SB 737 Background Information Summary of Listing Processes for Persistent, Bioaccumulative, and Toxic Chemicals: Final Report

Prepared for

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ACRONYMS

ACWA	Oregon Association of Clean Water Agencies
BAF	Bioaccumulation factor
BCF	Bioconcentration factor
CEPA	Canadian Environmental Protection Act
DDT	Dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
LOC	League of Oregon Cities
Log K_{OW}	Logarithm of the octanol-water partition coefficient
LRTAP	Long range transport of air pollutants
PCB	Polychlorinated biphenyl
PBDE	Polybrominated diphenyl ethers
PBT	Persistent, bioaccumulative, and toxic chemical
RCRA	Resource Conservation and Recovery Act
REACH	Registration and Evaluation of Chemicals
RSET	Regional Sediment Evaluation Team
SB	Oregon Senate Bill
$t_{1/2}$	Chemical half-life (in days)
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
UN	United Nations
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe
UN-GHS	United Nations Globally Harmonized System for Classification and Labeling of Chemicals
USEPA	U.S. Environmental Protection Agency
vPvB	Very persistent and very bioaccumulative substances
WDOE	Washington Department of Ecology
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Senate Bill (SB) 737 was passed by the Oregon Legislature in 2007, and directs DEQ to develop a priority list of persistent, bioaccumulative, and toxic (PBT) chemicals for which pollution prevention and toxics reductions programs will need to be developed by 52 of Oregon's largest wastewater treatment plants (WWTPs) by 2011. The Oregon Association of Clean Water Agencies (ACWA) and the League of Oregon Cities (LOC) supported development of the present report to assist DEQ and other interested parties by providing background information regarding the regulatory and scientific approaches used by other governments (state, federal, and international) to identify and rank PBT chemicals in the context of pollution prevention and reduction programs. The primary goal of this report is to compile and summarize PBT ranking schemes used by various government and international organizations, and to prepare an analysis that compares and contrasts the various PBT chemical listing processes to provide a basis for proposing a list of chemicals that meet the definition of "persistent pollutant" under SB 737.

BACKGROUND INFORMATION SUMMARY

Internet searches were conducted to compile pertinent information regarding the PBT schemes into Tables 1-4 (Appendix A). All tables are organized according to the geographic extent to which the schemes apply including: Inter/cross-national, US Federal Government, Canadian, European Union, Australian, New Zealand, and US States. Table 1 provides general descriptive information for each PBT scheme including regulatory purpose and approach(s) used to achieve PBT reductions in the environment, contact information, and internet links to general program information. Table 2 provides the persistence, bioaccumulation, and toxicity criteria for each of the PBT schemes. Table 3 includes other criteria and considerations for each of the PBT schemes such as: criteria for non-PBT parameters, chemical analytical detection and financial considerations, whether monitoring data were used in determining the PBT list, and financial Considerations. Table 4 identifies the substances that were ultimately classified as PBTs by each of the prioritization and management schemes.

DISCUSSION

Most PBT schemes we reviewed share similar goals of identifying chemicals of greatest concern to human health and environmental protection (the "worst of the worst") to support pollution prevention / reduction programs. Pollution prevention—as opposed to "end of pipe" discharge regulation—was likely selected because it is arguably difficult to mitigate or remove PBT chemicals once they are actually released into the environment. The types of pollution prevention programs used or supported in each PBT scheme ranged widely owing to the equally wide range of regulatory purposes or goals each scheme was selected to support.

Persistence

The persistence of a chemical substance is a key factor determining how long a chemical may remain in the environment and, hence, remain available for exposure to humans, aquatic organisms, or wildlife. Even though measuring or predicting the persistence of a chemical is a complex function of many physical and chemical parameters, most PBT schemes define "persistence" on the basis of chemical half-life, or $t_{1/2}$. Chemical half-life trigger values used by most PBT schemes were similar, and ranged from values of > 60 – 180 days (i.e., 2 – 6 months) for most environmental media (Table 2).

Bioaccumulation

The accumulation of a chemical from the environment into an organism can occur via many pathways, including direct exposure to environmental media such as water, air, and sediments, accumulation from the diet, or a combination of both. The amount of accumulation is generally measured as a ratio of the concentration in organisms tissues divided by the amount in the environmental media or food sources. These ratios are termed *bioaccumulation factor (BAF)* if accumulation is from environmental media plus the diet, or *bioconcentration factor (BCF)* if accumulation is from the environmental media only. Another measure of the tendency of a chemical to accumulate in organism tissues is a common physical property that measures the tendency of a chemical to partition from water into fats or lipids, and is known as the *log octanol-water partition coefficient* (log K_{OW}). Most PBT prioritization schemes used similar values that if exceeded, denote that a chemical is of bioaccumulative concern. For BCF and BAF values (Table 2), these generally were >1000 or >5000, with >1000 generally being used to distinguish "lower" levels of bioaccumulation concern. log K_{OW} threshold values were also quite similar for most PBT schemes at >5, but with some as low as >3.5.

Toxicity

As opposed to either persistence or bioaccumulation, criteria for evaluating whether a chemical is of *toxic* concern varied widely among the various PBT schemes we reviewed (Table 2). Some PBT schemes were fairly qualitative, using descriptors of toxicity such as *evidence of adverse effects or toxicity data that indicated potential for effects*, or the *potential to adversely affect human health/environment*. Several other schemes were more quantitative in that they provided specific toxicity test endpoint values that, if exceeded, denoted unacceptable adverse impacts to human health or the environment. However, there was little consistency among those PBT schemes that used quantitative measures of toxicity with respect to the toxicity endpoint (e.g., mortality vs. reproductive effects), or the specific numeric toxicity thresholds that were selected.

PBT Chemical Lists

Table 4 lists over 100 chemicals that have been included in one or more of the PBT prioritization and management schemes. Relatively few of the >100 chemicals listed in Table 4 were included in all PBT schemes even though many of the schemes used similar PBT identification and prioritization thresholds. The PBT chemicals identified most frequently were the 12 organic PBTs identified in the Stockholm Convention for POPs. Most of these 12 compounds are chlorinated and/or aromatic organic compounds, and these characteristics are most often associated with high levels of environmental persistence, bioaccumulation, and toxicity. Looking beyond this list of 12 compounds, the identity and number of chemicals considered to be PBT varied widely.

Scientific Uncertainties

Most of the PBT prioritization schemes summarized in Tables 1-4 are based on fairly simple, generic thresholds for persistence, bioaccumulation, and toxicity. However, any such simplification knowingly accepts that real environmental complexities are being ignored to provide a scheme that is practical to develop and apply, and easy to understand. Therefore, while the simpler PBT threshold approaches are practical to apply and usually environmentally conservative, proper application of these threshold approaches needs to keep in mind several key uncertainties:

- Most PBT prioritization schemes are conducted using category-based chemical hazard screening, which means that strict "pass/fail" decisions determine subsequent assessment outcomes (e.g., a chemical with a BCF $\geq$ 5000 is bioaccumulative, whereas one with a BCF < 5000 is not bioaccumulative).
- Reliable persistence, bioaccumulation, and toxicity data for any given chemical is not always available (and so must be modeled), and these data can sometimes vary substantially among different measurements for the same chemical.
- Multiple binary assessments and PBT definitions can dramatically influence the final list of chemicals ultimately selected for regulatory control (e.g., PBT lists that include chemicals that are persistent ***or*** bioaccumulative can be substantially larger than those that only include chemicals that are persistent ***and*** bioaccumulative).
- Most PBT prioritization schemes only evaluate potential environmental hazards, rather than actual or predicted environmental risks based on an integration of hazard data with chemical exposure concentrations.

RELATIONSHIP OF PBT SCHEMES TO SB 737 DEFINITION OF "PERSISTENT POLLUTANT"

The selection of one or more schemes for prioritizing PBT chemicals for the purposes of developing pollution prevention plans under SB 737 will likely be informed, in part, by which scheme(s) best meet the definition of "persistent pollutant" under SB 737. This definition is:

> *"Persistent pollutant" means a substance that is toxic and either persists in the environment or accumulates in the tissues of humans, fish, wildlife, or plants.*

The key aspect of this definition is that a "persistent" pollutant is one that *either* persists in the environment, *or* accumulates in organism tissues. However, most all of the schemes summarized in Tables 1-4 are built on PBT definitions of toxic substances that persist *and* bioaccumulate in the environment. The schemes we reviewed that used a PBT definition most similar to SB 737 thus include:

- Canadian Environmental Protection Act (CEPA) – PBT substances are those that are persistent ***or*** bioaccumulative and toxic
- USEPA's TRI – One of the criteria used to include a chemical on the TRI list is if a chemical can be shown to be either persistent and toxic, ***or*** bioaccumulative and toxic.

The primary implication of using a PBT prioritization scheme based on persistence ***or*** bioaccumulation is that the number of chemicals included can be substantially larger (possibly up to 5-fold larger) than one that defines PBT as persistence ***and*** bioaccumulation. To address this challenge, both of these PBT schemes that use the more inclusive persistence ***or*** bioaccumulation definition also generate a smaller list of higher priority chemicals using a persistence ***and*** bioaccumulation definition.

Secondly, PBT definitions similar to SB 737 that are based on persistence *or* bioaccumulation have the potential to include a large number of inorganic metals. Metals—by definition as elements—are clearly persistent in the environment and so virtually any metal could conceivably be included in a hazard ranking scheme based at least on persistence. However, even though most metals do ultimately accumulate to some degree in organism tissues, the latest scientific data on bioaccumulation for many metals do not currently support the use of generic BAF or BCF thresholds in chemical prioritization or classification schemes (e.g., for PBT prioritization).

The other aspect of the SB 737 definition of "persistent pollutant" is that bioaccumulation into wildlife and plant tissues are also included in addition to humans and fish. However, very few of the PBT schemes summarized in Tables 1-4 include any bioaccumulation data or toxicity considerations specifically tailored to address hazards to wildlife or plants.

1. INTRODUCTION AND PROJECT OBJECTIVES

Senate Bill (SB) 737 was passed by the Oregon Legislature in 2007, and directs DEQ to develop a priority list of persistent, bioaccumulative, and toxic (PBT) chemicals for which pollution prevention and toxics reductions programs will need to be developed by 52 of Oregon's largest wastewater treatment plants (WWTPs) by 2011 (Oregon Legislative Assembly 2007; see also Appendix B). SB 737 was enacted because it was recognized that several sources of known or suspected PBT chemicals exist, but that Oregon currently does not have a comprehensive statewide approach or any economically feasible alternatives for reduction of PBT chemicals. To meet this 2011 deadline, SB 737 requires that DEQ consult with all interested parties to:

- Develop a list of PBT chemicals that have been shown to cause adverse impacts to human health, wildlife, and aquatic life (due to the Legislature in June 2009), and to:
- Identify the point, non-point, and legacy sources of these priority PBTs in the state, and recommend approaches for source reduction and other controls needed to reduce point, non-point, and legacy discharges of these PBTs (due to the Legislature in June 2010).

PBT chemicals are substances that, owing to their chemical properties, tend to persist in the environment for long periods of time, and can accumulate in organisms or ecological food chains to concentrations that are harmful to humans or plants and animals in the natural environment. Most of the chemicals readily accepted as being "PBT" include "legacy[1]" organic compounds such as polychlorinated biphenyls (PCBs) dioxins and furans, organochlorine insect ides (e.g., chlordane, DDT), and in some cases, metals that readily accumulate in organism tissues such as mercury. These chemicals have been associated with a wide range of adverse human health effects such as reproductive and developmental problems, cancer, genetic damage, and effects on the nervous system (USEPA 2008). Some of these PBT chemicals can also be transported long distances and can readily move between air, land, and water. As a result, PBT chemicals pose a unique threat to human health and the environment, and so have been the subject of significant worldwide scientific and regulatory concern for several decades (Rodan et al. 1999, Lerche et al. 2002, Muir and Howard 2006).

In response to these widely recognized concerns, government bodies worldwide have developed strategies for preventing or minimizing the introduction, use, or transport of PBT chemicals. Notable examples include international treaties such as the *Stockholm Convention on Persistent Organic Pollutants* (UNEP 2001); a multi-agency program developed by the U.S. Environmental Protection Agency (USEPA): *Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Chemicals* (USEPA 1998); and one of the most comprehensive U.S. State programs developed by Washington's Department of Ecology (DOE) to reduce persistent, bioaccumulative toxins (PBTs) in Washington State (WDOE 2000) which led to development of the first formal statewide PBT rule (WAC 2006). Most of these PBT pollution prevention programs consist of two main elements:

- A scientific process for identifying and prioritizing which chemicals are most likely to have PBT properties of concern to human health and the environment. The scientific processes used typically estimate the potential hazard of a given compound based on its chemical tendencies to persist in the environment or accumulate in

[1] A "legacy" chemical typically refers to one that is present in the environment, but is no longer being used or discharged to the environment, or has been legally banned from manufacture or commerce.

organisms tissues, and the potential toxicity of the chemicals to humans, fish, or wildlife.

- Pollution prevention or mitigation programs focused on controlling or mitigating, to the extent practicable, the release or transport of a chemical in the environment, or the manufacture, distribution, or use of PBT chemicals before being released to the environment.

1.1 PROJECT OBJECTIVES

To initiate the SB 737 process for identifying and prioritizing PBT chemicals, DEQ has assembled a technical workgroup consisting of DEQ staff and a Persistent Pollutant Science Workgroup comprised of 7 qualified experts to provide advice and comment on the development of the priority PBT list. The Oregon Association of Clean Water Agencies (ACWA) and the League of Oregon Cities (LOC) supported development of the present report in collaboration with DEQ to assist this technical workgroup and other interested parties by providing background information regarding the regulatory and scientific approaches used by other governments (state, federal, and international) to identify and rank PBT chemicals in the context of pollution prevention and reduction programs. The primary goal of this report is to compile and summarize PBT ranking schemes used by various government and international organizations, and to prepare an analysis that compares and contrasts the various PBT chemical listing processes to provide a basis for proposing a list of chemicals that meet the definition of "persistent pollutant" under SB 737 (Oregon Legislative Assembly 2007). This definition is:

> *"Persistent pollutant" means a substance that is toxic and either persists in the environment or accumulates in the tissues of humans, fish, wildlife, or plants.*

Given the large amount of information available, the summary and analysis contained in this report is intended to assist DEQ's technical workgroup in efficiently identifying a PBT identification and prioritization scheme from amongst those currently available. We gathered and summarized background information on PBT prioritization and management programs from a wide range of state, regional, federal, and international agencies that bracketed the range of possible approaches to draw upon as examples. This information is synthesized into a comparative discussion of the available chemical prioritization and management programs, ultimately leading to a discussion of which program is most consistent with the definition of "persistent pollutant" under SB 737.

1.2 REPORT ORGANIZATION

This report is organized into three main sections. The first (Chapter 2) provides a summary of the methods used to gather relevant background information, with tables summarizing this information for each of the information sources provided in Appendix A. Chapter 3 provides a general synthesis of the PBT prioritization schemes and a discussion of their general relevance to the needs of SB 737. References are provided in Chapter 4. The full text of SB 737 is also included in Appendix B.

2. BACKGROUND INFORMATION SUMMARY

Internet searches were conducted to compile pertinent information regarding the PBT schemes into Tables 1-4 (Appendix A). All tables are organized according to the geographic extent to which the schemes apply including: Inter/cross-national, US Federal Government, Canadian, European Union, Australian, New Zealand, and US State.

The specific information sources reviewed were:

- Inter-cross-national
  - United Nations, Stockholm Convention on Persistent Organic Pollutants
  - USEPA and Environment Canada, Great Lakes Binational Toxics Strategy
  - International Joint Commission, 1987 Protocol Amending the 1978 Great Lakes Water Quality Agreement
  - United Nations, United Nations Environment Programme Governing Council Decision 18/32
  - United Nations Economic Commission for Europe, Convention on Long-range Transboundary Air Pollution (UNECE-LRTAP) Protocol on Persistent Organic Pollutants
  - OSPAR, The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention")
  - United Nations, Globally Harmonized System of Classification and Labeling of Chemicals
- U.S. Federal Government
  - USEPA, Final Water Quality Guidance for the Great Lakes System (the Great Lakes Initiative)
  - USEPA, Multimedia Strategy for Priority Persistent, Bioaccumulative, and Toxic (PBT) Chemicals
  - USEPA, National Waste Minimization Program
  - USEPA, Toxics Release Inventory (TRI) of the Emergency Planning and Community Right-to-know Act (EPCRA) & associated PBT Chemicals Final Rule
  - USEPA, Toxic Substances Control Act (TSCA) Premanufacture Notice (PMN) Categorization: Category for Persistent, Bioaccumulative, and Toxic New Chemical Substances
  - USEPA, PBT Profiler
- Canada
  - Environment Canada, Canada-Ontario Agreement Respecting the Great Lake Basin Ecosystem
  - Government of Canada, Canadian Environmental Protection Act (CEPA)
  - Environment Canada, Canadian Environmental Protection Act: Toxic Substances Management Policy - Persistence and Bioaccumulation Criteria

- European Union
  - European Union, Registration and Evaluation of Chemicals (REACH), Annex XIII
- Australia
  - Member of the Stockholm Convention on Persistent Organic Pollutants
- New Zealand
  - Member of the Stockholm Convention on Persistent Organic Pollutants
- U.S. States and Regions
  - Washington State, The PBT Rule, Chapter 173-333 WAC, Persistent Bioaccumulative Toxins (PBT)
  - Washington Department of Ecology, Strategy to Continually Reduce Persistent, Bioaccumulative, Toxic Chemicals (PBTs) in Washington State
  - Regional Sediment Evaluation Team (RSET), Northwest Regional Sediment Evaluation Framework
  - Oregon Department of Environmental Quality (DEQ), Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment

Table 1 introduces each of the PBT schemes summarized in this report by providing general information including:

- Title and sponsoring organization,
- Type of publication and date(s) of adoption and revisions,
- Regulatory purpose and approach(s) used to achieve PBT reductions in the environment,
- Process for updates/revisions, and
- Contact information and internet links to general program information and/or the publication itself.

Table 2 provides the persistence, bioaccumulation, and toxicity criteria for each of the PBT schemes. Many of the schemes included multiple PBT levels and each of these levels is included in this table alongside the chemical definition. Under persistence criteria $t_{1/2}$ is the chemical half-life, or time needed to degrade the total amount of chemical in the environment by 50%. Under bioaccumulation criteria, BCF is the bioconcentration factor, BAF is the bioaccumulation factor, and log K_{OW} is the logarithm of the octanol-water partition coefficient. This table is intended to be read from left to right. This is important because the language defining the PBT criteria often includes words such as "***and***" and "***or***" to relate to the persistence and bioaccumulation definitions. Therefore, the sequence and wording selections in each table cell are important for accurately understanding any given PBT prioritization scheme.

Table 3 includes other criteria and considerations for each of the PBT schemes such as:

- Criteria for non-PBT parameters, such as long-range transport,
- Chemical analytical detection and financial considerations, and
- Whether monitoring data were used in determining the PBT list, and

- Financial considerations.

Table 4 identifies the substances that were ultimately classified as PBTs by each of the prioritization and management schemes. Chemicals are grouped according to chemical classification.

3. DISCUSSION

This section provides a brief comparative discussion of the PBT prioritization and management schemes summarized in Tables 1-4. To help inform the process of selecting an appropriate PBT scheme for SB 737, this discussion will focus on summarizing the typical procedures used to identify or rank chemicals as persistent, bioaccumulative, and toxic, general similarities and differences in the chemicals included in the PBT schemes reviewed, any analytical chemistry considerations (e.g., detection limits), the types of ambient monitoring data used, and a summary of chemicals typically identified as PBT chemicals of concern. A brief discussion of which scheme(s) are most similar to the definition of “persistent pollutant” in SB 737 also is included.

It should be noted that the list of PBT prioritization and management schemes reviewed for this report is not an exhaustive list of all the available schemes used either in the U.S. or worldwide. Rather, the schemes reviewed here were selected specifically to include what we considered to be some of the most widely used or discussed (e.g., Stockholm Convention on POPs), or represented the widest range possible of approaches used to select chemical substances as priority PBTs. This was done to ensure that even though Tables 1-4 may not include every available PBT scheme, these tables do provide an accurate and comprehensive selection of the range of approaches used in the various PBT schemes worldwide.

With the exception of Washington’s PBT Rule, we are not aware of any other U.S. State that has a formal statewide program for the identification and prioritization of PBT chemical lists in support of a comprehensive pollution prevention program. Rather, most states seem to address individual PBT compounds that are of particular concern to human health or the environment (CIEL 2005). Notable examples include California’s efforts to phase out lindane and polybrominated diphenyl ethers (CIEL 2005), Maine’s efforts to control sources and pollution of mercury, PBDEs, and dioxins (CIEL 2005), and New York’s pollution prevention programs for mercury (NYDEC 2006).

3.1 COMPARATIVE ANALYSIS OF PBT IDENTIFICATION AND PRIORITIZATION SCHEMES

3.1.1 Regulatory Purpose and PBT Reduction Approaches Supported

Most PBT schemes we reviewed share similar goals of identifying chemicals of greatest concern to human health and environmental protection (the “worst of the worst”) to support pollution prevention / reduction programs. Pollution prevention—as opposed to “end of pipe” discharge regulation—was likely selected because it is arguably difficult to mitigate or remove PBT chemicals once they are actually released into the environment. The most notable exception to this is the 1995 ***Final Water Quality Guidance for the Great Lakes*** (i.e., the “Great Lakes Initiative”) that:

- Derives numerical ambient water quality criteria (AWQC) for protection of aquatic life and wildlife that were modified from National AWQC specifically to address risks to consumers of aquatic life (i.e., humans wildlife), and presents new methods for derivation of AWQC when toxicity datasets are limited.
- As amended in 2000, places restrictions on the use of mixing zones in derivation of National Pollutant Discharge and Elimination System (NPDES) discharge permits for bioaccumulative chemicals of concern (BCCs). These restrictions include prohibition of mixing zones for new dischargers and phase-outs of mixing zones for existing dischargers by the year 2010. These restrictions are also subject to certain exceptions

that would trigger more emphasis on pollution prevention programs, including promotion of water conservation programs, and technical and economic constraints.

The types of pollution prevention programs used or supported in each PBT scheme ranged widely owing to the equally wide range of regulatory purposes or goals each scheme was selected to support. For example, most of the internationally-focused PBT schemes are designed to prevent introduction of PBT chemicals through the use of outright bans of chemical production or sale, or by some other means of preventing the introduction of PBTs into commerce (e.g., U.S. TSCA, or Canada Environmental Protection Act "priority substances" for virtual elimination). More localized programs have similar goals of minimizing PBT threats by preventing release to the environment, but via more focused means such as development of multimedia chemical action plans (e.g., the State of Washington's PBT Rule), or selection of sediment management plans from contaminated sites potentially leading to possible mitigation via dredging (e.g., RSET's *Northwest Regional Sediment Evaluation Framework*, and Oregon DEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediments*). Some programs are structured around formal management schemes such as treaties (e.g., Stockholm Convention for POPs), chemical premanufacture approvals (e.g., REACH or USEPA's TSCA), or state rules (e.g., Washington PBT rule), whereas others are designed to provide tools for purely voluntary pollution prevention efforts (e.g., USEPA National Waste Minimization Programs). Some of the remaining PBT schemes reviewed in Table 1 provide supporting information and/or tools for other more formal management schemes such as USEPA's PBT profiler (used to identify new PBTs for USEPA's TRI program), or Washington Ecology's "strategy" to reduce PBT chemicals developed originally to support development of the formal state PBT rule (WDOE 2000).

3.1.2 Persistence

The persistence of a chemical substance is a key factor determining how long a chemical may remain in the environment and, hence, remain available for exposure to humans, aquatic organisms, or wildlife. Even though measuring or predicting the persistence of a chemical is a complex function of many physical and chemical parameters, most PBT schemes define "persistence" on the basis of chemical half-life, or $t_{1/2}$. A chemical half-life is a laboratory-derived or model-predicted determination of the time required for a chemical to degrade (usually measured in time units of days). Chemical half-life trigger values used by most PBT schemes were similar, and ranged from values of > 60 – 180 days (i.e., 2 – 6 months) for most environmental media (Table 2). Some exceptions included chemical half-life values as low as >16 days (UN *Globally Harmonized System of Classification and Labeling of Chemicals* for substances chronically hazardous to aquatic organisms), and as high as > 365 days (CEPA's "track 1" substances in sediments). Many PBT schemes used the same chemical half-life values in all environmental media, whereas others used lower values in water vs. sediments or soils (e.g., Stockholm Convention for POPs, or REACH).

With the exception of USEPA's TSCA (USEPA 1999), none of the PBT schemes reported scientific or regulatory reasons for selection of these specific threshold values as indicators of any specific level of chemical persistence. However, there is strong scientific support that chemicals with chemical half-life values > 6 months are clearly among the most persistent chemicals that can be identified, including all of the 12 Stockholm POPs (Rodan et al. 1999, USEPA 1999, Pennington 2001). In addition, even if these simple thresholds result in an "incorrect" definition of persistence compared chemicals identified using more sophisticated approaches, they are sufficiently conservative for regulatory purposes, and so do not result in false negatives (i.e., determining that a chemical is not persistent, when in fact it is persistent;

Pennington 2001). Persistence threshold values of about 2 months are typically used to delineate "lower" amounts of chemical persistence, even though there is little scientific basis for selection of this particular threshold value (USEPA 1999, Lerche et al. 2002).

3.1.3 Bioaccumulation

The accumulation of a chemical from the environment into an organism can occur via many pathways, including direct exposure to environmental media such as water, air, and sediments, accumulation from the diet, or a combination of both. Three terms are typically used to describe this process, including ***bioaccumulation*** (accumulation from environmental media plus the diet), ***bioconcentration*** (accumulation from the environmental media only), and ***biomagnification*** (process by which chemical concentrations in tissues increase at successively higher trophic levels in the food web). The amount of accumulation is generally measured as a ratio of the concentration in organisms tissues divided by the amount in the environmental media or food sources. These ratios are termed ***bioaccumulation factor (BAF)*** if accumulation is from environmental media plus the diet, or ***bioconcentration factor (BCF)*** if accumulation is from the environmental media only. Higher BAF or BCF factors denote a greater tendency for chemicals to bioaccumulate Another measure of the tendency of a chemical to accumulate in organism tissues is a common physical property that measures the tendency of a chemical to partition from water into fats or lipids, and is known as the ***log octanol-water partition coefficient*** (log K_{OW}). Similar to BAF and BCF values, higher log K_{OW} values denote a greater tendency for chemicals to bioaccumulate.

Most PBT prioritization schemes used similar values that if exceeded, denote that a chemical is of bioaccumulative concern. For BCF and BAF values (Table 2), these generally were >1000 or >5000, but at times were as low as 500 (OSPAR and UN Globally Harmonized System for chronic substances in the aquatic environment). BCF or BAF thresholds of >1000 were sometimes used to distinguish "lower" levels vs. >5000 as "higher" levels of bioaccumulation concern (e.g., PBT Profiler). log K_{OW} values were also quite similar for most PBT schemes at >5, but with some as low as >3.5 (RSET's *Northwest Regional Sediment Evaluation Framework*). For PBT schemes that presented all three types of accumulation measures, an exceedance of any one of the values (BAF, BCF, or log K_{OW}) was generally considered sufficient to indicate that a chemical was of bioaccumulative concern.

With the exception of USEPA's TSCA (USEPA 1999), none of the PBT schemes specifically reported scientific or regulatory reasons for selection of these specific threshold values (BAF, BCF, or log K_{OW}) as indicators of any specific level of chemical bioaccumulation. However, there is strong scientific support that chemicals with BCF or BAF values > 5000 are clearly amongst those with the highest bioaccumulation potential, including all of the 12 Stockholm POPs (Rodan et al. 1999, USEPA 1999, Muir and Howard 2006). Similar to persistence thresholds, lower bioaccumulations thresholds (e.g., BCF/BAF > 1000) are selected to generally denote a "lower" amount of bioaccumulation, even though there is little scientific basis for the value that is ultimately selected (USEPA 1999).

In addition to these specific numeric expressions of bioaccumulation, a few PBT schemes either allowed for or specifically included the use of monitoring data to empirically determine if a chemical substance was accumulating in organisms of concern. One example includes the Washington "strategy" for reducing PBTs in which chemicals were first screened for their presence in organism tissues in Washington in one of several reporting databases prior to their screening by PBT criteria. Another example is RSET's *Northwest Regional Sediment Evaluation Framework* criteria for determining bioaccumulative contaminants of concern in which the detection frequency of a chemical is considered along with log K_{OW} values to place chemicals into one of seven categories of concern.

3.1.4 Toxicity Categorization

As opposed to either persistence or bioaccumulation, criteria for evaluating whether a chemical is of *toxic* concern varied widely among the various PBT schemes we reviewed (Table 2). Some PBT schemes were fairly qualitative, using descriptors of toxicity such as *evidence of adverse effects or toxicity data that indicated potential for effects* (Stockholm Convention for POPs), or the *potential to adversely affect human health/environment* (UNECE-LRTAP). Several other schemes were more quantitative in that they provided specific toxicity test endpoint values that, if exceeded, denoted unacceptable adverse impacts to human health or the environment. One example is the UN's Globally Harmonized System of Chemical Classification (UN-GHS). Within each of four levels of overall PBT concern, several additional levels (3-4) were included based on ranges of either acute or chronic toxicity data. Thresholds of chronic toxicity concern to organisms in the environment used in the UN-GHS scheme used no-observed effect concentration (NOEC) ranges of > 10 mg/L (in water) as being of low concern, NOECs between 0.1 and 10 mg/L being of moderate concern, and NOECs less than 0.1 mg/L being of high concern. Human health impact categorizations were sometimes quite complex, including several different types of adverse effects thresholds for a wide range of endpoints including carcinogenicity, mutagenicity, neurotoxicity, developmental toxicity, etc. (e.g., UN-GHS for human health hazards).

It was usually difficult to determine whether the toxicity data requested for this category applied to any particular group of organisms such as fish, wildlife, or plants. Most toxicity definitions were relatively generic and just considered toxicity data for the "environment" with no further explanation. In particular, few of the PBT schemes address wildlife or plants in their definitions of toxicity except perhaps as they might be generically considered part of the "environment" along with fish or other aquatic organisms. The few exceptions to this include the UN-GHS toxicity definitions which accept toxicity data for algae and aquatic plants, and the Washington PBT Rule in which the toxicity criteria include that: *The chemical or chemical group has the potential to be toxic to humans or plants or wildlife* (WAC 2006).

3.1.5 Other Considerations

Other considerations for either PBT prioritization or use of this information in chemical management systems are summarized for each scheme in Table 3. The first column with "other non-PBT criteria" largely identify those schemes that use long-range atmospheric transport to determine whether a chemical is of concern to that particular chemical management program. These were usually international programs that would need to consider atmospheric transport of a substance across long distances (e.g., Stockholm Protocol for POPs and UNECE-LRTAP). Another notable example in this category was the Washington PBT rule that specifies that inorganic metals should only be included if they are present in forms that make them likely to bioaccumulate to a significant degree (e.g., mercury, which has organic forms with high bioaccumulative potential).

Analytical detection limits were considered in a few of the PBT schemes, not so much from the perspective of identifying whether a given chemical is of PBT concern, but rather from the perspective of managing chemicals once identified as PBT. An example of the former is RSET's *Northwest Regional Sediment Evaluation Framework* "non-numerical" bioaccumulation criteria summarized in Table 2, many of which include either frequency of detection or frequency of detection over minimum analytical detection limits.

Ambient monitoring data were also considered by many of the PBT schemes, mostly to evaluate progress towards achieving the ultimate pollution prevention goals (i.e., were not used to determine the PBT list). Others, however, do use ambient monitoring data to potentially include or add chemicals to the PBT list, including the Stockholm Convention for POPs, the OSPAR Convention, and the use of State or regional chemical detections in tissues to help identify PBTs of concern in the Washington "strategy" to reduce PBTs and RSET's *Northwest Regional Sediment Evaluation Framework*.

Lastly, financial considerations were summarized if specified in any of the PBT schemes. For the most part, financial considerations were included to help identify management strategies for achieving overall program pollution prevention goals, rather than being used to identify or prioritize PBT chemicals.

3.1.6 PBT Chemical Lists

Table 4 lists over 100 chemicals that have been included in one or more of the PBT prioritization and management schemes. Some chemical lists were too long for inclusion on this table such as OSPAR's list of 308 "substances of possible concern" or Environment Canada's list of chemicals for CEPA that are toxic, bioaccumulative, and persistent (393 chemicals currently listed). Relatively few of the >100 chemicals listed in Table 4 were included in all PBT schemes even though as discussed above, many of the schemes used similar PBT identification and prioritization thresholds.

The PBT chemicals identified most frequently were the 12 organic PBTs identified in the Stockholm Convention for POPs. Most of these 12 compounds are chlorinated and/or aromatic organic compounds, and these characteristics are most often associated with high levels of environmental persistence, bioaccumulation, and toxicity (Muir and Howard 2006). Even using fairly sophisticated models for determining P, B, or T thresholds compared to methods summarized in Table 2, these 12 chemicals would still be considered of high priority (Rodan et al. 1999). Therefore, there is good scientific support for inclusion of at least these 12 chemicals on most any PBT prioritization list.

Looking beyond this list of 12 compounds identified by the Stockholm Convention, the identity and number of chemicals considered to be PBT can vary widely. Examples of chemical groups that are not uniformly represented among the different PBT schemes include:

- ***Hexachlorocyclohexanes*** (the "gamma" form of which is also known as the pesticide Lindane) which is only included in a few of the international and USEPA schemes (Table 4)
- ***Phenols and phthalates***, which are mostly included in OSPAR and, to a lesser extent, USEPA's National Waste Minimization Program, and TRI PBT lists
- ***Polybrominated- or –chlorinated diphenyl ether flame retardants*** which are mostly only included in OSPAR and Washington's PBT Rule
- ***Polychlorinated naphthalenes*** are mostly only included in RSET's *Northwest Regional Sediment Evaluation Framework* (BCoC list 2, definition 2), the Washington PBT Rule, and OSPAR
- ***Polycyclic Aromatic Hydrocarbons (PAHs)*** are most fully represented as a group in USEPA's National Waste Minimization Program, and to a lesser extent (i.e., total number of PAHs listed) in programs such as the Great Lakes Binational Toxics Strategy, Environment Canada's Ontario Agreement Respecting the Great Lakes Basin Ecosystem, RSET's *Northwest Regional Sediment Evaluation Framework*, and DEQ's *Guidance for Evaluating Bioaccumulative Chemicals of Concern in Sediments*.

- ***Inorganic Metals*** are also represented in several of the PBT schemes, with lead, mercury, and cadmium appearing most often, and with arsenic, selenium, and tributyl tin also included in some schemes (e.g., RSET's ***Northwest Regional Sediment Evaluation Framework's*** BCoC List 1). Some of these metals have well-known organo-metallic phases that readily bioaccumulate in organism tissues (e.g., mercury, selenium), and so use of bioaccumulation data to categorize hazard are likely appropriate. However, one of the schemes (IJC's 1987 Protocol Amending the 1978 Great Lakes Water Quality Agreement) includes 10 inorganic metals, most probably because the IJC's scheme is based only on persistence (Table 2), and not bioaccumulation criteria.

  It should be noted that there are significant scientific concerns over the use of bioaccumulation data to evaluate or prioritize the hazard potential of metals, particularly in aquatic ecosystems. Metals—by definition as elements—are clearly persistent in the environment and so virtually any metal could conceivably be included in a hazard ranking scheme based at least on persistence. However, even though most metals do ultimately accumulate to some degree in organism tissues, prioritizing or ranking the hazard of metals based on simple bioaccumulation thresholds (e.g., BAFs or BCFs) is highly problematic (DeForest et al. 2007). USEPA's recent *Framework for Metals Risk Assessment* summarizes the unique properties of metal compounds that need to be considered in any evaluation of environmental hazard, risk, including any such evaluation based on the bioaccumulation of metals into organisms (USEPA 2007):

  - *Metals are naturally occurring constituents in the environment, and vary in concentration across geographic regions*
  - *All environmental media contain mixtures of metals, and metals are often introduced into the environment as mixtures*
  - *Some metals are essential for maintaining proper health of humans, animals, plants, and microorganisms*
  - *The environmental chemistry of metals strongly influences their fate and effects on human and ecological receptors*
  - *The toxicokinetics and toxicodynamics of metals depend on the metal, the form of the metal or metal compound, and the organism's ability to regulate and/or store the metal*

  As a result of these unique properties, the USEPA Framework goes on to specifically caution against the use of simple bioaccumulation criteria such as BAF or BCF-based thresholds to evaluate the potential environmental hazards of metals:

  > *The latest scientific data on bioaccumulation do not currently support the use of bioconcentration factor (BCF) and bioaccumulation factor (BAF) values when applied as generic threshold criteria for the hazard potential of inorganic metals in human and ecological risk assessment (e.g., for classification as a persistent bioaccumulative toxic [PBT] chemical)* (USEPA 2007; pg. 1-11).

3.1.7 Scientific Uncertainties in PBT Prioritization Schemes

As discussed above, most of the PBT prioritization schemes summarized in Tables 1-4 are based on fairly simple, generic thresholds for persistence, bioaccumulation, and toxicity. However, any such simplification knowingly accepts that real environmental complexities are being ignored to provide a scheme that is practical to develop and apply, and easy to understand. Furthermore, PBT prioritization schemes can only evaluate whether there is a potential ***hazard*** from a given substance, not ultimately whether there is the potential for actual ***risk*** based on both the predicted hazard as well as the exposure of this substance to humans or the environment (Arnot and Mackay 2008).

In a recent review of PBT prioritization methods, Arnot and Mackay (2008) summarized several primary uncertainties in the simple category-based schemes primarily represented in Tables 1-4). These uncertainties include:

- Hazard priorities are based on category-based screening, which means that strict PBT "pass/fail" values determine further assessment outcomes (e.g., BCF ≥ 5000 is "B", BCF < 5000 is not "B")
- Multiple binary assessments require judgment, e.g., "P and T; not B" or "T, not P and B"
- Reliability of category criteria determines further assessment outcomes, e.g., B criteria do not exist for air breathing organisms (see also: Kelly et al. 2007)
- Type I and II error potentially high in screening stages, e.g., BCF = 5,100 vs. 4,900
- Uncertainties not considered until risk assessment stage

In addition, substantial variability can exist in the individual PBT threshold values assigned to individual chemicals. In an evaluation of chemical persistence variability, chemical half-life values for individual chemicals can range as much as 10- to 40-fold (Fenner et al. 2003). In this example, chemical half-life values for perchloroethylene and atrazine ranged from 20.9 – 186 days, and 23.7 – 1,020 days, respectively. Depending on the persistence values selected for either of these chemicals, the lower value would not be considered persistent according to the typical 60-day definition (Table 2), whereas the higher values would be considered persistent. Similarly, chemical bioaccumulation values for a given chemical can range widely, with reported log K_{OW} values for total PCBs ranging from 3.90 – 8.23 (Linkov et al. 2005). When compared to a typical log K_{OW} threshold value of 5 (Table 2), PCBs could be categorized either as bioaccumulative or not bioaccumulative depending on the threshold value selected. These scales of variability thus can introduce significant uncertainty to the accurate PBT classification of any given chemical, and suggests the need for a critical analysis of the variability and accuracy of the measured or empirical threshold values selected.

As a result, use of any simple category-based scheme for prioritizing PBT substances should be done with caution, and an appreciation of both their strengths (e.g., simplicity and straightforward regulatory application) vs. the limitations noted above. More rigorous scientific methods do exist for prioritizing PBT chemicals with respect to environmental hazard (Rodan et al. 1999, Mackay et al. 2001, Mitchell et al. 2002, Muir and Howard 2006). But it should be noted that most of these methods are relatively complex, and rely heavily on mathematical models for predicting chemical characteristics and hazards that themselves are often limited by the lack of empirical data (Lerche et al. 2002, Muir and Howard 2006, Arnot and Mackay 2008).

3.2 RELATIONSHIP OF PBT SCHEMES TO SB 737 DEFINITION OF "PERSISTENT POLLUTANT"

The selection of one or more schemes for prioritizing PBT chemicals for the purposes of developing pollution prevention plans under SB 737 will likely be informed, in part, by which scheme(s) best meet the definition of "persistent pollutant" under SB 737. This definition is (Oregon Legislative Assembly 2007):

> *"Persistent pollutant" means a substance that is toxic and either persists in the environment or accumulates in the tissues of humans, fish, wildlife, or plants.*

The key aspect of this definition is that a "persistent" pollutant is one that ***either*** persists in the environment, ***or*** accumulates in organism tissues. This is particularly important given that most all of the schemes summarized in Tables 1-4 are built on PBT definitions of toxic substances that persist ***and*** bioaccumulate in the environment. The schemes we reviewed that used a PBT definition most similar to SB 737 include:

- Canadian Environmental Protection Act (CEPA) – PBT substances are those that are persistent ***or*** bioaccumulative and toxic
- USEPA's TRI – One of the criteria used to include a chemical on the TRI list is if a chemical can be shown to be either persistent and toxic, ***or*** bioaccumulative and toxic. However, chemicals that receive lower reporting limits specifically as "PBT" substances are identified using persistence ***and*** bioaccumulation (Table 2)

The primary implication of using a PBT prioritization scheme based on persistence ***or*** bioaccumulation is that the number of chemicals included could be rather large. For example, after Environment Canada conducted their prioritization of chemicals from the Domestic Substances List (DSL) according to the strict CEPA definition, they identified 2047 chemicals that were persistent and toxic, and 811 chemicals that were bioaccumulative and toxic (http://www.ec.gc.ca/CEPARegistry/subs_list/dsl/dslsearch.cfm). For comparison, only 393 chemicals were categorized as persistent ***and*** bioaccumulative ***and*** toxic. Therefore, including chemicals that are persistent ***or*** toxic can, at least in this example, increase the size of a PBT list roughly 5-fold over a list that would have considered only persistent ***and*** bioaccumulative toxic chemicals. To address this challenge, Environment Canada has been undertaking a further prioritization of PBT chemicals, recognizing that the lists generated according to the strict CEPA definition (persistence ***or*** bioaccumulation) was far too large to be practical (Hughes 2007). The two main approaches they selected to identify the highest priority chemicals were: 1) include only substances that are persistent ***and*** bioaccumulative and toxic, ***and*** those that were believed to be in commerce in Canada, and 2) chemicals that had the greatest potential for human exposure ***and*** were classified as posing a high hazard to human health.

The other aspect of the SB 737 definition of "persistent pollutant" is that bioaccumulation into wildlife and plant tissues are also included in addition to humans and fish. However, very few of the PBT schemes summarized in Tables 1-4 include any bioaccumulation data or toxicity considerations specifically tailored to address hazards to wildlife or plants. One of the key exceptions is the Washington PBT Rule in which the toxicity criteria include that: *The chemical or chemical group has the potential to be toxic to humans or plants or wildlife* (WAC 2006). USEPA's Final Water Quality Guidance for the Great Lakes System also was originated, in part, to ensure that risks to wildlife from bioaccumulative chemicals were addressed via revised methods for derivation of ambient water quality criteria specifically to ensure wildlife protection. Several other risk assessment methodologies are available for screening or prioritizing the risk of chemicals to wildlife, including DEQ's *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediments.* Therefore, even though most existing PBT schemes do not specifically address hazards to wildlife, methods are available that could potentially be applied to the needs of SB 737.

4. REFERENCES

Arnot, J. A., and D. Mackay. 2008. Policies for chemical hazard and risk priority setting: Can persistence, bioaccumulation, toxicity, and quantity information be combined? Environmental Science and Technology **42**:4648-4654.

CIEL. 2005. U.S. States and the global POPs treaty. Center for International Environmental Law, Washington, D.C.

DeForest, D. K., K. V. Brix, and W. J. Adams. 2007. Assessing metal bioaccumulation in aquatic environments: The inverse relationship between bioaccumulation factors, trophic transfer factors, and exposure concentration. Aquatic Toxicology **84**:236-246.

Fenner, K., M. Scheringer, and K. Hungerbuhler. 2003. Joint persistence of transformation products in chemicals assessment: Case studies and uncertainty analysis. Risk Analysis **23**:35-53.

Hughes, K. 2007. Prioritization of existing substances under the Canadian Environmental Protection Act. OEHHA-COEH Workshop on Practical Decision-making Tools for Identifying Safer Alternatives, Sacramento, CA.

Kelly, B. C. K., M. G. Ikonomou, J. D. Blair, A. E. Morin, and F. A. P. C. Gobas. 2007. Food web–specific biomagnification of persistent organic pollutants. Science **317**:236-239.

Lerche, D., E. van de Plassche, A. Schwegler, and F. Balk. 2002. Selecting chemical substances for the UN-ECE POP Protocol. Chemosphere **47**:617-630.

Linkov, I., M. R. Ames, E. A. C. Crouch, and F. K. Satterstrom. 2005. Uncertainty in octanol-water partition coefficient: Implications for risk assessment and remedial costs. Environmental Science and Technology **39**:6917-6922.

Mackay, D., L. S. McCarty, and M. MacLeod. 2001. On the validity of classifying chemicals for persisitence, bioaccumulation, toxicity, and potential for long-range transport. Environmental Toxicology and Chemistry **20**:1491-1498.

Mitchell, R. R., C. L. Summer, S. A. Blonde, D. M. Bush, G. K. Hurlburt, E. M. Snyder, and J. P. Giesy. 2002. SCRAM: A scoring and ranking system for persistent, bioaccumulative, and toxic substances for the North American Great Lakes--resulting chemical scores and rankings. Human and Ecological Risk Assessment **8**:537-557.

Muir, D. C. G., and P. H. Howard. 2006. Are there other persistent organic pollutants? A challenge for environmental chemists. Environmental Science and Technology **40**:7157-7166.

NYDEC. 2006. New York State Department of Environmental Conservation Mercury Work Group Recommendations to Meet the Mercury Challenge. New York Department of Environmental Conservation, Albany, NY.

Oregon Legislative Assembly. 2007. Senate Bill 737. 74th Oregon Legislative Assembly--2007 Regular Session, Salem, OR.

Pennington, D. W. 2001. An evaluation of chemical persistence screening approaches. Chemosphere **44**:1589-1601.

Rodan, B. D., D. W. Pennington, N. Eckley, and R. S. Boethling. 1999. Screening for persistent organic pollutants: Techniques to provide a scientific basis for POPs criteria in international negotiations. Environmental Science and Technology **33**:3482-3488.

UNEP. 2001. The Stockholm Convention on Persistent Organic Pollutants (POPs). United Nations Environmental Programme, Stockholm Convention Secretariat, Geneva, Switzerland.

USEPA. 1998. A multimedia strategy for priority persistent, bioaccumulative, and toxic (PBT) pollutants. U.S. Environmental Protection Agency, PBT Plenary Group, and Office Directors Multimedia and Pollution Prevention Forum, Washington, DC.

USEPA. 1999. Category for persistent, bioaccumulative, and toxic new chemical substances. Federal Register **64**:60194-60204.

USEPA. 2007. Framework for metals risk assessment. EPA 120/R-07/001, U.S. Environmental Protection Agency, Office of the Science Advisor, Washington, DC.

USEPA. 2008. Fact Sheet: Multimedia strategy for priority persistent, bioaccumulative, and toxic (PBT) chemicals. U.S. Environmental Protection Agency, Washington, DC.

WAC. 2006. Persistent bioaccumulative toxins. 173-333, Washington State Legislature, Olympia, WA.

WDOE. 2000. Proposed strategy to continually reduce persistent, bioaccumulative toxins (PBTs) in Washington State. 00-03-054, Washing Department of Ecology, Environmental Assessment Program, Olympia, WA.

APPENDIX A

Appendix A: Background Information Summary Tables

APPENDIX B

Appendix B: Full Text of Oregon Senate Bill 737 (2007 Session)