotherapy and, as such, are highly toxic substances with the potential to adversely affect non-target organisms. Endocrine-disrupting pharmaceuticals, such as natural and synthetic hormones, can result in the masculinizing and feminizing of populations of aquatic species. The release of estrogens to the environment may be responsible for the high incidence of hermaphroditic fish detected in English rivers in the vicinity of wastewater treatment plant discharges. Laboratory studies have shown that 17α-ethinyhlestradiol (EE2), a commonly used prescribed estrogen, and natural estrogens can cause estrogenic effects in fish exposed to concentrations similar to those which have been detected in the environment. EE2 is thought to be one of the important contributors to the feminizing effects observed in fish exposed to wastewater treatment plant effluents. This substance is bioaccumulative, persistent in the environment, and has a high potency. Available information on the effects of endocrine-disrupting PPCPs indicates that these substances could disrupt the development and reproduction of exposed organisms and their offspring in the natural environment (Pawlowski *et al.* 2004;Pickering and Sumpter 2003;Purdom *et al.* 1994).

Elevated levels of antibiotics in the environment can result in alterations in the structure of naturally occurring microbial communities. Large quantities of a diverse range of antibiotics are used for the treatment of both humans and animals. In addition, to the potential adverse effects of these drugs on non-target organisms, the release of antibiotics into the environment likely promotes antibiotic resistance in pathogens. A recent study noted an increased resistance in natural bacteria populations to two antibiotics detected in the environment (Costanzo *et al.* 2005) and resistance to oxytetracycline (a commonly used microbial agent) has been observed in aerobic bacteria in surface sediments collected at and near salmon farms in eastern Canada (Haya et al. 2002).

Although personal care products are not typically used for therapeutic purposes, several ingredients in personal care products have been detected in environmental samples and can illicit adverse effects in aquatic organisms. Antimicrobial agents are extensively used in personal care products such as toothpastes and hand soaps. Since these microbial agents are designed to be effective against a wide spectrum of microbials, it is likely that the release of these substances to the environment could disrupt natural resident microbial communities. Shifts in the structure of natural algal communities have been observed following exposure to ciprofloxacin (an antibiotic), Triclosan (an antimicrobial agent), and Tegitol NP 10 (a surfactant). The authors concluded that, in aquatic systems affected by these substances, such effects could result in alterations in the nutrient processing capacity and the structure of the food web (Wilson *et al.* 2003).

Personal care products enter municipal wastewater collection and treatment systems as a result of washing, showering and laundering clothes. They can also be released directly to the environment when people swim in oceans, lakes, and rivers. Some substances used in personal care products are lipophilic and have the potential to bioaccumulate. For example, organic ultraviolet light (UV) filters have been detected in the natural environment in both surface waters and fish. Organic UV filters are found in a wide range of personal care products including sunscreens and cosmetics such as skin creams, lipsticks, makeup, and hair products. The fact that concentrations of organic UV filters were much lower in WWTP effluents, than in the influents, indicates that significant removal occurs during wastewater treatment (Balmer *et al.* 2005).

The UV filter, 4-methylbenzylidene camphor (4-MBC), has demonstrated estrogenic activity (Schlumpf *et al.* 2001). However, very limited information is available on the potential adverse biological effects of most PPCPs in the environment. Even less is known about the potential synergistic, additive, or antagonistic effects which may result from simultaneous exposure to multiple PPCP substances and other environmental contaminants. However, since many of these products are designed to cross biological membranes while remaining active, and to be biologically active at very low concentrations, it is likely that their release to the environment would result in detrimental effects on non-target organisms. In consideration of these facts, it is prudent to exercise precautionary principles by minimizing releases to the environment.

An evaluation of the potential adverse effects of PPCPs on aquatic organisms in the south coastal area of BC is needed, particularly in the vicinity of WWTP discharges, aquaculture facilities, and in aquatic systems receiving significant inputs of urban or agricultural runoff.

There are currently no Canadian environmental quality guidelines for PPCPs.

3.6 Biological contaminants

Killer whales are exposed to a variety of biological agents, including viruses, bacteria, fungi and macroparasites as part of their everyday life through feeding, breathing and direct contact with air, water, and/or other individuals of their own or other species in the ocean. It is beyond the scope of this document to provide a comprehensive review of biological contaminants to which killer whales may be exposed to in British Columbia, but it is worth introducing as one of the anthropogenic risks posed to the marine environment. While many pathogens and parasites may be considered as either enzootic or 'naturally-occurring' in marine mammals and/or the coastal environment, humans can unwittingly introduce biological agents directly or indirectly to the marine environment (Daszak *et al.* 2001;Ross 2002).

Direct releases may come from sewage effluent, while indirect releases may come from agricultural and urban runoff (Miller *et al.* 2002). Ballast water discharges may release invasive species acquired by ocean-going vessels into a new environment (Levings *et al.* 2004). Migrations and transport of domestic animals (agricultural, zoo, pet, or rehabilitated and released) may lead to the introduction of new pathogens into a receiving environment or population (Vitousek *et al.* 1996). Climate change may change the abundance, distribution or vulnerability of host species and/or pathogens, leading to a 'spill-over' or emergence of a new infectious disease (Harvell *et al.* 1999). These are all important features when characterizing the threats to the health of killer whale populations, and in designing an appropriate recovery strategy. Understanding (documenting) the biological agents that may be inadvertently introduced by humans, our activities, or those of our animals, into killer whales or their environment is a vital part of delivering sound management practices. Targeting those activities that might release hazardous biological agents into killer whale habitat follows as an important step in reducing threats to the killer whale populations in coastal BC.

Biological pollution resulting from human activities in and around resident killer whale habitat has had implications for marine mammals in Canada and Washington State. For example, the identification of canine distemper virus (CDV) in river otters housed in a multi-species rehabilitation facility in BC provides a dangerous opportunity for a species transfer to harbour seals at the same site; although the patients were not released, such a re-introduction could cause a catastrophic outbreak in free-ranging pinniped populations (Measures 2004;Mos *et al.* 2003). A combination of PCB-associated immunosuppression and bacterial pollution from urban and agricultural activities were thought to underlie changes in the immunological profiles of free-ranging harbour seals in southern Puget Sound (Mos et al. 2006). Climate change may be partly to blame for the emergence of *Cryptoccus gattii* infections in BC marine mammals and humans (Stephen *et al.* 2002).

Killer whales are highly mobile animals which traverse multiple estuaries and, on exposure to novel bacteria, may recruit or be colonized by potentially pathogenic or resistant microbes. The antibiotic profile of nasal mucosa in small cetaceans alters to reflect existing environmental flora on introduction of animals to novel habitats. Ongoing efforts in California have identified bacteria and bacterial sensitivity profiles unique to individual river estuaries. These microbes (bacterial, viral, or parasitic) are likely introduced from contaminated human or animal feces or by organisms introduced from remote areas (exotics, domestic, or livestock). Farm discharges, with no pre-treatment, eventually gain access to a number of rivers and tributaries and may eventually reach ocean sites frequented by killer whales.

Exposure through the ingestion of contaminated water or feed may result in acute self-limiting enteritis (diarrhea), may lead to carrier status, or the condition may progress to fulminant sepsis (the young male J18 died in 2000 of this). These bacteria may be primary pathogens or secondary opportunists associated with either localized immunosuppression or generalized debility due to contaminants or other predisposing factors (e.g. stress or malnutrition).

In addition to antibiotic resistant bacteria, primary pathogens, such as the recently reported *Salmonella* isolates in harbour seals and porpoises, may pose a threat to killer whales. In a survey conducted along the British Columbia and Washington state coasts in August 2003, preliminary typing of *Escherichia coli* isolates yielded 8/136 samples positive for eae and 15/136 samples positive for EAST 1. The eae (intimin) is a virulence factor (but not primary) for hamburger disease and has been associated with diarrhea in piglets. In British Columbia, recent emergence of *Cryptococcus neoformans gatti* as a pathogen of Dall's and harbour porpoises suggests a similar tropism for killer whales. This organism likely reflects either a recent introduction from a subtropical region or emergence associated with global warming.

Indirect effects may include similar bacterial colonization, infection, and population impact in migrating Pacific salmon due to terrestrial or aquaculture farm practices. Excessive timber harvest and increases in the amount of suspended solids in rivers may enhance saprophytic bacterial proliferation, which may adversely impact salmon returns and spawned ova viability. In addition, for transient killer whales indirect exposure to toxoplasmosis, neosporosis, *Coxiella* spp, chlamydiosis and other pathogens may occur through consumption of harbour seals or sea otters which may been infected through exposure to human or animal sewage.

The need for strengthening the surveillance of killer whale and small cetacean mortalities to assess established and potentially emerging disease concerns has been identified. Potential pathogens which are recognized in British Columbia production animals and wildlife include *Toxoplasma gondii*, *Giardia lamblia, Cryptosporidium parvum, Isospora bell, Microsporidia Balantidium coli, Vibrio cholerae* (possible), *Vibrio parahemolyticus, Campylobacter jejunum, Yersinia sp., Edwardsiella tarda, Escherichia coli* (enteropathogenic, 0157). *Listeria monocytogenes*, *Salmonella* spp, and *Vibrio parahemolytica* have been isolated from harbour seals and small cetaceans in British Columbia waters (Stephen Raverty, BC Animal Health Center, personal communication).

Hepatitis A and B titers to HVB have been reported in captive killer whales and were detected in the killer whale A73. In contrast to HVA, where infection can be acquired through consumption of contaminated shellfish, HVB infection is parental.

It is unclear whether biotoxins represent a risk to killer whales These would include a variety of fish and algal toxins, including domoic acid, paralytic shellfish poisoning (PSP), Ciguatera, and Scombroid poisoning.

4 Jurisdictional Responsibilities and Existing Controls on the Release of Environmental Contaminants to the South Coastal Environment of British Columbia

In BC, federal, provincial and municipal governments are all involved in managing chemical contaminants through legislation, codes, and bylaws. The following is a summary of the primary federal and provincial legislation used to control the release of environment contaminants to the BC environment.

4.1 Relevant Federal Legislation

The federal government manages chemical substances under the federal Chemicals Management Plan (CMP) (http://www.chemicalsubstanceschimiques.gc.ca/plan/index_e.html). Regulations and enforcement are key components of the CMP. The following is a summary of the legislation and regulations used to control the release of chemical substances to the Canadian environment.

4.1.1 Canadian Environmental Protection Act (CEPA)

The federal *Canadian Environmental Protection Act, 1999* (Government of Canada 1999) is the primary legislative tool which is used by the federal government to assess and manage chemical substances in the environment. This Act is administered jointly by Environment Canada and Health Canada and authorizes the Ministers of the Environment and Health to investigate a wide variety of substances that may contaminate the environment and cause adverse effects on environmental or human health. The federal government is responsible for the management of risks to health and the environment posed by substances found to be toxic, as defined under CEPA 1999. Under the federal Toxic Substances Management Policy, which is administered under CEPA 1999, substances are considered toxic if they conform to the definition of a toxic substance as specified in the Act. CEPA-toxic substances are added to the Schedule 1 List of Toxic Substances (http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1). Many of these CEPA-toxic substances also pose a potential threat to killer whales and their prey.

CEPA 1999 sets time limits for developing management strategies for CEPA-toxic substances and management strategies have been developed, or are in the process of being developed, for substances on the current Schedule 1 List of Toxic Substances. The federal government approach for addressing toxic substances is called the Toxic Substances Management Process (TSMP). Under the TSMP, management strategies can include the preparation of regulations, pollution prevention plans, environmental emergency plans, environmental codes of practice, and environmental release guidelines. Once a substance is found to be CEPA-toxic, management strategies are developed with one of two possible objectives; 1) life-cycle management of the substance to prevent or minimize its release to the environment; or 2) virtual elimination of the substance from the environment. CEPA 1999 requires virtual elimination of CEPA-toxic substances which are also bioaccumulative, persistent, and anthropogenic. Several substances have been proposed for virtual elimination including PCBs, dioxins and furans, toxaphene, aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, PCBs, and mirex.

Under the authority of CEPA 1999, the Minister of the Environment can sign political commitments and agreements to address key issues of environmental protection and health. The Canadian Council of Ministers of the Environment (CCME), which includes federal, provincial, and territorial environment ministers, has signed such an agreement. Under the Canada-Wide Accord on Environmental Harmonization and the Canada-Wide Environmental Standards Sub-Agreement, CCME develops Canada-wide Standards (CWSs) with the objective of establishing and achieving common environmental standards throughout Canada. CWSs can target specific substances or a number of sectors, sources, and substances. Action relating to the CWSs is taken by the jurisdiction deemed most appropriate. For many of the CWSs, action will be implemented by the provinces and territories. Where the federal government is identified as the most appropriate jurisdiction, regulations, codes of practice, or other preventive control instruments may be developed under CEPA 1999.

Since pesticides in Canada are regulated by the federal government under the *Pest Control Products Act* (PCPA), CEPA 1999 is not used to regulate pesticides unless the active ingredient also has a non-pesticidal use and has been categorized as CEPA-toxic.

For more information, refer to the following websites:

- The management of toxic substances in Canada: http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=97324D33-1
- List of substances managed under CEPA (Schedule 1): http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1
- Existing regulations under CEPA: http://www.ec.gc.ca/CEPARegistry/regulations/default.cfm
- CEPA Codes and Guidelines:http://www.ec.gc.ca/CEPARegistry/guidelines/
- Canada-wide Standards: http://www.ccme.ca/ourwork/environment.html?category_id=108

Environment Canada regulates Disposal at Sea in Canadian waters and ensures that the *London Convention of 1972* (London Convention 1996) is adhered to through a permit system under the *Canadian Environmental Protection Act* (CEPA), and in particular, the *Disposal at Sea Regulations* (Porebski and Osborne 1998). Under CEPA 1999, Environment Canada is required to monitor representative disposal sites each year, which involves physical, chemical, and biological monitoring (Environment Canada 2006c). From 1976 – 1991, chemical screening was the only criteria used to classify sediments to be disposed at sea (Canada Gazette 2001). However, effects-based chemical guidelines including toxicity, persistence, and bioaccumulation, are required to complement some chemical monitoring (Porebski and Osborne 1998). Currently, CEPA uses two Action Levels to evaluate material proposed to be disposed of at sea. Action Level Low is a chemical screening to determine whether contaminant levels are low enough to be of no concern (CEPA 2001;Environment Canada 2006c). Lower Action Levels exist for mercury (750 $\mu g \cdot kg^{-1}$, dry weight), cadmium (600 $\mu g \cdot kg^{-1}$ dry weight), total PCBs (100 $\mu g \cdot kg^{-1}$ dry weight, Aroclor-based), and total PAHs (2,500 $\mu g \cdot kg^{-1}$ dry weight) (Environment Canada 2006c). Any sediments with concentrations above the Lower Action Level are assessed with three biological tests: (1) an acute lethality test, (2) two sub-lethal tests or (3) one sub-lethal test and one bioaccumulation test. If the acute lethality test or the other two tests fail to meet the criteria set out for those tests, then the sediments shall be considered to be above the Upper Level of the National Action List, and disposal at sea is prohibited (CEPA 2001;Environment Canada 2006c).

4.1.2 Fisheries Act

While responsibility for the administration and enforcement for the *Fisheries Act* lies primarily with the federal Minister of Fisheries and Oceans, since 1978, the Minister of the Environment has had responsibility for the administration and enforcement of subsection 36(3) of the Act. Subsection 36(3) of the *Fisheries Act* prohibits the deposit of substances that are deleterious to fish into a place where the substance may enter or does enter waters that are frequented by fish. Under this provision, the discharge of any quantity of a deleterious substance is prohibited, unless there is a regulation that permits that discharge. Under the *Fisheries Act*, any substance that may harm fish or alter fish habitat is considered deleterious. In addition, a number of sector-specific regulations under the *Fisheries Act* limit the release of toxic substances to the environment. These include the *Pulp and Paper Effluent Regulations*, *Metal Mining Effluent Regulations*, and *Petroleum Refinery Liquid Effluent Regulations*.

For additional information on the *Fisheries Act*, the general provisions of subsection 36(3), and the regulations pertaining to sector-specific releases of toxic substances, refer to the Government of Canada website http://laws.justice.gc.ca/en/F-14/index.html.

4.1.3 Pest Control Products Act (PCPA)

The federal *Pest Control Products Act* (PCPA) is administered and enforced by the Pest Management Regulatory Agency (PMRA) for the Minister of Health. The PCPA regulates the use of substances that claim to have a pest control use and also substances such as formulants, adjuvants, and contaminants that are contained in pest control products. All compounds used for pesticidal purposes in Canada must be registered under the PCPA. Applications for pest control product registrations are reviewed by PMRA. In consultation with Environment Canada, PMRA considers science-based health, environmental, value and efficacy assessments for each pesticide prior to approving its use. A revised PCPA (PCPA 2002) received Royal Assent on December 12, 2002, and came into force June 28, 2006. Under the revisions to the Act, PMRA will be able to provide to Environment Canada, scientific studies and data that were submitted by chemical companies to support product registration. In BC, Environment Canada, in consultation with Fisheries and Oceans Canada, advises the PMRA on regional concerns relating to unregistered pesticides and requests for emergency registrations.

For more information on the PCPA and the regulation of pesticides in Canada, refer to the PMRA website http://www.pmra-arla.gc.ca/english/index-e.html.

4.1.4 Canadian Environmental Assessment Act (CEAA)

This Act is administered by the Canadian Environmental Assessment Agency, which is accountable to Parliament through the Minister of the Environment. The CEAA specifies the responsibilities and procedures for conducting environmental assessments on projects conducted in Canada, which involve federal government decision making. The objective of the Act is to ensure that such projects do not cause significant adverse environment effects by promoting a cooperative approach under which the federal and provincial governments review the potential impacts of these projects before decisions and actions are taken by the federal government. The process provides an opportunity for First Nations and public participation. The regulations under this Act identify the projects and classes of projects whose potential for causing adverse environmental impacts is considered sufficient to require an assessment under the CEAA.

For more information on the CEAA, refer to website http://www.ceaa-acee.gc.ca/013/index_e.htm.

4.1.5 Migratory Birds Convention Act

Section 35(1) of the *Migratory Birds Convention Act* prohibits the deposit of oil, oil wastes or any other substance harmful to migratory birds in any area frequented by migratory birds. Under this Act it is offence to harm the habitat of migratory birds while the birds are in residence at the site. This includes the release of harmful substances (including pesticides) to areas frequented by them.

For more information on the *Migratory Birds Convention Act*, refer to http://www.ec.gc.ca/nature/default.asp?lang=En&n=C7564624-1.

4.1.6 Fertilizers Act

The *Fertilizers Act* is administered by Canadian Food Inspection Agency (CFIA). Fertilizers and supplements imported into or sold in Canada must be registered, packaged and labelled according to the requirements of this Act. In 1997, nonylphenol ethoxylates were banned as an active ingredient in soil supplements under the *Fertilizers Act.*

For more information on the *Fertilizers Act*, refer to the CFIA website http://www.inspection.gc.ca/english/plaveg/fereng/ferenge.shtml#actloi.

4.2 Relevant Provincial Legislation

4.2.1 Environmental Management Act (EMA)

The BC MOE is responsible for managing the release of wastes and other contaminants from the industrial and agricultural sectors, with the exception of waste discharges to the air in the Metro Vancouver area, which is under the jurisdiction of Metro Vancouver. The pertinent provincial legislation is the *Environmental Management Act* (EMA), which controls the handling, disposal and release of wastes from industrial, provincial and municipal sources. The EMA was brought into force on July 8, 2004 and replaced the BC *Waste Management Act* (WMA) and the old *Environmental Management Act.*

Through a permitting system, the old WMA enabled allowable releases to be determined based on scheduled standards (generally discharge volume, toxicity and chemical/compound concentration). Monitoring requirements in the permits depended on factors such as daily discharge rate and receiving environmental characteristics and, in some instances, receiving environment monitoring was required and was determined on a facility/site-specific basis. Under the existing old WMA, all discharges to the environment from industry, trades and businesses must be authorized by the Ministry. However, the new EMA takes a risk-based approach in the authorization to discharge waste and only "prescribed" activities, such as those activities considered to be of medium to high-risk, require authorization to discharge waste. Activities considered to be low risk do not require authorization to discharge, but remain subject to the requirement that they not cause pollution. BC MOE "prescribes" industries/activities/operations which require a waste discharge authorization through the EMA's *Waste Discharge Regulation*. Industries posing a high risk to the environment (such as mines and pulp mills) require a valid authorization such as a permit or adherence to an existing regulation. Industries or activities considered to pose a modest risk to the environment are required to adhere to province-wide codes of practice for that industry sector or activity. Operations will continue to require authorization through a permit, approval or regulation until accepted codes of practice have been established for that prescribed industry sector or activity. Codes of practice and regulations apply industry wide.

For more information on the *Environmental Management Act* (EMA), refer to http://www.env.gov.bc.ca/epd/main/ema.htm.

4.2.2 Integrated Pest Management Act (IPMA)

The *Integrated Pest Management Act* (IPMA) came into force on December 31, 2004 and replaced the *Pesticide Control Act*. Under this Act and regulation, the BC MOE sets conditions for the sale and use of pesticides through a pesticide classification system. The Act contains regulatory provisions and standards for these licences, certifications, permits, pest management plans, pesticide use notices, and pesticide use notice confirmations. It also specifies reporting, monitoring, and enforcement requirements.

Most pesticide uses do not require specific authorization other than registration of intention to use pesticides through a license or pesticide use notice confirmation. A permit is required for use of a permit restricted pesticide, aerial application of a pesticide (with exceptions), any use not described in the regulation and any use for which a deviation from the standard is requested.

All pesticide uses on public land, private land used for forestry, public utilities, transportation or pipelines, and all pesticides used by pest control service companies must be used as part of an IPM program. The IMPA also requires that a person may not sell, use, handle, release, transport, store, or dispose of a pesticide in a way that causes an unreasonable adverse effect.

The provincial integrated pesticide management program includes the licensing and certification of applicators and vendors, the issuing of permits for the use of certain pesticides, and compliance activities.

For more information on the IPMA and the Provincial integrated pest management program, refer to the BC MOE website http://www.env.gov.bc.ca/epd/ipmp/regs/index.htm.

4.2.3 Mines Act

The *Mines Act*, which is administered by the BC Ministry of Energy, Mines and Petroleum Resources, regulates the operation, health and safety of all BC mines. The regulations and orders under this Act prescribe most aspects of mine design and operation, like the stability of mine openings, dams and enclosures, and the prevention of pollution such as from acid rock drainage or acid rock drainage (ARD). Since 1969, this Act has required all mines to have bonds or letters of credit sufficient to ensure reclamation of the mined lands.

For more information on the provisions of the *Mines Act* which deal with ARD, refer to http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96293_01.

4.3 Provisions of Federal and Provincial Legislation which are Applicable to the Major Identified Sources of Contaminants to the South Coastal BC Environment

There are numerous sources of contaminants to the south coastal BC environment; however, the major identified sources include municipal WWTPs, the forest products industry, mines, CSOs, stormwater and urban runoff, atmospheric deposition, contaminated sites, aquaculture, pleasure boating and septic systems.

The provisions of the federal and provincial legislation which are applicable to releases from these sources to the south coastal environment are discussed in Table 8.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Municipal Wastewater Treatment Plant Effluents	
Summary of Legislative Authority: The primary jurisdictional responsibility and legislative authority to control effluents from municipal wastewater treatment plants in Canada lies with the provinces and the territories. In BC the primary legislation used for this purpose by the BC Ministry of the Environment (BC MOE) is the *Environmental Management Act.* Wastewater treatment and collection systems located on federal lands are the responsibility of the federal government. In addition, the federal government is responsible for managing risks posed by substances defined as toxic under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). Subsection 36(3) of the *Fisheries Act* is also used by the federal government to protect fish and fish habitat from adverse effects posed by the release of deleterious substances. Actions are being taken under the authority of both CEPA 1999 and the *Fisheries Act* to improve wastewater management in Canada and to reduce the risks associated with the release of wastewater treatment plant effluents.	
Federal Legislation	**Provincial Legislation**
***Canadian Environmental Protection Act, 1999* (CEPA 1999):** Environment Canada is developing a comprehensive federal strategy for municipal wastewater effluents, including a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999. A first step of the federal strategy was the publication of two risk management instruments to address risks associated with ammonia dissolved in water, inorganic chloramines, and chlorinated wastewater effluents. A notice requiring the preparation and implementation of pollution prevention plans for inorganic chloramines and chlorinated wastewater effluents and a guideline for the release of ammonia dissolved in water was published in the *Canada Gazette* on December 4, 2004. Although WWTPs have been identified as a source of nonylphenol and its ethoxylates, which are also on the CEPA 1999 Schedule 1 - List of Toxic Substances, the decision was made to address risks posed by these substances at the source by targeting importers and manufacturers of these products, as well as industrial users such as pulp and paper mills and textile mills. Manufacturers and importers of products containing nonylphenol and its ethoxylates and textile mills that use wet processing are required to prepare and implement pollution prevention plans in regards to these substances. The pulp and paper industry have voluntarily agreed to substantially reduce their uses of these substances (Brydon 2009;Ferry 2006).	***Environmental Management Act (EMA):*** In BC, the BC MOE uses the legislative authority of the EMA to control effluents from municipal WWTPs. Most of the sewage effluent discharges authorized by permits under the old WMA are still in effect under the new EMA; however, some small sewage discharges are exempt from requiring permits under EMA and regulations. Such discharges are under the jurisdiction of the BC Ministry of Health. Typical end-of-pipe monitoring requirements for municipal WWTPs are described in the *Municipal Sewage Regulation*, which went into effect in July 1999. This regulation sets standards for municipal wastewater discharges, but instead of requiring permits for sewage discharges, proponents can submit applications of registration which include confirmation that the provincial standards are being met. Discharge permits which were already in existence when this regulation went into effect have remained in force. The EMA also authorizes each regional district or municipality to develop Liquid Waste Management Plans (LWMPs) as long-range plans for the management of liquid wastes including municipal wastewater, stormwater, CSOs and agricultural runoff. These plans are subject to provincial approval. Waste discharge permits or registrations are not required for discharges that are authorized by operational certificates under approved liquid waste management plans. LWMPs have been,

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Municipal Wastewater Treatment Plant Effluents	
Federal Legislation	**Provincial Legislation**
Canadian Environmental Protection Act,* 1999 (CEPA 1999*)* cont.:** For additional information on the CEPA 1999 assessments for ammonia, inorganic chloramines, chlorinated wastewater effluents, nonylphenol and its ethoxylates, and textile mill effluents and the progress made with respect to the development of risk management strategies, refer to the Environment Canada website: http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1. ***Fisheries Act: Environment Canada is responsible for the enforcement of Subsection 36(3) of the *Fisheries Act.* In order to better manage wastewater discharges nationally, the Canadian Council of Ministers of the Environment (CCME), of which Environment Canada is a member, has developed a Canada-Wide Strategy for the management of municipal wastewater effluents. More information is available from the CCME's website at http://www.ccme.ca/ourwork/water.html?category_id=81#210. Environment Canada has stated its intention to develop wastewater effluent regulations under the *Fisheries Act* to achieve effluent standards for wastewater treatment systems equivalent in performance to conventional secondary treatment with additional treatment where required. The federal regulations that will be proposed by Environment Canada will apply to all wastewater systems across Canada and will be the federal government's principal tool to implement the CCME Canada-wide Strategy for the management of wastewater effluents. The comprehensive long-term federal approach will also address a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999. For more information, please refer to EC's website at http://www.ec.gc.ca/eu-ww/default.asp?lang=En&n=BC799641-1.	***Environmental Management Act (EMA)* (cont.):** or are currently being, developed voluntarily by numerous local governments throughout BC. It is expected that other municipalities and regional districts will also develop LWMPs voluntarily; however, the EMA now provides the authority for the Minister to direct a municipality to develop or revise LWMPs. For more information on the *Municipal Sewage Regulation* or on Liquid Waste Management Plans refer to the BC MOE website http://www.env.gov.bc.ca/epd/epdpa/mpp/mpp_home.htm.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Forest Products Industry	
Summary of Legislative Authority: The federal and provincial governments share responsibility for managing effluent discharges from pulp and paper mills. In the early 1990s, they worked with the CCME to coordinate a new regulatory framework. The federal regulatory package set national baseline standards for pulp and paper mills across Canada. At the same time, the province of BC (and other provinces) enacted new pulp and paper regulations to adopt these standards and apply best available technology, allowing stricter limits on individual mills as required (Boyd 2009). The province of BC leads in controlling the releases from log sorting and sawmill facilities. Permit applications and amendments are referred to the federal government for input with respect to the federal laws (e.g., general provisions of the *Fisheries Act*).	
Federal Legislation	**Provincial Legislation**
<u>Pulp and Paper Mills</u> ***Fisheries Act:*** The 1992 *Fisheries Act*, *Pulp and Paper Effluent Regulation* (PPER), prescribed stricter discharge limits for certain deleterious substances in the final effluent from pulp and paper mills and off-site treatment facilities: total suspended solids (TSS), biochemical oxygen demand (BOD). They also required non-acutely lethal effluent (96 hr rainbow trout LC_{50}>100%). The PPER also required mills which discharge to the aquatic environment to conduct environmental effects monitoring (EEM). PPER amendments passed in May, 2004, streamlined the monitoring and reporting requirements, but did not substantially change the regulations. The pulp and paper mills under the PPER which discharge to the aquatic receiving environment conduct EEM. The objectives are to evaluate if the effluent causes effects on fish, fish habitat, and/or the use of fisheries resources, as well as to assess the adequacy of existing regulations on a site-specific basis. EEM basic requirements include sublethal toxicity testing, a fish survey, and a benthic invertebrate survey. Evaluation of fish tissue for dioxins and furans may be required at mills using chlorinated bleaching. Problems of fish tainting must also be reported. Mills conduct EEM in 3 year cycles to determine if mill effluent effects exist. Mills showing no effects can reduce frequency of field monitoring to every other cycle. Mills showing effects exceeding critical sizes advance to determine extent, magnitude and cause of the effects. Once the cause is identified, a mill may implement site-specific actions; however, this is not a requirement of the PPER. Environment Canada, the provincial government (BC MOE), and other interested parties (e.g., ENGOs, First Nations) review the mill's EEM study designs and interpretive reports (Boyd 2009).	***Environmental Management Act (EMA):*** Pulp mills are considered to be high risk discharges under the new EMA risk classification system and, as such, still require authorization to release effluents in the form of waste discharge permits. A provincial regulation on pulp and paper mill liquid effluents is enforced under the authority of the EMA. All BC mills currently have discharge permits under EMA except for two mills which discharge to sewer and one with no effluent discharge. The two mills discharging to sewer have Metro Vancouver sewer discharge permits. EMA discharge permits usually specify allowable releases of AOX where as the federal regulations restrict dioxins and furans specifically. The EMA may have more stringent requirements for total suspended solids (TSS) and biological oxygen demand (BOD) than are specified under the federal *Fisheries Act* PPER. Also included in EMA permits are specifications regarding rate of discharge, temperature, oil and grease, and metals. These apply to all mill discharges including those considered "internal", such as effluent to a treatment plant. Environmental monitoring is generally covered by a requirement for the mills to conduct the federal PPER Environmental Effects Monitoring (EEM) requirements. Additional requirements for environmental monitoring may be occur on a site-specific basis. For more information on the EMA requirements relating to pulp mill liquid effluents, refer to the BC MOE website http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/index.htm.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Forest Products Industry *(cont.)*

Federal Legislation	**Provincial Legislation**
For more information on the PPER and EEM program, refer to the following websites: http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=3D1EC15C-1 http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=4B14FBC1-1 ***Canadian Environmental Protection Act, 1999* (CEPA 1999*):*** Two CEPA regulations passed in 1992 prevent the release of toxic substances (i.e., dioxins and furans) from pulp mill effluents: • *Pulp and Paper Mill Defoamer and Wood Chip Regulations* prevent the formation of dioxins and furans at pulp and paper mills using a chlorinated bleaching process. The defoamers are limited to a maximum concentration of 10 parts per billion (ppb) of dibenzodioxin and 40 ppb of dibenzofuran. In addition, the regulations prohibit the import, offer for sale, sale or use in a mill in Canada of wood chips that have been made of wood treated with chlorinated phenols (http://lois.justice.gc.ca/en/C-15.31/SOR-92-268/index.html. • *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations* prohibit the release of dioxins and furans in pulp and paper mill effluents. In many existing bleaching mills, significant process modifications were necessary to prevent dioxin and furan formation. Mills built prior to June 1, 1990 were required to submit to the Minister an implementation plan and schedule to achieve compliance by January 1, 1994; maximum discharge limit of 15 ppq for 2,3,7,8-TCDD and 50 ppq for 2,3,7,9-TCDF by January 1, 1994. The regulations require mill operators to collect composite effluent samples and report on concentrations of dioxins and furans (http://lois.justice.gc.ca/en/C-15.31/SOR-92-267/index.html).	

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Forest Products Industry *(cont.)*	
Federal Legislation	**Provincial Legislation**
<u>Wood Treatment Facilities</u> ***Canadian Environmental Protection Act, 1999* (CEPA 1999) (cont.):** Several of the substances found in commercial wood preservative formulations have been found to be toxic as defined by CEPA 1999. These include inorganic arsenic compounds found in ACA and CCA; hexavalent chromium compounds found in CCA; creosote-impregnated waste materials from creosote contaminated sites; dioxins, furans, pentachlorobenzene (PCb), and HCB found as micro-contaminants in PCP-based wood treatment formulations; and PAHs which are contained in very high concentrations in creosote. The main role of the federal government in addressing wood preservation chemicals is to implement control measures for these CEPA-toxic substances in accordance with the federal Toxic Substances Management Policy. Environment Canada released the Antisapstain Wood Protection – Recommendations for Design and Operation in 1994 and the Recommendations for the Design and Operation of Preservation Facilities in 1997. CEPA 1999 control measures include the Recommendations for the Design and Operation of Wood Preservation Facilities and a notice for Pollution Prevention Plans. In addition, PCDD/Fs, PCb, and HCB are targeted under the federal Toxic Substances Management Policy for virtual elimination (http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=13698512-1). HCB and PCb are also controlled under the *Prohibition of Certain Toxic Substances Regulations, 2005* (http://www.ec.gc.ca/CEPARegistry/regulations/detailReg.cfm?intReg=87). For more information on management strategies developed for wood preservation chemicals and for the wood preservation sector, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=C5039DE5-1&xml=C6502274-1535-467A-923D-34C2FE9102E8. ***Fisheries Act:*** The general pollution prevention provisions of the *Fisheries Act* (Subsection 36(3)) apply to discharges from wood treatment facilities and Environment Canada could take action in situations where releases are in violation of the provisions of Subsection 36(3).	***Environmental Management Act* (EMA) *(cont.):*** The control of wastes generated from antisapstain and wood preservation facilities are generally a provincial jurisdiction. Allowable levels of antisapstain chemicals in stormwater runoff from lumber sites are regulated by BC MOE under the EMA, which replaces the old *Waste Management Act* (WMA). The provincial *Antisapstain Chemical Waste Control Regulation* was introduced on September 1, 1990 and amended in 2001 under the old WMA. This regulation sets a non-toxic provision and maximum limits on the levels of TCMTB, chlorophenols, DDAC, IPBC and Cu-8 in effluents (including stormwater) from antisapstain facilities and treated lumber storage yards in BC. Emissions of these chemicals to the air from antisapstain chemical spray booth vents are also controlled under this regulation. For more information on the provincial requirements for antisapstain facilities refer to the BC MOE website: http://www.env.gov.bc.ca/epd/industrial/regs/antisapstain/index.htm and http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/toxicity_antisapstain.htm.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

<table>
<tr><th colspan="2">Forest Products Industry (cont.)</th></tr>
<tr><th>Federal Legislation</th><th>Provincial Legislation</th></tr>
<tr><td>

<u>Wood Treatment Facilities cont.</u>

Pest Control Products Act (PCPA):

All compounds used for pesticidal purposes must be registered under the PCPA, including antisapstain chemicals and heavy-duty wood preservatives. Chlorophenate compounds were de-registered under PCPA for antisapstain use on December 31, 1990. The PMRA has recently conducted a re-evaluation of all heavy-duty wood preservatives under the authority of the PCPA. In addition, the PMRA reached an agreement with Canadian manufacturers of this product to move away from the use of CCA for the treatment of lumber for residential use by December 31, 2003. Applications of CCA to wood for use on industrial sites were not affected by this agreement, nor were CCA-treated wood products already in use. PMRA is also currently conducting a re-evaluation under the *Pest Control Products Act* of TCMTB, CU- 8 and Borax. An interim re-evaluation report was published in 2004. This report can be viewed at http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rrd2004-08/index-eng.php.

For more information refer to the following websites:
- PMRA re-evaluation of heavy-duty wood preservatives: http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php
- CCA agreement for residential-use lumber: http://dsp-psd.communication.gc.ca/Collection/H113-5-2002-3E.pdf

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Integrated Pest Management Act (IPMA):

The *Integrated Pest Management Act* (IPMA) came into force on December 31, 2004 and replaced the *Pesticide Control Act*. Under the IPMA, the BC MOE addresses the application, storage, sale, transport and disposal of pesticides. The Act sets conditions for the sale and use of pesticides through a pesticide classification system and regulatory provisions for licenses, certification, permits, pest management plans, pesticide use notices, and pesticide use notice confirmations. It also specifies reporting, monitoring, and enforcement requirements. The Act requires the use of integrated pest management (IPM) for the development of pest management plans for large scale commercial uses of pesticides. For more information on the IPMA and the BC MOE Integrated Pest Management Program, refer to http://www.env.gov.bc.ca/epd/ipmp/index.htm.

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Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

<table>
<tr><th colspan="2">Metal Mines</th></tr>
<tr><td colspan="2">Summary of Legislative Authority:

Canada's provinces and territories have regulatory control over land and water use including mining. All mines, whether for metals, coal, industrial minerals, diamonds, placer gold, or construction aggregate, need provincial or territorial approval to operate. These approvals may regulate a mine's design, environmental impact, and health and safety, and may prescribe environmental monitoring programs. Federal controls for contaminants and effluents are superimposed on these provincial and territorial approvals.</td></tr>
<tr><th>Federal Legislation</th><th>Provincial Legislation</th></tr>
<tr><td>Fisheries Act:

All mines in Canada, whether operating or abandoned, are subject to Section 36(3) of the Fisheries Act, a general prohibition against the release of deleterious substances into waters frequented by fish unless authorized by a regulation. Environment Canada has responsibility for this section and the Metal Mining Effluent Regulations (MMER), which apply only to operating mines. The MMER prescribe allowable concentrations of specific substances like heavy metals, cyanide, and suspended solids, and also prohibit effluents which are acutely lethal to fish. The MMER also require mines to perform environmental effects monitoring similar to the provisions of the Pulp and Paper Effluent Regulations. The general provisions of Section 36(3) apply to abandoned mines with effluents and effluents from all non-metal mines, like those for coal, placer gold, and industrial minerals (Hagen 2009;McCandless 2006).

For more information refer to the following websites:
• Fisheries Act MMER:
http://laws.justice.gc.ca/en/F-14/SOR-2002-222/
• EEM Program for metal mines:
http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=034E4EF1-1</td><td>Environmental Management Act (EMA):

Under this Act, all British Columbia mines with effluents or emissions must hold permits or approvals which prescribe maximum concentrations, and maximum flows or volumes, for all air and water releases. Effluents from closed mines may not require a permit if concentrations are below prescribed limits but, if they are exceeded, the EMA provides powers to order mitigation or cleanup of polluting abandoned mines, and other contaminated sites (McCandless 2006).

Mines Act:

This Act regulates the operation, health and safety, environmental protection, and closure of all BC mines. Its regulations and orders prescribe most aspects of mine design and operation, including the prevention of pollution from such sources as acid rock drainage.

In addition, to ensure that acid rock drainage problems and reclamation problems are not encountered at future mine sites, potential problems and prevention techniques must be addressed in new mine proposals (Hagen 2009;McCandless 2006). New mining companies are required to post bonds to ensure that funding is available for future remediation and control acid rock drainage problems, should they develop.</td></tr>
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Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Metal Mines	
Federal Legislation	**Provincial Legislation**
Canadian Environmental Protection Act, 1999 **(CEPA 1999):** Like Canada's other industries, mines are subject to this Act and its regulations regarding the storage, release, and reporting of prescribed substances, emergency preparedness, and response to spills (Hagen 2009;McCandless 2006). A number of metals are considered to be CEPA-toxic and the federal Toxic Management Process has involved the development of management tools to decrease the release of metals from a variety of sectors including base metal smelting, coal-fired power generation, metal finishing, and steel manufacturing. No management tools have been developed under CEPA 1999 for the release of metals from mines.	

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Non-point Sources

Summary of Legislative Authority:

NPS pollution is largely unregulated, but is recognized as a high priority issue by all levels of government. This is a difficult and complex issue to manage due to the diffuse nature of the sources and to the fact that no one government jurisdiction has the sole responsibility for addressing NPS pollution. An effective management plan for the south coastal area of BC will require the formation of co-operative partnerships between stakeholder groups including all levels of government, stewardship groups, and the public. Educational and outreach programs involving business sectors, associations, community groups, and the general public are also essential to effectively addressing non-point source pollution.

Non-point sources in the south coastal region of BC release several substances of potential concern to killer whales and their prey. In particular, these include stormwater and urban runoff, agricultural runoff, CSOs, contaminated sites, and atmospheric deposition.

Federal Legislation	Provincial Legislation
***Canadian Environmental Protection Act, 1999* (CEPA 1999):** Although regulations under CEPA 1999 do not specifically address the release of toxic substances from non-point sources, some of the regulations, such as the *PCB Regulations*, the *PCB Treatment and Destruction Regulations*, the *Storage of PCB Material Regulations* and *Contaminated Fuel Regulations*, help to reduce non-point releases of these substances. Similarly, the *Disposal at Sea Regulations* under CEPA 1999 set limits on the concentrations of specific toxic substances in materials to be disposed at sea and, therefore, limit the loadings of those substances to the Ocean Disposal Sites. In addition, the substance-specific and sector-specific management tools, implemented under the federal Toxic Substances Management Process, to address issues associated with CEPA-toxic substances can be used to reduce releases from both point and non-point sources. In some cases, CEPA 1999 regulations are used to eliminate some, or all, of the current uses of a CEPA-toxic substance while, for other substances, Codes of Practice are developed with the objective of limiting the release of CEPA-toxic substances. For example, the introduction of codes or practice and recommendations for the design and operation of wood preservation facilities has reduced the release of several CEPA-toxic substances in stormwater from these facilities. For more information on substance-based and source-based risk management strategies for CEPA-toxic substances, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=97324D33-1.	***Environmental Management Act* (EMA)*:*** The *Environmental Management Act* (EMA) *is* the legislation which provides for the preparation of the Liquid Waste Management Plans (LWMPs) by municipalities and regional governments in BC. BC MOE guidelines for the development of LWMPs state that LWMPs should be consistent with the strategy of achieving zero pollution and should address all municipal liquid waste including sewage discharges and municipal sludge, as well as non-point sources such as CSOs, urban stormwater runoff, and agricultural runoff. Agricultural operations are not exempt from requirements under the EMA. Several regulations under the EMA apply to agricultural operations. In 1992, BC MOE introduced the *Agricultural Waste Control Regulations* and the Code of Agricultural Practice for Waste Management, which address activities associated with the use, storage and management of manure and other agricultural wastes. The *Hazardous Waste Regulation* under the EMA applies the management of waste oil, waste pesticides, pesticide containers and contaminated soils. The *Spill Reporting Regulation* under the EMA requires that the person who was handling the chemical at the time the spill occurred must report the spill to the Provincial Emergency Program as soon as it is discovered. This requirement applies to pesticide spills of more than five kilograms, fertilizer (including manure) of more than 50 kilograms, and petroleum products of more than 100 litres.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Non-point Sources	
Federal Legislation	**Provincial Legislation**
Fisheries Act The general pollution prevention provisions of the *Fisheries Act* (Subsection 36(3)) apply to non-point sources by prohibiting the release of deleterious substances to waters frequented by fish, unless a regulation allows this release. Environment Canada could take action in situations where releases are in violation of this subsection. For example, many farm products or wastes could be considered deleterious substances under the Act. However, due to the nature of both groundwater and stormwater collection and discharge, it can be very difficult to isolate upstream sources of contamination. For more information on the *Fisheries Act*, refer to http://laws.justice.gc.ca/en/F-14/.	***Environmental Management Act* (EMA) *(cont.):*** The EMA also includes standards for the identification, assessment and remediation of contaminated sites and other provisions in the EMA *Contaminated Sites Regulation*. The Crown Contaminated Sites Program in the BC Ministry of Agriculture and Lands manages high risk contaminated sites on provincial Crown land. The program utilizes cross-government policy on site management to ensure the protection of both environmental and human health. For more information refer to the following websites: • *EMA Contaminated Sites Regulation*: http://www.env.gov.bc.ca/epd/remediation/leg_regs/csr.htm • LWMPs under EMA: http://www.env.gov.bc.ca/epd/epdpa/mpp/gfdalwmp.html • *Agricultural Waste Control Regulations* and Code of Agricultural Practice for Waste Management: http://www.env.gov.bc.ca/epd/industrial/regs/ag_waste_control/index.htm and http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/10_131_92 • *EMA Hazardous Waste Regulation*: • http://www.env.gov.bc.ca/epd/hazwaste/regs/index.htm • Provincial Contaminated Sites program: http://www.env.gov.bc.ca/epd/remediation/cs101.htm

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Non-point Sources	
Federal Legislation	**Provincial Legislation**
Pest Control Products Act (PCPA): The de-registration of 'pesticides of concern' under the PCPA reduces the release of these chemicals to the environment from both agricultural and urban runoff and from atmospheric deposition. Under the authority of the PCPA, the PMRA sometimes conducts re-evaluations on current-use pesticides in Canada to determine whether their use in Canada needs to be further limited or discontinued. For example, the de-registration of tributyltin compounds for use as antifoulants has decreased the entry of these substances to the environment from marine structures and boat hulls. Similarly, the de-registration of chlorophenate-based formulations for sapstain control in lumber under the PCPA has effectively reduced the release of chlorophenols, HCB, and PCDDs/PCDFs in stormwater from wood protection facilities in Canada. PMRA has recently re-evaluated the use of all heavy-duty wood preservation chemicals in Canada. Other pesticides which have recently undergone, or are currently undergoing, re-evaluation include lindane, endosulfan, and atrazine. For more information on the PMRA re-evaluation program, refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/regist-homolog/_re-eval/index-eng.php ***Canadian Environmental Assessment Act (CEAA):*** Assessments of projects requiring federal government decisions would include consideration of potential environmental concerns including those associated with anticipated non-point source releases. As of June 1999, contaminated sites remediation has been included in the *Inclusion List Regulations,* which is a list of the projects which require an environmental assessment under the CEAA. For more information on the CEAA refer to http://www.acee-ceaa.gc.ca/default.asp?lang=En&n=9EC7CAD2-1.	***Integrated Pest Management Act (IPMA):*** The use of integrated pest management applies to pesticide use on all public land and on private land used for forestry, public utilities, transportation, and pipelines. A permit for the routine use of pesticides is not required if the user has a pest management plan (whose development has involved public consultation), has signed an agreement to comply with standards for human health and environmental protection, and has notified BC MOE of the intended pesticide use. The use of pest management plans, instead of pesticide use permits, for the above stated uses of pesticides was implemented by MOE following a 1998 amendment to the old *Pesticide Control Act,* which was replaced by the *Integrated Pest Management Act* in 2004. The regulation was not amended at that time (2004) to define the requirements for pest management plans. Pesticides are classified according to their licensing and permit requirements for sale and use. Under the IPMA, the Minister can designate pesticide uses that require a permit; only pesticide uses of high concern require permits. These include pesticide use for predator control, aerial application over residential areas, and the use of pesticides for which no ministry standards have been set. The application of pesticides by farmers on their own property is exempt from requirements for reporting pesticide use, obtaining a Pesticide Use Permit, or operating under a Pest Management Plan. For more information on the provincial IPM program refer to the BC MOE website http://www.env.gov.bc.ca/epd/ipmp/.

Table 8 Provisions of Federal and Provincial Legislation Applicable to Major Identified Sources of Contaminants

Non-point Sources	
Federal Legislation	**Provincial Legislation**
Migratory Birds Convention Act: Section 35(1) of the *Migratory Birds Convention Act* prohibits the deposit of oil, oil wastes or any other substance harmful to migratory birds in any area frequented by migratory birds. Under this Act it is offence to harm the habitat of migratory birds while the birds are in residence at the site. This includes the release of harmful substances (including pesticides) to areas frequented by migratory birds. For more information on the *Migratory Birds Convention Act*, refer to http://www.ec.gc.ca/nature/default.asp?lang=En&n=C7564624-1. ***Fertilizers Act:*** The *Fertilizers Act* requires that fertilizers and supplements imported into or sold in Canada must be registered, packaged and labelled according to the requirements of this Act. In 1997, nonylphenol ethoxylates were banned as an active ingredient in soil supplements under the *Fertilizers Act*, thus reducing the potential release of these substances in agricultural runoff. For more information, refer to http://laws.justice.gc.ca/en/F-10/index.html.	***Farm Practices Protection Act:*** The *Farm Practices Protection Act* states that farm practices must comply with the EMA, the IPMA, the *Health Act* and the *Fisheries Act* and their regulations. For more information, refer to http://www.alc.gov.bc.ca/alr/fppa.htm. ***Fish Protection Act::*** This Act and the associated *Riparian Areas Regulation*, addresses non-point source pollution indirectly by requiring buffer setbacks and protection during development. For more information, refer to http://www.env.gov.bc.ca/habitat/fish_protection_act/riparian/riparian_areas.html.

5 Actions and Initiatives Previously Implemented to Reduce Contaminants Releases to the South Coastal BC Environment (extracted from Garrett 2009)

There is a wide range of sources of contaminants to the south coastal environment of BC including municipal WWTPs, the forest products industry, mines, CSOs, stormwater and urban runoff, agricultural runoff, contaminated sites, and atmospheric deposition. However, the quantification of contaminant loadings to the environment from a number of these sources is lacking. In recent decades, concerns from the public, the fishing industry, First Nations, and ENGOs with respect to declining fish stocks, poor water quality, and compromised recreational opportunities have led to increasing pressure on regulatory agencies to address point sources of pollution. Increased regulatory actions, combined with an increased awareness and implementation of voluntary controls by industry, have significantly decreased the release of contaminants to south coastal BC from major point sources over the last two decades. Despite this considerable improvement, concerns associated with point source releases of contaminants remain. For example, the presence of PPCPs, pathogens, and several commercially used chemicals, including various estrogenic compounds, in WWTP discharges has been reported, but information is lacking on the efficacy of wastewater treatment practices in removing these substances and on their loadings to the environment. The magnitude of release and the potential for adverse environmental impacts in the BC aquatic environment as a result of the release of these contaminants have not been evaluated. However, BC MOE is in the final stages of developing a water quality guideline for 17α-ethinlyestradiol (Meayes 2009).

With the overall success of efforts in recent decades to reduce environmental loadings of contaminants from point source discharges, non-point sources, such as runoff from urban and agricultural areas and atmospheric deposition, are now recognized as the major contributors of many potentially harmful contaminants to the environment. Non-point sources often contribute a variety of contaminants to ambient surface waters and groundwater. Signs of contaminant stress in several watersheds in the south coastal area of BC have been attributed to non-point sources. Pesticides and nutrients enter streams through agricultural runoff and have also been detected at elevated concentrations in runoff and streams located in urban areas. Pollutants in groundwater may also enter streams or other surface water bodies through natural groundwater-surface water interaction. In addition, urban runoff contributes high loadings of PAHs, and some metals, to urban waterways. Many streams and ditches have been identified as critical habitat for wildlife, particularly amphibians and salmon fry. Adverse effects on amphibian populations and the community structure of benthic invertebrates have been observed in some urban and agricultural areas. In addition, non-point sources such as agricultural and urban runoff, releases from septic systems, CSO and stormwater discharges, and boating activity have resulted in fecal and chemical contamination of shellfish populations in coastal areas of BC. Atmospheric deposition has also been identified as an important source of both metals and organic contaminants to the south coast; however, more information is required on contributions from both local sources and long-range atmospheric transport. Developing a better understanding of non-point sources of contaminants to the Georgia Basin is a high priority.

Reductions in the release of metals and other toxic substances from a broad range of point and non-point sources have been achieved through both regulatory and non-regulatory initiatives implemented by federal, provincial and municipal government agencies, industry,

industry associations, and community groups. A number of successful non-regulatory initiatives were undertaken as a result of the Fraser River Estuary Management Program (FREMP), the Fraser River Action Plan (FRAP), the Burrard Inlet Environmental Assessment Plan (BIEAP), and the Victoria and Esquimalt Harbours Environmental Action Program (VEHEAP). These initiatives provided funding and support for studies to better identify and understand toxics issues in the south coastal region of BC and helped to increase the awareness of both industry and the public. The pollution abatement component of these initiatives developed a number of Best Management Practice documents (BMPs) aimed at reducing releases of toxics from industrial and commercial sources and emphasized the implementation of voluntary actions to prevent and reduce pollution through innovative technologies and techniques. The FRAP program was succeeded by the Georgia Basin Ecosystem Initiative (GBEI), whose objective was to address industries and activities impacting both the air and water of the Georgia Basin region. The GBEI was a partnership of federal, provincial and municipal levels of government. Management actions to reduce the release of metals and organic contaminants into the Georgia Basin addressed industrial discharges, municipal WWTPs, and non-point sources such as agricultural and urban stormwater runoff, CSOs, contaminated sites, and atmospheric deposition. The GBEI was renewed as the Georgia Basin Action Plan (GBAP), from 2003 to 2009, in order to build upon the work and accomplishments of GBEI.

Reductions in toxic releases were achieved through programs initiated under BIEAP, FRAP, and GBEI/GBAP, in conjunction with other initiatives; however, for many sources the available information is insufficient to determine the magnitude of reductions in loadings. A report prepared for Environment Canada identified wastewater sources of contaminants to the Georgia Basin environment and, where sufficient information was available, also estimated loadings of specific substances to the environment. Available information on releases from pulp mills, municipal wastewater treatment facilities, stormsewers, and CSOs in the Georgia Basin was included (ENKON Environmental Ltd. 2002). For more information on these initiatives refer to the following websites:

- FRAP: http://www.fraserbasin.bc.ca/about_us/history.html
- FREMP, and BIEAP: http://www.bieapfremp.org/
- GBEI and GBAP: http://www.ec.gc.ca/doc/ae-ve/ve-ae_123/s1_eng.htm
- VEHEAP: http://www.crd.bc.ca/partnerships/veheap/index.htm

There have been many successful initiatives to reduce the release of environmental contaminants to the south coastal environment. However, it is important to recognize that the increased generation of wastewater, other wastes, and urban runoff associated with the rapidly growing population of the south coastal area will create an even greater future need to minimize the release of contaminants to the environment. In addition, while the potential combined effects of low concentrations of the multitude of chemicals still entering the environment from these sources has been recognized, they have not been evaluated nor are they well understood. Many of the actions which have already been implemented to reduce the release of contaminants to the south coastal environment from major identified potential sources have been summarized following. However, this list is by no means complete and relevant websites which provide additional information have been included.

5.1 Municipal Wastewater Treatment Plants (WWTPs)

Federal Government Programs:

- Environment Canada has been working with provincial and territorial governments to develop a Canada-wide Strategy for the management of municipal wastewater effluents under the auspices of the Canadian Council of Ministers of the Environment (CCME). Environment Canada intends to develop a regulation under the *Fisheries Act* to achieve effluent standards for wastewater treatment systems equivalent in performance to conventional secondary treatment, with additional treatment where required. The federal regulations that will be proposed by Environment Canada will apply to all wastewater systems across Canada and will be the federal government's principal tool to implement the CCME Canada-wide Strategy for the management of municipal wastewater effluents. The comprehensive long-term federal approach for the management of municipal wastewater effluent will also address a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999 (Brydon 2009).
- Under GBAP, Environment Canada, in cooperation with other partners, undertook projects to:
    - conduct chemical characterization of solid and liquid wastes from municipal wastewater treatment plants (Metro Vancouver and CRD);
    - determine molecular level (genomic) toxicology of municipal wastewater effluents at receiving water concentrations to fish;
    - utilize in-house developed gene micro-arrays for salmonids to evaluate gene expression to either freshwater rainbow trout or Pacific salmon which have been acclimated to seawater. Effluents will be collected from Metro Vancouver and CRD and adjusted to relevant receiving water concentrations in concert with District staff;
    - develop capabilities to analyze for selected pharmaceuticals, personal care products and antibiotics suspected of causing endocrine disruption;
    - analyze select pharmaceuticals and fragrance compounds in-house and profile for molecular toxicity;
    - conduct sterol and select pharmaceutical chemistry on effluent sample (~60); and
    - support technical and scientific conferences such as the Annual BC Waste & Water Association Conference and Tradeshow.

  For more information on federal government initiatives on municipal WWTP plant effluents, refer to the following websites:
    - Environment Canada programs to address municipal WWTP effluents: http://www.ec.gc.ca/eu-ww/default.asp?lang=En&n=BC799641-1
    - GBAP initiatives: http://www.ec.gc.ca/doc/ae-ve/ve-ae_123/s1_eng.htm
    - CCME Canada-wide Strategy for the management of municipal wastewater effluents: http://www.ccme.ca/ourwork/water.html?category_id=81.
- Under the Federal Government's Chemicals Management Plan, which was introduced in December 2006, the Government of Canada will work with stakeholders on the health and

environmental assessment of over 9000 substances which are used in products regulated by the *Food and Drugs Act*. The government will also work with stakeholders to reduce the release of these pharmaceuticals and personal care products to the environment by promoting best practices for proper disposal. For more information, refer to http://www.chemicalsubstanceschimiques.gc.ca/plan/index_e.html#7http://www.chemicalsubstanceschimiques.gc.ca/plan/index_e.html#7

- The amended *Cosmetic Regulations* came into force on November, 16, 2006 and requires ingredient labelling on all cosmetic products.

Intergovernmental Partnership Programs:

- CCME developed a Canada-wide strategy for the management of municipal wastewater effluents. The strategy includes: 1.) a harmonized regulatory framework, 2.) coordinated science and research, and 3.) an environmental risk management model.
- CCME Canada-wide Standards (CWSs) on mercury for dental amalgam wastes was endorsed in 2001. Through the collection and recycling of amalgam wastes and the use of advanced amalgam separator units at dental clinics, the amount of mercury discharged to sewer systems will be reduced. The intent of the CWSs was to reduce environmental releases of dental amalgam in Canada by 95% by 2005, compared to releases in 2000.
  For more information, refer to the following websites:
    - CCME Strategy and initiatives to reduce the release of contaminants in WWTP effluent: (http://www.ccme.ca/ourwork/water.html?category_id=81
    - CCME MOU with the Canadian Dental Association: http://www.ccme.ca/ourwork/water.html?category_id=118

Metro Vancouver Programs:

- Past modifications at Metro Vancouver WWTPs in the Georgia Basin include the extension of the discharge outfall from Metro Vancouver's Iona Island WWTP beyond the intertidal area in 1988. Subsequent environmental surveys have reported a decline in metal concentrations in sediments and Macoma clams at Sturgeon Bank. In addition, in 1992, the discharge of sludge to the Burrard Inlet from the Lion's Gate WWTP was terminated and, as a result, the loadings of metals from this facility decreased by an estimated 40%. It is likely that the releases of other substances which bind to particulate matter have also been significantly decreased. For recent information on individual Metro Vancouver WWTPs, or to view the 2008 Quality Control Report, refer to the Metro Vancouver website (http://www.metrovancouver.org/services/wastewater/treatment/Pages/treatmentplants.aspx).
- Secondary treatment is employed by Metro Vancouver to treat wastewater from all three municipal WWTPs (Lulu Island, Annacis Island and Northwest Langley WWTPs) which discharge to the Fraser River. Metro Vancouver plans to upgrade the remaining two primary treatment plants (Iona Island and Lions Gate), which discharge to marine waters, to secondary treatment by 2020 and 2030, respectively. This will further reduce the concentrations of metals and other contaminants in municipal wastewater discharges to the Georgia Basin. For more information refer to the Liquid Waste Management Plan (LWMP) Biennial Report for 2008 (http://www.metrovancouver.org/services/wastewater/planning/Pages/default.aspx).

- Metro Vancouver and member municipalities have adopted a liquid waste management plan (LWMP) in accordance with the British Columbia *Environmental Management Act* (formerly the *Waste Management Act*). Member municipalities and electoral areas within Metro Vancouver include: the Cities of Burnaby, Coquitlam, Langley, New Westminster, North Vancouver, Port Coquitlam, Port Moody, Richmond, Surrey, Vancouver, and White Rock; the Corporation of Delta; the Districts of Langley, Maple Ridge, North Vancouver, Pitt Meadows and West Vancouver. In addition, although the Villages of Anmore, Belcarra, and Lions Bay; Bowen Island Municipality; and a portion of Electoral Area A are not members of the Metro Vancouver Sewerage and Drainage District, Metro Vancouver policies associated with non-point source pollution issues apply in these areas. For more information, refer to http://www.metrovancouver.org/services/wastewater/planning/Pages/default.aspx.
- Under the LWMP, Metro Vancouver committed to the development of an Environmental Monitoring Committee comprising representatives from federal, provincial and municipal governments, research institutions and the public. This committee is responsible for reviewing monitoring proposals, results, and risk assessments of waste discharges and providing recommendations for consideration by Metro Vancouver and member municipalities.
- Metro Vancouver has implemented source control programs to reduce the discharges of toxic substances to sewers as part of its LWMP. Sewer use Bylaw 299 was adopted on May 25, 2007 to supercede Bylaw No. 164. Bylaw 299 is now the primary bylaw regulating liquid waste discharges from non-residential facilities in Metro Vancouver. This bylaw includes a Code of Practice for Dental Operations which specifies that, by July 1, 2008, all dental operations using or removing dental amalgam must utilize a certified amalgam separator. In addition, the revised Metro Vancouver Sewer Use Bylaw includes other new Codes of Practice for photofinishing (for the discharge of silver) and dry cleaning (for the discharge of tetrachloroethylene. The new series of Bylaw amendments will consider the following (Bertold 2009):
    - additional requirements for the discharge to sewer of priority contaminants to sewer, in particular priority substances listed under CEPA 1999,
    - revising fees to better reflect user-pay and polluter-pay principles and to improve sustainability, fairness and effectiveness of the source control program,
    - codes of practice with requirements for various industrial, commercial and institutional sectors to allow an effective and efficient means of protecting Metro Vancouver's interests and the environment,
    - increasing maximum fines and allowing a broader array of regulatory tools, economic instruments and administrative penalties, and
    - Pollution Prevention Plans for the control of medical and laboratory discharges.

  For more information, refer to website http://www.metrovancouver.org/services/wastewater/sources/Pages/commercial.aspx**.**
- Metro Vancouver has also developed resources to address residential sewer use as well as guidance documents for homeowners to reduce contaminants releases to sewer systems. For more information, refer to website http://www.metrovancouver.org/services/wastewater/sources/Pages/resident.aspx**.**

Capital Regional District (CRD) Programs:

- A LWMP, which provides a strategy for managing liquid wastes over the next 25 years, was developed by the CRD and its municipal partners including Colwood, Esquimalt, Langford, Oak Bay, Saanich, Victoria and View Royal in 2000 (http://www.crd.bc.ca/wastewater/lwmp/documents/CALWMP.pdf). A separate LWMP was completed for the Saanich Peninsula communities of Central Saanich, North Saanich and Sidney (http://www.crd.bc.ca/wastewater/lwmp/saanich_lwmp.htm).
- Recently, the CRD engaged the Society of Environmental Toxicology and Chemistry (SETAC), a non-profit professional society, to do an independent review and performance audit of the CRD's LWMP. As per the terms of reference, SETAC selected an independent scientific and technical review panel to conduct a broad review of the components of the LWMP, the future risks (e.g., population growth and emerging concerns regarding specific chemicals), and alternative and new liquid waste management systems (Ferry 2006). This review was completed and provided to the CRD in July 2006 and can be viewed at http://www.crd.bc.ca/wastewater/documents/SETACCRDFinalReportv2_000.pdf.
- Of the eight WWTPs operated by the CRD, the Saanich Peninsula, Port Renfrew, Canon Crescent (on North Pender Island), and Maliview (on Saltspring Island) WWTPs employ secondary treatment; the Ganges Harbour WWTP on Saltspring Island employs tertiary treatment; and the two major facilities (Macaulay Point and Clover Point WWTPs) provide only preliminary treatment (fine screening prior to discharge). The CRD is currently in the process of planning upgrades to its wastewater treatment practices. To obtain more information and to view annual reports and compliance reports for each of the CRD WWTPs, refer to website http://www.crd.bc.ca/wastewater/marine/reports.htm.
- The CRD has implemented a source control programs to reduce the discharges of a range of contaminants to sewers. The CRD Regional Source Control Program (RSCP) is a pollution prevention program aimed at eliminating or reducing the amount of contaminants being discharged to sanitary sewers by businesses, institutions, and households. A combination of regulatory tools and education are used to achieve program goals. The main components of the RSCP include inspections, monitoring, enforcement, outreach, contaminants management, and planning and development. The CRD Sewer Use Bylaw is the main regulatory instrument for the RSCP. This bylaw limits the concentrations of specified contaminant levels in wastewaters entering the sewage system at the source. Under the bylaw, individual facilities and business sectors are regulated under permits, authorizations, or codes of practice. There are currently 11 codes of practice in place under this bylaw containing sector-specific pre-treatment requirements. These regulatory codes pertain to dental, food service, automotive repair, dry cleaning, photographic imaging, vehicle wash, carpet cleaning, fermentation, printing, laboratory and recreation facility operations. Facility inspections, including sector-specific outreach, are carried out on a regular basis. Enforcement is also an important component of the RSCP. The Regional Source Control Program Enforcement Policy can be viewed at http://www.crd.bc.ca/wastewater/sourcecontrol/monitor-enforce.htm. Permit compliance at each permitted facility is confirmed through regular self-monitoring and reporting. RSCP staff carries out audit monitoring two times per year at each permitted facility to check the self-monitoring data. Monitoring is also conducted annually by RSCP staff at a selected number of facilities in each sector

operating under codes of practice. The RSCP launched a new residential outreach campaign in February of 2007 to encourage householders to adopt simple contaminant reduction practices. For more information on the RSCP, refer to website http://www.crd.bc.ca/wastewater/sourcecontrol/index.htm.

5.2 Forest Products Industry

5.2.1 Pulp and Paper Mills

Federal and Provincial Government Programs:

- *Fisheries Act* 1992 *Pulp and Paper Effluent Regulations* (PPER) prescribed stricter discharge limits for certain deleterious substances in the final effluents of pulp and paper mills based on what secondary treatment could achieve. Restricted substances included total suspended solids (TSS), biochemical oxygen demand (BOD) and acutely lethal effluent (rainbow trout 96 hr LC_{50} <100%). Significant improvements resulted from imposed limits including a 94% reduction in BOD materials and a 70% reduction in TSS (kg/tonne). Acutely lethal effluents changed from 75% of the mills to generally 100% compliance (LC_{50} >100%) (Boyd 2009).
- PPER also required pulp and paper mills discharging to aquatic environments to conduct an environmental effects monitoring (EEM) program to assess if the stricter limits were adequate to protect fish, fish habitat, and the use of fisheries resources in all receiving environments. Mills conduct EEM in 3 year cycles to determine if the present mill effluent causes effects. EEM basic requirements include effluent sublethal toxicity testing, a fish survey, and a benthic invertebrate survey. Evaluation of fish tissue for dioxins and furans is required under certain conditions for mills with chlorinated bleach plants. Reporting of fish tainting complaints is also required. Environment Canada, BC MOE and other relevant parties (e.g., environmental groups or First Nations) review the EEM study designs and interpretive reports. The results of EEM monitoring conducted by BC mills are submitted to Environment Canada at the end of each cycle (Boyd 2009). For more information on EEM, refer http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=4B14FBC1-1.
- Two *Canadian Environmental Protection Act, 1999* (CEPA 1999) regulations were part of the 1992 federal regulatory package and reduced the release of dioxins and furans by 99%. These regulations include the *Pulp and Paper Mill Defoamer and Wood Chip Regulations*, which control the formation of dioxins/furans, and the *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations*, which control the release of dioxins/furans. These regulations were put in place because of elevated concentrations of dioxins and furans detected in the environment near BC pulp mills using the chlorine bleaching process in the late 1980s. The Department of Fisheries and Oceans (DFO) imposed fishery restrictions around several coastal mills using the chlorine bleaching process. The mills were required to monitor aquatic organisms for dioxins and furans based on sampling programs coordinated by Environment Canada, with input from DFO. Based on the results, DFO re-opened or maintained fishery restrictions with advice from Health Canada. Most mills achieved compliance with the regulation by substituting chlorine dioxide for chlorine bleaching. TEQ levels (measure of the toxic potential of the dioxins/furans) in crabs have declined by 95% since 1990. While some restrictions remain, pulp mills effluents are no longer major sources of dioxins and furans to the environment (Boyd 2009). For more information on reductions in dioxin and furan loadings to the BC environment from pulp and paper facilities, refer to the following Environment Canada website:
    - Environmental indicators: http://www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/dioxin_e.cfm

- A report prepared for BC MOE in 2008 summarized emission data for facilities using wood as fuel for heat and/or electrical power generation (including pulp mills). The report can be viewed at http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pdf/emissions_report_08.pdf.
- In the late 1980s, analysis of adsorbable organic halides (AOX) was introduced as a surrogate measure for chlorinated phenolics and other undefined chlorinated compounds in pulp and paper effluents. BC provincial permits for pulp and paper mills that use chlorine bleaching require AOX levels to be measured three times per week to estimate total loads of chlorinated organic compounds in pulp and paper effluents. AOX data has been used to demonstrate the decrease in chlorinated organics as pulp and paper mills reduced their use of chlorine. From 1991 to 2000, AOX releases from BC pulp mills were reduced by 83%.

Intergovernmental Partnership Programs:

- The major current source of dioxins and furans from pulp and paper mills is their release to the atmosphere from the combustion of salt laden wood. Hogged fuel, which includes bark and similar wood wastes, is a by-product of sawmills and is burned by pulp and paper plants to produce steam. At coastal mills, the wood absorbs salt, and consequently chlorine, from marine water during transport in log booms. Under certain conditions the burning of wood containing chlorine can result in the production of dioxins and furans. The majority of coastal mills burning salt-laden wood are located in BC and it has been estimated that this source releases 8.6 g TEQ/year to the atmosphere. Mill closures and voluntary industry initiatives have reduced releases by approximately 25% compared to 1990 releases. To address this issue, CCME developed Canada-wide Standards (CWS) for pulp and paper boilers burning salt-laden wood. These CWSs specified numeric targets and timeframes for reducing dioxin and furan emissions from boilers burning more than 10,000 oven-dried metric tonnes per year (t/yr) of salt-laden wood. The standard for existing pulp mill boiler emissions will be less than 500 pg/m^3 (based on TEQs) by 2006. The standard for new boilers constructed after May 1, 2001 is less than 100 pg/m^3 (based on TEQs). The CWSs are implemented by the province of BC, which has been working with stakeholder groups to address this issue since 2001.
  For more information refer to the following websites:
    - CCME CWSs: http://www.ccme.ca/ourwork/air.html?category_id=97
    - Pulp mill boiler emissions: http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pulp_paper_boilers.htm

Industry and Industry Association Programs:

- The Canadian pulp and paper industry made extensive process changes in the late 1980s and early 1990s to meet the stricter load limits imposed by the 1992 *Fisheries Act* and CEPA 1999 regulations. Most mills installed major pollution prevention technology, including secondary biological treatment. Chlorine bleaching plants substituted chlorine for elemental chlorine, among other changes. These measures significantly improved the quality of mill effluent releases (Boyd 2009).
- The Pulp and Paper Research Institute of Canada (Paprican) (now part of FP Innovations (http://www.fpinnovations.ca/) assisted with research and testing of stack

emissions for the implementation of the CCME developed CWSs for pulp and paper boilers burning salt-laden wood. For more information, refer to http://wcm.paprican.ca/wcmpaprican/publishing.nsf/AttachmentsByTitle/BO_Control_Emission_PDF_Eng/$FILE/0701-E-ControllingEmissionsCombustion.pdf.

- The Forest Products Association of Canada (FPAC), previously known as Canadian Pulp and Paper Association (CPPA), has been encouraging their members to consider possible alternatives to NP- and NPnEO-containing products since 1997. FPAC and Environment Canada conducted a national survey of pulp and paper mills to determine the use of nonylphenol (NP) and its ethoxylates (NPnEOs) in 2001. There was a 91% response rate to the survey and, of the 136 mills that responded, only 40 reported using these compounds in 2001. In addition, 32 of these 40 mills planned to replace the NP- and NPnEO-containing products with substitutes by 2003 (Environment Canada 2003). This report can be viewed at http://www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=64521013-1&offset=1&toc=show.

5.2.2 Wood Treatment Facilities

5.2.2.1 Antisapstain Facilities

Note: antisapstain chemicals are used by lumber mills for the short-term protection of recently produced lumber from fungus and mold during shipment to overseas markets.

Federal and Provincial Government Programs:

- Chlorophenate-based formulations for antisapstain control were de-registered in Canada under the federal *Pest Control Products Act* (PCPA) on December 31, 1990. These chemicals are no longer used for antisapstain purposes at BC mills.
- The PMRA conducted a re-evaluation under the PCPA of TCMTB, CU- 8 and Borax. An interim re-evaluation report was published in 2004 and determined that the registration of these antisapstain products should continue to be acceptable, with provisions. The PMRA report can be viewed at http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rrd2004-08/index-eng.php.For more information on PMRA re-evaluations refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/regist-homolog/_re-eval/index-eng.php.
- In 1983, the BC MOE published Chlorophenate Wood Protection: Recommendations for Design and Operation. In 1994, this “Code of Practice” for wood protection was updated by Environment Canada and BC MOE. This document provides guidance on the design and operation of chemical application facilities and on the prevention and control of chemical releases. In addition, the *Antisapstain Chemical Waste Control Regulation* under the BC *Environmental Management Act* was brought into force on September 1, 1990 and was revised in 2004. This regulation specifies effluent quality criteria as well as requirements for the design and operation of facilities utilizing antisapstain chemicals for the treatment of lumber in BC. Emissions of antisapstain chemical spray booth vents are also controlled under this regulation. The implementation of pollution control measures by wood protection facilities resulted in improvements to chemical handling and covered lumber storage. These measures, in combination with the compliance monitoring of the antisapstain industry by Environment Canada, have substantially reduced the release of antisapstain chemicals into the aquatic environment in BC (an estimated 99% reduction

in the volume of toxic surface runoff to the environment in BC). According to the Environment Canada Pacific and Yukon Region compliance report (99-14) on the Antisapstain Wood Preservation Industry in British Columbia, the compliance rate of antisapstain facilities with the recommendations increased from 33% in 1987 to 84% in 1998.

For more information refer to the following website:

- The BC MOE *Antisapstain Chemical Waste Control Regulation*: http://www.env.gov.bc.ca/epd/industrial/regs/antisapstain/index.htm

5.2.2.2 Heavy Duty Wood Preservation Facilities

Note: wood preservation chemicals are used for the long-term protection of wood from insects, fungus and marine borers

Federal Government Programs:

- Environmental codes of practice for the wood preservation industry were introduced in the 1980s. The implementation of these codes, in combination with an aggressive inspections and enforcement program under the federal FRAP initiative in the 1990s, resulted in significant decreases in the release of wood preservation chemicals (including creosote (PAHs), PCP (and associated contaminants such as dioxins/furans, HCB and CDPEs), copper, chromium and arsenic). According to the Pacific and Yukon Region compliance report (99-18) on the Heavy Duty Wood Preservation Industry in British Columbia, it was estimated that contaminated effluent discharge from these facilities was reduced by more than 90% due to the enforcement initiative targeted at this industry sector as a result of FRAP.
- A risk management strategy was developed for the wood preservation sector under the Strategic Options Process (SOP) of the earlier 1988 version of CEPA. The SOP involved the development of a risk management strategy in cooperation with various stakeholders from industry, government, and non-government organizations. The SOP report for the wood preservation sector was completed in 1999. Steering committees and working groups were formed to oversee the implementation of the report's recommendations concerning the release of CEPA-toxic substances from chemical manufacturing, treatment of wood, use of treated wood, and waste management of post-use treated wood. More information on the SOP initiatives for the wood preservation industry and for managing PAHs, hexavalent chromium compounds, and creosote-contaminated wastes can be found on Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1.
- In March 1999, Environment Canada published updated "Recommendations for the Design and Operation of Wood Preservation Facilities". Implementation of the codes is voluntary; however, as of March 31, 2000, all of the 68 wood preservation treating facilities operating in Canada signed onto the "voluntary program". Fifteen of these facilities were operating in BC. Each wood treatment facility signed a contract that commits them to meeting the objectives of the Technical Recommendations Document (TRD) over a five-year period. Audits

are conducted to confirm the implementation of the recommended requirements at each facility. A CEPA 1999 Pollution Prevention Notice will be issued for those facilities that have not implemented the recommended practices. On October 22, 2005 a CEPA 1999 notice was published which requires five wood preservation facilities, including one in BC, to develop and implement a pollution prevention plan. The TRD document was updated on April 2004 to include inorganic boron and new organometallic preservatives, namely ACQ and copper azole (CA-B), which were introduced following the voluntary withdrawal of CCA use for consumer products in 2003 (Liu 2006).
For more information on wood preservatives, refer to the Environment Canada website http://www.ec.gc.ca/pdb/websol/ToolBox/other/2002guidance/Wood2002/section1_e.cfm.

- The PMRA has conducted a re-evaluation under the federal PCPA of heavy duty wood preservatives including creosote, PCP, and CCA. For more information refer to the following websites:
  - PMRA re-evaluation process: http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/regist-homolog/_re-eval/index-eng.php
  - PMRA re-evaluation of the heavy duty wood preservatives: http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php

5.3 Metal Mines

(Hagen 2009;McCandless 2006;More 2009)

Federal Government Programs:

Canada has approximately 100 metal mines, most of which are in Ontario and Quebec. Environment Canada has no specific program focused on metal mines, but it has responsibility for Section 36(3) of the *Fisheries Act* and its related *Metal Mining Effluent Regulations.* Departmental inspectors visit the metal mines and ensure their compliance. Environment Canada maintains the web-based Regulatory Information Submission System (https://www.riss-sitdr.ec.gc.ca/riss/Global/Index.aspx) under which mines post their effluent flows and concentrations in accordance with those regulations. This information, which is compiled and published annually for all Canada's metal mines, is available to authorized persons only. Environment Canada does not taken an active regulatory role regarding coal, diamond, placer, industrial mineral and aggregate mines, but it does advise on potential environmental effects of new mines throughout Canada.

In BC, until 2005, Environment Canada played an active research and enforcement role in preventing pollution from abandoned mines. Some mines in the province's mountainous terrain have continuous drainage of acidic mine water, often contaminated with copper, zinc, aluminum and iron. Worst of these was the famous Britannia Mine, situated on Howe Sound, which released up to 1000 kilograms per day (kg/day) of dissolved copper and zinc into Howe Sound. In 2005, the province completed construction of a treatment plant for this drainage. More information can be obtained at http://www.agf.gov.bc.ca/clad/britannia/index.html.

Similar problems occurred at the long-closed Mt Washington copper mine on Vancouver Island, near Courtenay. In late 2003, construction of a passive treatment system lowered copper concentrations in site runoff to safe levels. This protected very important salmon habitat in the Tsolum River. More information can be found on the website http://www.tsolumriver.org/. Environment Canada Enforcement Branch actions continue at other abandoned mines in BC which have polluting drainage, including Anyox and Tulsequah Chief (which are both located outside of the Georgia Basin).

Provincial Government Programs:

High prices in 2004 and 2005 for mineral commodities like coal, copper and zinc greatly increased investment in this sector. As of January 2006, fourteen new mines were in the BC environmental assessment process and, at least, that many mine sites were undergoing advanced exploration and development. Despite the recent economic downturn, there are still numerous projects in the Environmental Assessment (EA) process. The province has no specific programs focused on the mining industry and environmental protection. Media releases from the Ministry of Energy and Mines state its intention to enhance the mine and mineral exploration approval processes, develop "user friendly" mining environmental and reclamation guidelines, and develop an integrated land use system for exploration and mining. The BC MOE has taken steps to reduce issuance of site-specific effluent and emission permits through applying codes of practice and regulations for specific sectors under the *Environmental Management Act*. While there are regulatory overlaps in regard to metal mines, the standards prescribed in provincial permits and regulations, approvals, and codes of practice usually meet or exceed requirements of the federal *Fisheries Act* and the *Canadian Environmental Assessment Act*.

The biggest concern relating to environmental contaminants associated with metal mining in BC has been the metal-contaminated acid rock drainage issues. However, requirements under the *Mines Act* will prevent and/or ensure polluter funding to remediate acid rock drainage pollution at BC mines in the future. For more information refer to the BC MOE website http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96298_01.

As previously discussed, the most recognized site of ARD is the Britannia Mine on Howe Sound (as described above). The authority for the regulation of these discharges lies with BC MOE under the authority of the EMA. The Crown Contaminated Sites Branch of BC MAL is now overseeing the remediation of the site. For more information refer to website http://www.agf.gov.bc.ca/clad/britannia/index.html

5.4 Non-Point Sources

Non-point sources (NPS) are major contributors of environmental contaminants to the south coastal BC environment. Despite the fact that these releases can be small when considered on an individual basis, the cumulative impact of the very large number of small sources within a watershed can result in the deterioration of groundwater, surface waters, drinking water as well as freshwater, estuarine and marine habitats. Non-point sources demonstrated to be significant sources of contaminants to the aquatic environment of the southern BC coast include CSOs, urban runoff and stormwater, agricultural runoff, boating activity, septic systems, spills, atmospheric deposition, and contaminated sites. These sources can contribute contaminants such as pesticides, fertilizers, metals, oils, pharmaceuticals, hormones, surfactants, nutrients and a wide range of other chemicals including plasticizers and fire-retardants, as well as biological contaminants. The relative contribution of the various non-point sources and the array of contaminants released to the environment from these sources, vary within the various watersheds and are highly influenced by land use. For example, in the highly urbanized Lower Mainland region, CSOs, stormwater and runoff associated with urban development are primary sources of oils, pharmaceuticals, surfactants and chemical contaminants such as PAHs and metals. However, the intensive agricultural activity in the Fraser Valley contributes pesticides, nutrients and veterinary drugs such as hormones and antibiotics to local streams and ditches.

5.4.1 General Non-Point Sources

Federal Government Programs:

- Environment Canada, in cooperation with interested partners, has undertaken GBAP-funded projects to address the following objectives:
    - assess, report, and track water quality status and trends of streams and rivers in the Georgia Basin. Seven new water quality sites were initiated under GBAP, in partnership with BCMOE, to look at impacts from a variety of anthropogenic activities (e.g., forestry, urbanization, 2010 Olympics). These are being reported on in the 2000 national CESI (Canadian Environmental Sustainability Indicators) report, and in two other regional (2009) reports. The data are also being reported on the Water Quality website at www.waterquality.ec.gc.ca.
    - assess and report on the status of streams and rivers in the Georgia Basin using benthic invertebrate community structure as an indicator and produce on-line biological assessment tools/indicator and training for the province, municipalities, environmental agencies, and stewardship groups that will be applied in identifying impaired waterways, and the associated human activities that are likely causing impairment to stream communities. This online training tool has been developed and training information is available on the CABIN website at http://cabin.cciw.ca.
    - promote environmental stewardship amongst the public, particularly in the Georgia Basin area, by informing them of environmental issues and human impacts through innovative and award winning tools like the “Interactive Non-Point Source Pollution Model” (which was developed under GBEI) by event and school appearances, and via the internet; and

- evaluate trends in water and sediment quality in the Sumas watershed in order to identify links between land use and aquatic habitat condition..

- Environment Canada completed a GBAP-funded study of the effects of non-point source pollution on small urban and agricultural streams in the Lower Fraser Valley. For more information, refer to website http://www.ecoinfo.ec.gc.ca/reports/reports_AqS_2_e.cfm.
- The results of this study have been published in a report which can be viewed at http://www.pyr.ec.gc.ca/georgiabasin/reports/nps_pollution/summary_e.htm.
- EC has prepared terrestrial and aquatic critical load estimates for the Georgia Basin. Mathematical modeling to estimate regional N and S deposition is complete and there have been efforts at empirical estimation of N and S deposition using passive samplers.

Provincial Government Programs:

- In 1999, BC MOE prepared an Action Plan for tackling non-point source water pollution in BC. This Action Plan identified needs related to education and training; pollution prevention at the site; land-use planning, coordination and local action; assessment and reporting; economic incentives; and legislation and regulation. The Action Plan did not include funding options or an implementation schedule. For more information refer to http://www.env.gov.bc.ca/wat/wq/bmps/npsaction_key.html.
- BC MOE has developed a website containing a compendium of best management practices (BMPs) from around the world aimed at reducing non-point source pollution. This compendium is useful to determine what BMPs are currently being used, their efficacy, and the need for the development of new BMPs to address non-point sources in BC. For more information, refer to the BC MOE website http://www.env.gov.bc.ca/wat/wq/nps/BMP_Compendium/nps_bmp.htm.

Other Programs:

- UBC Institute for Resources and Environment is developing an overview of nutrient loading and metal contamination in sediments of major tributaries to the Fraser River in the Lower Fraser Valley. In addition, a detailed assessment of NPS pollution impact by land use in the Salmon River Watershed in the Township of Langley will be conducted. This compliments other work being done through the Canadian Water Network.

5.4.2 Combined Sewer Overflows (CSOs)

Combined sewers were designed and installed many decades ago to carry both sanitary wastewater and stormwater in a single pipe. For this reason, they are considered to be sources of both point (sanitary sewers) and non-point (stormwater) pollution. Although the majority of the waste collected in combined sewers is transported to municipal wastewater treatment facilities, during heavy rainfall conditions the volume of wastewater can become too great for the system to handle. In these events, the mixture of sanitary and stormwater in these systems overflows to nearby waterways. These are referred to as combined sewer overflows. While this is acknowledged as an outdated and undesirable way of dealing with wastewater, they are extremely expensive to replace. It is estimated that combined sewers make up approximately 60% of the Vancouver sewer system, most of the New Westminster sewer system, and a much smaller part of the northwest Burnaby sewer system. Since CSO discharges to the environment are untreated, they are significant sources of a variety of chemical contaminants such as metals, nutrients, PAHs, personal care products and pharmacological agents, and a variety of other organic contaminants, as well as bacteria and other pathogens. While the magnitude of CSO contributions to the overall loadings of chemical contaminants to the south coastal BC environment, Metro Vancouver calculated loadings for some chemical contaminants from CSOs in different land use areas (residential, light industrial, and heavy industrial) (Lee 1998), and a recent report prepared for Environment Canada also estimated the loadings of select contaminants to the Georgia Basin (ENKON Environmental Ltd. 2002). The report provided loadings estimates for several metals, ammonia, naphthalene, benzo(a)pyrene, chrysene, chloroform, toluene and dioxins/furans. A 1993 FRAP study reported that 53 CSOs located in Burnaby, New Westminster, and Vancouver discharged to English Bay, Vancouver Harbour, False Creek, the Brunette River and the North Arm of the Fraser River (UMA Engineering Ltd. 1993). Projects are currently underway to reduce the discharge of untreated combined sewer overflow from Metro Vancouver and City of Vancouver CSOs.

Metro Vancouver (was GVRD) Programs:

- Metro Vancouver and member municipalities have developed a LWMP in accordance with the B.C *Environmental Management Act* (EMA). Member municipalities and electoral areas within Metro Vancouver include: the Cities of Burnaby, Coquitlam, Langley, New Westminster, North Vancouver, Port Coquitlam, Port Moody, Richmond, Surrey, Vancouver, and White Rock; the Corporation of Delta; the Districts of Langley, Maple Ridge, North Vancouver, Pitt Meadows and West Vancouver; the Villages of Anmore, Belcarra, and Lions Bay; Bowen Island Municipality; and a portion of Electoral Area A. However, since the three villages, Bowen Island Municipality, and Electoral Area A are not members of the Metro Vancouver Sewerage and Drainage District, only the policies associated with non-point source pollution issues apply in these areas. Provisions relating to CSOs under the LWMP include:
    - the formation of an Environmental Monitoring Committee comprising representatives from federal, provincial and municipal governments, research institutions and the public. The role of the committee is to review monitoring proposals, results, and risk assessments of waste discharges and to provide recommendations for consideration by Metro Vancouver and member municipalities; and
    - a commitment by Metro Vancouver to eliminate CSOs in the Vancouver Sewerage Area by the year 2052 and the Fraser Sewerage Area by 2077. According to the Metro Vancouver LWMP, priority will be given to reducing or eliminating CSOs which have been identified by the Environmental Monitoring Committee as having significant environmental impact. For example, Metro Vancouver and the municipalities of Vancouver and Burnaby will review the schedules for sewer separation and system upgrades necessary to fast-track the elimination of the Clark Drive CSO in Burrard Inlet.
- CSOs are located in the City of Vancouver, City of Burnaby, and City of New Westminster. In accordance with the LWMP, Metro Vancouver, BC MOE, City of Vancouver, City of Burnaby, and City of New Westminster are working on programs to eliminate CSOs by 2050. This is being accomplished by the separation of stormwater and sanitary sewers or by temporarily storing the overflow and redirecting the discharge to a WWTP once the capacity within the sewer system becomes available. The separation of sewers in the downtown Vancouver Granville and Yaletown areas are complete and work will continue in the False Creek area, the West side of the City, Downtown Eastside/Strathcona, Still Creek, and the Fraser River. The separation of the Clark Drive

CSO, in particular, will result in a significant decrease in the volume of discharge. Metro Vancouver monitors the quality of effluent at all Metro Vancouver-owned outfalls and also conducts environmental studies (Brekke 2006;City of Vancouver 2008;Metro Vancouver 2008).

- Since 1994, Metro Vancouver has reduced CSOs discharges to Burrard Inlet by 35% and it is expected that initiatives currently underway will result in a further 10% decrease over the next decade. Operational improvements to the New Westminster waterfront CSOs together with a CSO storage project are underway and are expected to be completed by 2007. It has been predicted that these changes will result in a 30% decrease in annual CSO volume discharged to the Fraser River (Lewis 2002).
- According to a recent report prepared for BIEAP (Brekke 2006), the 25 overflow outfalls which discharge into Burrard Inlet release approximately 36 billion litres of mixed wastewater and stormwater annually (based on Metro Vancouver data from 2000), with the Clark Drive CSO contributing over 40% of the total annual discharge (Hall et al. 1998). Metro Vancouver has reduced the volume of discharge to Burrard Inlet from CSOs, including discharges from the Clark Drive CSO, in which high levels of several metals and PAHs have been detected, by increasing storage capacity in the sewer systems and by directing more of the combined sewage flow to the Iona Island WWTP. For more information on CSO reduction plans within Metro Vancouver refer to websites http://public.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-CombinedSewers.pdf and http://vancouver.ca/engsvcs/watersewers/sewers/enviro/seperation.htm.

Capital Regional District (CRD) Programs:

- A summary prepared by CRD in 2004 indicated that there were 21 CSOs within the CRD. The CRD LWMP identifies the location and discharge of each of these 21 CSOs and also gives a sensitivity rating for each of the receiving areas and presents an Action Plan for each CSO. The CRD and its municipal partners identified a goal of eliminating CSO discharges to areas of environmental or public health sensitivity and reducing or eliminating overflows at areas of lower sensitivity (Capital Regional District (CRD) 2009a). However, according to a recent Scientific and Technical Review of the CRD LWMP (Stubblefield *et al.* 2006), sampling of these sources has been very limited and no treatment has been implemented. The review committee recommended that the CRD and member municipalities proceed with plans to replace trunk sewers and reduce CSOs on a prioritized basis.

5.4.3 Urban Runoff and Stormwater

Urban runoff originates from rainfall and snowmelt which runs off streets, parking lots, driveways, and roof tops. This runoff is collected in storm drains and enters storm sewers where it is transported and released to nearby streams, rivers, lakes, or the ocean. Stormwater management and the operation and maintenance of storm sewer systems to collect and transport stormwater are typically the responsibilities of municipal governments. A wide variety of contaminants enter runoff and stormwater in urban areas. These include wood treatment chemicals; copper from water pipes and brake linings; hydrocarbons, gasoline, oil, and PAHs from tire wear, vehicle exhaust and parking lot and driveway sealants; antifreeze; detergents and other cleaners from vehicle washing; and suspended solids. As well, a variety of unknown contaminants enter storm drains as a result of intentional releases to storm drains and inadvertent spills. Stormwater in urban areas also contributes significant amounts of pesticides to the aquatic environment. For many current-use pesticides, the largest usage is in urban areas and some studies have shown that pesticide concentrations can be higher in urban streams than in agricultural streams.

The concentrations of contaminants in stormwater discharges and their loading to the environment increase with both the vehicular traffic and the proportion of impervious surface areas (such as roadways, rooftops, driveways, and parking lots) in the municipality. Impervious areas prevent the natural penetration of rainwater into soil and result in the channelling of large volumes of surface runoff to storm sewers. For this reason, the increase in impervious areas that will accompany the predicted population growth for the south coastal area of BC will likely result in higher loadings of contaminants, particularly metals and PAHs, to the south coastal aquatic environment from stormwater discharges. These could result in increased areas of environmental and water quality degradation. The large development projects, which continue to be built as a result of the growing population within the Georgia Basin region, heighten the need for land use plans developed by municipalities to give careful consideration to the potential environmental impacts of contaminated stormwater and increases the importance of implementing innovative measures to minimize impervious surface area and manage stormwater in both new and existing areas of development.

A report prepared for Environment Canada concluded that stormwater is currently one of the most significant sources of contaminants to the Georgia Basin. This report concluded that, while adequate information was available to estimate loadings of several chemicals of interest, particularly metals, information on individual PAHs, pesticides, and dioxin/furans was too limited for loadings to be estimated (ENKON Environmental Ltd. 2002).

Federal Government, Provincial Government, and Intergovernmental Programs:

- FRAP programs put a strong emphasis on public education initiatives to encourage public awareness and involvement on urban runoff issues and included the preparation of publications, brochures, workshops promoting specific guidelines. The Non-Point Source Pollution Awareness Campaign was a joint project of Environment Canada, Fisheries and Oceans Canada, the Fraser Basin Management Program, and Metro Vancouver. This project focused on three primarily residential sources of non-point pollution including landscaping and lawn care, automobile washing and maintenance, and household maintenance and cleaning products. The NPS Pollution Awareness Campaign was undertaken by public education program (posters, fact sheets, stickers, newspaper, and TV ads). The Fraser River Interactive Pollution Urban Runoff model (3-D table top model) was designed for public and educational events. This hands-on model demonstrates what NPS is, where it comes from, and what actions people can take to reduce this pollution. For more information on the Fraser River Interactive Pollution Urban Runoff model refer to website http://www.pyr.ec.gc.ca/EN/_pdf/NPSP_English.pdf. Guidelines for the monitoring and protection of stormwater quality were also developed under FRAP.
- An important objective identified in BIEAP programs was the reduction of contaminant loading to the Burrard Inlet from urban runoff. Reductions have been achieved through public education and awareness programs implemented by the federal, provincial, and municipal government agencies; BMP development; and Metro Vancouver and City of Vancouver programs to encourage the use of energy-efficient options for transportation. However, the total loading reductions achieved as a result of these initiatives have not been determined.

- The Victoria and Esquimalt Harbours Environmental Action Program (VEHEAP) is an intergovernmental initiative which was established through a Memorandum of Understanding between various federal government agencies, the BC Ministry of Environment, and the Capital Regional District. This MOU establishes a management framework to coordinate activities to protect and improve the environmental health of Victoria and Esquimalt harbours. The Harbours Ecological Inventory and Rating (HEIR) project was initiated by VEHEAP to assist in the environmental management of harbours and adjacent lands. For more information on VEHEAP and the HEIR project, refer to http://www.crd.bc.ca/partnerships/veheap/index.htm.
- The Water Balance Model for BC is a web-based modeling tool which allows users to compare various scenarios for stormwater management. It was developed by a BC-based intergovernmental partnership including various local, regional, provincial, and federal agencies and is now being expanded to allow it to be used nationally (http://www.waterbucket.ca).
- Environment Canada, in cooperation with other partners, undertook the following GBAP-funded projects to address stormwater issues:
    - support the development and implementation of watershed-based Integrated Stormwater Management Plans (ISMPs). (These plans enable municipalities to set targets for maintaining or improving aquatic habitat values in specific priority watersheds. They identify engineering, planning, and environmental considerations required to meet these targets over time.);
    - assess the effectiveness of stormwater source controls, such as green roofs and rain gardens in the Silver Ridge Subdivision, to better understand how they can be used to prevent urban non-point source pollution;
    - promote understanding of urban non-point source pollution through an interactive web-based watershed outreach tool, “Interactive Non-Point Source Pollution Model”, which outlines potential sources and actions that can be taken to prevent non-point source pollution;
    - demonstrate how stormwater management and aquatic habitat protection targets can be met by planning, building, monitoring, and evaluating low impact development projects. (This will build confidence in low impact development strategies and to reduce risk over time.);
    - develop and promote the Water Balance Model, a web-based scenario modeling tool for stormwater management based on the water balance modeling approach;
    - monitor the effectiveness of a municipally-owned stormwater treatment system at removing total suspended solids and other contaminants;
    - develop Codes of Practice for Stormwater Quality in the Capital Regional District; and
    - encourage and, as possible, implement watershed-based approaches to reduce loadings of toxic substances to the Georgia Basin aquatic environment.
- A used oil recovery program was introduced by the province in an effort to reduce the release of used oils into storm sewers. In 1998 it was estimated that 56% of the approximately 50 million litres of waste lubricating oil from domestic and industrial users

in BC was recycled. For information on this and other provincial government recycling programs refer the BC MOE website http://www.env.gov.bc.ca/epd/recycling/.

- BC MOE led the development of a stormwater planning guidebook as a tool for local governments to use in planning early actions to prevent adverse effects resulting from the release of stormwater. For more information refer to the BC MOE website http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html.

Metro Vancouver Programs:

- The LWMP developed by Metro Vancouver and member municipalities in accordance with the British Columbia *Environmental Management Act* (EMA) (refer to Metro Vancouver activities under Section 5.4.1 Combined Sewer Overflows) contains the following provisions under the LWMP relate to urban runoff and stormwater:
    - the Metro Vancouver LWMP states that the District will not authorize any new stormwater connections to the sanitary sewer system and will continue their policy of eliminating stormwater contributions authorized under existing industrial permits. Industrial facilities will be required to develop and implement plans for eliminating stormwater contributions from their sanitary sewer discharge.
    - through the LWMP, member municipalities of Metro Vancouver have committed to completing ISMPs on 123 watersheds within Metro Vancouver over a twelve year period. These ISMPs will identify stormwater runoff BMPs that are appropriate for each watershed. Metro Vancouver is also developing a long-term stormwater monitoring program to assess the effects of stormwater runoff on small streams. This program includes the development of a Benthic Index of Biotic Integrity (B-IBI) monitoring, analysis, and assessment protocol. As part of the LWMP, watershed-based planning studies have been implemented. In one such program, the Brunette Basin Watershed Management Plan, the municipalities within the Brunette River Basin implemented a pilot watershed planning program. Stormwater BMPs are used to reduce runoff resulting from development. Stormwater management involves coordination and partnerships between all levels of government, businesses and communities.

  For more information on policies relating to stormwater in the LWMP refer to website http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-Stormwater.pdf.
- Metro Vancouver has prepared a number of technical reports on stormwater and drainage management for use by member municipalities.
- Although stormwater management is typically the responsibility of the member municipalities, Metro Vancouver provides stormwater management planning and operations services for two key watershed drainage areas including the Still Creek/Brunette River Drainage Areas (the Brunette Basin) and the Port Moody/Coquitlam Drainage Area.
- Efforts by municipalities to improve stormwater management and to protect the environment include street sweeping to remove debris and contaminants, storm drain cleaning, maintenance of creeks and watercourses and the enhancement of streams and habitat for aquatic life, monitoring stormwater quantity and quality, and the implementation of public education programs. For example, the yellow fish painted on

storm drains serve to remind the public that dumping materials into storm drains can be harmful to the environment.
For more information on Metro Vancouver initiatives to address stormwater discharges and to view available reports, refer to the Metro Vancouver website http://www.metrovancouver.org/services/wastewater/sources/Pages/StormwaterManagement.aspx.

Capital Regional District (CRD) Programs:

- The CRD and its municipal partners have developed a LWMP which includes stormwater management as an integral part. The member municipalities of the CRD include Colwood, Esquimalt, Langford, Oak Bay, Saanich, Victoria and View Royal. A separate LWMP was completed for the Saanich Peninsula communities of Central Saanich, North Saanich and Sidney.
- Since the management and regulation of stormwater discharges is a municipal government responsibility, the CRD Stormwater, Harbours and Watersheds program (SHWP) works with the municipalities to protect watercourses, and nearshore marine environments from stormwater contamination. The CRD forms partnerships with municipalities to manage stormwater quality. This includes the development of regulatory compliance tools such as bylaws, codes of practice, and best management practices. The SHWP and the member municipalities work together to develop these tools and models which are then provided to all member municipalities for adoption. The Model Storm Sewer and Watercourse Protection Bylaw provides member municipalities with the regulatory power to prohibit the release of specific wastes to stormsewers and watercourses. In addition, the model bylaw has provision for the development of Codes of Practice for business sectors. Municipalities within the CRD were invited by the CRD Board to adopt this bylaw. The enhanced bylaw is designed to allow the incorporation of regulatory stormwater codes of practice to prevent the pollution of stormwater. A number of codes of practice have been developed including Automotive and Parking Lot Operations, Streets and Roads, Construction and Development Activities, Recreation Facilities, Outdoor Storage Yard Operations, and Recycling Operations. In addition, Best Management Practices (BMPs) have been developed for both painting and powerwashing operations.
- CRD conducts annual stormwater quality monitoring and the results are published in annual reports (http://www.crd.bc.ca/watersheds/monitoring.htm). In addition, CRD measures chemical contaminants in sediments at select stormwater discharges under their Stormwater Quality Survey. When the concentrations of contaminants are too high, the CRD works with municipalities to identify and address the source of the contamination. A comparison of concentrations at these locations over a long period of time will permit the identification of trends in stormwater discharges. For more information on CRD stormwater programs refer to website http://www.crd.bc.ca/watersheds/index.htm. To view Annual Stormwater Reports, existing Codes of Practice and BMPs, Stormwater, Harbours and Watershed news, Watershed Plans and Assessments, and Liquid Waste Management Plans refer to website http://www.crd.bc.ca/watersheds/publications/listing.htm#plans.

Partnerships with Community Groups:

- Public involvement in addressing NPS pollution is essential and some community groups have initiated projects to reduce NPS pollution in affected watersheds. One such project was initiated at Cecelia Creek, which was considered to be one of the most contaminated creeks in Greater Victoria due to urban runoff. Unacceptably high concentrations of a variety of metals (and PAHs) were detected in the sediments. A partnership approach between the CRD, federal, provincial, and municipal agencies, and community groups focused on education and awareness. BMPs were compiled and local businesses were approached regarding their compliance with the BMPs. Of particular focus was the automotive industry which represents 58% of the business sector located within this catchment and contributed a large portion of the heavy metal contamination to the watershed. For more information refer to the CRD website http://www.crd.bc.ca/cecelia/.

- The Byrne Creek Watershed Business Inspection and Education Program is another watershed-based program addressing stormwater quality. Environment Canada and the City of Burnaby jointly launched this program to address the improper discharge of chemicals into storm sewers leading to Byrne Creek. The purpose of this program is to conduct inspections of commercial and industrial businesses within the Byrne Creek Watershed, develop business-specific BMP guides, conduct limited water quality sampling, and increase community awareness of potential impacts to the watershed.For more information refer to http://www.byrnecreek.org/.
- As an extension of a Georgia Basin Ecosystem initiative (the Shared Waters Roundtable), between 2004 and 2008, Environment Canada participated with the Shared Waters Alliance in efforts to reduce the contamination of Boundary Bay and key tributaries, such as the Little Campbell River. Shellfish harvesting in Boundary Bay shellfish harvest was once very important to First Nations and to the local economy. The Shared Waters Alliance is a Canada-US working group focused on improving water quality for Canadian-American shared waters. The group is focussed on non-point source pollution issues in the watershed, including urban and agricultural runoff and pollution source control initiatives. Members of the Shared Waters Alliance included representatives from federal (United States and Canada), provincial, state, and municipal agencies, First Nations, academia, and local community groups. In 2009, the Shared Waters Alliance began to focus on ambient water quality monitoring in Boundary Bay, in a coordinated effort led by Metro Vancouver. For more information, refer to the Shared Waters Alliance website http://www.sharedwaters.net/.
- Other partnerships between regional districts, government agencies, and community groups formed for the purpose of addressing NPS concerns. These included:
    - Esquimalt Lagoon Stewardship Initiative (http://www.elsi.ca/)
    - Bowker Creek Urban Watershed Renewal Initiative (http://www.crd.bc.ca/watersheds/protection/bowker/)
    - Gorge Waterway Initiative (http://crd.bc.ca/watersheds/protection/gorgewaterway/)

5.4.4 Agricultural runoff

Agricultural runoff has been identified as a leading source of water quality impact in rivers, lakes, estuaries, wetlands, and groundwater. The contamination of runoff in agricultural areas occurs as a result of the application of pesticides and fertilizers (natural and chemical), the production of excess amounts of manure in areas of high livestock density, and the administration of medications and growth-enhancing chemicals to livestock.

Inorganic fertilizers and manure, which are applied to agricultural lands to enhance crop production, are sometimes applied in amounts greater than those which can be taken up by the crops. This results in the release of excess concentrations of nutrients, such as nitrogen-based nutrients and phosphorus, to aquatic ecosystems and can result in the degradation of environmental quality. Similarly, in feed lots, and other areas where livestock are held in confined areas, the large amount of animal waste produced can result in the degradation of water quality as a result of the release of nutrients, oxygen-demanding substances and pathogens, and veterinary drugs. Impacts on water quality as a result of agricultural runoff have been documented in the Georgia Basin and in other areas of BC. Several studies in the Lower Fraser Valley, particularly in the Abbotsford-Sumas, Hopington and Brookswood areas, have identified aquifer contamination as a result of nutrient releases from manure and other fertilizers. In addition, fecal contamination from agricultural runoff has resulted in shellfish harvesting closures in Saanich Inlet and other enclosed or poorly flushed coastal areas.

A wide variety of pesticides are used by the agriculture sector for the control of pests and weeds. The improper application, spillage and improper storage, leaching from soils and runoff, and atmospheric transport and deposition of pesticides results in their entry to the aquatic environment and can adversely impact aquatic species. Surveys of pesticide use in BC in 1991, 1995 and 1999, and 2003 have provided valuable information on the amounts and types of pesticides used in BC and the trends in this usage but, in general, little information is available on the specific types and volumes of chemicals applied in various areas of the province. Several current-use and historical-use pesticides have been detected in ground, surface, and runoff waters in agricultural areas of BC. Information on the loadings of pesticides and veterinary drugs to the Georgia Basin as a result of agricultural runoff is lacking.

Federal Government, Provincial Government, and Intergovernmental Programs:

- The education of farmers and the public was recognized as an important component in efforts to reduce agricultural pollution under FRAP. A number of FRAP-supported studies addressed the management of agricultural waste and environmental issues associated with agricultural runoff. Environmental commodity guidelines were produced for some sectors to better communicate information on addressing environmental concerns to producers. The BC Horticultural Coalition used these guidelines for developing self-auditing protocols. In addition, a Watershed Stewardship Guide for Agriculture was developed by various FRAP partners as an educational product for farmers and agricultural organizations. In addition, FRAP supported the Sustainable Poultry Farming Group's Groundwater Protection Program (GPP). The GPP is a producer driven initiative that allows for excess manure to be transported away from the Abbotsford Aquifer so as to reduce the risk of manure over-application to the land.
- The development and subsequent implementation of agricultural BMPs or guidelines for procedures such as manure application/handling and agricultural runoff control strategies have been developed in this region and can be effective in reducing nutrient and pesticide releases to surface waters. The GBEI and GBAP partially funded some aspects of the work by the raspberry producers to minimize soil and water pollution with manure and by the Pacific Field Corn Association to develop Advanced Guides for Forage and for Silage Corn production. For more information on environmental initiatives and guidelines for agricultural producers refer to website http://www.farmwest.com/.
- FRAP and GBEI have contributed funds to help model and evaluate Agricultural Census results to better understand manure and nutrient loadings to land in the Lower Fraser Valley (Derksen 2006).

- Environment Canada, in cooperation with interested partners, undertook GBEI and GBAP-funded projects addressing the release of pesticides and/or nutrients to the Georgia Basin environment as a result of agricultural practices.
- The Agricultural Policy Framework is a five-year federal-provincial-territorial agreement on agriculture which was established in 2003 and is based on a 2001 agreement between the federal, provincial, and territorial Ministers of Agriculture. The Environment Chapter of the Agricultural Policy Framework (APF) identified soil, water, air, and biodiversity as the major areas of focus for producers. Agri-environmental programming encourages producers to voluntarily assess their current production activities and to utilize management practices that enhance their environmental stewardship. In BC, the program has been administered by the BC Agricultural Council (Derksen 2006). The three levels of government are now working toward delivering new programs for Canadian farmers through the Growing Forward Initiative. However, during the transition period to the new Growing Forward Initiative, existing APF programs will continue for a period of up to one year (ending April 2009). For more information on the transition of the APF to the Growing Forward programs refer to websites http://www.agr.gc.ca/cb/apf/index_e.php and http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1200339470715&lang=e.
- The Canada–British Columbia Environmental Farm Plan Program was launched in 2003 and is a partnership between Agriculture and Agri-Food Canada, the BC Ministry of Agriculture and Lands and the BC Agriculture Council. This program is being delivered by the BC Agriculture Council. For more information refer to http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/index.htm.
- In 2003, the BC Ministry of Agriculture and Lands developed, as part of their contribution to the APF, the Canada-British Columbia Environmental Farm Plan Program Reference Guide. The Reference Guide and its companion Planning Workbook were intended to assist agricultural planners and producers in the development of environmental action plans for their farms. Funding for identified risks is provided through the National Farm Stewardship and Greencover Programs. These reports are part of a series of publications prepared to support the implementation of the Canada-BC Environmental Farm Plan Program (Derksen 2006). For more information on the BC Environmental Farm Plan Program, refer to http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/index.htm.
- The Farm Practices in BC Reference Guide developed by the BC Ministry of Agriculture and Lands contains a variety of fact sheets containing environmental guidelines for various agricultural producer groups including: beef producers, berry producers, dairy producers, field vegetable producers, tree fruit and grape producers, greenhouse growers, horse owners, mushroom producers, and the nursery and turf industry. For more information refer to the BC Ministry of Agriculture and Lands website http://www.agf.gov.bc.ca/resmgmt/fppa/refguide/intro.htm.
- In 1992, BC MOE introduced the *Agricultural Waste Control Regulation* and the Code of Agricultural Practice for Waste Management under the *Environmental Management Act* (EMA). These address activities associated with the use and storage of manure and other agricultural wastes. This was an important step forward in addressing agricultural pollution in BC; however, the success of these initiatives in reducing nutrient releases to the south coastal BC environment has not been assessed. For more information on the *Agricultural Waste Control Regulation* and the Code of Agricultural Practice for Waste Management refer to website http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/131_92.htm.

- The BC provincial LWMP states that municipalities must take agricultural runoff into consideration during integrated stormwater management planning. For more information refer to http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-NonPointSource.pdf.

Regional Government Programs:

- Metro Vancouver's LWMP states that "municipalities will consider stormwater runoff from agricultural lands when undertaking integrated stormwater management planning for their municipality". In addition, the District will compile past findings of scientific studies to determine base-line data for water quality in agricultural watersheds, and will include waterways in agricultural areas in its water quality monitoring and environmental assessment program. For information on the LWMP refer to the Metro Vancouver website http://www.metrovancouver.org/about/publications/Publications/LiquidWasteManagementPlan2001.pdf.

5.4.5 Atmospheric deposition

Atmospheric deposition has been identified as an important NPS for both metals and many organic contaminants in the Georgia Basin; however, currently available information is limited to deposition estimates for select contaminants and specific areas such as the Brunette River and Abbotsford. Atmospheric releases from various local industrial activities, waste incinerators, fossil fuel combustion, domestic burning, slash burning, motor vehicles, railways, marine vessels, the application of pesticides and fertilizers in agricultural areas, and forest fires release contaminants including nitrogen and sulphur compounds, metals, PAHs, dioxins and furans and a variety of other organic chemicals.

Atmospheric deposition is thought to be the major source of PAHs to the Georgia Basin. Sources include residential heating (especially the use of wood for fuel); transportation; municipal incinerators; agricultural, forest slash, and other open air-burning; beehive burners at sawmills; and forest fires. In addition, numerous current-use pesticides and nutrients have been detected in air and precipitation samples and deposition measurements have been reported for some agricultural areas of BC. Similarly, deposition measurements for various metals have been estimated for some areas within the Georgia Basin, particularly for the Brunette watershed. Although atmospheric releases of dioxins and furans from pulp mills in BC have been significantly reduced in recent years, the burning of salt-laden hogged fuel and wood waste to produce steam for energy is the major source of pulp mill-related releases of dioxin and furan release to the BC environment.

Long-range atmospheric transport and deposition is likely a significant source of both conventional and new POPs to the Georgia Basin environment; however, information on loadings from this source is limited. Several studies have attributed the presence of conventional and emerging POPs in high-altitude regions, in the Chilliwack River watershed, and in certain other regions of the Georgia Basin, at least in part, to long-range atmospheric transport and deposition. The sources and fate of POPs in the Georgia Basin are now being studied through the use of modeling and mass balance calculations based on PCBs and PBDEs (Shaw 2009). However, deposition measurements for atmospherically transported contaminants at several locations is required to determine loadings directly to the Georgia Basin, to large lakes and reservoirs, to land surfaces at various elevations.

Environmental management decisions to control local sources depend on knowledge of the relative importance of local versus global sources. The better understanding of local versus global inputs of contaminants to the Georgia Basin has been identified as a priority research need.

Federal Government, Provincial Government, and Intergovernmental Programs:

- The Inventory of Sources and Emissions of Toxic Air Contaminants in BC (1995), prepared under FRAP, catalogued emissions for 1990 in all of BC and included emissions from point, area, and mobile sources. Prior to FRAP, only common air pollutants were inventoried, while toxic air pollutants were not. The results of an updated inventory for 2000 are available on website ftp://ftp.env.gov.bc.ca/pub/outgoing/Air_Resources_Branch/Emission%20Inventory/2000_Inventory_Report.pdf. Other emission inventories can be viewed at http://datafind.gov.bc.ca/query.html?qp=url%3Awww.env.gov.bc.ca&mi=&qt=emission+inventory.
- Information on provincial programs, regulations, guidelines, codes of practice, and monitoring relating to industrial emissions in BC can be viewed at http://www.env.gov.bc.ca/air/industrial/index.html.
- The federal National Pollutant Release Inventory (NPRI) is a legislated, nationwide, publicly-accessible inventory which provides information on annual releases of specific key pollutants to air, water, land and disposal or recycling from all sectors (including industrial, government, commercial, etc.) in Canada. However, only facilities which meet the reporting requirements of this program are required to report releases. Mobile sources of pollutants (such as vehicles), facilities which release pollutants on a smaller scale, and some sector activities (including agriculture) are not included in the NPRI. This program collects information on releases of dioxins/furans, PCBs, metals, PAHs, nonylphenol and its ethoxylates, and many other substances. For more information about the NPRI program refer to the Environment Canada website http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm/. Additional information on Environment Canada national emissions inventories can be viewed at http://www.ec.gc.ca/pdb/cac/cac_home_e.cfm.
- Environment Canada, in cooperation with interested partners, undertook a GBAP-funded project to assess sources and fate of PCBs and PBDEs in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin through a combination of mass balance and exchange process modeling as well as focused sampling to address critical data gaps identified in the modeling.

Regional Government Programs:

- Metro Vancouver led a collaborative project with other levels of government, including Environment Canada, to assess the toxicity of existing atmospheric pollutants in the Lower Fraser Valley ("Air Toxics Emission Inventory and Health Risk Assessment – Summary Report", 2007), which is available at http://www.metrovancouver.org/about/publications/Publications/Air_Toxics_Emission.pdf. The report found that diesel particulate matter (diesel PM) is a key driver of human health risk. Sources of diesel PM include on-road diesel vehicles, marine vessels, and non-road engines. Of the significant risk drivers, three substances (benzene, formaldehyde, and 1,3-butadiene) are predominantly from "mobile" sources, with lesser contributions from “point” and “area” sources. Hexavalent chromium and carbon tetrachloride are more heavily influenced by point and area sources.

- Metro Vancouver conducts regular air quality monitoring at specific locations in the Lower Fraser Valley to compare concentrations of key air contaminants to air quality objectives. Information on Metro Vancouver air quality monitoring programs and air quality reports are available at http://www.metrovancouver.org/services/air/monitoring/Pages/default.aspx.
- Metro Vancouver works with the Fraser Valley Regional District to conduct emission inventories for the Lower Fraser Valley. Detailed inventories are conducted every five years and identify and track common air contaminants and their sources and greenhouse gas releases. For more information refer to http://www.metrovancouver.org/services/air/emissions/Pages/default.aspx.
- A 2004 report commissioned by the Fraser Valley Regional District (FVRD), in cooperation with Environment Canada, inventories agricultural emissions in the Lower Fraser Valley and summarizes best management practices (BMPs) to reduce these emissions. To view this report and for more information on air quality in the FVRD, refer to http://www.fvrd.bc.ca/Services/AirQuality/Pages/default.aspx

5.4.6 Contaminated Sites

Contaminated sites are areas of land where soils, groundwater, sediments or vapours arising from those environmental media contain hazardous wastes or toxic substances at concentrations exceeding provincial standards or federal environmental quality standards or at concentrations which are above background. In addition, federal sites would also be considered contaminated where concentrations are above background and are likely to pose a hazard to human or environmental health. These concentrations render the site unsuitable for specific uses. At certain sites, the concentrations of some substances are high enough to be of concern to human and/or environmental health. The most commonly detected substances at contaminated sites in BC are petroleum hydrocarbons and heavy metals, such as lead, arsenic, cadmium, and mercury. However, chlorophenols and PAHs are commonly detected at old wood treatment facilities and PCBs are commonly detected at sites where electrical equipment, such as transformers and capacitors, were used.

Federal Government Programs:

- The federal government is responsible for the management of contaminated sites on federal lands. In 1995, the Contaminated Sites Management Working Group (CSMWG) was established to ensure an efficient and consistent approach to the management of federal contaminated sites. The CSMWG comprises representatives from 15 federal departments and is co-chaired by Environment Canada and the Department of National Defence. In 2003, the Government of Canada announced its two-year Federal Contaminated Sites Accelerated Action Plan (FCSAAP). In 2003, $175 million were committed for FCSAAP. In 2004, the government announced an additional contribution of $3.5 billion for this program. In 2005, the additional funding was committed and the initial Plan was extended to a 15 year program and was renamed the Federal Contaminated Sites Action Plan (FCSAP). FCSAP provides funding, on a cost-sharing basis, to federal custodial departments for reducing human and environmental health risks associated with federal contaminated sites (FCSAP Guidance Manual 2008). Federal legislation pertinent to the management of contaminated sites includes CEPA 1999, the

Fisheries Act, and the *Canadian Environmental Assessment Act* (CEAA). For more information on the federal contaminated sites program refer to the Environment Canada website http://www.federalcontaminatedsites.gc.ca/index-eng.aspx.

- Federal departments and agencies are required to maintain a database of contaminated sites for which they are responsible. This information is used to annually update the Federal Contaminated Sites Inventory (FCSI). The FCSI can be viewed at the Treasury Board of Canada website http://www.tbs-sct.gc.ca/fcsi-rscf/home-accueil.aspx?Language=EN&sid=wu69121627377.
- DFO (IOS) has begun working on ocean dumping of contaminated sediments in killer whale critical habitat, concentrations of PCBs and PBDEs in sediments and mussels of contaminated harbours (Vancouver and Victoria), and PAHs in sediments, under the auspices of the Federal Contaminated Sites Program (Johannessen 2009;Ross 2009).

Provincial Government Programs:

- Amendments to the British Columbia *Environmental Management Act* (EMA) and to the *Contaminated Sites Regulation* have improved the ability of the province to deal with contaminated sites. Annual amendments to the regulations will be conducted by the province to ensure that the environmental quality standards continue to reflect the most recent scientific knowledge. For more information on the provincial contaminated sites program, refer to the BC MOE website http://www.env.gov.bc.ca/epd/remediation/. For more information on the management of contaminated sites on provincial Crown lands refer to the BC Ministry of Agriculture and Lands website http://www.agf.gov.bc.ca/clad/ccs/. The BC MOE 2006-2007 and 2007-2008 Annual Report of the Land Remediation Section can be viewed online at http://www.env.gov.bc.ca/epd/remediation/annual_reports/index.htm.
- .The BC provincial Site Registry is a publicly accessible on-line provincial database which contains information on sites that have been investigated and cleaned up since 1988 and also information on sites that are currently being investigated to determine whether they should be considered contaminated. Since the Site Registry was initiated, more than 8500 sites have been registered; however, this number includes both confirmed contaminated sites and sites that are being screened to determine whether, in fact, they should be classified as contaminated sites. For more information refer to the BC MOE website http://www.env.gov.bc.ca/epd/remediation/index.htm.

5.4.7 Pleasure Boating

The operation and maintenance of boats can result in the release of environmental contaminants to both fresh and marine waters and can ultimately contribute to the impairment of water quality making it unsuitable for drinking, recreational activities, fish habitat, and shellfish harvesting. Sources of contaminants and/or pathogen release to the environment from recreational boating include discharges of sewage, garbage, food and grey water, bilge and ballast water; the release of oil and grease, fuel, and cleaning agents; and the leaching of chemicals from new paint during application and operation and from paint scrapings removed during maintenance. In addition, the presence of creosoted pilings in marinas and other areas of boat operation can be a source of PAHs to the environment. Environmental concerns are highest in marinas, small harbours, and heavy-use boating areas located in shallow, low flush regions.

Federal Government, Provincial Government, and Intergovernmental Programs:

- Laws and policies, Best Management Practices (BMPs), and various fact sheets and other BMPs relating to recreational boating in BC have been developed and can be viewed at the Environment Canada website http://www.pyr.ec.gc.ca/boatyards/index_e.htm.
- The BC MOE brochure entitled "Clean Water …It Starts with You – Pleasure Boating" can be viewed on the BC MOE website http://www.env.gov.bc.ca/wat/wq/brochures/boating.html.
- The provincial LWMP contains a policy on the release of pleasure craft sewage (http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-NonPointSource.pdf.

Non-Government Agency Programs:

- In 2007, Georgia Strait Alliance produced the comprehensive Guide to Green Boating. This document and additional information on green boating can be viewed on the Georgia Strait Alliance website http://www.georgiastrait.org/?q=node/51.
- Georgia Strait Alliance (GSA) has established a new project: to develop a voluntary environmental recognition program for marinas, harbour authorities, yacht clubs and boatyards in BC. GSA conducted a pilot program with one initial marina in Sidney, BC during 2007 and 2008, and has since added several additional marinas. "Clean Marine BC" is modelled on the highly successful "Clean Marine" program run by the Ontario Marine Operators Association (OMOA). The program includes a reference handbook that will enable marina and boatyard operators to identify where improvements are needed and what standards they must meet, such as BMPs for stormwater or waste management, vessel repair procedures, emission controls, hazardous materials handling or control of hydrocarbons. Each facility in the program will commit to the Clean Marine BC Policy. Once ready for inspection, the marina will undergo an independent audit to determine its level of environmental responsibility. The independent auditor will determine an eco-rating for the facility of between 1 and 5 anchors, with 5 being the highest level of Environmental Best Practices. GSA has awarded marinas that have passed the audits with a certificate of recognition and the right to fly the Clean Marine BC flag. Facilities that join the program and those that become eco-rated will be eligible for a range of benefits including insurance discounts.
- Based on the Guide to Green Boating produced by the Georgia Strait Alliance, a Green Boating Guide for commercial boat operators has been prepared by the T Buck Suzuki Environmental Foundation and can be viewed at http://bucksuzuki.org/publications/booklets/CGBG20Feb2007.pdf.

5.4.8 Aquaculture

As of 2006, a total of 741 aquaculture facilities in BC produced cultured finfish, shellfish, and marine plants (13 finfish species, 15 shellfish species, and four marine plant species). The majority of these operations were farming salt-water species on Crown land tenures; however, over 100 freshwater facilities were operating on private land. BC is the fourth largest producer of Atlantic salmon in the world.

Environmental concerns associated with aquaculture include the high concentrations of nutrients which enter the environment as a result of the discharge of organic waste such as fish feces and unconsumed fish food at fish farms. It has been estimated that aquaculture releases an estimated 2,276 t/yr of nitrogen to inland and coastal waters in Canada (Chambers *et al.* 2001;Environment Canada 2001).

Other possible sources of contaminants to the environment include the intermittent use of therapeutants to treat farmed fish, fish food with nutritional additives, disinfectants, and chemicals to prevent fouling of net pens.

Chemical therapeutants, such as antibiotics, are sometimes used to treat fish for bacterial infections. Crowded conditions and poor water quality at aquaculture facilities can stress fish and lower their resistance to disease. The administration of antibiotics to BC farmed fish is veterinarian prescribed and all therapeutants used by the aquaculture industry must be registered with and approved by Health Canada (Pest Management Regulatory Agency or Veterinary Drugs Directorate).The drug emamectin benzoate (SLICE®) is administered to farmed fish when a sea lice outbreak is confirmed. This product is also used only under veterinary prescription. A variety of antibiotics are used to treat salmon at aquaculture facilities. Oxytetracycline, trimethoprim80%/sulphadiazine20%, sulfadimethoxine80%/ormetoprim20%, and florfenicol are registered for use in Canada. In BC, quantities of antibiotics used by the BC aquaculture industry in 2004, 2005 and 2006 were 18,530 kg, 12,103 kg, and 7,956 kg, respectively, indicating a declining trend over this period (Burridge 2003;Burridge *et al.* 2008). These products are added to the feed or directly into the water.

A number of pesticides have been considered for use as parasiticides in aquaculture, but are not currently permitted in Canada. These include cypermethrin, deltamethrin, dichlorvos, ivermectin, and azamethipos. However, deltamethrin and azamethiphos (the active ingredients for AlphaMax and Salmosan) received a temporary approval for use in select areas of New Brunswick (Burridge et al. 2008).

Tributyltin (TBT), an organotin compound, was once widely used in BC as an antifoulant and was the active ingredient in marine paints applied to net pens to prevent net fouling at aquaculture facilities. Organotin compounds were de-registered for use as antifoulants under the *Pesticide Control Products Act* in 2002. Sampling conducted while these products were still in use in BC detected elevated concentrations of butyltins at some BC salmon farms (Garrett and Shrimpton 1997). Copper-based antifoulants are now widely-used as replacements for organotin-based products. Several studies have found that concentrations of copper in sediments are elevated in comparison with reference areas. In addition, zinc, which is added to fish food at salmon farms for nutritional purposes, has also been detected at elevated concentrations in the sediments in some BC salmon farms. However, it was reported that, because of the presence of high sulphide levels, the zinc was not bioavailable (Brooks 2000;Brooks 2001;Brooks and Mahnken 2003;Brooks *et al.* 2003;Obee 2009;Sutherland *et al.* 2007).

A number of persistent organic pollutants (POPs) have also been in commercially farmed salmon in BC, likely due to the presence of these contaminants in commercial fish food (Easton *et al.* 2002;Hites *et al.* 2004a;Kelly *et al.* 2008a). While some studies indicate that the concentrations of POPs are higher in farmed salmon that in wild Pacific salmon (Hites et al. 2004a), the concentrations of POPs and metals in farmed salmon are very low (Foran *et al.* 2004;Kelly *et al.* 2008b).

While some information is available on the types of chemicals in use at BC facilities, more specific information on types and volume of chemicals used is needed.

Federal Government Programs:[1]

- Responsibility for aquaculture management and development is shared between the Federal, Provincial, and Territorial governments. Fisheries and Oceans Canada (DFO), the lead federal department responsible for aquaculture management, works with other levels of government to develop policy and regulations to address both public and industry needs.
- DFO has the primary responsibility to ensure the preservation and conservation of wild fish stocks and reviews aquaculture applications to ensure the protection of wild fisheries and the marine environment. DFO administers, monitors, and enforces compliance with regulations relating to the environment (under the *Fisheries Act* Section 35(1) and (2) and aquatic animal health (*Fish Health Protection Regulations*). At the same time, DFO is responsible for helping to improve the business climate for aquaculture.
- Environment Canada administers the pollution prevention provisions of the *Fisheries Act* (section 36(3)), which prohibits the deposit of deleterious substances into waters frequented by fish unless authorized by regulation.
- For additional information on the roles and responsibilities of DFO and other government agencies, general information on aquaculture in Canada, and the results of scientific research pertaining to aquaculture refer to the DFO website http://www.dfo-mpo.gc.ca/aquaculture/aquaculture-eng.htm.
- The Canadian Food Inspection Agency (CFIA) conducts spot audits to check for the presence of drug residues in farmed fish; however, the use of these products results in their release to the environment.
- A report on the use and potential environmental effects of emamectin benzoate in the Canadian aquaculture industry was prepared for Environment Canada in 2005 and can be viewed at http://dsp-psd.pwgsc.gc.ca/Collection/En4-51-2005E.pdf.
- A report on organic waste and feed deposits on bottom sediments from aquaculture operations was published by Environment Canada in 2009 as part of the federal government's Science-Based Solutions series and can be viewed at http://dsp-psd.pwgsc.gc.ca/collection_2009/ec/En13-1-14-2009E.pdf.
- Elevated concentrations of butyltin compounds were detected in water, sediments, and biota in the vicinity of BC aquaculture facilities in the late 1980s and early 1990s (prior to the de-registration of organotin antifoulants) (Garrett and Shrimpton 1997).

Provincial Government Programs:

- In February 2010, the federal government will take over sole responsibility for the regulation of finfish aquaculture in BC. However, at present, there are two main provincial agencies which share the responsibility with DFO for the regulation and management of aquaculture. These include the Ministry of Agriculture and Lands (BC MAL) and the Ministry of Environment (BC MOE). BC MAL has the lead provincial role in aquaculture development and administers the *Aquaculture Regulation* under the *British Columbia Fisheries Act*. BC MOE is responsible for the development and

[1] NOTE: In February 2010, the federal government will take over sole responsibility for the regulation o f finfish aquaculture in BC.

enforcement of waste standards for the aquaculture industry under the *Finfish Aquaculture Waste Control Regulation* and the *Land-based Finfish Waste Control Regulation*. The *Finfish Aquaculture Waste Control Regulation* is currently under review. To view these regulations, and proposed revisions, refer to the BC MOE website http://www.env.gov.bc.ca/epd/industrial/aquaculture/index.htm. For more information on the aquaculture industry in BC, refer to the BC MAL website at http://www.al.gov.bc.ca/fisheries/index.htm.

- Annual environment monitoring at fish farms is conducted by the BC MOE to ensure compliance with the regulation and to assess effects on the environment. Reports on sampling programs can be viewed at http://www.env.gov.bc.ca/epd/industrial/aquaculture/salmon_farming.htm.
- The sale of medicated feeds is monitored by BC MAL and recorded in a database (to view antibiotic use in BC aquaculture from 1995 to 2006 refer to http://www.al.gov.bc.ca/ahc/fish_health/Antib%20Use%2095-2006%20graphs%20only.pdf). In addition, the salmon farmers must document and track the administration of all therapeutants. The drug emamectin benzoate (SLICE®) is administered to farmed fish when a sea lice outbreak is confirmed. This product is also used only under veterinary prescription. Ivermectin is another product which is available for the treatment of sea lice; but as SLICE® is considered safer for the environment, the use of ivermectin has decreased.

Non-Government Agency Programs:

- A document titled "Sustainable Shellfish: Recommendations for Responsible Aquaculture" was prepared by the David Suzuki Foundation and is available online at http://www.davidsuzuki.org/Oceans/Aquaculture/Shellfish/.

5.4.9 Septic Systems (Sewerage Systems)

Numerous homes and cottages located in rural areas on freshwater lakes, rivers, and streams and in coastal areas of BC utilize septic systems (also called sewerage systems) for on-site sewage treatment. However, the improper installation and/or maintenance of septic systems can result in the release of nutrients, contaminants, and pathogens to the environment. While releases of nutrients and pathogens are the primary concerns, septic systems are also a potential source of various other contaminants including cleaning compounds, pharmaceuticals, and personal care products.

Federal Government, Provincial Government, and Intergovernmental Programs:

- As of May 31st, 2005 a new provincial regulation under the *Health Act* puts the onus on the homeowner to ensure that systems are designed, installed, and maintained properly. Under the new regulation, the *Sewerage System Regulation*, a septic or sewage system must be installed by a Registered Onsite Wastewater Practitioner. However, it has been quite widely suggested that these provisions are not adequate and should be revised. For more information on the *Sewerage System Regulation* refer to website http://www.hls.gov.bc.ca/protect/lup_regulation.html.
- Environment Canada, in cooperation with other partners, undertook a GBAP-funded project to educate homeowners on the correct ways to care for their septic systems through the development and distribution of a video.

- For information on septic systems and their proper maintenance and operation of septic systems refer to the following websites:
  - the BC Ministry of Health website http://www.bchealthguide.org/healthfiles/hfile21.stm
  - the BC MOE website http://www.env.gov.bc.ca/wat/wq/nps/NPS_Pollution/Onsite_Sewage_Systems2/Onsite_Main.htm;
  - the BC *Sewerage System Regulation* can be viewed at on the BC Ministry of Health website http://www.qp.gov.bc.ca/statreg/reg/H/Health/326_2004.htm; and
  - the Canada Mortgage and Housing Corporation website http://www.cmhc-schl.gc.ca/en/co/maho/gemare/gemare_009.cfm.

Regional Government Programs:

- Information on septic systems and their proper maintenance and operation is provided on the following regional government websites:
  - the Interior Health website http://www.interiorhealth.ca/health-and-safety.aspx?id=496, and.
  - Capital Regional District (CRD) website http://www.crd.bc.ca/wastewater/septic/savvy.htm.

6 Research, Monitoring, and Management Actions Needed to Address Environmental Contaminants Concerns in South Coastal BC

6.1 Research and Monitoring

Several past reports, including several prepared under the FRAP, GBEI, and GBAP initiatives, have made recommendations for filling knowledge gaps relating to contaminants in the south coastal environment of BC. The most comprehensive recent review was prepared by the British Columbia Toxic Work Group (BCTWG), a multi-agency group reporting to the Puget Sound/Georgia Basin International Task Force (PS/GB ITF). The BCTWG conducted an extensive review of existing information on contaminants in the Georgia Basin (Garrett 2004). The purpose of this review was to identify the highest priority issues and to develop recommendations relating to research, monitoring, and management actions needed to address these issues. Members of the BCTWG consulted extensively within their organizations to identify the highest priority issues and then, developed, by consensus, developed recommendations relating to future research, monitoring, and management actions. The recommendations of the BCTWG are presented in a report, which is currently being finalized (Garrett 2009).

In addition, reports prepared by Grant and Ross (2002) and Johannessen and Ross (2002) have identified, and made recommendations pertaining to, contaminants issues of specific concern to killer whales and their prey. Many of the contaminants and issues identified in these reports are the same as those which were identified by the BCTWG to be of the highest priority in the Georgia Basin. These include issues pertaining to:

- *conventional or legacy POPs,*
- *new and emerging POPs,*
- *current-use pesticides,*
- *metals, and*
- *pharmaceuticals and personal care products (PPCPs)*

While the BCTWG considered only chemical contaminants, other reports have also identified *biological contaminants* to be of concern to marine mammals, including killer whales

With respect to future research and monitoring for these contaminants, the BCTWG identified the highest priority needs to be:

- *develop a system for the better sharing, management and communication of information and data on priority toxic substances to stakeholders;*
- *establish a long-term coordinated monitoring programs to allow the identification of emerging issues and temporal trends and to determine the efficacy of management actions implemented to control releases of toxic substances;*
- *develop a better understanding of the potential biological impacts of priority toxic substances on local species and the factors which affect toxicity;*

- *develop a better understanding of the environmental fate and distribution of several priority contaminants; and*
- *better define sources (especially non-point sources) and loadings of priority substances to the Georgia Basin.*

6.2 Management Actions

The BCTWG also identified needs and made recommendations for management actions to reduce or eliminate releases of priority contaminants to the Georgia Basin. These recommendations are intended to reduce the exposure of vulnerable aquatic species, including killer whales and their prey, to contaminants of concern. The recommendations focus on both source- and sector-based and watershed-based approaches and the BCTWG stressed the need for regulatory agencies and other stakeholders to work together to identify priority sectors and watersheds for action.

The BCTWG recommended a management action plan which is based on a series of sequential steps. These include:

- *review past and current initiatives and support and further promote those which have been shown to be successful;*
- *implement measures to address identified hotspots in the environment and to protect priority watersheds;*
- *utilize voluntary pollution prevention and pollution control initiatives, where possible. Where the need for additional management actions is identified, the first option considered should be the development and implementation of voluntary measures such as the preparing and promoting Best Management Practices and focusing on education and awareness;*
- *review existing controls and, where required, develop mandatory regulatory activities. Where voluntary initiatives are not feasible, or are not effective, regulatory measures and compliance promotion activities should be implemented; and*
- *assess and ensure the efficacy of management actions, as this is a critical component in any successful management plan. The measurement of end outcomes must be included in all future management actions. Ultimately, future monitoring programs should evaluate changes in appropriate indicators of environmental health and, thereby, make it possible to link the implementation of management actions to environmental health.*

Overall, the recommendations of the BCTWG are considered appropriate for addressing contaminants of concern to killer whales and their prey and, as such, have been adopted for the purposes of this report. The recommendations are summarized in Tables 9 and 10 following and have been categorized according to the priority needs identified above. In addition, recommendations specific to killer whales and their prey, as identified by Grant and Ross (2002) and Johannessen and Ross (2002), have also been included.

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need I: Develop a System for the Better Sharing, Management, and Communication of Information/Data on Toxic Substances

Background:

The need to improve the reporting and dissemination of toxics-related information between stakeholders has long been acknowledged. Very little of the available data and information is available on shared or linked databases and much of it remains in paper files, which are difficult to access. This limits the ability to effectively analyze existing information, both geographically and temporally, and is a major impediment to the better understanding and tracking of concerns associated with toxic substances in the Georgia Basin. The inventory and mapping of information on both sources and environmental levels of priority toxic substances in the Georgia Basin in a centralized database and GIS system, or through linkages of databases on the web, has been identified as a high priority in addressing this long-standing problem.

Recommendation 1:

Establish a central link to data sources and contacts for issues relating to toxic substances in the Georgia Basin in order to improve the reporting and dissemination of information to stakeholders. This could be accomplished by the development of a publicly accessible, GIS-linked repository of current and published information on environmental levels and sources of environmental contaminants to the Georgia Basin.

Recommendation 2:

Communicate research and monitoring issues to environmental and community groups and work with these groups to effectively implement voluntary instruments such as BMPs and codes of practice and to monitor the implementation and efficacy of such instruments.

Need II: Develop a Long-term Monitoring Program and Obtain Current Information on Environmental Levels of Priority Toxic Substances in the Georgia Basin

Background:

Recent information on environmental levels of many priority chemical contaminants in the Georgia Basin, particularly in the marine environment, is limited due to the lack of long-term monitoring programs. Long-term monitoring is essential for identifying temporal trends and evaluating the efficacy of control measures. In addition, it is important to monitor the impacts of new stressors, such as land use changes and climate change. For example, there are areas within the Georgia Basin which have been identified for urbanization within the next several years, and these areas provide an opportunity for studying the effects of urbanization on the levels, transport, fate and impacts of contaminants on vulnerable biological communities and/or populations. In addition, as inputs and run-off from most human activities in the Lower Fraser Valley/Metro Vancouver area pass through the Lower Fraser, the water quality and ecosystem condition of this ecologically important reach should be routinely assessed. Future work within the Georgia Basin should include more extensive sediment core studies, in order to put current contaminant concentrations and fluxes into a historical context. In addition, existing tissue archives (e.g., bird eggs) should be maintained and new ones created (e.g., aquatic biota and sediments), to allow future studies on temporal trends for future contaminants of concern. More emphasis should also be placed on baseline aquatic (including groundwater) and terrestrial ecosystem

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need II: Develop a Long-term Monitoring Program and Obtain Current Information on Environmental Levels of Priority Toxic Substances in the Georgia Basin (cont.)

Background (cont.):

monitoring at an increased number of reference sites for improved assessment of environmental conditions in hotspots (e.g., harbours, contaminated sites, and aquaculture areas).

While more extensive long-term monitoring programs in the Georgia Basin are required, some monitoring programs have already been implemented and should be acknowledged. These include a joint ambient monitoring program in the Georgia Basin, which is being conducted jointly by DFO and Metro Vancouver; an ambient monitoring program in the Fraser River, which being implemented by Metro Vancouver; routine water quality monitoring at several river sites in the Georgia Basin under the Canada-BC Water Quality Monitoring Agreement; and CRD's marine environmental research and monitoring program in the vicinity of three sanitary wastewater outfalls. Future studies should be coordinated with programs already underway in order to build on this work and to avoid duplication.

Recommendation 3:

Establish long-term coordinated monitoring programs to allow the identification of emerging issues and temporal trends; the evaluation of the efficacy of implemented control measures; and the assessment of the effects of stressors such as urbanization and climate change on the levels, transport, fate, and impacts of toxic substances. Monitoring programs should include the collection of sediment cores, samples from baseline and reference sites, and the archiving of representative samples of sediment and biota.

Specifically, more information is needed on:

- ***Conventional POPs***: current environmental levels (congener specific), particularly in tributaries of the Fraser River and other freshwater sources to south coastal waters, alpine lakes, snowmelt, and in harbours, basins and inlets of the south coast
- ***Emerging POPs:*** environmental levels (congener specific) of APs, APEOs, PCNs, chlorinated paraffins, and FOCs (use of SPMDs and SPMEs should be included); identification of potential hotspots in the environment for halogenated diphenyl ethers and phthalate esters; phthalate ester concentrations in shellfish for human consumption, aquatic birds, mammals and amphibians; development of reliable sample collection and analytical methods
- ***Current-use pesticides***: environmental levels of parent compounds and metabolites, particularly in groundwater and surface water in urban and agricultural areas impacted by runoff
- ***Wood treatment chemicals***: presence of DDAC and IPBC in deposition zones in the Fraser River and downstream from mills during rainstorm events; improved analytical methods
- ***Antifouling chemicals***: current environmental levels of organotins in past hotspots to determine if levels are declining as a result of the implementation of regulations; the presence or organotins in marine mammals; current levels of copper to determine whether the use of copper-based antifoulants have unacceptably increased environmental levels of copper in harbour areas, marinas and boating areas

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need II: Develop a Long-term Monitoring Program and Obtain Current Information on Environmental Levels of Priority Toxic Substances in the Georgia Basin (cont.)

Recommendation 3 (cont.):

Establish long-term coordinated monitoring programs to allow the identification of emerging issues and temporal trends; the evaluation of the efficacy of implemented control measures; and the assessment of the effects of stressors such as urbanization and climate change on the levels, transport, fate, and impacts of toxic substances. Monitoring programs should include the collection of sediment cores, samples from baseline and reference sites, and the archiving of representative samples of sediment and biota.

Specifically, more information is needed on (cont.):

- ***Metals***: a means of measuring biologically-available forms of silver; the presence of elevated concentrations of mercury in fish including rockfish from the vicinity of BC salmon farms, freshwater bass from Vancouver Island, and rockfish from the west coast of Vancouver Island
- ***PPCPs***: the identification of chemicals of high priority and relevance in the south coastal environment; environmental levels in sediments and biota from the south coast, particularly in the vicinity of WWTPs, aquaculture facilities, and agricultural sources

Specific Needs Relating to Killer Whales and Their Prey:

- More information is needed on the levels and patterns of contaminants in important killer whale prey species, especially salmonids. In particular, information is needed on both conventional and emerging POPs, PPCPs, and current-use pesticides

Need III: Develop a Better Understanding of Potential Biological Impacts of Priority Toxic Substances on Local Species and the Factors that Affect Toxicity

Background:

Elevated concentrations of some priority substances, sometimes in excess of the Canadian environmental quality guidelines, have been identified in some areas of the Georgia Basin. The biological impacts of these concentrations on local species are not known, particularly in aquatic systems with multiple stressors. In addition, for many of these substances, their fate, distribution and factors influencing their potential to cause adverse effects in Georgia Basin biota are not well understood. More information is needed on the specific forms of metals and other substances present under local environmental conditions; the bioavailability of metal species and other substances present in local hotspots and contaminated sites; and the local environmental factors which could affect their potential to cause biological impacts on local species. Long-term monitoring of biological communities is required in order to assess contaminant stress within a context of high natural variability in health status caused by

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need III: Develop a Better Understanding of Potential Biological Impacts of Priority Toxic Substances on Local Species and the Factors that Affect Toxicity

Background (cont.):

climatic, habitat-related, and competitive (e.g., invasive species) stresses. Cumulative contaminant stress must be evaluated in aquatic environments with multiple stressors such as exposure to "traditional" pollutants (e.g., ammonia, nitrate, and nitrite), stressful physical-chemical conditions (e.g., low/high pH, low dissolved oxygen, and high turbidity), and toxicants (e.g., pesticides, combustion products, surfactants, and "legacy" POPs) episodically, simultaneously, and/or in sequence.

Recommendation 4:

Obtain additional information on the potential biological impacts of priority substances in the Georgia Basin on local species and the factors which affect toxicity by identifying:

a.) the specific forms of metals and other environmental contaminants present in the Georgia Basin environment, their bioavailability and potential to cause adverse biological effects in local organisms, and the local factors and environmental conditions which may affect their potential to adversely affect local species;

b.) individual watersheds and communities which are exposed to cumulative stress and/or multiple stressors;

c.) the presence of long-term stress in communities with impaired performance due to chronic/episodic exposure to contaminant mixtures at low levels;

d.) non-persistent and non-bioaccumulative toxicants causing additional stress; and

e.) watersheds and ecosystems within the Georgia Basin where there is a potential for endocrine-disrupting effects to occur

f.) bird and fish kills which are known or suspected to be caused by exposure to CUPs and other toxic substances through more consistent and complete documentation

Specifically, more information is needed on:

- ***Conventional POPs:*** potential for cumulative effects from exposure to low concentrations of many POPs; effects on early life stages of aquatic species (particularly salmon); relative toxic stress contributions of local and global sources; the potential for endocrine disrupting and other toxic effects; innovative bioassay methods (e.g., gene chip technology) for long-term monitoring of dioxin-like and endocrine-disrupting compounds; the health of ecosystems exposed to high concentrations of PAHs; the potential for photo-induced PAH toxicity in shallow waters and sediments
- ***Emerging POPs:*** toxicity of AP and APEOs to local aquatic species (especially sediment-dwelling organisms and mammalian/avian consumers of aquatic organisms) and the influence of local environmental conditions; contribution of AP, APEOs and other emerging POPs to endocrine-disrupting effects in biota in agricultural and urban areas and in the vicinity of WWTP discharges; potential impacts of elevated concentrations of halogenated diphenyl ethers on local aquatic species; toxicity of phthalate esters in sediments; potential for cumulative effects from exposure to low concentrations of many POPs; effects on early life stages of aquatic species (particularly salmon); relative toxic stress contributions of local and global sources; innovative bioassay methods (e.g., gene chip technology) for long-term monitoring of dioxin-like and endocrine-disrupting compounds;

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need III: ***Develop a Better Understanding of Potential Biological Impacts of Priority Toxic Substances on Local Species and the Factors that Affect Toxicity (cont.)***

Recommendation 4 (cont.):

Obtain additional information on the potential biological impacts of priority substances in the Georgia Basin on local species and the factors which affect toxicity by identifying:

a.) the specific forms of metals and other environmental contaminants present in the Georgia Basin environment, their bioavailability and potential to cause adverse biological effects in local organisms, and the local factors and environmental conditions which may affect their potential to adversely affect local species;

b.) individual watersheds and communities which are exposed to cumulative stress and/or multiple stressors;

Specifically, more information is needed on (cont.):

- ***Current-use Pesticides***: potential impacts, including endocrine-disrupting effects, of current-use pesticides, their transformation products, and the various carrier compounds/adjuvants in high-use agricultural areas and in stormwater affected areas; bird and fish kills attributed to CUPs (more consistent documentation is needed)
- ***Wood Treatment Chemicals:*** the toxicity of DDAC and IPBC to sensitive life-stages of local species and the potential effects of simultaneous exposure; toxicity of DDAC and IPBC associated with sediments and suspended particulates near mills; effects of simultaneous exposure to DDAC and IPBC und simultaneous exposure to DDAC/IPBC and metals, under various conditions of pH and water hardness; toxicity to sediment-dwelling invertebrates
- ***Antifouling Chemicals***: current incidence of imposex in historically contaminated areas. The periodic monitoring of imposex in gastropods in historically affected areas should be used as a tool to evaluate the efficacy of existing controls on organotins; significance of elevated concentrations of organotins in grebes and seaducks
- ***Metals:*** significance of trend toward increased cadmium concentrations in northerly seabird colonies along the BC coast; bioavailability of high nickel levels in the Sumas River sediments and suspended solids; adequacy of the present criteria/guidelines for silver are protective of salmonids (hatchery and wild fry) by assessing the toxicity of sliver to anadromous salmonids (particularly fry) in soft freshwater habitats; potential risks of use of silver in disinfectants and water purification; significance of zinc toxicity in stormwater runoff from wood treatment facilities or other facilities with zinc roofs or other construction materials
- ***PPCPs***: potential for biological effects on aquatic species in areas receiving inputs from WWTPs, agricultural runoff or urban runoff, and aquaculture facilities

Specific Needs Relating to Killer Whales and Their Prey:

- research on the potential effects of conventional and new POPs and other priority pollutants on the health of killer whale and other marine mammals and also important prey species, such as salmonids. In particular, the potential effects of pollutants on endocrine and immune systems and their potential to cause reproductive and developmental abnormalities needs to be investigated.
- minimally-invasive methods to study contaminant levels and their health effects in killer whales. This would likely involve the use of biomarker/biopsy-based studies, sentinel or surrogate species, and a “weight of evidence” approach to determine risk in the absence of cause-and-effect evidence.

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need IV: Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances in the Georgia Basin

Background:

The environmental fate and distribution of contaminants is strongly influenced by local environmental conditions. It is difficult to accurately assess the potential long-term impacts of priority environmental contaminants in the Georgia Basin without adequate information on the potential persistence, mobility, and routes of transport of these substances in watersheds and regions where elevated environmental concentrations and/or significant loadings to receiving waters have been identified.

Recommendation 5:

Assess the potential for concerns associated with the release of metals and organic contaminants to overlying waters as a result of sediment disturbance in harbour areas.

Recommendation 6:

Further investigate the routes/mechanisms for local transport and the distribution of endocrine-disrupting substances in environmental media.

Specifically, more information is needed on:

- ***Conventional POPs:*** environmental fate and behaviour of individual congeners under various environmental conditions; implications of contaminant recycling from abiotic sedimentary basin storage to the biotic compartment; effect of bioturbation on POPs distribution and re-distribution; watershed pathways to characterize the movement of POPs from snow to freshwater systems and ultimately, to the marine waters of the south coast; sinks for PAHs discharged to the Fraser River during low and high tides
- ***Emerging POPs:*** fate of AP and APEOs and other emerging POPs in the environment and in sludges and biosolids; effects of photolysis on AP and APEOs; uptake and elimination of AP and APEOs in local species; effect of pH on bioavailability of AP and APEOs; bioaccumulation and biomagnification potential of phthalate esters
- ***Current-use Pesticides***: transformation, persistence, transport, bioconcentration and biomagnification of high in-use pesticides and their transformation products; determine the presence, transport; persistence of CUPs in groundwater
- ***Wood Treatment Chemicals***: persistence, transport and bioavailability of DDAC and IPBC discharged to local receiving waters in dissolved and particulate-adsorbed forms; persistence and availability of DDAC and IPBC in association with bottom sediments and suspended particulates in deposition zones, especially in marine and estuarine areas; effect of environmental conditions such as pH and water hardness on bioavailability
- ***Antifouling Chemicals:*** transport of antifoulant chemicals beyond harbours via currents and biotic transport
- ***Metals***: trophic transfer processes for biologically available cadmium in light of the enriched cadmium concentrations detected in BC oysters (also refer to recommendations from DFO workshop on this subject); silver geochemistry and chemical speciation in the Georgia Basin
- ***PPCPs***: transformation, persistence, transport, bioavailability, and bioconcentration potential

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need V: Better Define Sources (especially Non-Point Sources) and Loadings of Priority Toxic Substances to the Georgia Basin

Background:

A better understanding of sources, particularly non-point sources (NPS), of priority substances to the Georgia Basin is a high priority. In recent years, the implementation of regulations, combined with voluntary initiatives by industry, has successfully reduced environmental loadings of contaminants from point source discharges. NPS, including runoff from urban and agricultural areas and atmospheric deposition, is now recognized as the major contributor of many potentially toxic substances to the environment. Local watersheds within the Georgia Basin show signs of contaminant stress from these sources; however, very little is known about the contribution of NPS to the overall toxic loadings to the Georgia Basin. Urban and agricultural streams show elevated levels of substances such as metals, PAHs, and nutrients in water and sediments and several pesticides and carrier compounds have been identified as endocrine-disrupting compounds (EDCs). In some agricultural areas, amphibian populations have been affected and changes have been observed in the community structure of benthic invertebrates in urban and agricultural areas. Atmospheric deposition has been identified as an important NPS for many metals and organic contaminants in the Georgia Basin. However, currently, available information is limited to select contaminants and specific areas, such as the Brunette River and Abbotsford. A monitoring program is required to measure the dry and wet deposition of atmospherically transported contaminants at a greater number of locations in order to determine annual loadings directly to the Strait of Georgia; to large lakes/reservoirs; to land surfaces at low, medium and high elevations; and to assess gradients along the axes of the Georgia Basin. In addition, it is important to better understand the chemical loading contributions of local sources in relation to global sources such as long-range atmospheric transport.

Recommendation 7:

Obtain and compile more information on the agricultural runoff, urban stormwater, freshwater input and other non-point sources (NPS) and point sources of contaminants to various watersheds within the Georgia Basin.

Recommendation 8:

Obtain more information on the atmospheric deposition of metals and organic contaminants to the Georgia Basin.

Recommendation 9:

Determine the ratios of regional (e.g., municipal WWTP effluent, agricultural runoff, freshwater input) to global (e.g., atmospheric long-range transport, bio-transport) sources of persistent pollutants in a variety of environmental media.

Recommendation 10:

Prepare a synthesis of information on loadings of contaminants, both “legacy” and “new” (especially current-use pesticides), in runoff from representative urban and agricultural areas in order to allow extrapolation of the land use/export relationship developed at these locations to the entire basin. This will allow for the identification of priority watershed areas for further study and for the implementation of management actions to reduce loadings.

Table 9 Priority Needs and Recommendations for Future Research and Monitoring to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need V: Better Define Sources (especially Non-Point Sources) and Loadings of Priority Toxic Substances to the Georgia Basin (cont.)

Recommendations 7- 10 (cont.):

Specifically, more information is needed on:

- ***Conventional POPs:*** local and global sources and inputs including atmospheric deposition and contributions from the Fraser River and other freshwater sources to the marine coastal region; update information on annual import and stockpiles of in-use and banned POPs in the Georgia Basin area; use of parking lot sealcoats and their relative contribution of PAHs to urban waterways in urban runoff; loadings from current sources of PAHs, including specific information for individual PAH compounds
- ***Emerging POPs:*** usage and suspected sources of emerging POPs in the Georgia Basin; identification of major controllable sources of phthalate esters and other emerging POPs; loadings of AP and APEOs and other emerging POPs from potential sources such as WWTP discharges, storm sewers, CSOs, pulp mills, other industrial sources, urban runoff, agricultural runoff, and landfills
- ***Current-use Pesticides***: watershed specific use and loadings of current-use pesticides in heavy pesticide use areas;
- ***Wood Treatment Chemicals***: annual and seasonal loadings of wood treatment chemicals from antisapstain facilities in southern BC; significance of the other sources of DDAC (i.e., industrial disinfectants) by determining loadings from stormwater and WWTP discharges; protocols for use of automatic samplers with flow proportional interval sampling
- ***Antifouling Chemicals***: current and continuing adherence of the shipbuilding and repair industry to applicable BMPs and to assess the effectiveness of these measures in reducing loadings to the environment
- ***Metals***: develop the ability to distinguish manganese in the environment from MMT from other sources; sources of silver discharged to municipal sewers
- ***PPCPs***: use, sources, and loadings of PPCPs, including veterinary drugs, to the south coastal area from WWTPs, urban and agricultural runoff, and aquaculture facilities

Table 10 Priority Recommendations for Management Actions to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need I: Review past and existing initiatives and support and further promote those which have been shown to be successful

The successes and failures of past and current initiatives to address high priority toxics-related issues in the Georgia Basin should be reviewed and evaluated. Initiatives which have proved successful should be promoted and expanded, where possible, while less successful initiatives should be re-evaluated.

Recommendation 1:

Review/follow-up of FRAP, BIEAP, and GBEI outcomes and recommendations to identify outstanding issues and to evaluate the effectiveness of initiatives under these programs.

Background:

Past initiatives to reduce the release of toxic substances to the Georgia Basin have resulted in the implementation of successful actions by a number of sectors and within various watersheds, municipalities, and regional districts. For example, concepts of the recommendations of the management plan described following are incorporated as an integral part of the Liquid Waste Management Plans (LWMPs) of both the CRD and Metro Vancouver. In addition, there have been some successful initiatives to clean-up contaminated areas within specific priority watersheds. It is important to highlight these successes and to encourage the implementation of similar measures more widely throughout the Georgia Basin area.

Specifically, action is needed on:

- ***Current-use Pesticides***: review and improve the tracking of regional pesticide usage and application; evaluating measures implemented under the Agricultural Policy Framework (APF), which was in effect between 2003 and 2008 and the new "Going Forward Initiative" which replaces it; more consistent documentation and verification of fish and/or bird kills associated with the use of pesticides or other substances
- ***Antifouling Chemicals:*** active promotion of BMPs for marinas, shipbuilding and repair facilities, and conduct follow-ups to encourage compliance and to determine the effectiveness of BMPs

Need II: Implement measures to address identified hotspots and priority watersheds

Background:

While several high priority and "at-risk" watersheds within the Georgia Basin have been identified and some "hotspots" within watersheds have been documented, it will be necessary for regulatory agencies and other stakeholders to collaborate on the development of mutually agreeable criteria for selecting priority watersheds or priority areas within watersheds. The development of these criteria may be difficult as various factors must be considered for their development. These include the current state of watershed health, risks from toxics in comparison with other water quality issues, and the criteria which are being used for defining water quality (e.g., biological models vs. chemical loading). Watersheds with elevated concentrations and loadings of toxic substances (particularly metals, PAHs, current-use pesticides, and nutrients) and/or observed biological impacts should be considered high priority for management action, where there is a likelihood of rehabilitation success. The percent total impervious area (TIA) within a watershed has been linked to the loadings of a variety of contaminants, including metals and PAHs, to the watershed and TIAs of more than 15% have been linked to adverse effects on fish populations. However, the TIAs for most watersheds within the Georgia Basin have not yet been

Table 10 Priority Recommendations for Management Actions to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need II: Implement measures to address identified hotspots and priority watersheds (cont.)

Background (cont.):

determined. There is a need for information on existing TIAs in watersheds within the Georgia Basin as well as for mechanisms by which to track actual and/or projected changes over time. In order to protect clean watersheds (not currently impacted), those that are potentially at risk, due to impending development or other activity, should also be considered high priority.

Recommendation 2:

Incorporate water quality protection and improvements into existing planning processes which include stakeholder involvement. This would include the integration of actions to minimize runoff contaminated with nitrogen-based nutrients or other priority substances into agricultural and urban planning processes (e.g., OCP, LWMP, and ISMP); the investigation and encouragement of innovative approaches to improving water quality through low impact development techniques; and methods to minimize or, where needed, reduce total impervious surface areas.

(*Note:* *This recommendation acknowledges that water quality is intrinsically tied to other activities and cannot be managed as a separate issue. OCPs currently do not explicitly address water quality, but opportunities exist to achieve water quality objectives by managing the location and type of development in a particular watershed.)*

Specifically, action is needed on:

- *Emerging POPs*: develop marine and freshwater sediment quality guidelines
- *Current-use Pesticides:* as needed, implement measures to reduce pesticide losses to the environmental as a result of agricultural practices, including pesticide application and uncontrolled surface runoff, aquaculture practices, urban activities, and stormwater runoff
- ***Metals:*** as needed, develop options to reduce zinc in stormwater from galvanized roofs on wood treatment facilities or other facilities where zinc levels in stormwater are of concern.

Need III: Utilize voluntary pollution prevention and pollution control initiatives, where possible

Background:

Where past and current initiatives are shown to be inadequate and the need for additional management action is confirmed, future efforts should focus first on the development and implementation of voluntary pollution prevention and pollution control initiatives such as Best Management Practices (BMPs) and education. The implementation of voluntary initiatives should include stakeholder groups (community groups, industry associations, etc.), encourage site audits, and promote education.

Table 10 Priority Recommendations for Management Actions to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need III: Utilize voluntary pollution prevention and pollution control initiatives, where possible (cont.)

Recommendation 3:
Implement non-CEPA pollution prevention/control initiatives to address discharges of toxic substances (focusing on PAHs/metals) to sanitary sewers. Sewer use bylaws exist in some areas and could be expanded to others.

Recommendation 4:
Continue to implement and expand pollution prevention and control initiatives to address discharges and spills of toxic substances (focusing on metals, PAHs, high-use toxic pesticides, and nitrogen-based nutrients) to urban stormwater and agricultural runoff (e.g., Cecelia Creek in Victoria).

Recommendation 5:
Implement, more widely, pollution prevention/control initiatives (e.g., BMPs) to address automotive related industries, electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories, dental offices, parking lots, ship repair, street sweeping, aquaculture, landscaping and other small and medium-sized enterprises, and also those pertaining to agriculture.

Recommendation 6:
Use economic measures and fiscal instruments such as cost-sharing pollution prevention/control initiatives with facilities; innovative funding schemes (e.g., money for mercury coupons for car washes/car repair to eliminate release to the environment through leaks) and business recognition; involvement of an independent third party/peer group for assistance and mentoring; and tax incentives for pollution reduction.

Need IV: Review existing controls and, where required, develop mandatory regulatory activities

Background:

In cases where voluntary measures are not effective, the implementation of regulatory measures may be required. The strong enforcement of existing regulations and codes, where necessary, is an important component of management actions to reduce toxics releases to the environment.

Table 10 Priority Recommendations for Management Actions to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need IV: Review existing controls and, where required, develop mandatory regulatory activities (cont.)

Recommendation 7:
Develop regulatory requirements for pollution prevention (e.g., source control) such as regulatory Codes of Practice for high priority industry and business sectors, where voluntary pollution prevention/control initiatives have not been effective.

Recommendation 8:
Encourage local regulations such as stormwater bylaws and changes to Official Community Plans to promote low impact development and re-development (such as minimizing TIAs) in order to reduce the release of toxic substances.

Recommendation 9:
Ensure regulations and requirements on Crown lands are, at a minimum, equivalent to those on non-Crown lands (e.g., contaminated sites).

Specifically, action is needed on:

- ***Emerging POPs:*** develop site-specific objectives from the national guidelines to reflect the fate and behaviour of AP and APnEOs and the sensitivity of ecologically significant species in the Georgia Basin; develop regulations/guidelines for halogenated diphenyl ethers, if deemed necessary, based on the results of future work on toxicity to local species, source inventories, and current environmental levels; develop marine and freshwater sediment quality guidelines for phthalate esters
- ***Current-****use Pesticides:* review existing mechanisms for tracking regional pesticide usage and make improvement where necessary
- ***Wood Treatment Chemicals:*** develop sediment quality guidelines for DDAC and IPBC; reconvene the Antisapstain Subcommittee of the Federal/Provincial Toxic Chemicals Coordinating Committee to evaluate possible implications on the efficacy of existing stormwater guidelines based on the more recent aquatic toxicity information
- ***Antifouling Chemicals:*** develop sediment quality guidelines for organotins

Need V: Assess and ensure the efficacy of management actions

Background:

An emphasis on monitoring the results of management actions is critical to assessing their effectiveness in reducing releases of toxic substances to the Georgia Basin. The measurement of end outcomes must be included as part of implementation plans for all future management actions and, ultimately, future monitoring programs should evaluate changes in appropriate indicators of environmental health and, thereby, link management actions to environmental health. Goals of management actions should include improvements in water quality and the overall health of aquatic ecosystems.

Recommendation 10:

Improve the reporting, management and sharing of information/data on priority issues to both encourage partnerships between stakeholders and to promote the monitoring of the efficacy of pollution reduction initiatives.

Table 10 Priority Recommendations for Management Actions to Address Environmental Contaminants in the South Coast Region of BC (from Garrett 2009)

Need V: Assess and ensure the efficacy of management actions (cont.)

Recommendation 11:

Conduct follow-up inspections and monitoring to ensure that initiatives meet their intended goals (e.g., routinely monitor the effectiveness of management options including the efficacy of existing BMPs).

Recommendation 12:

Ensure the remediation of contaminated sites to prevent the release of toxics to the environment by employing scientifically-based guidelines and standards which are regularly reviewed for efficacy.

Specifically, action is needed on:

- ***Current**-use Pesticides:* continue to strongly encourage and monitor the use of an integrated pest management approach within the Georgia Basin; track and evaluate measures implemented under the Agricultural Policy Framework (APF), which was in effect between 2003 and 2008, and the new "Going Forward Initiative" which replaced it. These initiatives address priority agricultural environmental issues throughout BC.
- ***Antifouling Chemicals:*** determine the adherence of marinas and the shipbuilding/repair industry to BMPs for these facilities and assess the adequacy of existing BMPs in reducing releases of antifouling chemicals.

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