

# **Toxic Substances Management Policy - Persistence and Bioaccumulation Criteria**

Final Report  
of the *ad hoc* Science Group on Criteria

Companion document to the  
Toxic Substances Management Policy

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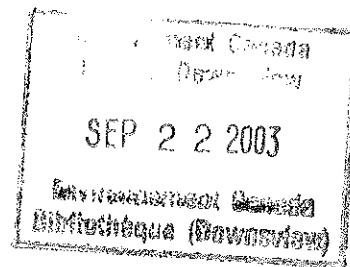
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## 1.0 INTRODUCTION

In the Toxic Substances Management Policy, the federal government has developed a framework for action on substances in the environment that it considers to be of concern. The Policy is intended to ensure the protection of the environment and human health and it is supported by two key objectives: virtual elimination from the environment of substances that are toxic, predominantly anthropogenic, persistent, and bioaccumulative (Track 1); and life-cycle management of other toxic substances and substances of concern to prevent or minimize their release into the environment (Track 2). The purpose of this document is to provide the government's selection of criteria for persistence and bioaccumulation to identify substances for Track 1.

Although a substance must meet all four criteria to be placed on Track 1, the criteria for "toxic" and "predominantly anthropogenic" are not addressed here, as they are defined in the Policy. Under the Policy, a substance is toxic if it meets or is equivalent to the definition of "toxic" found in Section 11 of the *Canadian Environmental Protection Act* ("CEPA-toxic" or "CEPA-toxic Equivalent"). The Policy considers a substance "predominantly anthropogenic" if, based on expert judgment, its concentration in an environmental medium is largely due to human activity, rather than to natural sources or releases.

The remaining two criteria, *i.e.*, those to be used to select substances that are persistent and bioaccumulative, are discussed in this report. These criteria were developed by an *ad hoc* group of government scientists (Appendix I) charged with developing criteria that would identify, among substances that are toxic and predominantly anthropogenic, those substances that are the most persistent and the most bioaccumulative, *i.e.*, those that have the greatest potential impact on the health of ecosystems, including humans. Track 1 of the Policy, therefore, is particularly concerned with lipophilic substances (*i.e.*, those that have an affinity for fats) such as PCBs, dioxins, and several organochlorine pesticides, as they can bioaccumulate and biomagnify to levels causing effects at the top of the food web.

In presenting this report, the *ad hoc* Science Group recognizes that measured (field and laboratory) values for persistence and bioaccumulation strongly depend on specific study conditions, and that caution should therefore be used in the application of the values to general situations. Expert opinion and a weight-of-evidence approach must play important roles in the interpretation of scientific data and in the application of the criteria presented here. This is particularly the case where persistence and bioaccumulation data identified for a substance are close to the critical values recommended.

Background information on environmental persistence and bioaccumulation, including definitions of terms used, can be found in Appendix II.

## **2.0 REVIEW OF CRITICAL VALUES FOR PERSISTENCE AND BIOACCUMULATION DEVELOPED FOR OTHER INITIATIVES IN CANADA**

Critical values for persistence and bioaccumulation have been developed in Canada for different purposes, and these existing values were examined in this exercise as a starting point for establishing critical values for the Policy. The main sets include those developed by the International Joint Commission (IJC) for its Critical Pollutants List; the Ontario Ministry of Environment and Energy (MOEE) for its Primary List for Bans and Phase-outs; and Environment Canada (EC) for List A of the Accelerated Reduction and Elimination of Toxics (ARET) Program. Also considered were the critical values proposed by Environment Canada (EC) and Health Canada (HC) to screen substances for nomination to the revised CEPA Priority Substances List (referred to as PSL2).

It cannot be overemphasized that these sets of critical values were developed for purposes other than for targeting substances for virtual elimination from the Canadian environment, e.g., screening and identification of substances for voluntary action (ARET); screening and identification of substances for further assessment (PSL2); targeting releases of substances in a specific geographical location - the province of Ontario (MOEE) and the Great Lakes (IJC).

The sets of criteria under the four initiatives, reviewed below and summarized in Table 1, were established using scientific information as well as expert judgment based on available knowledge on the release, fate and effects of toxic, persistent and bioaccumulative substances in the environment. In some instances (e.g., ARET, PSL2), the sets of criteria have been subjected to critical reviews and consultations with stakeholders. Due to obvious similarities, the MOEE and ARET criteria have been grouped below under the same heading.

### **2.1 IJC Critical Pollutants**

In 1985, under the Great Lakes Water Quality Agreement (GLWQA), administered by the IJC, the Great Lakes Water Quality Board identified eleven critical pollutants that are persistent, that bioaccumulate in living organisms, and that cause adverse human and environmental health effects. The Board defined persistent toxic substances as "any toxic substances with a half-life in water of greater than eight weeks" (IJC, 1989). In its Sixth Biennial Report, the IJC recommended that the Parties expand the definition of persistent toxic substances to encompass "all toxic substances with a half-life in any medium -- water, air, soil, or biota -- of greater than eight weeks, as well as those substances that bioaccumulate in the tissue of living organisms" (IJC, 1993).

The GLWQA does not provide a criterion for bioaccumulation, and no numerical criterion for bioaccumulation was used when the critical pollutants list was established in 1985. In 1993, the IJC Virtual Elimination Task Force

Table 1. Comparison of persistence and bioaccumulation criteria used by IJC, MOEE, ARET<sup>1</sup>, and those recommended for PSL2.

	IJC	MOEE/ARET	PSL2
<b>PERSISTENCE</b>  Half-life (Days)	56 days in water  (as defined in GLWQA)	Scoring system <sup>2</sup> (for persistence in air, water or sediment)  Half-life Score  $\leq 10 = 0$ $> 10 \text{ to } 50 = 4$ $> 50 \text{ to } 100 = 7$ $> 100 = 10$	Medium      Half-life  Surface water $> 50$ Groundwater $> 100$ Sediment $> 180$
<b>BIOACCUMULATION</b>  Bioaccumulation Factor (BAF) or Bioconcentration Factor (BCF)  OR  Octanol-Water Partition Coefficient (log $K_{ow}$ )	no numerical criteria <sup>4</sup>	Scoring system <sup>3</sup> (BCF in freshwater fish preferred over other species or log $K_{ow}$ )  BCF Score  $\leq 20 = 0$ $> 20 \text{ to } 500 = 4$ $> 500 \text{ to } 15000 = 7$ $> 15000 = 10$  log $K_{ow}$ Score  $\leq 2.0 = 0$ $> 2.0 \text{ to } 4.0 = 4$ $> 4.0 \text{ to } 6.0 = 7$ $> 6.0 = 10$	BAF or BCF $> 500$ (in freshwater fish)   $3 < \text{Log } K_{ow} < 7$

<sup>1</sup> Due to obvious similarities, the MOEE and ARET criteria have been grouped under one heading.

<sup>2</sup> Substances with persistence scores of 7 or 10 (i.e., half-life greater than 50 days) meet the selection criterion for persistence.

<sup>3</sup> Substances with bioconcentration scores of 7 or 10 (i.e., BCF greater than 500) meet the criterion for bioaccumulation.

<sup>4</sup> The Great Lakes Water Quality Agreement (IJC, 1989) does not specify any bioaccumulation criterion. However, the IJC Task Force on Virtual Elimination recommends the use of BAF over BCF, because BAF takes into account the accumulation through the food chain; the Task Force also recognizes that chemicals that pose a hazard to biota generally have BAF above 1000 ; a BAF above 5000 is considered a high concern (IJC, 1993).

recommended the use of the bioaccumulation factor (BAF). Although the Task Force recognized that BAF scoring is relatively arbitrary, it indicated that chemicals that pose a hazard to biota generally have a BAF above 1000. A chemical with a BAF above 5000 is considered to be of high concern (IJC, 1993).

## **2.2 MOEE Primary List for Bans and Phase-Outs and ARET List A**

The purpose of the MOEE Primary List for Bans and Phase-out and the ARET List A was to identify chemical substances that would be targeted for actions leading to zero discharge. MOEE used a scoring criteria system based on toxicity, persistence and bioaccumulation data available in the Chemical Evaluation Search and Retrieval System (CESARS) database. ARET adopted a system which was very similar to the MOEE process. In most cases, MOEE scoring was adopted by ARET without modification.

Environmental persistence in air, water and sediment was considered by MOEE. However, the scoring system did not establish different half-life values for the various media. Chemicals with half-lives of between 50 and 100 days were given a score of 7 while those with a half-life of greater than 100 days were given the highest score of 10. Persistence in groundwater was not considered.

Measured bioconcentration factors (BCF) or bioaccumulation factors (BAF) in freshwater fish were preferred over octanol-water partition coefficients ( $K_{ow}$ ). Data for invertebrates and other non-fish organisms were also used, but with discretion. BCF values between 500 and 15,000 were given a score of 7, and values above 15,000 were given the highest score of 10. Log  $K_{ow}$  values between 4 and 6 were given a score of 7, while values above 6 were scored at 10.

## **2.3 Proposed Technical Criteria for Screening Substances Nominated for the Revised PSL**

Environment Canada and Health Canada proposed a series of criteria to screen candidate substances for priority consideration under the CEPA Priority Substances List (EC/HC, 1993). They recommended that critical values be used, rather than a scoring system, in order to simplify the process. These critical values were established on the basis that they broadly screened in most of the known substances of concern. After consultations with stakeholders, the following critical values were proposed: half-life in surface water > 50 days, groundwater > 100 days and sediments > 180 days; BCF or BAF > 500 applied to freshwater fish (data for non-fish species would be used with judgment); log  $K_{ow}$  between 3 and 7.



### **3.0 SELECTION OF PERSISTENCE AND BIOACCUMULATION ENDPOINTS AND CRITICAL VALUES FOR THE POLICY**

As a starting point, the *ad hoc* Science Group compiled data on persistence and bioaccumulation for the 68 substances (see Appendix III) identified on the IJC Critical Pollutants List, the MOEE Primary List for Bans and Phase-outs, the ARET List A, and those substances assessed as priority substances and determined to be "toxic" under CEPA.

The data consisted of persistence in air, water, soil and sediment as well as bioaccumulation in aquatic vertebrates, invertebrates and plants. For the over 30 substances on the list that were considered to be predominantly anthropogenic within the terms of the Policy, the data were used to study the endpoints most commonly measured and the range of values within which critical values may fall. In addition, they helped to test proposed critical values (or combinations of values) for their selectivity with respect to substances known to be highly persistent and bioaccumulative.

Following this exercise, the various factors influencing persistence in each medium (e.g., rates of transformation, environmental properties) were considered, and computer modelling of environmental persistence was used, in developing rationales for selecting specific critical values. Results from these activities are presented below.

#### **3.1 Persistence**

The following observations were made for the data pertaining to persistence:

- 1) data, expressed as half-lives, were predominantly available for air and surface waters;
- 2) the reported half-lives were mainly based on transformation, not movement between media or dilution; and
- 3) for some substances, wide ranges of half-lives within the same medium were apparent, depending on the degradation process studied or the site-specific conditions.

The manipulation of the data also confirmed that persistence is medium dependent and that criteria must therefore be developed for each medium. Several scenarios using various combinations of half-lives in different media were considered, starting with use of the proposed PSL screening criteria, in order to identify reasonable critical values (or ranges) for the identification of the most highly persistent substances. Based on this analysis, the *ad hoc* Science Group identified appropriate ranges of critical values for half-lives as: 1) air: of the order of a few days to one week; 2) water: between 2 and 8 months; 3) soil

and sediment: between 2 months and 2 years. Factors considered in refinement of these values to the critical values recommended in this report are briefly summarized below for each medium.

### 3.1.1 Air

A critical value for the persistence of organic compounds in air is needed to prevent transport from where they are used, generated or released to where they are not wanted. The atmosphere differs from other compartments (water, sediment, soil) in that it functions primarily as a transport vehicle rather than a medium for exposure. However, in some situations, the atmosphere can be a significant route of exposure, e.g., farm worker and wildlife exposure following pesticide applications, human exposure to secondary tobacco smoke and pollutants in indoor air.

The chief concern for persistence in air is to avoid long-range transport of contaminants to remote regions where they bioaccumulate through the aquatic and terrestrial food web and can ultimately be passed on to humans. Atmospheric transport of PCBs and organochlorine pesticides to the Arctic is well documented (Barrie *et al.*, 1992), and has resulted in contamination of marine (Muir *et al.*, 1992), terrestrial (Thomas *et al.*, 1992) and freshwater (Lockhart *et al.*, 1992) animals at all trophic levels. The result has been increased human exposure to organochlorines.

The persistence of many organic compounds is far longer in cold climates than in temperate regions. Therefore, if a compound is atmospherically transported to the Arctic, persistence estimates for water and sediments at lower latitudes cannot be applied. As an example, the hydrolysis half-life of  $\alpha$ - and  $\gamma$ -hexachlorocyclohexanes (HCHs) in seawater at 25°C is 140-190 days, but increases to 60-100 years at 0°C (Ngabe *et al.*, 1993). Hydrolysis rates of chlorinated aliphatic compounds (Jeffers *et al.*, 1989) show a similar dependence on temperature, indicating that greatly increased persistence at colder temperatures is to be expected.

Organic compounds are removed from the atmosphere by chemical-photochemical destruction, precipitation scavenging, dry particle deposition and exchange of gaseous species across lake and sea surfaces. Compounds are distributed between the particulate and gaseous phases in ambient air, and their reactivities and deposition mechanisms are strongly influenced by this partitioning. Gas-phase reaction with OH radicals is the most important destruction pathway for most organics, although photolysis and reaction with ozone and oxides of nitrogen also play a role. Chemical and photochemical reaction rates for organic compounds sorbed to particles are generally lower than in the gas phase. Such reactions depend greatly on the nature of the particle, temperature and humidity, as well as on the concentration of oxidant species. World-wide atmospheric dispersion of organic compounds takes place

under clean-air (low aerosol) conditions. Under these conditions, organic compounds will be predominantly in the gas phase and their removal from the atmosphere will occur mainly by reaction and deposition of gaseous species.

Atmospheric transport of organic compounds to the Arctic and other remote regions probably occurs not in a single event but through a series of stepwise exchanges between air-water, air-vegetation, and air-soil (Wania and Mackay, 1993). Persistence in air and the ability to undergo "global fractionation" are important factors which govern the transport potential of a chemical. In an attempt to establish a critical value for persistence in air, we rely to a large extent on observations. The presence of organochlorine pesticides and PCBs in Arctic air, snow, water, and biota is well established. Several of these compounds have estimated OH radical half-lives on the order of a few days. Cases in point are dieldrin (1 day), DDT and DDE (2-4 days) and chlordane (8 days). Endosulfan, which is widespread in air and snow in the Arctic, has a photolytic half-life of 7 days (U.S. Department of Health and Human Services, 1993). Although direct measurements of PCDDs and PCDFs have not been attempted in Arctic air, long-range transport of these compounds is implicated by their presence in Arctic biota (Muir *et al.*, 1992). The more toxic members of this group (tetra and pentachloro congeners) have gas-phase OH half-lives in the range of 1-15 days.

It is obvious that long-range transport of some organic compounds can take place even if their OH radical reaction half-lives are only a few days. Based on the above evidence, the *ad hoc* Science Group recommends that the atmospheric criterion for defining substances with the potential for long-range transport be: 1) an estimated or experimental reaction half-life of greater than or equal to 2 days, or 2) evidence for atmospheric transport to remote regions such as the Arctic. For a more detailed discussion of persistence of organic substances in air, the reader is referred to Bidleman (1995).

### **3.1.2 Water**

Empirical analyses of the available data suggested that an appropriate critical value is between 2 and 8 months. The overall degradation rate of a substance in water depends on the specific rates of each degradation process. As persistent substances are generally resistant to the major abiotic processes, hydrolysis and photolysis, biodegradation will usually be the most significant degradation process. In the water column, biodegradation is mainly due to heterotrophic microbial activity at particulate surfaces which is influenced by the concentrations and size of the suspended materials and the nature and density of the heterotrophs. The makeup of the microbial community will be strongly influenced by nutrient levels and limnological conditions of the system. Degradation in sediments is dealt with in a separate sub-section, but it will have an impact on the rate of degradation in the water column as influenced by the extent to which there is resuspension of the bottom sediment material.

Two situations in particular require additional comments, namely marine environments and groundwater. In addition to the many factors influencing freshwater systems, saline marine environments have more varied and different microbial assemblages. This is likely to result in changes in the overall rate of degradation of any substance in such a medium when compared to freshwater. In contrast to both freshwater and marine systems, groundwater is often anaerobic. The absence of oxygen and/or light in groundwater severely limits the number and density of life forms present. In addition, the type of abiotic processes are different in groundwater where, for example, the absence of light prevents photolysis as a degradative process. Persistence of toxic substances in marine and groundwater has been poorly studied. It was decided that marine water and groundwater would be covered by the general water criterion; this may change as more information becomes available.

Substances, such as many of the organochlorine pesticides (e.g., DDT and dieldrin) or other organics such as dibenzodioxins, are of concern as they persist in surface waters and their associated sediments for long periods. The continued reporting of residues in the Canadian environment supports this assumption. Based on the evaluation of available data and expert judgment, it was considered that a half-life of six months would capture the substances that are of most concern.

Based on the empirical analysis of the available data and on the above considerations, the *ad hoc* Science Group recommends a critical value for half-life in water of greater than or equal to 6 months.

### 3.1.3 Soil

The empirical analysis of available data suggested that an appropriate critical value for half-life in soil would be around 6 months. Further justification for this conclusion is provided by using a simple first-order kinetics model of fate in soil.

From the equation:  $\ln C = \ln C_0 - 0.693 t / t_{1/2}$

the concentration (C) at any time (t) can be calculated. Figure 1 shows calculated relative concentrations of a substance in soil over time, for half-lives ( $t_{1/2}$ ) of 60 days, 180 days and 1 year, assuming that the same amount is applied each year. Half-lives of <60 days result in essentially zero residue after 365 days and little long term carry-over. A  $t_{1/2}$  of 1 year results in an increasing fraction persisting to a concentration maximum which approximately equals the annual application. A  $t_{1/2}$  of ~6 months results in a slow build up of residue to a maximum of about 30% of the annual application. The fate in soils of several persistent organochlorines, e.g., aldrin, dieldrin, DDT and chlordane, has been examined under the repeated application scenario and found to follow this trend.

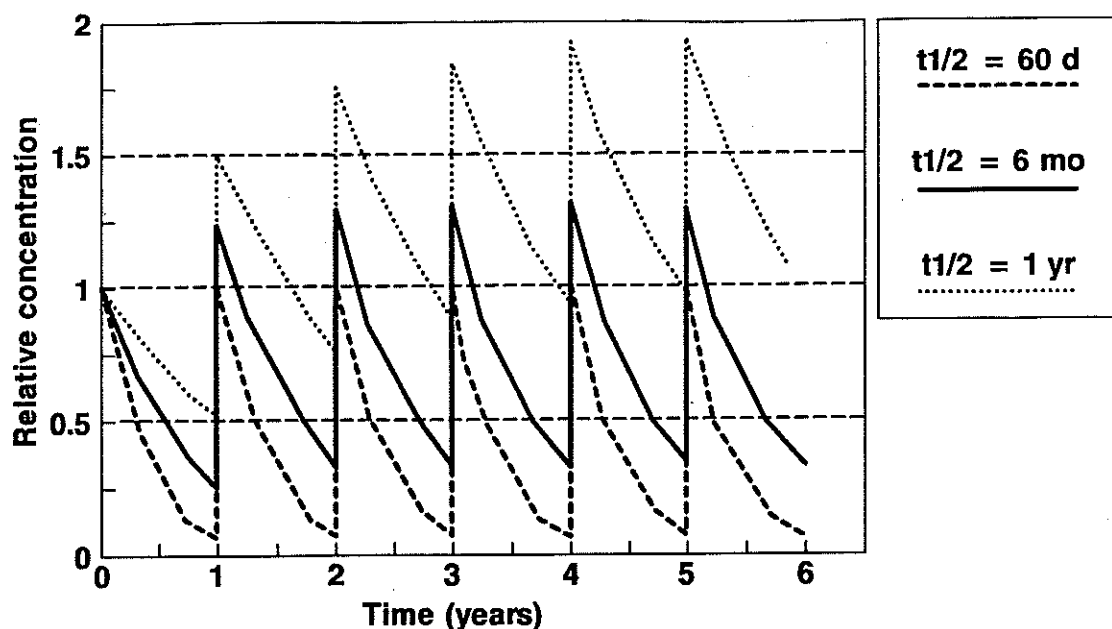


Figure 1. Long-term persistence of substances with various half-lives in soils following repeated annual applications at the same rate each year (calculated using the first-order kinetic rate equation).

This simple modelling approach offers an alternative rationale for viewing the consequences of selecting various half-lives for substances in soils. The annual application scenario is a worst case scenario for most substances. However, smaller, more frequent applications would yield essentially the same results. A 6 month critical value is thus acceptable from a number of points of view: a) it encompasses most known persistent and bioaccumulative substances; b) simple first-order modelling shows that a soil  $t_{1/2}$  of  $\geq 6$  months will, all other factors being equal, result in a build up of the substance in soil if it is repeatedly applied (build up may occur for substances with  $t_{1/2}$  of  $\leq 6$  months, but it is relatively minor and within the margin of uncertainty of the model); c) under Canadian climatic conditions, 6 months is a reasonable "window" of time in which soil temperature and moisture conditions favour biodegradation of many substances in most parts of the country. Half-lives longer than 6 months can result in a substantial fraction of that substance persisting throughout the winter months. There are many documented examples of this latter situation in the case of moderately persistent herbicides like trifluralin and triallate in Saskatchewan and Manitoba soils.

Based on the empirical analysis of the available data and on the above considerations, the *ad hoc* Science Group recommends a critical value for half-life in soil of greater than or equal to 6 months.

#### 3.1.4 Sediment

The data set on the persistence of substances in sediments is very limited; only about half of the predominantly anthropogenic substances in Appendix III have easily available information, and the range of half-lives is so wide as to make them problematic for generating a critical value. In addition, detailed analyses of dated sediment cores in the Great Lakes (e.g., Eisenreich *et al.*, 1989; Oliver *et al.*, 1989) and in a mid-continental transect (Muir *et al.*, 1995) indicate that a large number of organochlorine pesticides, chlorobenzenes, and PCB congeners have sediment half-lives >30 years, which is considerably greater than the half-lives experimentally measured or predicted for the same substances.

As in the case for soil, models predict that substances with half-lives >6 months will gradually build up a significant residue burden with time. However, the situation for sediments is more complicated because of sedimentation of inorganic and organic materials generated in the water column or entering the water via tributary inputs or from the atmosphere. Sedimentation serves to bury the substances and effectively dilute their concentrations. Resuspension and bioturbation are also important - they will smear the deposited substance and broaden the band of substance that is deposited. While we have indicated that the persistence criteria should not include dilution and movement, for sediments there is really no alternative other than to take these major processes into account.

There are many relatively simple models for fate of contaminants in sediment. The Quantitative Water Air Sediment Interaction (QWASI) model of Southwood *et al.* (1989), which predicts fate in sediments and water column, has been applied to the fate of PCBs in Lake Ontario and PCDD/Fs in Siskiwit Lake (Astle *et al.*, 1987). QWASI can be used to explore the implications of a 0.5, 1 and 2 year half-life critical value for substances in sediments. Annual additions equivalent to the original application were assumed. The results are essentially similar to the situation for soil in Figure 1, i.e.,  $t_{1/2} = 6$  months does not result in a large build up of substances in sediment but  $t_{1/2} = 2$  years does. The effect of higher resuspension and sedimentation rates is to remove and/or dilute the substance concentrations. Taking into account variations in sedimentation and resuspension and smaller incremental additions of contaminant (which might be more typical of natural sediments), it is reasonable to assume that half-lives <1 year should result in relatively little build up of substance in sediments over time.

Based primarily on the above considerations, the *ad hoc* Science Group recommends a critical value for half-life in sediment of greater than or equal to 1 year.

### 3.2 Bioaccumulation

The potential for a substance to bioaccumulate can be expressed in terms of the bioconcentration factor (BCF), the bioaccumulation factor (BAF) or, for lipophilic substances, the octanol-water partition coefficient ( $K_{ow}$ ) (see Appendix II for definitions and background information). BCF and BAF are environmentally more relevant than  $K_{ow}$  because they take into account the response of the organism, including metabolism, steric effects at the gill/water interface, etc. In addition, bioavailability of the substance is considered, especially for BAF. Field data (e.g., BAFs) are preferred over laboratory data (e.g., BCFs) which, in turn, are preferred over chemical properties (e.g.,  $\log K_{ow}$ ). However, in terms of measurement, standardization, reliability of estimates (range) and availability of data, the reverse order is more practical. The *ad hoc* Science Group recommends the use of BCF over  $\log K_{ow}$  because of its greater environmental relevance.

The lipid content of an organism is one of the numerous factors influencing the bioaccumulation processes within that organism. In order to reduce some of the data variability, BCF's are sometimes expressed on a lipid basis. However, correlations between BCF and  $\log K_{ow}$  are generally based on whole-body, wet weight basis. While it would be possible to develop a new set of equations for data on a lipid basis, the data are not readily available today. Therefore, the *ad hoc* Science Group recommends that BCF (or BAF) be considered on a whole-body, wet weight basis.

The *ad hoc* Science Group recommends that a BCF critical value of greater than or equal to 5000 be selected. Substances with a BCF of  $> 5000$  include several organochlorine insecticides such as DDT and chlordane as well as PCBs. These substances have been shown in the field to bioaccumulate and biomagnify into the tissues of upper trophic level wildlife, such as piscivorous birds and mammals, to levels resulting in effects on populations.

In the absence of BCF data, the  $\log K_{ow}$  can be used as a surrogate endpoint. The *ad hoc* Science Group recommends that a  $\log K_{ow}$  critical value of greater than or equal to 5 be selected.  $\log K_{ow}$  however should be used with caution in predicting BCF, as most correlations developed between BCF and  $\log K_{ow}$  hold only for certain types of substances, e.g., chlorobenzenes and PCBs. For substances such as chloronitrobenzenes and bromobenzenes, the correlations do not respond in a comparable manner. In addition, there are other substances like PAHs that have high  $\log K_{ow}$  values and that may be bioaccumulated in fish during waterborne exposure, yet they do not bioaccumulate at the higher trophic levels since they are metabolized.

In summary, the *ad hoc* Science Group recommends that a BCF critical value of greater than or equal to 5000 be selected. In the absence of BCF data, the  $\log K_{ow}$  can be used as a surrogate endpoint, with a critical value of greater than or equal to 5. As outlined earlier, since bioaccumulation processes are influenced by numerous factors, appropriate expert opinion should be used when considering bioaccumulation endpoints and data.

### 3.3 Recommendations

The recommended critical values for persistence in environmental media and bioaccumulation are based on empirical analyses of available data, computer modelling, expert opinion and group consensus.

In summary, the recommended endpoints and critical values are:

For Persistence:

Any one of the following: Half-life in air  $\geq 2$  days <sup>a</sup>

Half-life in water  $\geq 6$  months

Half-life in soil  $\geq 6$  months

Half-life in sediment  $\geq 1$  year

<sup>a</sup> or evidence of atmospheric transport to remote regions such as the Arctic.

For Bioaccumulation:

BCF or BAF  $\geq 5000$  <sup>a</sup>

and/or

$\log K_{ow} \geq 5$  <sup>b</sup>

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<sup>a</sup> Evidence of bioaccumulation in freshwater, marine and terrestrial organisms (including human) is relevant to the Policy. However, since the critical value was derived from BCFs for freshwater fish, data for other organisms could be used but only with appropriate expert judgement.

<sup>b</sup> Values above 7 should be used cautiously. In all cases, expert judgement should be used to evaluate the data.



Because there are several test methods for measuring persistence and bioaccumulation, all measured values should be interpreted with caution. When interpreting persistence and bioaccumulation data, all test conditions should be taken into account.

#### **4.0 OTHER CONSIDERATIONS**

##### **4.1 Protocols and test methods**

At this stage, specific protocols and test methods are not prescribed by the *ad hoc* Science Group. As much as possible, internationally accepted methods (e.g., OECD protocols) should be used to generate the appropriate data. In the absence of such protocols, methods generally recognized and acceptable within the scientific community should be used.

##### **4.2 Data quality**

Because of the inherent complexity of measurements and the numerous factors influencing persistence and bioaccumulation processes, there will often be a wide range of values for any one criterion for a given substance. For this reason, the *ad hoc* Science Group recommends the use of expert judgment to assess the quality of the data. In assessing quality, consideration should be given, among other things, to 1) the age of the data, objectives of the study, and discussion or acknowledgement of conflicting and supporting evidence; 2) the documentation of specific environmental and/or experimental conditions; 3) the method(s) used, its limitations, precision and accuracy.

##### **4.3 Revision of criteria**

The current criteria for bioaccumulation and persistence were derived from empirical analyses of available data, computer modelling and expert judgment, i.e., our current knowledge of the lipophilic substances that are considered among the most persistent and bioaccumulative substances. In the future, with scientific progress in our understanding of persistence and bioaccumulation processes and methodological developments, there may be a need to revise both the criteria and the critical values.

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## **APPENDIX II      Background Information on Persistence and Bioaccumulation**

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### **Persistence**

Environmental persistence refers to the length of time a substance resides in the environment. A common measure of a substance's environmental persistence is its half-life, *i.e.*, the time required for the concentration of a substance to diminish to half of its original value in the particular environmental medium of interest. Only degradation through chemical, biochemical and photochemical processes are considered. Transport and dilution are only included in special cases. In other words, for the purposes of the Policy, degradation refers to the breakdown of the substance rather than removal by advective processes.

The persistence of a substance in the environment depends on various factors, *e.g.*, the intrinsic properties of the substance and the nature of the surrounding environment. Among other things, the persistence of a substance will vary depending upon the medium in which it is found, *i.e.*, air, soil, water or sediment. Factors such as sunlight intensity, hydroxyl radical concentration, the nature of the microbial community, the temperature, etc., will also affect the persistence of a substance in the environment (Mackay *et al.*, 1992). Because of the numerous factors influencing persistence, it is impossible to determine a single half-life value for any medium that is relevant to all ecosystems. There are various methods, none of which are simple, for assessing degradation processes including both controlled experimentation and estimation techniques (modelling). It is not unusual for a wide range of half-life values to be reported for one specific medium.

### **Bioaccumulation**

A substance is bioavailable when some of that substance in the surrounding environment can be taken up by an organism. The environment may include water, sediment, suspended particles and food. The bioavailability of a substance is a function of the substance itself (*i.e.*, its properties), and the physical and chemical environment in which it is found.

Bioaccumulation is a general term describing a process by which substances are accumulated by organisms directly from the surrounding media and through consumption of food containing the substances (CCME, 1987).

Bioconcentration is a process by which there is a net accumulation of a substance directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gills or epithelial tissues) and elimination (CCME, 1987).

Biomagnification results from the processes of bioaccumulation and bioconcentration by which tissue concentrations of bioaccumulated substances increase as they are passed up through two or more trophic levels. The term implies an efficient transfer from food to consumer, so that residue concentrations increase systematically from one trophic level to the next (CCME, 1987). The extent of biomagnification is also influenced by several factors, e.g., the substance being accumulated, the number of stages in the food web, the kind of organisms in the food web, the ability of these organisms to metabolize the substance, the concentration of the substance at each level of the web, etc.

The BCF is a comparison (ratio) of the concentrations observed in biota with respect to concentrations in the water to which it is exposed under steady-state conditions. BCFs are usually calculated from controlled laboratory tests where the intake of the biota (usually fish) is derived from dissolved substances in the medium. When the ratio is derived from accumulation through both the medium and the food chain, it is called the bioaccumulation factor (BAF). BAFs are often calculated from field data. Both the IJC's Virtual Elimination Task Force and the UN-ECE Task Force on Persistent Organic Pollutants acknowledge that BAFs are preferable to BCFs, although BCFs are frequently used due to availability of data and standardized tests. BAF is technically more difficult to measure than BCF. Calculated BCF and BAF values are often highly variable, even within the same organism. Variability can be due to the test conditions, the test organism or its physiological state which, in the field, could be influenced by season, predation, availability of food, etc.

The octanol-water partition coefficient,  $K_{ow}$ , provides an estimation of a substance's lipophilicity or partitioning tendency from water to organic media such as lipids. Various regression equations have been developed for estimating BCF values for aquatic organisms, based on the  $K_{ow}$  and other physico-chemical properties. There are various methods for estimating  $K_{ow}$  either experimentally or by calculation, e.g., from the molecular structure. The  $K_{ow}$  is easier to measure, although less environmentally relevant, than either the BCF or the BAF. It is generally accepted that a log  $K_{ow}$  value of approximately 5 corresponds to a BCF for fish of the order of 5000. Estimated log  $K_{ow}$  values above 7 for substances should be used with caution as these substances may not accumulate at levels predicted from  $K_{ow}$  relationships.

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## APPENDIX III      Summary of Substances Studied <sup>a</sup>

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1,4-Dichlorobenzene	PAHs
3,3'-Dichlorobenzidine	1,6-Dinitropyrene
1,2-Dichloroethane	1,8-Dinitropyrene
$\alpha$ -1,2,3,4,5,6-Hexachlorocyclohexane	Acenaphtene
$\gamma$ -1,2,3,4,5,6-Hexachlorocyclohexane	Anthracene
4,4'-Methylene bis(2-chloroaniline)	Benzo[a]pyrene
1,1,1-Trichloroethane	Benzo[e]pyrene
Aldrin	Benzo[ghi]perylene
Alkylated lead	Benz[a]anthracene
Benzene	Benzo[b]fluoranthene
Benzidine	Benzo[j]fluoranthene
Bis(chloromethyl) ether	Benzo[k]fluoranthene
Bis(2-ethylhexyl) phthalate	Chrysene
Chlordane	Dibenz[a,h]anthracene
Chlorinated paraffins - short chain	Dibenzo[a,i]pyrene
Chlorinated wastewater effluents	Dibenz[a,j]acridine
Chloromethyl methyl ether	7H-dibenzo[c,g]carbazole
Creosote-contaminated sites	Fluoranthene
DDT (+DDD+DDE)	Fluorene
Dichloromethane	Indeno[1,2,3-c,d]pyrene
Dieldrin	Naphthalene
Effluents - pulp mills using bleaching	Perylene
Endosulfan (inclu. isomers & sulphate)	Phenanthrene
Endrin	Pyrene
Heptachlor	Pentachlorophenol
Hexachlorobenzene	Polychlorinated biphenyls
Hexavalent chromium compounds	Polychlorinated dibenzodioxins
Inorganic arsenic compounds	Polychlorinated dibenzofurans
Inorganic cadmium compounds	Refractory ceramic fibre
Inorganic fluorides	Tetrachloroethylene
Methyl mercury	Toxaphene
Mercury and compounds	Tributyltin
Mirex	Trichloroethylene
Octachlorostyrene	Trifluralin
Oxidic, sulphidic and soluble inorganic nickel compounds	

<sup>a</sup> Substances identified on the IJC Critical Pollutants List, the MOEE Primary List for Bans and Phase Outs, ARET List A, and those PSL substances determined to be toxic under CEPA.

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