Summary

Technical Background Information

for

The Draft PBT List

December 2004

DRAFT

Introduction

Ecology distributed a draft PBT rule to the PBT Advisory Committee on December 8, 2004. The December 8th draft PBT rule includes a list of 26 chemicals and chemical groups (Table 1). The purpose of this document is to summarize the technical information that Ecology considered when preparing the draft PBT list.

Table 1 - Initial PBT List (Draft)

Aldrin/Dieldrin
Cadmium (pending review of bioavailability)
Chlordane
Chlordecone (Kepone)
DDT
Endrin
Heptachlor/Heptachlor epoxide
Hexabromobiphenyl
Hexabromocyclodecane
Hexachlorobenzene
Hexachlorobutadiene
Lead (pending review of bioavailability)
Mercury
Mirex
Pentachlorobenzene
Perfluorooctane sulfonates (PFOS)
Polyaromatic hydrocarbons (PAHs)
Polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/PBDF)
Polybrominated diphenyl ethers (PBDE)
Polychlorinated biphenyls (PCBs)
Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF)
Polychlorinated napthalenes (PCN)
Short-chain chlorinated paraffins (SCCP)
Tetrabromobisphenol A
Tetrachlorobenzene, 1,2,4,5-
Toxaphene

PBT Criteria

Ecology used the PBT criteria included in December 8th draft PBT rule (WAC 173-333-320) when evaluating whether to include a chemical or chemical group on the draft PBT list. The draft PBT criteria include:

- ***Persistence**:* Persistence indicates how long a chemical is expected to exist in the environment and be available for exposure. In order to be included on the PBT List, Ecology must determine that a chemical can persist in the environment based on evidence that the half-life of the chemical in surface water, soil and/or sediment is greater than or equal to 60 days (WAC 173-333-320(2)(a)).
- ***Bioaccumulation Potential**:* Bioaccumulation potential is defined as "… the capacity of a chemical to increase in concentration or accumulate (be stored in tissue) in an organism as a

result of uptake from all environmental sources over a period of time." (EPA, 1998b). In order to be included on the PBT List, Ecology must determine that a chemical's bioconcentration factor or bioaccumulation factor in aquatic species for the chemical is greater than 1000 or, in the absence of such data, that the chemical's log-octanol water partition coefficient (log K_{ow}) is greater than five (5) (WAC 173-333-320(2)(b)).

- ***Toxicity:*** Toxicity refers to a chemical's potential to cause adverse effects on human health and/or the environment. In order to be included on the PBT List, Ecology must determine that the chemical or chemical group has the potential to be toxic to humans or plants and wildlife based on evidence that:
  - The chemical or a chemical group is known to cause or can reasonably be anticipated to cause cancer or teratogenic effects, reproductive effects, neurological disorders or other acute or chronic health effects; or
  - The chemical or chemical group is known to cause or can reasonably be anticipated to cause adverse effects in aquatic and terrestrial plants and animals. (WAC 173-333-320(2)(c))
- ***Bioavailability of metals***: In order for a metal to be included on the PBT list, Ecology must determine that it is likely to be present in forms that are bioavailable (WAC 173-333-320(2)(d)).

Organization of this Document

The rest of this document is divided into 26 sections (1-3 pages in length) that summarize the rationale for the chemicals and chemical groups included on the initial PBT List. Each section includes the following subsections:

- ***Background Information***: This subsection includes a brief description of the chemical or chemical group, the uses and sources of the chemical or chemical group and information on whether the chemical or chemical group is being addressed under other federal or international PBT programs.
- ***PBT Characteristics***: This subsection includes a brief summary of information on the persistence, bioaccumulation potential, toxicity and (for metals) bioavailability for the particular chemical or chemical group.
- ***Conclusions***: This subsection includes a very brief rationale for Ecology's decision to include the particular chemical or chemical group on the initial PBT List.

Aldrin

Background: Aldrin[1] (CAS 309-00-2) is one of several chlorinated cyclodiene insecticides derived from hexachlorocyclopentadiene. Aldrin was used as a pre-emergence soil insecticide for the control of corn root worms, wireworms, etc.. It was widely used to protect crops such as corn and potatoes and to protect wooden structures from termites. The Environmental Protection Agency banned the importation and manufacture of aldrin in 1974.

Aldrin has been found in fish tissue[2] and sediment[3] samples collected in Washington. Aldrin has been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

Aldrin has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), a PBT chemical in the EPA National PBT Strategy (EPA, 1998a), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POP) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of aldrin.

- ***Persistence****:* Aldrin is converted to dieldrin in the environment. Mackay et al. (1997) published average half life values for aldrin in surface water (@ 2 years), soils (@ 2 years) and sediments (@ 6 years). These values are consistent with the range of soil half-life values (291 days – 9 years) considered by EPA when evaluating aldrin under the Toxics Release Inventory (TRI) program (EPA, 1999a). EPA (1998b) also used the EQC multi-media model to estimate a regional half-life of 2532 hours.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of bioaccumulation factors/bioconcentration factors available for aldrin and used a BCF value of 3,715[4] to characterize the bioaccumulation potential of this substance. This value is based on a measured bioconcentration factor included in the Syracuse Research Corporation BCF database file. The OSPAR fact sheet for aldrin identifies Log K_{ow} values of 3 and 7 and BCF values ranging from 3,700 to 141,000 (OSPAR, 2004c). The ECOTOX database contains BCF values ranging from 50 to 28,636 (EPA, 2002c)

- ***Human Toxicity (Non-cancer)****:* Exposure to aldrin is associated with a wide range of adverse health effects (e.g. liver damage, central and peripheral nervous system damage, etc.)

[1] 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-endo-1,4-exo-5,8-dimethanonaphthalene.
[2] SAIC (2001) compiled readily available fish tissue data and found that 4 - 6 percent of fish tissue samples analyzed for aldrin contained measurable amounts of aldrin.
[3] SAIC (2001) compiled readily available sediment data and found that @ 6 percent of marine sediment samples analyzed for aldrin contained measurable amounts of aldrin.
[4] This value was also used by EPA (1999a) when evaluating whether to include aldrin on the list of PBT chemicals for purposes of reporting pursuant to the Toxics Release Inventory (TRI) program.

EPA has established an oral RfD value (0.00003 mg/kg/day)[5] that is published in the IRIS database (EPA, 2004a). ATSDR (2000a) has also established a Minimal Risk Level (0.00003 mg/kg/day) for chronic oral exposure based on liver effects observed in animal bioassays.

- ***Human Toxicity (Cancer)***: EPA has classified aldrin is classified as a probable human carcinogen (B2) based on an increased tumor response in three strains of mice (both males and females).[6] EPA has established an oral cancer slope factor (17 (mg/kg/day)-1) that is published in the IRIS database (EPA, 2004a).[7]

- ***Ecological Toxicity***: Aldrin is very toxic to aquatic organisms. However, the toxicity is quite variable, with aquatic insects being the most sensitive group of invertebrates. EPA has established a Tier II Secondary Chronic Value (SCV) (0.00003 mg/L) which was developed through the Great Lakes Water Quality Initiative (EPA, 1996)[8]. The OSPAR fact sheet for aldrin states that the EC50 value (0.0002 mg/L) observed in an acute toxicity test with Daphnia magna formed the basis for including aldrin on the List of Substances of Possible Concern (OSPAR, 2004c)

Conclusions: Ecology has determined that aldrin meets the draft PBT criteria specified in WAC 173-333-320.

[5] The RfD value is based on a chronic feeding study in rats. The critical effect is liver toxicity and 1000-fold safety factor was applied to the LOAEL of 0.025 mg/kg/day. EPA assigned a medium level of confidence to the study, the database and the RfD.
[6] IARC (2004a) has placed aldrin and dieldrin in Group 3 ("Not classifiable as to carcinogenicity in humans").
[7] Aldrin is classified as a probable human carcinogen (B2) based on an increased tumor response in three strains of mice (both males and females). The cancer slope factor was calculated using the linearized multistage procedure.
[8] EPA (1998b) states that "…[a]n SCV is an estimated average concentration of a chemical in water that should not result in "unacceptable adverse effects" on aquatic organisms exposed for long-term durations (e.g., greater than four days). The Tier II methodology, however, has less rigorous data requirements than the methodology used to calculate the Tier I FCVs. The Tier II methodology uses statistically derived "adjustment factors" to calculate an SCV (40 CFR 132 Appendix A). The SCV also has minimum data requirements (e.g., the data set must include a daphnia test and meet specified acceptability criteria)." The source document for the Tier II SCV for aldrin is the 1995 Technical Support Document for the Hazardous Waste Identification Rule Risk Assessment (EPA, 1995b).

Cadmium

Background: Cadmium is a naturally occurring element that is used as a protective plating for steel, stabilizer for vinyl chloride, as a pigment in plastics and glasses, as electrode material in nickel-cadmium batteries and as a component of various alloys. Cadmium is also present in the Washington environment as a result of natural processes such forest fires and weathering and erosion of cadmium-bearing rocks and other anthropogenic processes such as stationary fuel combustion (power generation and heating), transportation, solid waste disposal, and sewage sludge application.

Cadmium has been found in fish tissue[9] and sediment[10] samples collected in Washington. Cadmium has been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b). Based on the National Toxics Inventory, SAIC (2001) estimated that Washington source release 15,675 lbs/year of cadmium into the atmosphere.

Cadmium has been identified as a candidate substance for bans, phaseouts, and reductions (OME, 1993), a Tier II substance under the Bi-National Toxics Strategy (GLNPO, 1997), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b)[11].

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential, toxicity and bioavailability of cadmium.

- ***Persistence:*** EPA (1998b) assigned a persistence score of three (greater than 580 hours) to cadmium and cadmium compounds. Cadmium does not break down in the environment, but it may be affected by physical and chemical processes that modify its mobility, bioavailability, and residence time in different environmental media.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of bioaccumulation factors/bioconcentration factors available for cadmium and used a BCF value of 4,190 to characterize the bioaccumulation potential of this substance. This value is a measured BCF obtained from the Ambient Water Quality Criteria document for cadmium (EPA, 1984).[12] This value is consistent with the range of BCF values currently included in EPA's ECOTOX database (EPA, 2002c).[13]

- ***Human Toxicity (Non-cancer)****:* Exposure to cadmium is associated with a wide range of adverse health effects (e.g. kidney damage, skeletal effects, hypertension and cardiovascular

[9] SAIC (2001) compiled readily available fish tissue data and found that @ 40 percent of fish tissue samples analyzed for cadmium contained measurable amounts of cadmium.
[10] SAIC (2001) compiled readily available sediment data and found that @ 60 percent of marine sediment samples analyzed for cadmium contained measurable amounts of cadmium.
[11] The OSPAR Commission included cadmium chloride on the List of Substances of Potential Concern.
[12] EPA. 1985. Ambient Water Quality Criteria for Cadmium - 1984. PB85-227031.
[13] However, it is important to note that EPA (2000a) concluded that "…most studies reviewed contained data which suggest that cadmium is not a highly mobile element in aquatic food webs, and there appears to be little evidence to support the general occurrence of biomagnification of cadmium within marine or freshwater food webs…".

effects etc.). EPA has established an oral RfD value (0.0005 mg/kg/day)[14] which is published in the IRIS database (EPA, 2004a). The Agency for Toxic Substances and Disease Registry (ATSDR) has established an MRL of 0.0002 mg/kg/day (ATSDR, 1999a) based on kidney damage observed in animal bioassays.

- ***Human Toxicity (Cancer)****:* EPA (2004a) has classified cadmium as a probable human carcinogen (Group B2)[15]. EPA has established an Inhalation Unit Risk value (0.0018 $(ug/m^3)^{-1}$) which is published in the IRIS database (EPA, 2004a).[16]

- ***Ecological Toxicity****:* Cadmium is toxic to aquatic organisms. EPA has established a Tier I Final Chronic Value (FCV) (0.0014286 mg/L) that was developed through the Great Lakes Water Quality Initiative (EPA, 1996) [17] and an AWQC FCV (0.001 mg/L) which was developed by EPA's Office of Water.[18]

- ***Metal Bioavailability****:* The mobility and bioavailability of cadmium in aquatic environments are enhanced under conditions of low pH, low hardness, low suspended matter levels, high redox potential, and low salinity. The movement of cadmium in soil and potential accumulation by biota is enhanced by low pH, low organic matter content, large soil particle size, and high soil moisture.

Conclusions: Ecology has concluded that cadmium meets the criteria for persistence, bioaccumulation and toxicity in WAC 173-333-320(2). However, Ecology has not completed its review of information relevant to making a determination on whether cadmium is "...likely to be present in forms that are bioavailable..." (WAC 173-333-320(2)(d)). Ecology intends to complete that review and make a determination on whether to include cadmium on the PBT list prior to distributing the proposed rule for public review and comment.

[14] The RfD value was based on a chronic study of humans exposed to cadmium in food and water. The critical effect was proteinuria and 10-fold safety factor was applied to the NOAEL of 0.005 mg/kg/day. EPA assigned a high level of confidence to the database and the RfD (EPA, 2004a).

[15] IARC (2004a) has placed cadmium and cadmium compounds in Group 1 (Carcinogenic to humans). The National Toxicology Program (NTP, 2002a) has also concluded that cadmium and cadmium compounds are reasonably anticipated to carcinogenic to humans.

[16] Cadmium is classified as a probable human carcinogen (B1) based on limited evidence of carcinogenicity in humans and sufficient evidence in animals. The inhalation unit risk value is based upon a study of occupational exposure to cadmium.

[17] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for cadmium is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

[18] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Chlordane

Background: Chlordane[19] (CAS 57-74-9) is one of several chlorinated cyclodiene insecticides derived from hexachlorocyclopentadiene. Chlordane is a broad spectrum contact insecticide that was primarily used on agricultural crops including vegetables, small grains, maize, potatoes, sugar beets, fruits and nuts. It was also extensively to control termites. The Environmental Protection Agency suspended the registrations for agricultural crops in 1976 and banned the importation and manufacture of chlordane in 1988.

Chlordane has been found in fish tissue[20] and sediment[21] samples collected in Washington. Chlordane has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

Chlordane has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998a), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of chlordane.

- ***Persistence****:* Mackay et al. (1997) published recommended half life values for chlordane in surface water (@ 2 years), soils (@ 2 years) and sediments (@ 6 years). These values are consistent with the range of soil half-life values (0.4 – 8 years) considered by EPA when deciding whether to include chlordane among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). This is also consistent with the range of half life values (283 days – 3.8 years) reported in EPA (2000a). EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 6682 hours.

- ***Bioaccumulation****:* EPA (1998) evaluated the range of bioaccumulation factors/bioconcentration factors available for chlordane and used a BCF value of 21,877 to characterize the bioaccumulation potential of this substance. This value is based on a measured bioconcentration factor included in the Syracuse Research Corporation BCF database file. EPA (1999a) used a BCF value of 11,050 to characterize the bioaccumulation potential of chlordane when evaluating whether to include chlordane on the list of PBT chemicals for purposes of reporting pursuant to the Toxics Release Inventory (TRI) program. In addition, EPA (1999a) listed a BAF value (> 6,000,000) for piscivorous fish. Ritter et al. (1996) reported bioconcentration factors of 37,800 and 16,000 for fathead minnows and sheepshead minnows, respectively. These values are consistent with the range BAF values

[19] 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene.
[20] SAIC (2001) compiled readily available fish tissue data and found that @ 19 percent of fish tissue samples analyzed for chlordane contained measurable amounts of chlordane.
[21] SAIC (2001) compiled readily available sediment data and found that 9-10 percent of marine sediment samples analyzed for chlordane contained measurable amounts of chlordane.

summarized in EPA (2000a). The OSPAR fact sheet for chlordane identifies Log K_{ow} values ranging from 3 to 7 and BCF values ranging from 990 to 12,303 (OSPAR, 2004d).

- ***Toxicity (Non-cancer)****:* Exposure to chlordane is associated with a wide range of adverse health effects (e.g. liver damage, central and peripheral nervous system damage, etc.) EPA has established an oral RfD value (0.00006 mg/kg/day[22]) that is published in the IRIS database (EPA, 2004a). OSPAR (2004e) has identified chlordane as a potential endocrine disruptor.

- ***Toxicity (Cancer)****:* EPA has classified chlordane as a probable human carcinogen (Group B2)[23]. EPA has established an oral cancer slope factor of 1.3 $(mg/kg/day)^{-1}$ that is published in the IRIS database (EPA, 2004a).

- ***Ecological Toxicity****:* Chlordane is very toxic to aquatic organisms. EPA has established an AWQC FCV (0.000004 mg/L) that was developed by EPA's Office of Water.[24] OSPAR appears to have used a NOEC value (0.0003 mg/L) from a chronic fish toxicity test to characterize the toxicity of chlordane for purposes of determining whether chlordane should be identified as a PBT chemical on the List of Substances of Possible Concern (OSPAR, 2004e)

Conclusions: Ecology has determined that chlordane meets the draft PBT criteria specified in WAC 173-333-320.

[22] The RfD value was based on a chronic feeding study in rats. The critical effect was liver toxicity and 1000-fold safety factor was applied to the LOAEL of 0.025 mg/kg/day. EPA assigned a medium level of confidence to the study, the database and the RfD.
[23] IARC (2004a) has placed chlordane in Group 2B (Possibly carcinogenic to humans).
[24] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996). EPA (1998b) also identified available information from the OPPT (Measured Chronic data = 0.0158 mg/L)

Chlordecone (Kepone)

Background: Chlordecone[25] (CAS 143-50-0) is a chlorinated insecticide that was used on tobacco, ornamental shrubs, bananas, and citrus trees, and in ant and roach traps. Chlordecone also occurs as a degradation product of Mirex. EPA banned the importation and manufacture of chlordecone in 1978.

Chlordecone has been identified as a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Potential Concern (OSPAR, 2004). The United Nations Economic Commission for Europe is currently evaluating whether to include chlordecone on the list of persistent organic pollutants under the Stockholm Convention. Chlordecone was also identified as a regionally-specific persistent toxic substance in the North America Regional Report (UNEP, 2002).

Listing Considerations*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of chlordecone.

- ***Persistence***: UNEP (2002) estimates that chlordecone has a half-life of 1-2 years in soils. The Swedish Chemical's Inspectorate/EPA (2004) concluded that chlordecone was likely to be highly persistent because of the continued widespread occurrence of chlordecone in soil and birds in areas where chlordecone was previously used and by an estimated half-life of 2-5 months in humans.

- ***Bioaccumulation:*** Chlordecone has a relatively high fat solubility (log K_{ow} 4.5 – 6). ATSDR (1995) reported that chlordecone has been shown to have a very high bioaccumulation potential in fish and other aquatic organisms. ATSDR (1995a) summarized BCF ranges for Atlantic menhaden (2,300 – 9,500), Atlantic silver sides (21,700-60200), oyster (6918-10,000), mysids (13,000), grass shrimp (11,000), sheepshead minnows (7,000) and spot (3,000). The Swedish Chemical's Inspectorate/Environmental Protection Agency (2002) reported that studies in marine fish species have given BCF-values between 1,800 and 7,100. The OSPAR fact sheet for chlordecone (2004f) identifies BCF values that range from 800 to 60,200.

- ***Human Toxicity (Non-Cancer)*:** Based on studies in exposed workers and animal bioassays, exposure to chlordecone has been associated with a wide range of harmful effects on the nervous system, skin, liver, kidney and reproductive system. ATSDR (1995a) has established Minimal Risk levels for acute exposure (0.01 mg/kg/day) and intermediate/chronic exposure (0.0005 mg/kg/day). The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2002) hypothesized that reproductive toxicity may be due to hormonal effects and the OSPAR Commission identified chordecone as a potential endocrine disrupter.

[25] 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-1,3,4-metheno-2H-cyclobuta(cd)pentalen-2-one.

- ***Human Toxicity (Cancer)***: IARC (2004a) has classified chlordecone as possibly carcinogenic in humans (Group 2B) based on increased incidence of liver tumours are observed in mice and rats.

- ***Ecological Toxicity*:** Chlordecone is very toxic to aquatic organisms. The Swedish Chemicals Inspectorate/EPA (2002) concluded that the acute toxicity of chlordecone is high in algae (7-days EC_{50} <1 µg/l in four species) and fish (96 h $LC_{50} \leq 70$ µg/l in four species). OSPAR identified a NOEC value (0.000013 mg/L) from a chronic fish toxicity test and used that value to characterize the toxicity of chlordecone for purposes of determining whether chlordecone should be identified as a PBT chemical on the List of Substances of Possible Concern (OSPAR, 2004f)

Conclusions: Ecology has determined that chlordecone meets the draft PBT criteria specified in WAC 173-333-320.

DDT

Background: DDT[26] (CAS 50-29-3) is a chlorinated insecticide that has been extensively used throughout the world on a variety of agricultural crops and for the control of malaria, typhus and other insect-transmitted diseases. At the height of its use in the United States (@ 1963), DDT was registered for use on 334 agricultural commodities. DDT was banned for all but essential public health use in the United States on January 1, 1973.

DDT has been found in fish tissue[27] and sediment[28] samples collected in Washington. DDT has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

DDT has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a), a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

Listing Considerations: Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of DDT.

- *Persistence:* Mackay et al. (1997) published average half life values for DDT in surface water (@8 months), soils (@ 2 years) and sediments (@ 6 years). These values are consistent with the range of soil half-life values (2 – 15.6 years) for DDT and its breakdown products (DDD and DDE) that are listed in EPA (2000a). EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 36,422 hours.

- *Bioaccumulation:* EPA (1998b) evaluated the range of BCF/BAF values available for DDT and used a BCF value of 29,152[29] to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This value is also consistent with the range of BCF values for DDT currently included in EPA's ECOTOX database (EPA, 2002c) and the bioaccumulation factors and biota-sediment accumulation factors (BSAFs) summarized in EPA (2000a).

[26] 2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane.
[27] SAIC (2001) compiled readily available fish tissue data and found that @ 69 percent of fish tissue samples analyzed for DDT contained measurable amounts of this substance.
[28] SAIC (2001) compiled readily available sediment data and found that perc 90-100 percent of marine sediment samples analyzed for DDT contained measurable amounts of this substance.
[29] EPA (1998b) also listed BCF values for DDD (8,709) and DDE (51,286). The value for DDD is an estimated BCF value predicted using BCFWin (a bioconcentration factor estimation program developed by Syracuse Research Corporation). The value for DDE is based on a measured bioconcentration factor included in the Syracuse Research Corporation BCF database file.

- *Toxicity (Non-cancer):* Exposure to DDT is associated with a wide range of neurological and hepatic effects. EPA has established an oral RfD value (0.0005 mg/kg/day)[30] that is published in the IRIS database.

- *Toxicity (Cancer)*: EPA has classified DDT as a probable human carcinogen (Group B2).[31] EPA has established an oral cancer slope factor of 0.34 $(mg/kg/day)^{-1}$ that is published in the IRIS database (EPA, 2004a).

- *Ecological Toxicity:* DDT is highly toxic to aquatic organisms. EPA has published an AWQC FCV (0.000001 mg/L) that was developed by EPA's Office of Water (EPA, 1996a)[32] and a Tier II Secondary Chronic Value (SCV)[33] of 0.00001 mg/L that was developed as part of the Great Lakes Water Quality Initiative (EPA, 1995a).

Conclusions: Ecology has determined that DDT meets the draft PBT criteria specified in WAC 173-333-320.

[30] The RfD value was based on the results from a 27-week rat feeding study. The critical effect was liver lesions and a 100-fold uncertainty factor was applied to the NOEL of 0.05 mg/kg/day. EPA assigned a medium level of confidence to the study, the database, and the RfD.
[31] IARC (2004a) has placed DDT in Group 2B (Possibly carcinogenic to humans).
[32] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996).
[33] The source document for the Tier II SCV value for DDT is the Technical Support Document for the Hazardous Waste Identification Rule (HWIR) Risk Assessment.

Dieldrin

Background: Dieldren[34] (CAS 60-57-1) is one of several chlorinated insecticides derived from hexachlorocyclopentadiene. Cyclodiene insecticides were primarily used as (1) pre-emergence soil insecticides for the control of corn root worms, wireworms, etc., (2) as seed treatments, (3) as soil poisons to control beetles, termites and ants, and (4) in specific public health situations – to control disease carriers like mosquitoes and tsetse flies. The Environmental Protection Agency banned the importation and manufacture of dieldrin in 1974.

Dieldrin has been found in fish tissue[35] and sediment[36] samples collected in Washington. Dieldrin has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

Dieldrin has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a), a persistent organic pollutant (POP) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on (1) the persistence, bioaccumulation potential and toxicity for dieldrin.

- *Persistence:* Mackay et al. (1997) published recommended half life values for dieldrin in surface water (@ 2 years), soils (@ 2 years) and sediments (@ 6 years). These values are consistent with the range of soil half-life values (175 days – 3 years) listed in EPA (2000a).[37] EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 1366 hours.

- *Bioaccumulation:* EPA (1998b) evaluated the range of bioaccumulation factors/bioconcentration factors available for dieldrin and used a BCF value of 4,466 to characterize the bioaccumulation potential of this substance. This value is based on a measured bioconcentration factor included in the Syracuse Research Corporation BCF database file. This value is consistent with the range of BCF values summarized in EPA (2000a). The OSPAR fact sheet for dieldrin identifies a range of Log K_{ow} values (3 to 6) and BCF values ranging from 1,995 to 115,000 (OSPAR, 2004g).

- *Toxicity (Non-cancer):* Exposure to dieldrin is associated with a wide range of adverse health effects (e.g. liver damage, central and peripheral nervous system damage, etc.) EPA has established an oral RfD value (0.00003 mg/kg/day)[38] that is published in the IRIS

[34] 6,7-epoxy aldrin.
[35] SAIC (2001) compiled readily available fish tissue data and found that @ 6 percent of fish tissue samples analyzed for dieldrin contained measurable amounts of this substance.
[36] SAIC (2001) compiled readily available sediment data and found that @ 6 percent of marine sediment samples analyzed for dieldrin contained measurable amounts of this substance.
[37] EPA (2000a) states that "…dieldrin is one of the most persistent of the chlorinated hydrocarbons and is highly resistant to biodegradation and abiotic degradation…" (p. 382)
[38] The RfD value was based on the results of a two-year rat feeding study. The critical effect was liver lesions and 100-fold uncertainty factor was applied to the NOAEL of 0.005 mg/kg/day. EPA assigned a low level of confidence to the study and a medium level of confidence to the database and the RfD. (EPA, 2004a)

database (EPA, 2004a). ATSDR (2004a) has established Minimal Risk Levels for dieldrin for intermediate exposures (0.0001 mg/kg/day) and chronic exposures (0.00005 mg/kg/day). The OSPAR Commission (2004g) has identified dieldrin as a potential endocrine disruptor.

- *Toxicity (Cancer):* EPA has classified dieldrin as a probable human carcinogen (B2). EPA has established an oral cancer slope factor (16 $(mg/kg/day)^{-1}$) that is published in the IRIS database (EPA, 2004a).[39]

- *Ecological Toxicity:* Dieldrin is very toxic to aquatic organisms. EPA has established (1) a Sediment Quality Tier I FCV[40] (0.000062 mg/L),(2) a Tier I Final Chronic Value (FCV) (0.000557 mg/L) developed through the Great Lakes Water Quality Initiative [41] and (3) an AWQC FCV (0.000002 mg/L) developed by EPA's Office of Water.[42] OSPAR appears to have used an EC50 value (0.0002 mg/L) from an acute fish toxicity test to characterize the toxicity of dieldrin for purposes of determining whether dieldrin should be identified as a PBT chemical on the List of Substances of Possible Concern (OSPAR, 2004g)

Conclusions: Ecology has determined that dieldrin meets the draft PBT criteria specified in WAC 173-333-320.

[39] Dieldrin is classified as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity in animals The cancer slope factor was calculated using the linearized multistage procedure based on increased rates of liver carcinoma in mice. (EPA, 2004a)
[40] The Sediment Quality Tier I FCV values are compiled in Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996a)
[41] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for dieldrin is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).
[42] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996a)

Endrin

Background: Endrin[43] (CAS 72-20-8) is one of several chlorinated insecticides derived from hexachlorocyclopentadiene. Cyclodiene insecticides were primarily used as (1) pre-emergence soil insecticides for the control of corn root worms, wireworms, etc., (2) as seed treatments, (3) as soil poisons to control beetles, termites and ants, and (4) in specific public health situations – to control disease carriers like mosquitoes and tsetse flies. The Environmental Protection Agency banned the importation and manufacture of endrin in 1976.

Endrin has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a), a persistent organic pollutant (POP) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for endrin.

- *Persistence:* EPA (1998b) estimated half life values for endrin in surface water (60 days), soils (60 days) and sediments (240 days) using the Ultimate Source Model and HYDROWIN computer program. EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 34,732 hours. The OSPAR Commission (2004h) characterized endrin as "not readily biodegradable" and UNEP Chemicals (UNEP, 2002) stated that endrin "...[i]s highly persistent in soils (half-lives of up to 12 years have been reported in some cases)..."

- *Bioaccumulation:* EPA (1998b) evaluated the range of BCF/BAF values for endrin and used a BCF value of 4,571 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This value is also consistent with the range of BCF values for endrin currently included in EPA's ECOTOX database (EPA, 2004b) and the bioaccumulation factors and biota-sediment accumulation factors (BSAFs) summarized in EPA (2000a). The OSPAR Commission (2004h) identified BCF values ranging from 1,995 to 49,218.

- *Toxicity (Non-cancer):* Exposure to endrin is associated with a wide range of neurological effects. EPA has established an oral RfD value (0.0003 mg/kg/day) that is published in the IRIS database (2004a). ATSDR (1996a) has established Minimal Risk Levels for endrin for intermediate exposures (0.002 mg/kg/day) and chronic exposures (0.0003 mg/kg/day).

- *Toxicity (Cancer)*: EPA (2004a) reviewed the evidence for carcinogenicity and concluded that endrin is not classifiable as to human carcinogenicity (D).

- *Ecological Toxicity:* Endrin is very toxic to aquatic organisms. EPA has published an AWQC FCV (0.0000023 mg/L) that was developed by EPA's Office of Water.

Conclusions: Ecology has determined that endrin meets the draft PBT criteria specified in WAC 173-333-320.

[43] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo-1,4-endo-5,8-dimethanonaphthalene..

Heptachlor/Heptachlor epoxide

Background: Heptachlor[44] (CAS 76-44-8) is one of several chlorinated insecticides derived from hexachlorocyclopentadiene. Heptachlor is transformed into heptachlor epoxide[45] (CAS 1024573) when released into the environment. Cyclodiene insecticides were primarily used as (1) pre-emergence soil insecticides for the control of corn root worms, wireworms, etc., (2) as seed treatments, (3) as soil poisons to control beetles, termites and ants, and (4) in specific public health situations –to control disease carriers like mosquitoes and tsetse flies. The Environmental Protection Agency suspended the registrations for agricultural crops in 1976 and banned the importation and manufacture of heptachlor in 1988.

Heptachlor/heptachlor epoxide have been found in fish tissue[46] and sediment[47] samples collected in Washington. Heptachlor has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

Heptachlor/heptachlor epoxide has been identified as a Level II substance under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998a), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for heptachlor/heptachlor epoxide.

- *Persistence:* Heptachlor is metabolized in soils, plants and animals to heptachlor epoxide which is more persistent in the environment. Mackay et al. (1997) includes suggested half life values for heptachlor in surface water (@ 21 days), soils (@ 60 days) and sediments (@ 240 days). EPA (1999a) used a range of soil half-life values (1.5 – 20 years) to characterize the persistence of heptachlor/heptachlor epoxide when deciding whether to include heptachlor among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). EPA (2000a) stated that "….heptachlor is resistant to degradation and, therefore, persistent in the environment...". EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 2,545 hours.

- *Bioaccumulation:* EPA (1998b) evaluated the range of BAF/BCF values available for heptachlor epoxide and used a BCF value of 14,454 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This value is consistent with the value (19,953) that EPA used when deciding whether to include heptachlor among the substances identified

[44] 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanondene.
[45] 1,4,5,6,7,8,8-heptachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanondene
[46] SAIC (2001) compiled readily available fish tissue data and found that @ 15 percent of fish tissue samples analyzed for heptachlor contained measurable amounts of this substance.
[47] SAIC (2001) compiled readily available sediment data and found that @ 1 percent of marine sediment samples analyzed for heptachlor contained measurable amounts of this substance.

as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). This value is also consistent with the range of BCF values currently included in EPA's ECOTOX database (EPA, 2002b) and BCF values summarized in EPA (2000a).

- *Toxicity (Non-cancer):* Exposure to heptachlor/heptachlor epoxide is associated with a wide range of adverse health effects (e.g. liver damage, central and peripheral nervous system damage, etc.) EPA has established an oral RfD value (0.000013 mg/kg/day)[48] that is published in the IRIS database (EPA, 2004a).

- *Toxicity (Cancer):* EPA has classified heptachlor and heptachlor epoxide as probable human carcinogens (B2). EPA has established oral cancer slope factors for heptachlor (4.5 $(mgkg/day)^{-1}$) and heptachlor epoxide (9.1 $(mg/kg/day)^{-1}$) that are published in the IRIS database (EPA, 2004a).[49]

- *Ecological Toxicity:* Heptachlor and heptachlor epoxide are very toxic to aquatic organisms. EPA has published a Tier II Secondary Chronic Value (FCV) (0.0005 mg/L) developed through the Great Lakes Water Quality Initiative [50] and an AWQC FCV (0.000004 mg/L) developed by EPA's Office of Water.[51]

Conclusions: Ecology has determined that heptachlor/heptachlor epoxide meet the draft PBT criteria specified in WAC 173-333-320.

[48] The RfD value was based on the results of a 60-week dog feeding study. The critical effect was increased liver-to-body weight ratios in males and females and 1000-fold uncertainty factor was applied to the LEL of 0.0125 mg/kg/day. EPA assigned a low level of confidence to the study and the RfD and a medium level of confidence to the database. (EPA, 2004a)

[49] Heptachlor epoxide is classified as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity in animals. The cancer slope factor was calculated using the linearized multistage procedure based on increased rates of liver carcinomas in mice. (EPA, 2004a)

[50] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for cadmium is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

[51] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Hexabromobiphenyl

Background: Hexabromobiphenyl (CAS 67774-32-7) is one of several technical products that are included in broader category of polybrominated biphenyls (PBBs) (CAS 59536-65-1). [52] These products were formerly used as brominated flame retardants in synthetic fibers and molded plastics. The sole U.S. producer of hexabromobiphenyl ceased production in November 1974. The Swedish Chemical's Inspectorate/Environmental Protection Agency concluded that hexabromobiphenyl is not currently used in consumer products, but may still be present in older products. (SCI/SEPA, 2002).

Hexabromobiphenyl is currently identified as a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b). The United Nations Economic Commission for Europe is currently evaluating whether to include hexabromobiphenyl on the list of persistent organic pollutants under the Stockholm Convention. Hexabromobiphenyl was also identified as a regionally-specific persistent toxic substance in the North America Regional Report (UNEP, 2002).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of hexabromobiphenyl.

- *Persistence:* WHO (1994) concluded that PBBs are stable and persistent in the environment. EPA (1998b) estimated half life values for hexabromobiphenyl in surface water (60 days), soils (60 days) and sediments (240 days) using the Ultimate Source Model and HYDROWIN computer program. EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 34,732 hours. The Swedish Chemicals Inspectorate/Environmental Protection Agency (2002) concluded that hexabromobiphenyl is persistent in all media with half-lives ranging from weeks to several years.
- *Bioaccumulation:* WHO (1994) concluded that PBBs are lipophilic and, when released to the environment, are able to bioconcentrate in the food chain. EPA (1998b) evaluated the range of available BAF/BCF values and used a BCF value of 18,197 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF value included in the Syracuse Research Corporation BCF database file. The Swedish Chemical's Inspectorate/Environmental Protection Agency (2002) reviewed the information on hexabromobiphenyl and concluded that hexabromobiphenyl has a very high lipophilicity (Log K_{ow} = 7) and BCF values well above 5000.
- *Toxicity (Non-cancer):* PBBs are structural analogues to the chlorinated dioxins and, consequently, very toxic to most mammals after repeated exposure. Hexabromobiphenyl is one of three technical products included within the polybrominated biphenyl (PBBs) group. A wide range of adverse effects have been reported in animal studies: reproductive toxicity; developmental toxicity; immunotoxicity; and toxicity to the liver, thyroid and skin EPA has established an oral RfD (0.000007 mg/kg/day) for polybrominated biphenyls that is published in the HEAST database (EPA, 1997). ATSDR (2002) has established a draft acute Minimal Risk Level (MRL) for polybrominated biphenyls (0.01 mg/kg/day) based on endocrine effects.

[52] Polybrominated biphenyl mixtures also include octabromobiphenyl (CAS 61288-13-9) and decabromobiphenyl (CAS 13654-09-6).

- *Toxicity (Cancer)*: EPA has classified PBBs as a probable human carcinogen (B2) and established a cancer slope factor (8.9 (mg/kg/day)-1) which is published in the HEAST database (EPA, 1997). IARC (2004a) has classified hexabromobiphenyl as a possible human carcinogen (IARC group 2B).

- *Ecological Toxicity*: Hexabromobiphenyl is predicted to be very toxic to aquatic organisms. EPA (1998b) includes a geometric mean maximum acceptable toxicant concentration (GMATC) of 0.00004 mg/L based on structure-activity relationships.

Conclusions: Ecology has determined that hexabromobiphenyl meets the draft PBT criteria specified in WAC 173-333-320.

Hexabromocyclododecane

Background: Hexabromocyclododecane (CAS No. 25637-99-4) is a brominated flame retardant. The National Academy of Sciences (NAS, 2000) stated that it is used primarily in expanded polystyrene foams and other styrene resins. NAS also states the this substance is also used in latex binders, unsaturated polyesters and polyvinyl chloride wire, cable and textile coatings.

Hexabromocyclodocane is currently identified as a PBT chemical on the OSPAR Commission's List of Chemicals for Priority Action (OSPAR, 2004a). The United Nations Economic Commission for Europe is currently evaluating whether to include hexabromocyclododecane on the list of persistent organic pollutants under the LRTAP and Stockholm Conventions.

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of hexachlorocyclododecane:

- ***Persistence****:* EPA (1998b) estimated half life values for hexabromocyclodocane in surface water (38 days), soils (38 days) and sediments (150 days) using the Ultimate Source Model and HYDROWIN computer program. EPA (1998b) also used the EQC multi-media model to estimate a regional half-life of 1742 hours. The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2002) reviewed available information and concluded that hexabromocyclodocane is not readily biodegradable[53].

- ***Bioaccumulation:*** EPA (1998b) evaluated the range of available BAF/BCF values and used a BCF value of 11,220 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This is consistent with the information identified by the Swedish Chemical's Inspectorate/Environmental Protection Agency (2002) who concluded that this substance meets the United Nation's bioaccumulation criteria (BCF > 5000) based on the results of two fish studies where BCF values of 9,000-18,000 were reported.

- ***Toxicity (Non-cancer)****:* The National Academy of Sciences (NAS 2000) reviewed the available toxicological information on hexabromocyclododecane. Based on the results from several animal bioassays, the NAS panel concluded that exposure to elevated levels of hexabromocyclododecane is associated with increased liver weights and abnormal fatty accumulation in the liver. They also found evidence that suggests that hexabromocyclododecane may affect the thyroid and may also be a mild skin irritant and allergen. The NAS panel calculated an oral RfD (0.2 mg/kg/day) based on a LOAEL of 925 mg/kg/day for increased liver weights and application of an uncertainty factor of 3000. The Swedish Chemical's Inspectorate/Environmental Protection Agency also reported that repeated exposure to hexabromocyclododecane is associated with liver and thyroid effects, but concluded that no conclusive NOAEL can be set.

[53] The Chemical's Inspectorate/Environmental Protection Agency concluded that they were not able to reach a conclusion on whether this substance meets the persistence criteria used by the United Nations. They noted that the European Union is currently (as of November 2002) conducting simulation half life studies that will allow a conclusion on whether the criterion is met or not. However, they noted that the presence of hexabromocyclodocane in different environmental samples (sewage treatment plants, soil, fish, birds, and seals) supports a relatively high persistence.

- ***Toxicity (Cancer)****:* No information was found in readily-available information sources.

- ***Ecological Toxicity****:* Hexabromocyclododecane is predicted to be toxic to aquatic organisms. EPA (1998b) includes a geometric mean maximum acceptable toxicant concentration (GMATC) of 0.009 mg/L based on structure-activity relationships. This is consistent with findings and conclusions reached by the Swedish Chemical's Inspectorate/Environmental Protection Agency (2002) who reported that hexabromocyclododecane affects the growth of algae (*Skeletonema costatum*, EC_{50} (72 h) = 11 µg/l) and growth, reproduction, and survival of *Daphnia magna* (NOEC (3 ug/L)).

Conclusions: Ecology has determined that hexabromocyclododecane meets the draft PBT criteria specified in WAC 173-333-320.

Hexachlorobenzene

Background: Hexachlorobenzene (CAS 118-74-1) was formerly used as a pesticide to protect the seeds of onions, sorghum, and wheat against fungus until 1965. Currently, there are no commercial uses in the US, but it is a by-product from making other chemicals.

Hexachlorobenzene has been found in fish tissue[54] and sediment[55] samples collected in Washington. Hexachlorobenzene has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b). Based on information in the National Toxics Inventory, SAIC (2001) estimated that 424 lbs/year of hexachlorobenzene is released by Washington sources.

Hexachlorobenzene has been identified as a Level I substance under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998a), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for hexachlorobenzene.

- ***Persistence****:* Mackay et al. (1991) published average environmental half life values for hexachlorobenzene in surface water (@ 6 years), soils (@ 6 years) and sediments (@ 6 years). Howard et al. (1990) lists a sediment half-life (@5,000 days). These values are consistent with the range of soil half-life values (1.5 – 20 years) considered by EPA when deciding whether to include hexachlorobenzene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 18,757 hours.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for hexachlorobenzene and used a BCF value of 18,620 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. EPA (1999a) listed a range of BCF values (29,600 – 66,000) and a bioaccumulation factor for piscivorous fish (> 2,500,000) when deciding whether to include hexachlorobenzene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). This value is consistent with the range of BCF values currently included in EPA's ECOTOX database (EPA, 2002c).

[54] SAIC (2001) compiled readily available fish tissue data and found that @ 4 percent of fish tissue samples analyzed for hexachloroabenzene contained measurable amounts of hexachlorobenzene.
[55] SAIC (2001) compiled readily available sediment data and found that @ 8 percent of marine sediment samples analyzed for hexachlorobenzene contained measurable amounts of hexachlorobenzene.

- ***Toxicity (Non-cancer)****:* Exposure to hexachlorobenzene is associated with a wide range of adverse health effects (e.g. immune system, nervous system, liver damage, reproductive effects, etc.). EPA has established an oral RfD value (0.0008 mg/kg/day)[56] that is published in the IRIS database (EPA, 2004a).

- ***Toxicity (Cancer)****:* EPA has classified hexachlorobenzene as a probable human carcinogen (B2) and established an oral cancer slope factor (1.6 $(mg/kg/day)^{-1}$) that is published in the IRIS database (EPA, 2004a).

- ***Ecological Toxicity***: Hexachlorobenzene is toxic to aquatic organisms. The AQUIRE database lists an EC50 (0.016 mg/L) based on reproductive effects observed in a 14-day study with daphnia. EPA (1998b) also includes ECOSAR concentrations for chronic (0.012 mg/L) and acute (0.000911 mg/L) exposures. UNEP (2002) states that LC50 for fish vary between 50 and 200 ug/L (0.05 to 0.2 mg/L) and the OSPAR Commission fact sheet for hexachlorobenzene (OSPAR, 2004j) reports acute toxicity algae IC50 values (0.002 – 0.03 mg/L), acute toxicity daphnia EC50 (0.0006 to 10 mg/L), acute toxicity fish LC50 (0.0075 to 12 mg/L), chronic toxicity daphnia NOEC (0.005 and 0.0013 mg/L) and chronic toxicity fish NOEC (0.00476 to 32 mg/L).

Conclusions: Ecology has determined that hexachlorobenzene meets the draft PBT criteria specified in WAC 173-333-320.

[56] The RfD value was based on the results of a two-year rat feeding study. The critical effect was liver lesions and 100-fold uncertainty factor was applied to the NOAEL of 0.005 mg/kg/day. EPA assigned a low level of confidence to the study and a medium level of confidence to the database and the RfD. (EPA, 2001a)

Hexachlorobutadiene

Background: Hexachlorobutadiene (CAS 87-68-3) is formed mainly as a by-product during the manufacture of certain chlorinated hydrocarbons. It is used as a chemical intermediate in the manufacture of rubber compounds, and in lesser amounts as a solvent, heat transfer liquid, and hydraulic fluid. Hexachlorobutadiene has also been used in the past as a fumigant.

Hexachlorobutadiene has been found in fish tissue[57] and sediment[58] samples collected in Washington. Hexachlorobutadiene has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b). Based on information in the National Toxics Inventory, SAIC (2001) estimated that Washington sources released 2 lbs/year of hexachlorobutadiene during 1999.

Hexachlorobutadiene has been identified as a PBT chemical under EPA's Waste Minimization Program (EPA, 1998d), a bioaccumulative chemical of concern pursuant to EPA water quality guidance for the Great Lakes (EPA, 1995a), a Level II substance under the Bi-National Toxics Strategy (GLNPO, 1997) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b). The United Nations Economic Commission for Europe is currently evaluating whether to add hexachlorobutadiene to the list of persistent organic pollutants under the Stockholm and LRTAP Conventions.

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for hexachlorobutadiene.

- *Persistence:* Howard et al. (1990) include environmental half-life values for hexachorobutadiene in surface water (28 - 180 days), soil (28-180 days) and sediments (284 days). EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 4,506 hours.[59]

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for hexachlorobutadiene and used a value of 6,918 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This value is consistent with, but somewhat higher than, the BAF values used by EPA to update the ambient water quality criteria for hexachlorobutadiene. In that analysis, EPA used BAF values of 1,518, 2,389 and 1,294 for trophic levels two, three and four, respectively (EPA, 1998e).[60] The OSPAR fact sheet for

[57] SAIC (2001) compiled readily available fish tissue data and found that @ 2 percent of fish tissue samples analyzed for hexachlorobutadiene contained measurable amounts of hexachlorobutadiene.
[58] SAIC (2001) compiled readily available sediment data and found that @ 4 percent of marine sediment samples analyzed for hexachlorobutadiene contained measurable amounts of hexachlorobutadiene.
[59] Test data regarding degradability is scarce and the estimations reported in the "Preliminary Risk Profile" document cannot clarify the picture. Accordingly, that document reaches the conclusion that insufficient evidence is available on the persistence of hexachlorobutadiene but that the substance probably is recalcitrant to biodegradation under aerobic conditions (2). This assumption could also be supported by the relative abundance of monitoring data as regards hexachlorobutadiene. The substance can be found in different compartments of the environment including biota, primarily in industrial regions but has also been detected in biota in northern Canada (2).
[60] The Swedish EPA (2004) recommended using a Kow value 4.9 to characterize the bioaccumulation potential of HBCD which they concluded indicates a high potential for bioaccumulation. They stated that although just below

hexachlorobutadiene identifies a range of Log K_{ow} values (3 to 5) and BCF values ranging from 435 to 29,000 (OSPAR, 2004j).

- ***Toxicity (Non-cancer)****:* Hexachlorobutadiene has been shown to cause kidney damage in mice and rats. EPA has established an oral RfD value (0.0002 mg/kg/day) that is published in the HEAST database (EPA, 1997)[61]. ATSDR (2004a) has established a Minimal Risk Level for chronic oral exposure (0.0002 mg/kg/day) that is based on increased incidence of kidney damage observed in animal studies.

- ***Toxicity (Cancer)****:* EPA has classified hexachlorobutadiene as a possible human carcinogen (WOE = C) and established a cancer slope factor ($(0.078\ mg/kg/day)^{-1}$) that is published in the IRIS database (EPA, 2004a). IARC has placed hexachlorobutadiene in Group 3 (not classifiable as to human carcinogenicity).

- ***Ecological toxicity****:* Hexachlorobutadiene is toxic to aquatic organisms. The AQUIRE database lists an acute LC50 (0.09 mg/L) based on in a four-day study with goldfish. EPA (1998b) includes a geometric mean maximum acceptable toxicant concentration (GMATC) of 0.089 mg/L that is based on structure-activity relationships. The Swedish Chemical's Inspectorate/Environmental Protection Agency (2004) concluded aquatic toxicity has been shown to be very high based on studies representing several different groups of organisms. They reported the lowest acute LC_{50} value available is 0.032 mg/l for crustaceans and the lowest NOEC value is 0.0065 mg/l for fish. The OSPAR Commission (2004j) concluded hexachlorobutadiene is toxic/very toxic to aquatic organisms based on acute toxicity algae IC50 values (1.194 and 10 mg/L), acute toxicity daphnia EC50 values (0.059 to 1.2 mg/L), acute toxicity fish LC50 values (0.09 to 470 mg/L), a chronic toxicity NOEC value for daphnia (0.234 mg/L) and chronic toxicity NOEC values for fish (0.005 – 0.03 mg/L).

Conclusions: Ecology has determined that hexachlorobutadiene meets the draft PBT criteria specified in WAC 173-333-320.

the limit of the screening criterion of the Stockholm Convention, there are several bioaccumulation studies confirm a high level of bioaccumulation of hexachlorobutadiene, showing BCF values of up to 19,000, clearly fulfilling the bioaccumulation criterion.

[61] EPA published an oral reference dose (0.0002 mg/kg/day) in the IRIS database in 1991. However, EPA withdrew that value in May, 1993 as a result of further review.

Lead

Background: Lead is a naturally occurring element used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield x-rays. Due to health concerns, lead from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years.

Lead has been found in fish tissue[62] and sediment[63] samples collected in Washington. Lead has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b). Based on information in the National Toxics Inventory, SAIC (2001) estimated that Washington sources released 284,981 lbs of lead into the atmosphere during 1999.

Lead and/or lead compounds have been identified as a Level I substance (alkyl-lead) under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals (alkyl-lead) identified by EPA (EPA, 1998b) and a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of lead.

- ***Persistence****:* Lead does not break down in the environment, but it may be affected by physical and chemical processes that modify its mobility, bioavailability, and residence time in different environmental media. EPA (1998b) assigned a persistence score of three to lead and lead compounds.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for lead and used a BCF value of 1,700 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF used by EPA when preparing the ambient water quality criteria document for lead (EPA, 1985). This value is consistent with the range of BCF values included in EPA's ECOTOX database (EPA, 2002c).[64]

- ***Toxicity (Non-cancer)****:* Lead poisoning is considered to be the most common and serious environmental problem affecting young children in the United States (CDCP, 2003). Infants and small children are particularly vulnerable to the effects of lead poisoning because lead can adversely affect the development of the brain and nervous system. Studies performed over the last 25 years indicate that blood lead concentrations above 10 ug/dL are associated with adverse impacts on intellectual development and social behavior. Such studies led the Centers for Disease Control and Prevention (CDCP) and the World Health Organization

[62] SAIC (2001) compiled readily available fish tissue data and found that @ 10 percent of fish tissue samples analyzed for lead contained measurable amounts of lead.
[63] SAIC (2001) compiled readily available sediment data and found that @ 80 percent of marine sediment samples analyzed for lead contained measurable amounts of lead.
[64] EPA (200a) concluded that "…the amount of bioavailable lead in sediment is controlled, in large part, by the concentration of acid volatile sulfides (AVS) and organic matter [3, 4, 5]. Lead is accumulated by aquatic organisms equally from water and dietary exposure [6]. In sediments, a portion of lead can be transformed to trimethyllead and tetraalkyllead compounds through chemical and microbial processes. The organolead compounds are much more toxic to aquatic organisms than are the inorganic lead compounds [7]. Bioaccumulation of organolead compounds is rapid and high; these compounds concentrate in the fatty tissues of aquatic organisms…."

(WHO) to identify a blood lead concentration of 10 ug/dL or higher as a "level of concern" (CDC, 1991; WHO, 1995). Research findings published since 1991 suggest that adverse effects from lead exposure occur at blood lead concentrations below 10 ug/dL (Canfield et al. 2003; Schwartz 1994; Lanphear et al. 2000). A work group formed by the Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recently concluded that "...the consensus of the WG is that the overall weight of available evidence supports an inverse association between blood lead levels in the range less than 10 ug/dL and the cognitive function of children..." (Work Group, 2004). The work group also "...concluded that, while available evidence does not permit a definitive causal interpretation of the observed associations between higher BLLs in the range < 10 ug/dL and adverse health indicators, the weight of evidence favors, and does not refute, the interpretation that these associations are, at least in part, causal..." No threshold for effects on children's IQ has been identified.

- ***Toxicity (Cancer)****:* EPA has classified lead as a probable human carcinogen (Weight of Evidence = B2) (EPA 2004a). However, EPA has not established a cancer slope factor.

- ***Ecological Toxicity****:* Lead is toxic to aquatic organisms. EPA has published an AWQC FCV (0.0025 mg/L) that was developed by EPA's Office of Water[65]. EPA (1998b) also lists an OPPT measured chronic data (0.125 mg/L) that represents "a threshold concentration of a chemical in water at which statistically significant effects on an aquatic test population's survival, growth, or reproduction are expected to occur".

Conclusions: Ecology has determined that lead meets the criteria for persistence, bioaccumulation and toxicity in WAC 173-333-320(2). However, Ecology has not completed its review of information relevant to making a determination on whether lead is "...likely to be present in forms that are bioavailable..." (WAC 173-333-320(2)(d)). Ecology intends to complete that review and make a determination on whether to include lead on the PBT list prior to distributing the proposed rule for public review and comment.

[65] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Mercury

Background: Mercury is a naturally occurring element that is used in numerous products (e.g., thermometers, thermostats, fluorescent lights, preservatives, electrical switches, dental amalgams) and used in several manufacturing processes (e.g., production of chlorine gas and caustic soda). Many of these uses are being reduced or discontinued due to health concerns. Mercury is also released during coal combustion. Metallic mercury is used to produce chlorine gas and caustic soda. Mercury salts are sometimes used in skin lightening creams and as antiseptic creams and ointments.

Mercury is present in many products used in Washington and is released by a variety of sources. Mercury has been found to be present in surface waters, soils, sediments and biota in Washington. Information on uses, releases and environmental concentrations are summarized in the Washington State Mercury Chemical Action Plan (Ecology and Health, 2003)

Mercury has been identified as a Level I substance under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998b), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for mercury.

- ***Persistence****:* Mercury and methylmercury are highly persistent and EPA used a range of soil half-life values (1.5 – 20 years) to characterize the persistence of mercury when deciding whether to include mercury among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a).

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for mercury and used a BAF value of 6,800,000 to characterize the bioaccumulation potential of this substance. This value is based on a measured bioaccumulation factor included in the Mercury Report to Congress (EPA, 1997a). EPA used a range of BCF values (7,000 – 36,000)[66] to characterize bioaccumulation potential when deciding whether to include mercury and mercury compounds among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a).

- ***Toxicity (Non-cancer)****:* Several developmental and neurological effects are associated with exposure to mercury. EPA has established an inhalation RfC value (0.0003 mg/m3)[67] and an oral RfD value (0.0001 mg/kg/day) that are published in the IRIS database.

[66] EPA (1999a) listed a range of BCF values (29,600 – 66,000) and a bioaccumulation factor for piscivorous fish (> 2,500,000)

[67] The RfD value was based on the results of a 60-week dog feeding study. The critical effect was increased liver-to-body weight ratios in males and females and 1000-fold uncertainty factor was applied to the LEL of 0.0125 mg/kg/day. EPA assigned a low level of confidence to the study and the RfD and a medium level of confidence to the database. (EPA, 2001a). Since 1998, the National Academy of Sciences (NAS, 2001a) has completed a review

- ***Ecological Toxicity:*** Mercury is highly toxic to aquatic organisms. EPA has established a Tier I Final Chronic Value (FCV) (0.0009081 mg/L) developed through the Great Lakes Water Quality Initiative [68], a Tier II Secondary Chronic Value (FCV) (0.0013 mg/L) developed through the Great Lakes Water Quality Initiative [69] and an AWQC FCV (0.0011 mg/L) developed by EPA's Office of Water.[70]

Conclusions: Ecology has determined that mercury meets the draft PBT criteria specified in WAC 173-333-320.

of the toxicological effects associated with mercury exposure and concluded that a RfD for methylmercury of 0.0001 mg/kg/day is a "scientifically justifiable level for the protection of public health." In July 2001, EPA updated the IRIS database to reflect these conclusions.

[68] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for cadmium is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

[69] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for cadmium is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

[70] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Mirex

Background: Mirex[71] (CAS 2385-85-5) was used as a flame retardant in plastics, rubber products, paints, etc. It was also used as an insecticide to control ants (WHO, 1984). The Environmental Protection Agency has banned the importation and manufacture of mirex.

Mirex has been identified as a Tier I substance under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a) and a persistent organic pollutant (POP) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for mirex.

- ***Persistence****:* WHO (1984) identified mirex as one of the most stable chemicals in use in the early 1980s. Mackay et al. (1997) published average half life values for mirex in surface water (@ 7 days), soils (@ 6 years) and sediments (@ 6 years). This is consistent with the conclusions reached by UNEP (2002) who stated that "...Mirex is considered to be one of the most stable and persistent pesticides, with a half-life in soils of up to 10 years...".

- ***Bioaccumulation****:* In their review of the available data on mirex, Ritter et al. (1996) stated that bioconcentration factors of 2,600 and 51,400 have been observed in pink shrimp and fathead minnows, respectively. The EPA ECOTOX database (EPA 2004b) includes a wide range of BCF values (< 10 – 40,900). The OSPAR fact sheet for mirex (OSPAR, 2004l) identifies two BCF values from peer-reviewed scientific literature (18,100 and 51,300) and an estimated BCF of 40,738 based on quantitative structure activity relationship models.

- ***Toxicity (Non-cancer)****:* Exposure to mirex is associated with a wide range of neurological effects. EPA has established an oral RfD value (0.0003 mg/kg/day) that is published in the IRIS database.

- ***Toxicity (Cancer)***: The National Toxicology Program (NTP, 2004a) has concluded that mirex is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity in animals. This conclusion was reached based on an increased incidence of neoplastic nodules in the liver of male and female rats observed during a two year feeding study conducted by the NTP. EPA's Office of Pesticide Programs and the International Agency for Research on Cancer have classified mirex as "a probable human carcinogen (B2)" and "possibly carcinogenic to humans (group 2B), respectively.

- ***Ecological Toxicity****:* WHO (1984) and Ritter et al. have concluded that Mirex is highly toxic to a variety of aquatic organisms with crustaceans (particularly the larval and juvenile stages) being the most sensitive. Ritter et al. reported that delayed mortality was observed occurred among larval crabs following exposure to 1 and 10 ug/l of mirex. The OSPAR Commission fact sheet for mirex (OSPAR, 2004l) identifies acute toxicity algae IC50 values (0.0002 and

[71] 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo-1,4-endo-5,8-dimethanonaphthalene..

0.1 mg/L), acute toxicity daphnia EC50 (0.1 and 0.3 mg/L), acute toxicity fish LC50 (0.999 and 20 mg/L), chronic toxicity daphnia NOEC (0.000025 and 0.0024 mg/L) and chronic toxicity fish NOEC (0.000038 to 0.13 mg/L).

Conclusions: Ecology has determined that mirex meets the draft PBT criteria specified in WAC 173-333-320.

Pentachlorobenzene

Background: Pentachlorobenzene (CAS 608-93-5) was formerly used as a fungicide and as a flame retardant. Environment Canada (2003) briefly summarized several sources including pulp and paper mills, refineries, sewage treatment plants and iron and steel manufacturing. Pentachlorobenzene is an impurity of up to 2% in hexachlorobenzene and has previously been an impurity in the pesticide quintozene.

Pentachlorobenzene has been identified as a Level II substance under the Bi-National Toxics Strategy (GLNPO, 1997), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a Track 1 Substance subject to virtual elimination under the Canadian Toxics Substances Management Policy (Environment Canada, 2003) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b). The United Nations Economic Commission for Europe is currently evaluating whether to include pentachlorobenzene on the list of persistent organic pollutants under the LRTAP and Stockholm Conventions.

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for pentachlorobenzene.

- ***Persistence****:* Mackay et al. (1992) estimated average half-lives in surface water (@ 8 months), soils (@ 2 years) and sediments (@ 2 years). These values are consistent with the range of soil half-life values (194 – 7800 days) considered by EPA when deciding whether to include pentachlorobenzene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). Environment Canada (2003) reviewed the Mackay et al. information, laboratory studies and sediment core data and concluded that pentachlorobenzene meet the persistence criteria in the Persistence and Bioaccumulation Regulations of the Canadian Environmental Protection Act (Government of Canada, 2000)[72] EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 3656 hours.

- ***Bioaccumulation:*** EPA (1998b) evaluated the range of BAF/BCF values available for pentachlorobenzene and used a BCF value of 8,314 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. This value is virtually identical to the value EPA used when deciding whether to include pentachorobenzene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). Environment Canada (2003) reported that BAFs for pentachlorobenzene of 810 and 20,000 for mussels and rainbow trout, respectively (BAF for earthworms = 401,000) and concluded that pentachlorobenzene meets the bioaccumulation criteria in the Persistence and Bioaccumulation Regulations of the Canadian Environmental

[72] Under the Canadian Persistence and Bioaccumulation Regulations, a substance is considered persistent if it meet at least one of the following half-life criteria: air (> 2 days); water (> 182 days); sediment (> 365 days) or soil (> 182 days).

Protection Act (Government of Canada, 2000)[73]. The Swedish Chemical's Inspectorate/Environmental Protection Agency (2002) reported that measured BCF values vary between 3,400 and 13,000. The OSPAR Commission (OSPAR, 2004m) fact sheet for pentachlorobenzene includes a range of BCF values (1,905 to 260,000).

- ***Toxicity (Non-cancer)***: Pentachlorobenzene has been shown to cause liver and kidney damage in animal studies. EPA has established an oral RfD value (0.0008 mg/kg/day) that is published in the IRIS database (EPA 2004a).

- ***Toxicity (Cancer)***: EPA (2004a) reviewed the evidence for carcinogenicity and concluded that pentachlorobenzene is not classifiable as to human carcinogenicity (D).

- ***Ecological Toxicity****:* Pentachlorobenzene is toxic to aquatic organisms. EPA has established a Tier II Secondary Chronic Value (SCV) (0.0005 mg/L) developed through the Great Lakes Water Quality Initiative.[74] Based on toxic effects in benthic organisms, Environment Canada (2003) concluded that pentachlorobenzene meets the definition of "toxic" under the under the Canadian Environmental Protection Act. The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2004) concluded that "…aquatic toxicity has been tested on several species representing different groups of organisms and has been shown to be very high. The lowest acute LC_{50} value available for freshwater organisms is 0.25 mg/l for fish and the lowest NOEC value is 0.01 mg/l for crustaceans…" The OSPAR Commission fact sheet for pentachlorobenzene (OSPAR, 2004m) reports acute toxicity algae IC50 values (1.3 and 1.98 mg/L), acute toxicity daphnia EC50 (0.122 to 5.3 mg/L), acute toxicity fish LC50 (0.18 to 2.76 mg/L), chronic toxicity daphnia NOEC (0.01 mg/L) and chronic toxicity fish NOEC (0.055 mg/L).

Conclusions: Ecology has determined that pentachlorobenzene meets the draft PBT criteria specified in WAC 173-333-320.

[73] Under the Canadian Persistence and Bioaccumulation Regulations, a substance meets the bioaccumulation criteria if it has a BAF > 5000, a BCF > 5000 or a log Kow > 5.

[74] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for pentachlorobenzene is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

Perfluorooctane Sulfonates (PFOS)

Background: PFOS (Molecular formula $C_8F_{17}SO_3$) is a member of a group of organic compounds that consists of an eight-carbon chain where the hydrogen atoms have been substituted with fluorine atoms and a reactive sulfonate group at one end of the chain. PFOS derivatives and salts include: PFOS - acid (CAS 1763-32-1); PFOS - ammonium salt (CAS 29081-56-9); PFOS - diethanolamine salt (CAS 70225-14-8); PFOS - lithium salt (CAS 29457-72-5); and PFOS - potassium salt (CAS 2795-39-3).

The Swedish Chemicals Inspectorate/Environmental Protection Agency (2004) identified a wide range of uses for PFOS: textile, carpet and leather protection; metal plating; paper and paper packaging; fire fighting foams; industrial and household cleaning products; coatings and coating additives; photographic industry; photolithography and semiconductors; hydraulic fluids in the aviation industry; and other uses. The SCI/EPA noted that 3M's voluntary phaseout of PFOS production had resulted in a significant reduction in PFOS uses for most of these purposes. The OECD (2002) report summarizes results of blood serum testing in a Seattle elderly care facilities. Reported levels (geometric mean = 31 ppb) were similar (but somewhat lower) than levels measured in the general population in other parts of the US, Europe and Japan.

The United Nations Economic Commission for Europe is currently evaluating whether to include PFOS on the list of persistent organic pollutants under the LRTAP and Stockholm Conventions. PFOS was also identified as a regionally-specific persistent toxic substance in the North America Regional Report (UNEP, 2002).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for PFOS.

- ***Persistence***: The Swedish Chemicals Inspectorate/Environmental Protection Agency (2002, 2004), EPA (2002a,b) and the OECD (2004) have all concluded that PFOS is highly stable and persistent in the environment. The rationale for these conclusions include: (1) hydrolysis half-life of 41 years; (2) photolytic half-life of 3.7 years; (3) no signs of degradation in aerobic and anaerobic studies performed with activated sewage sludge, sediment and soil cultures; (4) chemistry of C-F binding[75]; and (5) the presence of PFOS in blood plasma samples collected from fish and wildlife in remote locations[76].

- ***Bioaccumulation*:** The Swedish Chemical Inspectorate/Environmental Protection Agency (2004) concluded that PFOS meets the UNEP bioaccumulation criterion based on the "…extremely high concentrations that have been measured in top predators at various

[75] The Swedish Chemicals Inspectorate/Environmental Protection Agency (2002) wrote "...[t]his stability is typical for perflourinated compounds and the reason for that is that the carbon chain, which is the backbone of the molecule, is totally surrounded by fluorine atoms with strong bindings to all positions of the carbon chain. These C – F bindings are probably the strongest bindings in nature. PFOS is therefore assessed to be very persistent in the environment, and to fulfil the criterion for persistence…."

[76] The Swedish Chemicals Inspectorate/Environmental Protection Agency (2002) wrote "…[t]occurrences of PFOS in the environment confirm this statement [meeting the UNEP persistence criterion] through findings in blood plasma (up to 1,047 ppb) in birds (eagles, albatross) and fish. PFOS has also been detected in polar bears and seals in the arctic, dolphins in the Mediterranean Sea and Ganges and turtles in Mississippi…"

locations such as the Artic, the U.S. and Sweden…" In reaching that conclusion, they considered several types of information: (1) PFOS's tendency to bind to proteins in the liver and blood (as opposed to accumulate in fat tissue); (2) reported BCF values in fish ranging from 2,796 to 3,100; and (3) evidence of bioaccumulation and biomagnification in mammals. EPA (2002d) reviewed the results of three studies evaluating the bioaccumulation potential of the ammonium salt of PFOS and concluded it does not appear to bioaccumulate in fish.

- ***Toxicity (Non-Cancer)***: EPA (2002a,b), OECD (2002) and the Swedish Chemicals Inspectorate/Environmental Protection Agency (2004) reviewed available toxicological studies. Key observations included: (1) PFOS is well absorbed and distributes primarily to the liver and serum; (2) PFOS is formed as a metabolite of other perfluorinated sulfonates and elimination from the body is very slow; (3) PFOS shows moderate acute toxicity in oral studies[77] and mildly irritating to the eye; (4) pre-and postnatal deaths and developmental effects (including neurological development) were observed in rat and rabbit studies[78]; and (5) PFOS is immunotoxic in mice.

- ***Toxicity (Cancer)***: EPA (2002a, b) concluded that animal studies indicate that APFO is weakly carcinogenic based on an increased incidence of (1) Leydig cell adenomas in male rats, (2) mammary fibroadenomas in female rats and (3) liver and pancreatic tumors in rats. However, EPA (2002b, d) reported that PFOS was negative in mutagenicity studies.

- ***Ecological Toxicity*:** The Swedish Chemicals Inspectorate/Environmental Protection Agency (2002, 2004), OECD (2002) and EPA (2002a, b) have concluded that PFOS is toxic to aquatic organisms. OECD (2002) concluded that PFOS shows moderate acute toxicity to aquatic organisms, but that PFOS may be very toxic to honey bees. The SCI/EPA reported that (1) adverse effects (e.g. growth inhibition and decreased survival) have been observed in studies where fish were exposed to 0.3 mg/L of the potassium salt of PFOS for 42 days and (2) adverse effects (inhibition and impact on the reproduction) were observed in studies where Mysid shrimp were exposed to 0.25 mg/L of the potassium salt of PFOS for 35 days. EPA (2002d) reviewed @30 studies conducted with several different test species (fathead minnow, bluegill sunfish, water flea and green algae). Tests with fathead minnows and bluegill sunfish indicated low acute toxicity. Tests with algae and daphnia magna (water fleas) also indicated low to moderate acute and chronic toxicity.

Conclusions: Ecology has determined that PFOS meets the draft PBT criteria specified in WAC 173-333-320.

[77] Deaths were observed at doses as low as 0.75 mg/kg/day in a 6 month study of cynomolgus monkeys.
[78] Postnatal deaths and other developmental effects were reported at low doses in offspring in a 2-generation reproductive toxicity study in rats. The NOAEL and LOAEL for the second-generation offspring (F2 pups) were 0.1 mg/kg/day and 0.4 mg/kg/day, respectively, based on reduction in pup body weight.

Polyaromatic hydrocarbons (PAHs)

Background: PAHs are a large group of substances which consist of molecules with 2 to 3 or more aggregated benzene rings. PAH compounds are coal tar, creosote and asphalt products that are extensively used in Washington. However, the largest source of PAH releases is incomplete combustion of fossil fuels and other organic materials.

PAHs been found in fish and shellfish tissue and sediment[79] samples collected in Washington. One or more PAHs have also been identified as parameters of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b). Based on information in the National Toxics Inventory, SAIC (2001) estimated that Washington sources released 221,938 lbs of PAHs into the atmosphere during 1999.

One or more PAH compounds have been identified as Level I and II substances under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a), as PBT chemicals for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d), as PBT chemicals for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), as a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b). The United Nations Economic Commission for Europe is currently evaluating whether to include PAHs on the list of persistent organic pollutants under the Stockholm Convention.

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for PAHs.

- ***Persistence****:* EPA (1999a) used a range of soil half-life values (20 days – 14.6 years) to characterize the persistence of individual PAH compounds when deciding whether to include several PAHs among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program. EPA (1998b) used the EQC multi-media model to estimate regional half-life values for several PAH compounds that ranged from 586 to 24,652 hours.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for several PAH compounds and used a range of BAF/BCF values from 602 to 25,703 to characterize the bioaccumulation potential of this substance. Those values are summarized in Table 3. Most of these values are based on either (1) measured BCFs included in the Syracuse Research Corporation BCF database file or (2) BCF values predicted using BCFWin (a bioconcentration factor estimation program developed by Syracuse Research Corporation). BCFWin estimates BCF values based on chemical structure and logKow values. This range of value is consistent with the range of BCF values[80] considered by EPA when deciding whether to include various PAH compounds among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI)

[79] SAIC (2001) compiled readily available sediment data and found that @ 55 percent of marine sediment samples analyzed for PAHs contained measurable amounts of one or more PAH compounds.
[80] EPA identified 22 polycyclic aromatic compounds as PBT chemicals. BCF values ranged from 800 to 28,620.

program (EPA, 1999a). The BCF values are based on lower trophic organisms because higher organisms metabolize PAH compounds.

- ***Toxicity (Non-cancer):*** Chronic animal bioassays where animals were exposed by ingestion, intratracheal installation and dermal application have resulted in a wide range of adverse effects on the cardiovascular, respiratory, nervous, gastrointestinal and immune systems and skin, blood and liver. EPA has established oral RfD values for benzo([a]pyrene (0.0005 mg/kg/day), anthracene (0.3 mg/kg/day), fluoranthene (0.04 mg/kg/day), fluorene (0.04 mg/kg/day) and pyrene (0.03 mg/kg/day) which are published in the IRIS database (EPA, 2004a).

- ***Toxicity (Cancer:*** IARC (2004a) has classified several PAH compounds as "probably carcinogenic to humans" (Group 2A) and "possibly carcinogenic to humans" (Group 2B). EPA has established an oral cancer slope factor (7.3 (mg/kg/day)-1) for benzo(a)pyrene that is published in the IRIS database (EPA, 2004a).[81] EPA (1993), Nisbet and Lagoy (1992) and others have developed relative potency or toxic equivalency approaches for PAHs. Using these approaches, the cancer potency of PAH compounds can be estimated based on their relative potency to benzo(a)pyrene. Table 2 summarizes the relative potency estimates for PAH compounds classified in IARC Group 2A and Group 2B.

Table 2: Weight of Evidence Classifications and Estimated Cancer Slope Factors (CSF)

		Nisbet and Lagoy (1992)		EPA (1993)	
Compound	IARC Group	TEF	Estimated CSF	TEF	Estimated CSF
Benzo[a]anthracene	2A	0	0	0.145	1.1
Benzo[a]pyrene	2A	1	7.3	1.0	7.3
Benzo[b]fluoranthene	2B	0.1	0.7	0.167	1.2
Benzo[j]fluoranthene	2B				
Benzo[k]fluoranthene	2B	0.1	0.7	0.02	0.1
Dibenz[a,h]acridine	2B				
Dibenz[a,j]acridine	2B				
Dibenz[a,h]anthracene	2A	5	36.5	1.11	8.1
7H-Dibenzo[c,g]carbazole	2B				
Dibenzo[a,e]pyrene	2B				
Dibenzo[a,h]pyrene	2B				
Dibenzo[a,i]pyrene	2B				
Dibenzo[a,l]pyrene	2B				
Indeno[1,2,3-cd]pyrene	2B	0.1	0.7	0.055	0.4

[81] The cancer slope factor represents a geometric mean of four slope factors obtained by different modeling procedures using the results from several oral bioassays with rats and mice (EPA, 2004a)

- ***Ecological Toxicity**:* PAH compounds are very toxic to aquatic organisms. EPA has established an AWQC FCV (0.000001 mg/L) developed by EPA's Office of Water[82] and Tier II SCV (0.00001 mg/L) developed as part of the Great Lakes Water Quality Initiative.

Conclusions: PAHs are a group of compounds composed of two or more fused aromatic rings. Ecology has determined that the following PAH compounds meet the draft PBT criteria in WAC 173-333-320(2): dibenzo(a,h)anthracene (CAS 53-70-3); 3-methylchlolanthrene (CAS 56-49-5); benzo(r,s,t)pentaphene (CAS 189-55-9); dibenzo(a,h)pyrene (CAS 189-64-4); benzo(g,h,i)perylene (CAS 191-24-2); dibenzo(a,e)pyrene (CAS 192-65-4); indeno(1,2,3-cd)pyrene (CAS 193-39-5); 7H-dibenzo(c,g)carbazole (CAS 194-59-2); perylene (CAS 198-55-0); benzo(j)fluoranthene (CAS 205-82-3); benzo(b)fluoranthene (CAS 205-99-2); fluoranthene (CAS 206-44-0); benzo(k)fluoranthene (CAS 207-08-9); benzo(a)phenanthrene (CAS 218-01-9); dibenzo(a,j)acridine (CAS 224-42-0); and dibenzo(a,h)acridine (226-36-8).

[82] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Table 3: Information on the Persistence, Bioaccumulation Potential and Toxicity of PAH Compounds

Chemical	CAS	Regional Half Life (days)	Surface Water Half Life	Data Source (EPA Data Preference)	Soil Half-Life	Data Source (EPA Data Preference)	BAF or BCF	Data Source	Weight of Evidence	Carcinogenicity Value	Data Source	Non-Cancer Health Effect Value	Data Source	Ecological Toxicity Value	Data Source
Benzo(a)pyrene	50328	2525	< 1	Howard	57 - 529	Howard	912	SRC (M)	B2	7.3	IRIS	10	RQ	0.000001	GL-Tier II SCV
Dibenzo(a,h)anthracene	53703	6052	< 1 - 32	Howard	361 - 942	Howard	45709	BCFWin	B	4.1	CalEPA			0.496	AQUIRE (acute)
3-Methylcholanthrene	56495	15275	610 - 1400	Howard	610 -1400	Howard	17378	BCFWin		26	EPA CSF			0.001	ECOSAR(chronic)
Benzo(a)anthracene	56553	4234	< 1	Howard	102 - 679	Howard	800	HWIR (P)	B	1.1	EPA CSF			0.00003	GL-Tier II SCV
7,12-Dimethylbenz(a)anthracene	57976	693	20 - 28	Howard	20 - 28	Howard	5888	BCFWin		25	EPA CSF			0.002	ECOSAR(chronic)
Acenapthene	83329	491	12.5	Howard	12 - 102	Howard	389	SRC (M)				0.06	IRIS	0.023	SED Tier I FCV
Phenanthrene	85018	869	< 1	Howard	16 -200	Howard	3981	SRC (M)	D					0.0063	SED Tier I FCV
Fluorene	86737	586	32 - 60	Howard	32 -60	Howard	1288	SRC (M)	D			0.4	IRIS	0.0039	GL-Tier II SCV
Naphthalene	91203	239	20	Howard	16.6 - 48	Howard	427	SRC (M)	SE			0.01	MRL	0.024	GL-Tier II SCV
Anthracene	120127	1850	< 1	Howard	50 - 450	Howard	602	SRC (M)	D			0.3	IRIS		AQUIRE (acute)
Pyrene	129000	8349	< 1	Howard	210 - 1898	Howard	776	SRC (M)	D			0.03	IRIS	0.035	AQUIRE (acute)
Benzo(r,s,t)pentaphene	189559	11910			232 - 371	TRI	26303	BCFWin	C	120	CalEPA			0.0007	ECOSAR(chronic)
Dibenzo (a,h)pyrene	189644	1400	37	WMPT	232 - 371	TRI	26303	BCFWin	C	120	CalEPA			0.0007	ECOSAR(chronic)
Benzo(g,h,i)perylene	191242	24652	590 - 650	Howard	590 - 650	Howard	25703	BCFWin	D					0.002	ECOSAR(chronic)
Dibenzo (a,e)pyrene	192654	1400	37	WMPT	232 - 371	TRI	6918	BCFWin	C	12	CalEPA			0.0007	ECOSAR(chronic)
Benzo(e)pyrene	192972	1340	37	WMPT	37	WMPT	18197	BCFWin	D					0.006	ECOSAR(chronic)
Indeno(1,2,3-cd)pyrene	193395	6731	125 -250	Howard	560 - 720	Howard	28840	BCFWin	C	0.4	EPA CSF			0.002	ECOSAR(chronic)
7H-Dibenzo(c,g)carazole	194592	1214	37	WMPT	> 160	TRI	16982	BCFWin	C	12	CalEPA			0.02	ECOSAR(chronic)
Perylene	198550	1308	60	Mackay	720	Mackay	12882	BCFWin	D					0.006	ECOSAR(chronic)
Benzo(j)fluoranthene	205823	1273	37	WMPT	3780	TRI	10000	BCFWin	C	1.2	CalEPA			0.006	ECOSAR(chronic)
Benzo(b)fluoranthene	205992	4617	30	Howard	360 - 560	Howard	5623	BCFWin	C	1.2	CalEPA			0.006	ECOSAR(chronic)
Fluoranthene	206440	2642	2.6	Howard	140 440	Howard	5100	HWIR (M)	D			0.04	IRIS	0.0081	SED Tier I FCV
Benzo(k)fluoranthene	207089	13287	< 1 - 20	Howard	900 - 2140	Howard	10000	BCFWin	C	1.2	CalEPA			0.006	ECOSAR(chronic)
Acenaphthylene	208968	462	42.5 - 60	Howard	42.5 - 60	Howard	213	BCFWin						0.038	ECOSAR(acute)
Benzo(a)phenanthrene (Chrysene)	218019	5906	60	Mackay	360 - 600	Howard	3467	BCFWin	D					0.019	ECOSAR(chronic)
Dibenzo(a,j)acridine	224420	1314	< 1	TRI	> 160	TRI	18621	BCFWin	C	1.2	CalEPA			0.017	ECOSAR(chronic)
Dibenzo(a,h)acridine	226368	1277	<1	TRI	> 160	TRI	18621	BCFWin	D					0.017	ECOSAR(chronic)

Polybrominated Dibenzo-p-dioxins (PBDDs)/Polybrominated dibenzofurans (PBDFs)

Background: PBDDs/PBDFs consist of two groups of tricyclic aromatic compounds with similar chemical and physical properties. PBDDs/PBDFs are generated as unintentional by-products in various chemical processes, but can also be formed during various combustion processes or photolytic degradation of PBDEs and bromophenols.

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for PBDDs/PBDFs.

- ***Persistence****:* WHO (1998) summarized the chemical properties of these substances and suggested that they will demonstrate environmental behavior similar to PCDDs/PCDFs. Based on a screening level evaluation performed using EPA's PBT Profiler (EPA, 2004) several PBDD/PBDFs are likely be persistent in the environment. For example, 2,3,7,8-TBDD, 2,3,7,8-TBDF, 1,2,3,7,8-PBDD and 1,2,3,7,8-PBDF were all predicted to have half-lives in surface water (180 days), soil (360 days) and sediments (3600 days).

- ***Bioaccumulation****:* WHO (1998) presented information on predicted Log K_{ow} values for PBDDs/PBDFs (i.e. K_{ow} values ranged from 5 to 10) which indicate a high potential for bioaccumulation. The EPA PBT Profiler (EPA, 2004) predicts that 2,3,7,8-TBDD and 2,3,7,8-TBDF is expected to bioaccumulate in the food chain based on BCF values of 3,800 and 27,000, respectively. However, the PBT Profiler predicted that other more brominated congeners are not likely to bioaccumulate in the food chain (BCF < 1000).

- ***Toxicity (Non-Cancer)****:* WHO (1998) reported that PBDDs/PBDFs are potent inducers of certain CYP-dependent enzymes.

- ***Toxicity (Cancer)****:* IARC has classified 2,3,7,8-TCDD as a Group 1 carcinogen based on limited evidence in humans, sufficient evidence in animals and extensive mechanistic information that indicates TCDD acts through a mechanism involving the aryl hydrocarbon receptor (AhR). WHO (1998) reported that studies show that PBDD/PBDFs also bind to the AhR receptor and are potent inducers of certain CYP-dependent enzymes.

- ***Ecological Toxicity****:* WHO (1998) summarized the results of Hornung et al. (1996) in which PBDD/PBDFs were found to produce TCDD-like toxic effects and mortality and rainbow trout sac fry early life stage mortality bioassay. In particular, single exposures to 2,3,7,8-TBDD and 2,3,7,8-TBDF were found to be more potent than their chlorinated analogues. The EPA PBT Profiler (2004) predicted that 2,3,7,8-TBDD and 2,3,7,8-TBDF have chronic fish toxicity values that may cause adverse effects. The PBT Profiler could not determine fish chronic toxicity values for more brominated congeners. However, ecological toxicity values predicted using ECOSAR are generally well below 0.1 mg/L for the more brominated congeners.

Conclusions: Ecology has determined that, based on the similarities to polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs), the following PBDD/PBDF congeners meet the draft PBT criteria in WAC 173-333-320(2): 2,3,7,8-tetrabromodibenzo-p-

dioxin (CAS 50585-41-6) and); 2,3,7,8-tetrabromodibenzofuran (CAS 67733-57-7). Based on current information, the bioaccumulation potential for other 2,3,7,8 substituted PBDDs/PBDFs do appear to meet the draft bioaccumulation criterion in WAC 173-333-320(2)(b)[83].

[83] These include the following congeners: 1,2,3,7,8-pentabromodibenzo-p-dioxin (CAS 109333-34-8); 1,2,3,4,7,8-hexabromodibenzo-p-dioxin (CAS 110999-44-5); 1,2,3,6,7,8-hexabromodibenzo-p-dioxin (CAS 110999-44-6); 1,2,3,7,8,9-hexabromodibenzo-p-dioxin (CAS 110999-44-7); 1,2,3,4,6,7,8-heptabromodibenzo-p-dioxin (CAS 1,2,3,7,8-pentabromodibenzofuran (CAS 107555-93-1); 2,3,4,7,8-pentabromodibenzofuran (CAS 131166-92-2); 1,2,3,4,7,8-hexabromodibenzofuran (CAS); 1,2,3,6,7,8-hexabromodibenzofuran (CAS 107555-94-2); 1,2,3,7,8,9-hexabromodibenzofuran (CAS); 2,3,4,7,8,9-hexabromodibenzofuran (CAS); 1,2,3,4,6,7,8-heptabromodibenzofuran (CAS 107555-95-3); 1,2,3,4,7,8,9-heptabromodibenzofuran (CAS).

Polybrominated diphenyl ethers (PBDEs)

Background: PBDEs are a class of chemicals with the general chemical formula of $C_{12}H_{(9-0)}Br_{(1-10)}O$ with the sum of H and Br atoms always equal to 10. There are theoretically 209 congeners which can be divided into 10 homologues or congener groups (mono- through decabromodiphenyl ethers). PBDEs are brominated flame retardants that are widely used in different polyurethane (PUR) applications as for furniture and upholstery in automotive industry and domestic furnishing. Other possible minor uses are in rigid polyurethane elastomers (e.g., in instrument casings), in epoxy resins and phenol resins (electric and electronic appliances).

There are three main commercial mixtures of PBDEs: Penta-BDE; Octa-PBDE; and Deca-BDE. The three mixtures have different combinations of homologues with pentabromodiphenyl ethers, heptabromodiphenyl ethers and decabromodiphenyl ethers being the main homologue groups in Penta-BDE, Octa-BDE and Deca-BDE, respectively. Studies indicate that the more highly brominated homologues (e.g. decabromodiphenyl ether) can degrade to penta- and tetra-homologues in the environment.

PBDEs are present in many products used in Washington and have been found in fish caught in Washington waters. Information on uses and environmental concentrations are summarized in the Washington State PBDE Chemical Action Plan (Ecology and Health, 2004)

PBT Characteristics and Conclusions*:* Ecology and Health (2004) have reviewed the available information on the persistence, bioaccumulation potential and toxicity for PBDEs. Based on that review, Ecology has determined that PBDE meets the draft PBT criteria specified in WAC 173-333-320. Specifically, Ecology has determined that the following congeners meet the draft PBT criteria in WAC 173-333-320(2) and/or degrade to congeners that meet the draft PBT criteria in WAC 173-333-320(2): pentabromodiphenyl ether (CAS 32534-81-9); octabromodiphenyl ether (CAS 32536-52-0); and decabromodiphenyl ether (CAS 13654-09-6).

Polychlorinated biphenyls (PCBs)

Background: PCBs (CAS are complex mixtures of individual chlorobiphenyls that contain 1 to 10 chlorine atoms. Industrial PCBs were mixtures of up to 50-60 congeners with the composition being determined by reaction conditions and manufacturing processes. PCBs have been used for a wide range of purposes because of insulating properties (e.g., insulation for electrical wires and cables, coolant and lubricant in transformers, capacitors, and lighting ballasts). PCBs are currently found in transformers and capacitors manufactured before EPA banned the production and most uses of PCBs in 1977.

The various combinations of chlorine atoms on the biphenyl molecule results in 209 possible chemical structures (congeners). A WHO expert panel (van den Berg, 1998) concluded that 12 coplanar PCB congeners (i.e. those congeners with no chlorine substitution at the ortho position) display biological and toxicity characteristics that are similar to the 2,3,7,8-substituted PCDDs and PCDFs.

PCBs have been found in fish tissue[84] and sediment[85] samples collected in Washington. PCBs have also been identified as parameters of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

PCBs have been identified as Level I substances under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998a), PBT chemicals for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP, 2001) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for PCBs.

- ***Persistence****:* Most PCB congeners are extremely persistent in the environment. However, the persistence is congener-specific with less chlorinated congeners generally being more likely to degrade. EPA (1999a) used a range of soil half-life values (1.5 – 20 years) for eleven of the twelve co-planar PCBs congeners identified by WHO (1997) when deciding whether to identify PCBs as PBT chemicals under the Toxics Release Inventory (TRI) program (See table below). These values are generally consistent with soil-half life values reported in Mackay et al. (1992) and (2000a)[86]. EPA (1998b) used the EQC multi-media model to estimate a regional half-life values ranging from 441 to 2578 hours for total PCBs and various Aroclors.

- ***Bioaccumulation****:* The potential for bioaccumulation varies between different congeners with the more chlorinated PCBs having a much higher potential for bioaccumulation than

[84] SAIC (2001) compiled readily available fish tissue data and found that @ 84 percent of fish tissue samples contained measurable amounts of PCBs.
[85] SAIC (2001) compiled readily available sediment data and found that @ 36 percent of marine sediment samples contained measurable amounts of PCBs.
[86] EPA (2000a) states that "…PCBs are among the most stable organic compounds known, and chemical degradation rates in the environment are thought to be slow…" (p. 548)

less-chlorinated congeners. EPA (1999a) used a range of bioaccumulation factors (from > 200,000 to > 141,000,000) and bioconcentration factors (4,922 to 196,900) to characterize the bioaccumulation potential of the eleven co-planar PCBs congeners (See Table 4). EPA (1998b) evaluated the range of BAF/BCF values available for PCB's and used a BAF value of 29,494,339 to characterize the bioaccumulation potential of this substance. This value is based on a predicted bioaccumulation factor included in HWIR database.

- ***Toxicity (Non-cancer)****:* Numerous adverse health effects have been documented in chronic animal studies including hepatic, immunological, dermal, endocrine effects, neurological effects and reproductive and development effects. EPA has established oral RfD values for Arochlor 1254 (0.00002 mg/kg/day) and Arochlor 1016 (0.00007 mg/kg/day) which are published in the IRIS database (EPA, 2004a).

- ***Toxicity (Cancer)***: PCBs are classified as a probable human carcinogen (B2), EPA has established an oral cancer slope factor (2 (mg/kg/day)-1) that is published in the IRIS database (EPA, 2004a).[87] Since the 2,3,7,8-substituted PCDDs/PCDFs and coplanar PCBs are believed to act through a common toxicological mechanism, the World Health Organization (van den Berg, 1998) and others have established a toxic equivalency factor (TEF) approach for evaluating dioxins and dioxin-like compounds. Using these approaches, the cancer potency of the eleven coplanar PCB congeners can be estimated based on their relative potency compared to TCDD. The TEF values developed by the WHO expert panel and the cancer slope factors generated using the TEF values are summarized in the Table 4.

- ***Ecological Toxicity***: PCBs are highly toxic to aquatic organisms. EPA has established an AWQC FCV (0.00001 mg/L) that was developed by EPA's Office of Water.[88]

Conclusions: Ecology has determined that PCBs meet the draft PBT criteria specified in WAC 173-333-320.

[87] PCBs are classified as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity in animals [This is equivalent to "known/likely" category reflected in the1996 proposed revisions to the Agency's carcinogen classification system (EPA, 1996). To date, EPA has not issued final revised cancer guidelines.] The cancer slope factor was calculated using a linear extrapolation below the LED10 value that was based on increased rates of liver carcinomas in rats. (EPA, 2001a)

[88] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996)

Table 4: Information on the Persistence, Bioaccumulation Potential and Toxicity of PCB Congeners

			Persistence		Bioaccumulation		Carcinogenicity			
Chemical	IUPAC	CAS	Soil Half-Life (years)	Data Source	BAF or BCF	Data Source	Weight of Evidence	Carcinogenicity Value	Toxicity Equivalence Factor (TEF)	Data Source (EPA Data Preference)
3,3',4,4' Tetrachlorobiphenyl	77	32598133	0.9-4.8	TRI	105,900	TRI	B2	15.6	0.0001	WHO (1997)
3,3',4,4',5 Pentachlorobiphenyl	126	57465288	0.9-7.2	TRI	196,900	TRI	B2	15,600	0.1	WHO (1997)
2',3',4,4',5 Pentachlorobiphenyl	123	65510443	0.9-7.2	TRI	196,900	TRI	B2	15.6	0.0001	WHO (1997)
2,3',4,4',5 Pentachlorobiphenyl	118	31508006	0.9-7.2	TRI	184,300	TRI	B2	15.6	0.0001	WHO (1997)
2,3,4,4',5 Pentachlorobiphenyl	114	74472370	0.9-7.2	TRI	196,900	TRI	B2	78	0.0005	WHO (1997)
2,3,3',4,4' Pentachlorobiphenyl	105	32598144	0.9-7.2	TRI	196,900	TRI	B2	15.6	0.0001	WHO (1997)
3,3',4,4',5,5' Hexachlorobiphenyl	169	32774166	3.4-5.0	TRI	73,840	TRI	B2	1,560	0.01	WHO (1997)
2,3',4,4',5,5' Hexachlorobiphenyl	167	52663726	3.4-5.0	TRI	37,590	TRI	B2	1.6	0.00001	WHO (1997)
2,3,3',4,4',5' Hexachlorobiphenyl	157	69782907	3.4-5.0	TRI	37,590	TRI	B2	78	0.0005	WHO (1997)
2,3,3',4,4',5 Hexachlorobiphenyl	156	38380084	3.4-5.0	TRI	37,590	TRI	B2	78	0.0005	WHO (1997)
2,3,3',4,4',5,5' Heptachlorobiphenyl	189	39365319	3.9-5.0	TRI	4,922	TRI	B2	15.6	0.0001	WHO (1997)

Polychlorinated dibenzo-p-dioxins (PCDDs)/Polychlorinated dibenzofurans (PCDFs)

Background: PCDDs/PCDFs consist of two groups of planar tricyclic aromatic compounds with similar chemical and physical properties. Dioxins and furans have no known uses and are not produced commercially. They are produced as unwanted byproducts in many industrial and combustion processes. WHO (2003) identified several categories of current sources: (1) stationary sources (e.g. waste incineration, recycling plants and energy production); (2) diffuse sources (e.g. traffic, home heating, spills, fires including PCBs); (3) secondary sources of PCDDs/PCDFs are environmental matrices or products that serve as reservoirs for these substances (e.g. soil, sediment, PCP-treated wood, PCB-containing transformers, sewage sludge, etc.)and (4) natural sources (e.g. forest fires).

PCDDs/PCDFs may contain any where from 1 to 8 chlorine atoms. Consequently, dioxins and furans have 75 and 135 possible positional isomers, respectively. The 17 congeners that have chlorine atoms in the 2,3,7 and 8 positions of the parent molecule are considered to be far more toxic, persistent and bioaccumulative than the congeners lacking this configuration. These seventeen congeners are listed in the Table 5 below.

PCDDs/PCDFs have been found in fish tissue, sediment[89] and soil samples collected in Washington. PCDDs/PCDFs have also been identified as parameters of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

PCDDs and PCDFs have been identified as Tier I substances under the Bi-National Toxics Strategy (GLNPO, 1997), as one of the initial PBT chemicals identified by EPA (EPA, 1998a), a PBT chemical for purposes of reporting under the Toxics Release Inventory program (EPA, 1999a), a persistent organic pollutant (POP) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for PCDDs/PCDFs.

- ***Persistence****:* EPA (1999a) used a range of soil half-life values (1.5 – 20 years) to characterize the persistence of 2,3,7,8 TCDD when deciding whether to identify dioxin and dioxin-like compounds as PBT chemicals under the Toxics Release Inventory (TRI) program (EPA, 1999a). EPA (1999a) used a soil-half life of 20 years to characterize the persistence of the sixteen (16) other 2,3,7,8-substituted PCDDs/PCDFs. EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 10,986 hours for 2,3,7,8-TCDD.

- ***Bioaccumulation****:* EPA (1999a) evaluated the range of available BAF/BCF values for dioxins/furans and used BCF values ranging from 1,259 to 42,500 to characterize the bioaccumulation potential of the various 2,3,7,8-substituted PCDDs/PCDFs. (see Table 5 below).

[89] SAIC (2001) compiled readily available sediment data and found that @ 40 percent of marine sediment samples analyzed for PCDDs/PCDFs contained measurable amounts of these compounds.

- ***Toxicity (Non-Cancer)****:* Numerous adverse health effects have been documented in chronic animal studies including hepatic, immunological, dermal, endocrine effects, neurological effects and reproductive and development effects. The most commonly observed health effect among workers exposed to elevated levels of PCDDs/PCDFs is chloracne – a severe and prolonged acne-like skin disorder. The ATSDR (2004a) has established a Minimal Risk Levels for 2,3,7,8-TCDD for acute (0.0000002 mg/kg/day), intermediate (0.00000002 mg/kg/day) and chronic (0.000000001 mg/kg/day) exposures. ATSDR (2004a) has also developed MRLs for 2,3,4,7,8-PDCF for acute (0.000001 mg/kg/day) and intermediate (0.00000003 mg/kg/day) exposures.

- ***Toxicity (Cancer)****:* IARC has classified 2,3,7,8-TCDD as a Group 1 carcinogen based on limited evidence in humans, sufficient evidence in animals and extensive mechanistic information that indicates TCDD acts through a mechanism involving the aryl hydrocarbon receptor (AhR). EPA has developed an oral cancer slope factor for (1) 2,3,7,8 TCDD (156,000 (mg/kg/day)-1) that is published in the Health Effects Assessment Summary Tables (HEAST)[90] and (2) hexachlorodibenzo-p-dioxins (6,200 $(mg/kg/day)^{-1}$) that is published in the IRIS database (EPA, 2004a). Since the 2,3,7,8-substituted PCDDs/PCDFs and coplanar PCBs are believed to act through a common toxicological mechanism, the World Health Organization (van den Berg, 1998) and others have established a toxic equivalency factor (TEF) approach for evaluating dioxins and dioxin-like compounds. Using these approaches, the cancer potency of dioxin and dioxin-like compounds can be estimated based on their relative potency compared to TCDD. The TEF values developed by the WHO expert panel and the cancer slope factors generated using the TEF values are summarized in the Table 5 below.

- ***Ecological Toxicity****:* PCDDs/PCDFs are toxic to terrestrial wildlife and aquatic organisms. EPA (1998a) lists an acute EC50 for growth rate (0.25 mg/L) based on a 4-day study with oysters. The OSPAR Commission fact sheet for 2,3,7,8-TCDD (OSPAR, 2004) reports acute toxicity fish LC50 (0.01 and 9 mg/L) and chronic toxicity fish NOEC (0.00021 and 0.0000001 mg/L).

Conclusions: Ecology believes that PCDDs/PCDFa meet the draft PBT criteria and listing factors specified in WAC 173-333-320. Ecology has determined that the following PCDD/PCDF congeners meet the draft PBT criteria in WAC 173-333-320(2): 2,3,7,8-tetrachlorodibenzo-p-dioxin (CAS 1746-01-6); 1,2,3,7,8-pentachlorodibenzo-p-dioxin (CAS 40321-76-4); 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin (CAS 39227-28-6); 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin (CAS 576-53-8); 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin (CAS 19408-74-3); 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin (CAS 35822-46-9); 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin (CAS 3268-87-9);): 2,3,7,8-tetrachlorodibenzofuran (CAS 51207-31-9); 1,2,3,7,8-pentachlorodibenzofuran (CAS 57117-41-6); 2,3,4,7,8-pentachlorodibenzofuran (CAS 57117-41-4); 1,2,3,4,7,8-hexachlorodibenzofuran (CAS 70648-26-9); 1,2,3,6,7,8-hexachlorodibenzofuran (CAS 57117-44-9); 1,2,3,7,8,9-hexachlorodibenzofuran (CAS 72918-21-9); 2,3,4,7,8,9-hexachlorodibenzofuran (CAS 60851-34-5); 1,2,3,4,6,7,8-heptachlorodibenzofuran (CAS 67562-39-4); 1,2,3,4,7,8,9-heptachlorodibenzofuran (CAS 55673-89-7); 1,2,3,4,6,7,8,9-octachlorodibenzofuran (CAS 39001-02-0).

[90] Dioxin mixtures (ICDD, PCDD, HxCDD) are classified as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity. The cancer slope factor was calculated using the linearized multistage procedure based on increased rates of liver carcinoma in mice and rats. (EPA, 2001a)

Table 5: Information on the Persistence, Bioaccumulation Potential and Carcinogenicity of Selected PCDD/PCDF Congeners

				Bioaccumulation		Carcinogenicity			
Chemical	CAS	Soil Half-Life (years)	Data Source	BAF or BCF	Data Source	EPA Weight of Evidence	Carcinogenicity Value	Toxicity Equivalence Factor (TEF)	Data Source (EPA Data Preference)
Polychlorinated Dioxins									
2,3,7,8 Tetrachlorodibenzo-p-dioxin	1746016	1.5-20	TRI	5,755	TRI	B2	156,000	1	HEAST (High)
1,2,3,7,8 Pentachlorodibenzo-p-dioxin	40321764	20	TRI	10,890	TRI	B2	156,000	1	WHO (1997)
1,2,3,4,7,8 Hexachlorodibenzo-p-dioxin	39227286	20	TRI	5,176	TRI	B2	6,200	0.1 (not used)	IRIS (Highest)
1,2,3,6,7,8 Hexachlorodibenzo-p-dioxin	576538	20	TRI	3,981	TRI	B2	6,200	0.1 (not used)	IRIS (Highest)
1,2,3,7,8,9 Hexachlorodibenzo-p-dioxin	19408743	20	TRI	1,426	TRI	B2	6,200	0.1 (not used)	IRIS (Highest)
1,2,3,4,6,7,8 Heptachlorodibenzo-p-dioxin	35822469	20	TRI	1,466	TRI	B2	1,560	0.01	WHO (1997)
1,2,3,4,6,7,8,9 Octachlorodibenzo-p-dioxin	3268879	20	TRI	2,239	TRI	B2	15.6	0.0001	WHO (1997)
Polychlorinated Dibenzofurans									
2,3,7,8 Tetrachlorodibenzofuran	51207319	20	TRI	2,042	TRI	B2	15,600	0.1	WHO (1997)
1,2,3,7,8 Pentachlorodibenzofuran	57117416	20	TRI	33,750	TRI	B2	7,530	0.05	WHO (1997)
2,3,4,7,8 Pentaachlorodibenzofuran	57117314	20	TRI	42,500	TRI	B2	75,300	0.5	WHO (1997)
1,2,3,4,7,8 Hexachlorodibenzofuran	70648269	20	TRI	3,586	TRI	B2	15,600	0.1	WHO (1997)
1,2,3,6,7,8 Hexachlorodibenzofuran	57117449	20	TRI	3,586	TRI	B2	15,600	0.1	WHO (1997)
1,2,3,7,8,9 Hexachlorodibenzofuran	72918219	20	TRI	10,300	TRI	B2	15,600	0.1	WHO (1997)
2,3,4,7,8,9 Hexachlorodibenzofuran	60851345	20	TRI	3,586	TRI	B2	15,600	0.1	WHO (1997)
1,2,3,4,6,7,8 Heptachlorodibenzofuran	67562394	20	TRI	3,545	TRI	B2	1,560	0.01	WHO (1997)
1,2,3,4,7,8,9 Heptachlorodibenzofuran	55673897	20	TRI	3,545	TRI	B2	1,560	0.01	WHO (1997)
1,2,3,4,6,7,8,9 Octaachlorodibenzofuran	39001020	20	TRI	1,259	TRI	B2	15.6	0.0001	WHO (1997)

Polychlorinated napthalenes (PCNs)

Background: Polychlorinated napthalenes (PCNs) are a group chlorinated napthalenes that contain 1 to 8 chlorine atoms. PCNs are structurally similar to PCBs and, consequently, have similar uses (i.e. cable insulation, in capacitors). PCNs were also used as wood preservatives, engine oil additive, in electroplating and in dye production, The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2002) concluded there are no current uses of PCNs in the industrialized world. However, Van de Plaasche and Schwegler (2002) concluded that PCNs may be released to the environment as a result of incomplete combustion of chlorinated compounds and releases from landfills

Several polychlorinated napthalenes are currently identified as PBT chemicals on the OSPAR Commission's List of Chemicals of Potential Concern and List of Chemicals for Priority Action (OSPAR, 2004a). The United Nations Economic Commission for Europe is currently evaluating whether to include PCNs on the list of persistent organic pollutants under the LRTAP and Stockholm Conventions.

PBT Characteristics*:* Ecology has reviewed available information on the persistence, bioaccumulation potential and toxicity for PCNs.

- ***Persistence:*** Howard et al. (1992) provides estimated half-live values for hexachloronapthalene in surface waters (256 days) and soils (256 days) and surface sediments (1025 days). EPA (1998b) estimated half life values for the other four polychlorinated napthalenes in surface water (38 – 60 days), soils (38 – 150 days) and sediments (150 – 240 days) using the Ultimate Source Model and HYDROWIN computer program (See table below). Van de Plaasche and Schwegler (2002) concluded that (1) there was insufficient evidence on the persistence of PCNs in surface water, soils and sediments to reach a conclusion on whether PCNs met the persistence criterion specified in the United Nations POPs protocol; and (2) indirect evidence from monitoring data indicate that PCNs meet the persistence criterion. The Chemical's Inspectorate/Environmental Protection Agency (2004) reached a similar conclusion when evaluating whether PCNs should be nominated as a POP under the Stockholm and LRTAP Conventions.

- ***Bioaccumulation***: EPA (1998b) used BCF values ranging from 7,079 to 239,883 (See Table 6 below) to characterize the bioaccumulation potential of the five polychlorinated napthalenes. These BCF values were estimated by using a bioconcentration factor estimation program (BCFWin) developed by Syracuse Research Corporation). Van de Plaasche and Schwegler (2002) summarized the results of several bioaccumulation studies in fish which indicate that the BCF of PCNs increase with increasing chlorination up through pentachloronapthalenes. Measured BCF values for tri-, tetra- and pentachloronapthalenes ranged from 3,388 to 33,133. Both Van de Plaasche and Schwegler and the Swedish Chemical's Inspectorate/ Environmental Protection Agency (2004) concluded that PCNs meet the criterion for bioaccumulation in the POPs Protocol.

- ***Human Toxicity (Non*-cancer**): Van de Plaasche and Schwegler (2002) summarized several studies in rats and guinea pigs that demonstrate that high levels of PCNs (particularly penta- and hexachloronapthalenes) cause liver damage. They also noted that several studies suggest that PCN toxicity may be due to a mechanism that is similar to TCDD which is

believed to act through a mechanism involving the aryl hydrocarbon receptor (AhR). Several researchers have developed relative potency values or toxicity equivalent factors for penta- and hexachloronapthalenes that range from 0.001 to 0.004. These values are similar to the TEFs developed by WHO (1997) for coplanar PCBs.

- ***Human Toxicity (Cancer)***: No carcinogenicity studies were identified. However, as noted above, there are studies that suggest PCNs act through a mechanism that is similar to TCDD.
- ***Ecological Toxicity***: PCNs are very toxic to many aquatic organisms. The Swedish Chemical's Inspectorate/Environmental Protection Agency (2004) noted that this may be due to the structural resemblance with the chlorinated dioxins. Based on structure-activity relationships, EPA calculated chronic ECOSAR values that ranged from 0.0004 to 0.044 mg/L (See Table 6 below). Van Paasche and Schwegler (2002) reported that LC_{50} values of 0.008-0.44 mg/l have been observed for highly chlorinated technical mixtures in two fish species. The OSPAR Commission fact sheet for hexachloronapthalene (OSPAR, 2004) includes an acute toxicity algae IC50 (1.32 mg/L) and an acute toxicity daphnia EC50 (0.0075 mg/L).

Conclusions: Ecology has determined that the following compounds meet the draft PBT criteria in WAC 173-333-320(2): heptachloronaphthalene (CAS 32241-08-0); hexachloronaphthalene (CAS 1335-87-1); pentachloronaphthalene (CAS 1321-64-8); tetrachloronaphthalene (CAS 1335-88-2); and trichloronaphthalene (CAS 1321-65-9)

Table 6: Polychlorinated Napthalenes
Summary of Information on Persistence, Bioaccumulation and Ecological Toxicity From the WMPT Datasheets

CASRN	Chemical Name	Air Half-Life Value (hr)	Data Source	Water Half-Life (days)	Data Source	Soil Half-Life (days)	Source	Sediment Half-Life (days)	Data Source	BAF/ BCF Value	Data Source	Eco. Toxicity Value	Data Source
1321659	Trichloronaphthalene	63.8	AOPWIN	38	USM	38	WMPT	150	WMPT	7,079	BCFWIN	4.4E-02	ECOSAR-C
1335882	Tetrachloronaphthalene	140.9	AOPWIN	38	USM	38	WMPT	150	WMPT	22,387	BCFWIN	1.4E-02	ECOSAR-C
1321648	Pentachloronaphthalene	310.8	AOPWIN	38	USM	38	WMPT	150	WMPT	69,183	BCFWIN	4.0E-03	ECOSAR C
1335871	Hexachloronaphthalene	1034.1	Howard	256	Howard	256	Howard	1,025	Howard	239,883	BCFWIN	1.3E-03	ECOSAR-C
32241080	Heptachloronaphthalene	1513.3	AOPWIN	60	USM	60	WMPT	240	WMPT	31,623	BCFWIN	4.0E-04	ECOSAR-C

Short-chained chlorinated paraffins (SSCPs)

Background: "Chlorinated paraffins" is a term used to describe chlorinated derivatives of straight-chained hydrocarbons. Commercial mixtures contain compounds with several chain lengths and varying degrees of chlorination. Short-chained chlorinated paraffins (SCCP) (CAS 85535-84-8) have carbon chains ranging from 10 to 13 carbon atoms and a chlorine content ranging from 50-70% by weight. SSCPs are used in metal working fluids, as plasticizer in paints, coatings and sealants, as flame retardant in rubbers and textiles, and in leather processing.

Releases of SSCPs are reported as a category ("polychlorinated alkanes") through EPA's Toxics Release Inventory. Total air emissions in Washington during 2002 were reported to be _____.

SSCPs are currently identified as a PBT chemical on the OSPAR Commission's List of Chemicals for Priority Action (OSPAR, 2004a). The United Nations Economic Commission for Europe is currently evaluating whether to include SSCPs on the list of persistent organic pollutants under the LRTAP and Stockholm Conventions. The United Nations Environmental Program also identified SSCPs as a regionally-specific persistent toxic substance in the North America Regional Report (UNEP, 2002).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for SSCPs.

- ***Persistence***: SCCPs are generally considered very persistent. They do not readily hydrolyze in water and are not considered readily biodegradable nor inherently biodegradable (OSPAR, 2001; European Commission, 2000). The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2002) and Environment Canada (2003b) have both concluded that SCCPs meet the persistence criterion in the United Nations POPs protocol.

- ***Bioaccumulation***: The log K_{ow} for SCCP is reported as 4.4-8.7 (Swedish Chemical's Inspectorate/Environmental Protection Agency, 2002) and 5.06 to 8.12 (Environment Canada 2003b). Bioaccumulation factors between 1000 and up to 140,000 have been reported in fresh- and seawater organisms. The Substance Dossier prepared by Environment Canada (2003) and the EU Risk Assessment (European Commission, 2000) summarize the results of several studies and scientific review papers: Muir et al. 2000; Tomy et al. 1998; Madeley and Maddock, 1983; Madeley and Thompson, 1983. Muir et al. reported BAF values for SSCP homologue groups in western Lake Ontario lake trout that range from 21,250 (C10) to 114,444 (C13) with an overall BAF for SSCPs (C_{10} – C_{13}) of 36,500. Madeley and Maddock (1983) reported BCFs of 3,600 to 5,300 in rainbow trout. Biconcentration factors in mussels were reported by Madeley et al (24,800 – 40,900), Madeley and Thompson (5,785 – 25,952) and Tomy et al. (up to 140,000). The Swedish Chemical's Inspectorate/ Environmental Protection Agency (2002) and Environment Canada (2003b) have both concluded that SCCPs meet the bioaccumulation criterion in the United Nations POPs protocol.

- ***Toxicity (Non-Cancer)***: The National Academy of Sciences (NAS 2000) reviewed the available toxicological information on SSCPs. Based on the results from several animal bioassays, the NAS panel concluded that chronic exposure to elevated levels of SSCPs is

associated with increased liver weights and abnormal fatty accumulation in the liver. They also found that repeated exposure resulted in increased kidney and thyroid with accompanying histopathological changes. The NAS did not develop an oral RfD value for SSCPs.

- ***Toxicity (Cancer)***: The International Agency for Research on Cancer (IARC 2004a) and the National Toxicology Program (2004a) have concluded that chlorinated paraffins (C_{12} and @ 60% chlorine) are "possibly carcinogenic to humans" and "reasonably anticipated to be human carcinogens", respectively. These conclusions are based on the results of a NTP bioassay in which increased incidence of liver tumors were observed in male and female mice and rats exposed to chlorinated paraffins administered via gavage (NTP 1986).
- ***Ecological Toxicity***: The Swedish Chemical Inspectorate/Environmental Protection Agency (2002) and Environment Canada (2003b) have both concluded that SCCP exhibits a high toxicity towards aquatic organisms. Environment Canada (1993, 2003b) summarized several studies that provide evidence that SSCPs are toxic to aquatic invertebrates and fish at the ug/L level[91]. Environment Canada (2003b) calculated NOEC values for benthic organisms using two equilibrium-partitioning approaches. The first approach is typically used by Environment Canada (based on Di Toro et al., 1991) and yielded a $NOEC_{benthic}$ of 19.95 ug/g DW. The second approach is from the European Technical Guidance Document for risk assessments and yielded a $NOEC_{benthic}$ of 2.17 ug/g DW. The European Union Risk Assessment Report (European Commission, 2000) and the OSPAR Commission (2004) report an acute toxicity algae IC50 (0.043 mg/L), an acute toxicity daphnia EC50 (0.3 mg/L), acute toxicity fish LC50 (100 mg/L), chronic toxicity daphnia NOEC (0.005 mg/L) and chronic toxicity fish NOEC (0.28 mg/L).

Conclusions: Ecology has determined that SSCPs meet the draft PBT criteria in WAC 173-333-320.

[91] Environment Canada (1993) wrote (p. 14): "....[s]tatistically significant effects were observed in the common mussel following chronic exposure to concentrations greater than and equal to 9.3 ug/L of a short chain CP (58% Cl) (Thompson and Shillabeer, 1983). Fifty percent mortality occurred for daphnia after 6 days exposure to 10 ug/L (Thompson and Madeley, 1983a) and for the mysid shrimp after 96 h exposure to 14 ug/L (Thompson and Madeley, 1983b). Lethal effects of a 58% Cl SCCP were observed in rainbow trout at concentrations greater and equal to 33 ug/L, after 9-12 days (Madeley and Maddock, 1983a). The most sensitive measurement endpoint identified for pelagic freshwater aquatic species is 5 ug/L which is the 21-day chronic No-Observed-Effect-Concentration (NOEC) for Daphnia magna (Thompson and Madeley, 1983a). This was also the same endpoint used by the European Union (European Commission, 2000) to determine their Predicted No-Effect Concentration for the aquatic environment. Effects on Daphnia magna have been reported at concentrations not much higher than the NOEC, for example, in a 14-day static-renewal study using daphnids, 50% mortality was observed after 5 days at 10 ug/L (Thompson and Madeley, 1983a). the most sensitive measurement endpoint identified for marine species by Government of Canada (1993a) and by European Commission (2000) is 7.3 ug/L, which is the 28-day chronic NOEC for the mysid shrimp Mysidopsis bahia (Thompson and Madeley, 1983b)...".

Tetrabromobisphenol A (TBBPA)

Background: TBBPA (CAS) is a white to off-white powder that is produced by the bromination of BPA (bisphenol A) with various solvents. TBBPA is used as a reactive flame retardant in epoxy, vinyl esters and polycarbonate resins. It is used also as a flame retardant in polymers such as ABS, polystyrenes, phenolic resins, adhesives, paper, and textiles and others.

TBPPA has been identified as a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics*:* Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for TBBPA.

- ***Persistence****:* EPA (1998b) used half-lives in surface water (64 days) and soils (89 days) to characterize the persistence of this substance. EPA states these values were based on expert review. EPA (1999a) identified a range of surface water (48-84 days) and soil (44 – 179 days) in the Federal Register notice establishing lower reporting thresholds for PBT chemicals under the Toxics Release Inventory. WHO (1995) reported that TBPPA is partially degraded in soils and sediments under both aerobic and anaerobic conditions. They reported that 40-90% of TBPPA remained in soils after 56-64 days with degradation rates varying with soil type and composition, temperature and humidity.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for TBPPA and used a BCF value of 3,200 to characterize the bioaccumulation potential of this substance. EPA stated this value was based on expert review. EPA (1998b) also includes a predicted BCF (13,490) that was calculated using the BCFWin computer model. EPA (1999a) listed three BCF values (780, 1,200 and 3,200) in the Federal Register notice establishing lower reporting thresholds for PBT chemicals under the Toxics Release Inventory. The WHO (1995) states that accumulation studies on aquatic organisms indicate bioconcentration factors ranging from 20 to 3,200. The OSPAR Commission (OSPAR, 2004) fact sheet for tetrabromobisphenol used a BCF of 1235 (which is identified as a representative value for fish) to characterize the bioaccumulation potential for this substance.

- ***Toxicity (Non-cancer)****:* TBPPA has been shown to cause several adverse health effects in animal studies (e.g. increased liver and kidney weights, histological changes in the liver, kidney and thyroid). EPA has not published an oral reference dose in the IRIS or HEAST databases. However, ATSDR (2004a) has established a Minimal Risk Level (0.001 mg/kg/day) for intermediate exposure (14 – 364 days).

- ***Toxicity (Cancer)****:* No studies were found. The National Institute for Environmental Health Sciences (NIEHS) has nominated TBPPA for chronic toxicity, metabolism and carcinogenicity studies through the National Toxicology Program.

- ***Ecological Toxicity****:* TBPPA is toxic to aquatic organisms. EPA (1998b) used an acute toxicity value (0.4 mg/L) to characterize the toxicity of TBPPA. This was based on expert review. The OSPAR Commission fact sheet for TBPPA (OSPAR, 2004) reports an acute

toxicity daphnia EC50 (0.96 mg/L based on a measured 48 hour LC50), acute toxicity fish LC50 (0.54 mg/L based on a measured 96 hour LC50), chronic toxicity daphnia NOEC (0.3 mg/L based on a measured 21 day NOEC) and chronic toxicity fish NOEC (0.16 mg/L based on a measure 35 day NOEC (larval survival)).

Conclusions: Ecology has determined that tetrabromobisphenol A meets the draft PBT criteria specified in WAC 173-333-320.

1,2,4,5-Tetrachlorobenzene

Background: 1,2,4,5-Tetrachlorobenzene (CAS 95-94-3) was formerly used as an insecticide and an intermediate in the production of herbicides and defoliants (Lewis, 1993). It is also a degradation product of pentachlorobenzene and hexachlorobenzene (Environment Canada, 2003). EPA (1988) identified several uses and sources of chlorinated benzenes including use as solvents in the manufacturing of dyes, as lubricants and degreasing agents.

1,2,4,5-Tetrachlorobenzene has been found in the Washington environment. SAIC (2001) reported that 1,2,4,5 tetrachlorobenzene was present in marine and freshwater sediments (approximately 4 percent of marine and freshwater sediment samples analyzed for 1,2,4,5-tetrachlorobenzene contained measurable amounts of this substance).

1,2,4,5-Tetrachlorobenzene has been identified as a Level II substance under the Bi-National Toxics Strategy (GLNPO, 1997), a PBT chemical for purposes of promoting voluntary reductions under the Waste Minimization Plan (EPA, 1998d), a Track 1 substance subject to virtual elimination under Canada's Toxic Substances Management Policy (Environment Canada, 2003) and a PBT chemical on the OSPAR Commission's List of Substances of PossibleConcern (OSPAR, 2004b).

PBT Characteristics: Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity of 1,2,4,5-tetrachlorobenzene.

- ***Persistence:*** Mackay et al. (1992) estimated average half-lives in surface waters and soils (@ 8 months) and surface sediments (@ 2 years). Environment Canada (2003) reviewed the Mackay et al. information, laboratory studies and sediment core data and concluded that tetrachlorobenzenes meet the persistence criteria in the Persistence and Bioaccumulation Regulations of the Canadian Environmental Protection Act (Government of Canada, 2000)[92] EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 2393 hours.

- ***Bioaccumulation****:* EPA (1998b) evaluated the range of BAF/BCF values available for 1,2,4,5-tetrachlorobenzene and used a BCF value of 4,073 to characterize the bioaccumulation potential of this substance. This value is based on a measured BCF included in the Syracuse Research Corporation BCF database file. Environment Canada (2003) reported that BAFs for tetrachlorobenzenes ranged between 1,180 and 135,000 for fathead minnows, rainbow trout, guppy and earthworms and concluded that tetrachlorobenzenes meet the bioaccumulation criteria in the Persistence and Bioaccumulation Regulations of the Canadian Environmental Protection Act (Government of Canada, 2000)[93]. The OSPAR fact sheet for 1,2,4,5-tetrachlorobenzene identifies a range of Log K_{ow} values (3 to 5) and BCF values ranging from 741 to 4,830 (OSPAR, 2004).

[92] Under the Canadian Persistence and Bioaccumulation Regulations, a substance is considered persistent if it meet at least one of the following half-life criteria: air (> 2 days); water (> 182 days); sediment (> 365 days) or soil (> 182 days).

[93] Under the Canadian Persistence and Bioaccumulation Regulations, a substance meets the bioaccumulation criteria if it has a BAF > 5000, a BCF > 5000 or a log Kow > 5.

- ***Toxicity (Non-cancer)****:* Adverse effects on the liver and kidney have been reported in animal bioassays where rats were fed diets contain 1,2,4,5-tetrachlorobenzene. EPA has established an oral RfD value (0.0003 mg/kg/day)[94] that is published in the IRIS database (EPA 2004a).

- ***Toxicity (Cancer)***: EPA (2004a) states that 1,2,4,5-tetrachlorobenzene has not undergone a complete evaluation and determination under the IRIS program for human carcinogenic potential.

- ***Ecological toxicity****:* 1,2,4,5-Tetrachlorobenzene is toxic to aquatic organisms. EPA (1998) identified an EC50 of 0.01 in a 2-day study with diatoms. Based on structure-activity relationships, EPA calculated an acute (0.028 mg/L (mysid shrimp) ECOSAR value. Based on toxic effects in benthic organisms, Environment Canada (2003) concluded that tetrachlorobenzenes meet the definition of "toxic" under the under the Canadian Environmental Protection Act. The OSPAR Commission fact sheet for 1,2,4,5-tetrachlorobenzene (OSPAR, 2004) reports acute toxicity algae IC50 values (0.27 and 4.97 mg/L), acute toxicity daphnia EC50 (1.48 and 530 mg/L), acute toxicity fish LC50 (0.3 to 26.4 mg/L) and chronic toxicity fish NOEC (0.069 to 0.18 mg/L).

Conclusions: Ecology has determined that 1,2,4,5-tetrachlorobenzene meets the draft PBT criteria in WAC 173-333-320.

[94] EPA (1991) identified a NOAEL of 0.34 mg/kg/day using the results from 13 week rat feeding study. EPA applied an uncertainty factor of 1000. EPA assigned a medium level of confidence to the study. However, EPA also assigned a low confidence level to the database and the RfD because the database lacks a true chronic study and adequate reproductive and teratogenic bioassays. NOTE: The IRIS listing states that an EPA contractor has identified more recent toxicological studies pertinent to the RfD for this substance.

Toxaphene

Background: Toxaphene (CAS 8001-35-2) is one of several chlorinated insecticides derived from hexachlorocyclopentadiene. It is a non-systematic and contact insecticide that was used primarily on cotton, cereal grains, nuts and vegetables. It was also used to control ticks and mites in livestock. It was the most widely used insecticide in the United States in 1975. The Environmental Protection Agency has banned the importation and manufacture of toxaphene.

Toxaphene has been found to be present in the Washington environment[95]. Toxaphene has also been identified as a parameter of concern for several waterbodies or segments included on Washington's 303(d) list (Ecology, 2000c; Ecology 2004b).

Toxaphene has been identified as a Level I substance under the Bi-National Toxics Strategy (GLNPO, 1997), one of the initial PBT chemicals identified by EPA (EPA, 1998a), a PBT chemical for purposes of reporting under EPA's Toxics Release Inventory program (EPA, 1999a) and a persistent organic pollutant (POPs) by the United Nations Environmental Program (UNEP, 2001), a persistent organic pollutant (POP) under the 1998 Aarhus Protocol on Persistent Organic Pollutants (UN-ECE, 2004a) and a PBT chemical on the OSPAR Commission's List of Substances of Possible Concern (OSPAR, 2004b).

PBT Characteristics: Ecology has reviewed readily available information on the persistence, bioaccumulation potential and toxicity for toxaphene.

- ***Persistence:*** Mackay et al. (1997) estimated average half-lives in surface water (6 years), soils (6 years) and surface sediments (6 years). These values are consistent with the range of soil half-life values (1.5 – 20 years) considered by EPA when deciding whether to include toxaphene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). Ritter et al. (1996) reported that toxaphene's soil half-life ranges from 100 days to 12 years, depending on the soil type and climate. EPA (1998b) used the EQC multi-media model to estimate a regional half-life of 39,526 hours.

- ***Bioaccumulation:*** EPA (1998b) evaluated the range of BAF/BCF values available for toxaphene and used a BAF value of 40,000,000 to characterize the bioaccumulation potential of this substance. This value is based on a measured BAF included in the HWIR database. This value is considerably higher than the BCF value (34,050) that EPA used when deciding whether to include toxaphene among the substances identified as PBT chemicals for purposes of reporting under the Toxics Release Inventory (TRI) program (EPA, 1999a). Ritter et al. (1996) reported bioconcentration factors of 4,247 and 76,000 in mosquito fish and brook trout, respectively.

- ***Toxicity (Non-cancer):*** Toxaphene has been shown to cause several adverse health effects in animal studies (e.g. increased liver and kidney weights, histological changes in the liver, kidney and thyroid). EPA has not published an oral reference dose in the IRIS or HEAST

[95] Based on an initial data query, Ecology found that @ 11 percent of environmental samples included in the Environmental Information Management database (as of March 2002) that had been analyzed for toxaphene had measurable levels of this substance.

databases. However, ATSDR (2004a) has established a Minimal Risk Level (0.001 mg/kg/day) for intermediate exposure (14 – 364 days).

- ***Toxicity (Cancer)****:* EPA has classified toxaphene as a probable human carcinogen (B2) and established an oral cancer slope factor (1.1 $(mg/kg/day)^{-1}$) that is published in the IRIS database (EPA, 2004a).[96]

- ***Ecological Toxicity****:* Toxaphene is highly toxic to aquatic organisms. EPA has established an AWQC FCV (0.0000002 mg/L) developed by EPA's Office of Water[97], a Tier II Secondary Chronic Value (SCV) (0.00001 mg/L) developed through the Great Lakes Water Quality Initiative [98] and an OPPT measured chronic data (0.00035 mg/L) that corresponds "a threshold concentration of a chemical in water at which statistically significant effects on an aquatic test population's survival, growth, or reproduction are expected to occur". Ritter et al. (1996) concluded that toxaphene is highly toxic, with 96-hour LC50 values in the range of 0.0018 mg/L in rainbow trout and 0.022 mg/L in bluegill.

Conclusions: Ecology has determined that toxaphene meets the draft PBT criteria specified in WAC 173-333-320.

[96] Toxaphene is classified as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity in animals [This is equivalent to "known/likely" category reflected in the 1996 proposed revisions to the Agency's carcinogen classification system (EPA, 1996). To date, EPA has not issued final revised cancer guidelines.] The cancer slope factor was calculated using the linearized multistage procedure based on increased rates of hepatocellular carcinomas and neoplastic nodules in mice. (EPA, 2001a)

[97] The Ambient Water Quality Criteria FCV values were developed in the mid-1980's and distributed for public review. The values are compiled in the Ecotox Thresholds ECO Update (Volume 3 No. 2) (EPA, 1996).

[98] The GLWQI values were derived using the same methods that EPA uses to derive ambient water quality criteria in cases where final residues values are not used. The source document for the Tier I FCV for cadmium is the Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water (EPA, 1995b).

VII. References

Agency for Toxic Substances and Disease Registry. 2004a. Minimal Risk Levels (MRLs) for Hazardous Substances (January 2004). ATSDR. Atlanta GA.

Agency for Toxic Substances and Disease Registry. 2000a. Toxicological Profile for Aldrin/Dieldrin (Draft). ATSDR, Atlanta GA.

Agency for Toxic Substances and Disease Registry. 2000b. Toxicological Profile for Endrin. ATSDR, Atlanta GA.

Agency for Toxic Substances and Disease Registry. 1999a. Toxicological Profile for Cadmium. ATSDR, Atlanta GA.

Agency for Toxic Substances and Disease Registry. 1995a. Toxicological Profile for Mirex and Chlordecone. ATSDR, Atlanta GA.

Canfield, R.L., Henderson, C.R., Cory-Slechta, D.A., Cox, C., Jusko, T.A. and B.P. Lanphear. 2003. Intellectual Impairment in Children with Blood Lead Concentrations below 10 ug per Deciliter. N Engl. J. Med. 348: 1517-1526.

Centers for Disease Control and Prevention (CDCP). 2002. Managing Elevated Blood Lead Levels Among Young Children: Recommendations from the Advisory Committee on Childhood Lead Poisoning Prevention. Atlanta, GA.

Centers for Disease Control and Prevention (CDCP). 1997. Screening Young Children for Lead Poisoning: Guidance for State and Local Public Officials. Atlanta, GA.

Centers for Disease Control (CDC). 1991. Preventing Lead Poisoning in Young Children: A Statement by the Centers for Disease Control. Atlanta, GA (October 1991).

Darnerud, P. O., G. Eriksen, T. Johannesson, P.B. Larsen and M. Viluksela. 2001. Polybrominated Diphenyl Ethers: Occurrence, Dietary Exposure, and Toxicology. Environmental Health Perspectives: 109 (1): 49 – 68.

Environment Canada. 2003a. Follow-up Report on Five PSL1 Substances for Which There Was Insufficient Information to Conclude Whether the Substances Constitute a Danger to the Environment: 1,2-Dichlorobenzene; 1,4-Dichlorobenzene; Trichlorobenzenes; Tetrachlorobenzenes; and Pentachlorobenzene. December 2003.

Environment Canada. 2003b. Short Chain Chlorinated Paraffins (SSCP) Substance Dossier (Final Draft II). Prepared for UNECE ad hoc Expert Group on POPS (Revised May 16, 2003).

Environment Canada and Ontario Ministry of the Environment and Energy. 1994. The ARET Substance Selection Process and Guidelines. January 1994.

Environment Canada and Health and Welfare Canada. 1993. Priority Substances List Supporting Document: Chlorinated paraffins. Ottawa, Canada.

Environmental Protection Agency. 2004a. Integrated Risk Information System (IRIS). Washington DC.

Environmental Protection Agency. 2004b. ECOTOX Database. Washington DC.

Environmental Protection Agency. 2004c. PBT Profiler. Prepared by Environmental Science Center for the Office of Pollution Prevention and Toxic Substances, EPA. Version 1.203.

Environmental Protection Agency. 2002a. Perfluoroalkyl Sulfonates; Significant New use Rule; Final Rule and Supplemental Proposed Rule. Federal Register (March 11, 2002).

Environmental Protection Agency. 2002b. Revised Draft Hazard Assessment of Perfluorooctanoic Acid and Its Salts. Prepared by Office of Pollution Prevention and Toxics, Risk Assessment Division. November 4, 2002.

Environmental Protection Agency. 2002c. ECOTOX Database. Washington DC.

Environmental Protection Agency. 2000a. Bioaccumulation Testing and Interpretation for the purpose of Sediment Quality Assessment: Status and Needs. Office of Water/Office of Solid Waste. EPA-823-R-00-001.

Environmental Protection Agency. 1999a. Persistent Toxic (PBT) Chemicals; Lowering of Reporting Thresholds for Certain PBT Chemicals; Addition of Certain PBT Chemicals; Community Right-to-Know Toxic Chemicals Reporting. Final Rule. October 29, 1999 (64 FR 58666).

Environmental Protection Agency. 1999b. Category for Persistent, Bioaccumulative and Toxic New Chemical Substances. Policy Statement. November 4, 1999 (64 FR 60194)

Environmental Protection Agency. 1999c. Residual Risk: Report to Congress. Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA-453/R—99-001.

Environmental Protection Agency. 1999d. Proposal to Amend the Final Water Quality Standards for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern. October 4, 1999 (64 FR 53632 – 53648)

Environmental Protection Agency. 1998a. A Multi-Media Strategy for Priority Persistent, Bioaccumulative and Toxic (PBT) Pollutants. Prepared by the USEPA Persistent, Bioaccumulative and Toxic Pollutants Plenary Group and the USEPA Office Directors Multi-media and Pollution Prevention Forum. November 16, 1998.

Environmental Protection Agency. 1998b. Waste Minimization Prioritization Tool Spreadsheet Document for the RCRA Waste Minimization PBT Chemical List Docket (# F-98-MMLP-FFFFF). September 1998.

Environmental Protection Agency. 1998c. Waste Minimization Prioritization Tool: Comment Response Document for the RCRA Waste Minimization PBT Chemical List Docket (#F-98-MMLP-FFFFF). September 1998.

Environmental Protection Agency. 1996a. Ecotox Thresholds. ECO Update. Washington, DC: Office of Emergency and Remedial Response. EPA540/F-95/038.

Environmental Protection Agency. 1995a. Final Water Quality Guidance for the Great Lakes System. Final Rule. March 23, 1995. (60 FR 15366)

Environmental Protection Agency. 1995b. Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Humans and Ecological Receptors. Volume I. Office of Solid Waste. Washington DC.

Environmental Protection Agency. 1985. Ambient Water Quality Criteria for Cadmium - 1984. PB85-227031.

European Environment Agency. 2001. Late lessons from early warnings: the precautionary principle 1896 – 2000. Copenhagen, Denmark.

European Commission. 2000. European Union Risk Assessment Report. Alkanes, C_{10-13}, chloro. Brussels.

Government of Canada. 2000. Persistence and bioaccumulation Regulations. Canada Gazette, Part II, 134: 607-611.

Great Lakes National Program Office (GLNPO). 1997. The Great Lakes Bi-National Toxics Strategy, Canada United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin. Level I and II targeted persistent toxic substances. April 7, 1997.

Hornung M.W., Zabel E.W. and R.E. Peterson. 1996. Additive interactionsbetween pairs of polybrominated dibenzo- *p*-dioxin, dibenzofuran, and biphenyl congeners in a rainbow trout early life stage mortality bioassay. Toxicol Appl Pharmacol, 140: 345-355.

Hornung, M.W., Zabel E.W., and R.E. Peterson. 1996b. Toxic equivalency factors of polybrominated dibenzo- *p*-dioxin, dibenzofuran, biphenyl, and polyhalogenated diphenyl ether congeners based on rainbow trout early life stage mortality. Toxicol Appl Pharmacol, 140: 227-234.

International Agency for Research on Cancer (IARC). 2004a. Overall Evaluations of Carcinogenicity to Humans: As evaluated in IARC Monographs Volumes 1-88 (a total of 900 agents, mixtures and exposures). http://www-cie.iarc.fr/monoeval/crthall.html.

Lanphear, B.P., Dietrich, K., Auinger, P. and C. Cox. 2000. Cognitive Deficits Associated With Blood Lead Concentrations < 10 microg/dL in U.S. Children and Adolescents. Public Health Reports 115 (6): 521-529.

Lewis, R.J. 1993. Hawley's Condensed Chemical Dictionary (12th Edition). Van Nostrand Reinhold. New York, NY.

Mackay, D., W.Y. Shiu and K.C. Ma. 1997. Illustrated Handbook of Physical Chemical Properties and Environmental Fate for Organic Chemicals. Volume V: Pesticide Chemicals. Lewis Publishers, New York NY.

Mackay, D., W.Y. Shiu and K.C. Ma. 1995. Illustrated Handbook of Physical Chemical Properties and Environmental Fate for Organic Chemicals. Volume IV: Oxygen, Nitrogen and Sulfur Containing Compounds. Lewis Publishers, New York NY.

Mackay, D., W.Y. Shiu and K.C. Ma. 1993. Illustrated Handbook of Physical Chemical Properties and Environmental Fate for Organic Chemicals. Volume III. Volatile Organic Chemicals. Lewis Publishers, New York NY.

Mackay, D., W.Y. Shiu and K.C. Ma. 1992. Illustrated Handbook of Physical Chemical Properties and Environmental Fate for Organic Chemicals. Volume II: Polynuclear Aromatic Hydrocarbons, Polychlorinated Dioxins, and Dibenzofurans. Lewis Publishers, New York NY.

Mackay, D., W.Y. Shiu and K.C. Ma. 1991. Illustrated Handbook of Physical Chemical Properties and Environmental Fate for Organic Chemicals. Volume I: Monoaromatic Hydrocarbons, Chlorobenzenes and PCBs. Lewis Publishers, New York NY.

National Academy of Sciences. 2000. Toxicological Risks of Selected Flame Retardant Chemicals. National Academy Press, Washington DC.

National Toxicology Program. 2002a. Report on Carcinogens, Tenth Edition. U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program. December, 2002.

Nisbet, I.C.T. and P.K. Lagoy. 1992. Toxic Equivalency Factors for polycyclic aromatic hydrocarbons (PAHs). Regulatory Toxicology and Pharmacology 16: 290-300.

Organization of Economic Cooperation and Development (OECD). 2002. Hazard Assessment of Perfluorooctane Sulfonate (PFOS) and its Salts. ENV/JM/RD(2002)17/FINAL. November 21, 2002.

OSPAR Commission. 2004a. OSPAR List of Chemicals for Priority Action (Reference number 2004-12). Annex 7. OSPAR Convention for the Protection of the Marine Environment of the North-East.

OSPAR Commission. 2004b. OSPAR List of Substances of Possible Concern (Reference Number 2002-17).

OSPAR Commission. 2004c. Fact Sheet for Aldrin. Downloaded November, 2004.

OSPAR Commission. 2004d. Fact Sheet for Cadmium. Downloaded November 2004.

OSPAR Commission. 2004e. Fact Sheet for Chlordane. Downloaded November 2004.

OSPAR Commission. 2004f. Fact Sheet for Chlordecone. Downloaded November 2004.

OSPAR Commission. 2004g. Fact Sheet for Dieldrin. Downloaded November 2004.

OSPAR Commission. 2004h. Fact Sheet for Endrin. Downloaded November 2004.

OSPAR Commission. 2004i. Fact Sheet for Hexabromobiphenyl. Downloaded November 2004.

OSPAR Commission. 2004j. Fact Sheet for Hexachlorobenzene. Downloaded November 2004.

OSPAR Commission. 2004k. Fact Sheet for Hexachlorobutadiene. Downloaded November 2004.

OSPAR Commission. 2004l. Fact Sheet for Mirex. Downloaded November 2004.

OSPAR Commission. 2004m. Fact Sheet for Pentachlorobenzene. Downloaded November 2004.

OSPAR Commission. 2004. Fact Sheet for Pentabromodiphenyl ether, mixed isomers. Downloaded November 2004.

OSPAR Commission. 2004. Fact Sheet for Hexachloronapthalene. Downloaded November 2004.

OSPAR Commission. 2004. Fact Sheet for short-chained chlorinated paraffins. Downloaded November 2004.

OSPAR Commission. 2004. Fact Sheet for 1,2,4,5-Tetrachlorobenzene. Downloaded November 2004.

OSPAR Commission. 2001. Background Document on Polycyclic Hydrocarbons.

OSPAR Commission. 2001. Background Document on Short Chain Chlorinated Paraffins. OSPAR 01/4/8.

Research Triangle Institute. 1998a. Chemical Screening Report for the RCRA PBT List Docket: Final Report. Prepared for the EPA Office of Solid Waste. September 30, 1998.

Research Triangle Institute. 1998b. Revised Chemical Methodology Testing Results. Prepared for the EPA Office of Solid Waste. August, 1998.

Ritter, L., K.R. Solomon, J. Forget, M. Sternoff and C.O. Leary. 1996. Persistent Organic Pollutants. An Assessment Report on: DDT-Aldrin-Dieldrin-Endrin-Chlordane Heptachlor-Hexachlorobenzene Mirex-Toxaphene Polychlorinated Biphenyls Dioxins and Furans. Prepared for the International Programme on Chemical Safety.

Science Applications International Corporation (SAIC). 2001. PBT Chemical Screening. Technical Memorandum Prepared for the Washington Department of Ecology. June 2001.

Schwartz, J. 1994. Low-level Lead Exposure and Children's IQ: A Meta-Analysis and Search for a Threshold. Environmental Research 65(1): 42-55.

Swedish Chemicals Inspectorate/Swedish Environmental Protection Agency (SCI/SEPA). 2004. Perflourooctane Sulfonate (PFOS): Dossier prepared in support for nomination of PFOS to the

UN-ECE LRTAP Protocol and the Stockholm Convention. Preliminary Risk Profile. August 2004. Stockholm, Sweden.

Swedish Chemicals Inspectorate/Swedish Environmental Protection Agency (SCI/SEPA). 2002. Prioritisation of POP Candidates. Interim Report. November 29, 2002. Stockholm, Sweden.

United Nations Environmental Program. 2002a. Regionally Based Assessment of Persistent Toxic Substances: North America Regional Report (Canada, Mexico, United States of America). UNEP Chemicals. December 2002.

United Nations Economic Commission for Europe. 2004a. The 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs). Convention on Long Range Transboundary Air Pollution. http://www.unece.org/env/lrtap/pops_h1.htm.

United Nations Environmental Program. 2001. Stockholm Convention on Persistent Organic Pollutants.

United Nations. 1999a. 1979 Convention on Long-Range Transboundary Air Pollution, 1998 Protocol on Persistent Organic Pollutants. ECE/EB.Air/66.

Van den Berg, M. et. al. 1998. Toxic Equivalency Factors (TEFs) for PCB, PCDDs, PCDFs for Humans and Wildlife. Environmental Health Perspectives 106: 775-792.

Van de Plassche and A. Schanger. 2002. Polychlorinated Napthalenes (Preliminary Risk Profile). Royal Haskoning, The Netherlands. August 6, 2002.

Virtual Elimination Task Force. 1993. A Strategy for Virtual Elimination of Persistent Toxic Substances: Report of the Virtual Elimination Task Force to the International Joint Commission. Windsor, Ontario.

Washington Department of Ecology and Washington Department of Health. 2004. Washington State PBDE Chemical Action Plan. October 11, 2004. Department of Ecology Publication No. 04-03-045; Department of Health Publication No. 333-060.

Washington Department of Ecology. 2004a. Environmental Information Management System.

Washington Department of Ecology. 2004b. Washington State's Water Quality Assessment [303(d)] List for 2002/2004. Second public review draft. http://www.ecy.wa.gov/gov/programs/wq/303d.

Washington Department of Ecology and Washington Department of Health. 2003. Washington State Mercury Chemical Action Plan. Department of Ecology Publication No. 03-03-001; Department of Health Publication No. 333-051.

Washington Department of Ecology. 2000a. Draft Strategy to Continually Reduce Persistent, Bioaccumulative, Toxic Chemicals (PBTs) in Washington State. Publication # 00-03-002.

Washington Department of Ecology. 2000b. Proposed Strategy to Continually Reduce Persistent, Bioaccumulative Toxins in Washington State. Publication #00-03-054.

Washington Department of Ecology. 2000c. Washington State's Water Quality Assessment List for 1998. http://www.ecy.wa.gov/gov/programs/wq/303d.

World Health Organization-International Programme of Chemical Safety (WHO-IPCS). 1997. Environmental Health Criteria 192: Flame Retardants: A General Introduction. Geneva, World Health Organization.

World Health Organization-International Programme of Chemical Safety (WHO-IPCS). 1994. Environmental Health Criteria 156: Hexachlorobutadiene. Geneva, World Health Organization.

World Health Organization-International Programme of Chemical Safety (WHO-IPCS). 1994. Environmental Health Criteria 152: Polybrominated biphenyls. Geneva, World Health Organization.

World Health Organization-International Programme of Chemical Safety (WHO-IPCS). 1991. Environmental Health Criteria 128: Chlorobenzenes other than Pentachlorobenzene. Geneva, World Health Organization.

World Health Organization-International Programme of Chemical Safety (WHO-IPCS). 1984. Environmental Health Criteria 44: Mirex. Geneva, World Health Organization.