CANADIAN ENVIRONMENTAL QUALITY GUIDELINES (WATER, SEDIMENT, AND TISSUE) FOR DIOXINS AND FURANS TO PROTECT AQUATIC LIFE AND WILDLIFE

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Introduction

Canadian Environmental Quality Guidelines (EQGs) are developed by the Canadian Council of Ministers of the Environment (CCME) using formal protocols (i.e., CCME 1991, 1995, 1998) to provide a consistent, scientifically defensible approach for assessing and managing toxic substances in the environment. These guidelines are numerical concentrations in various media (water, sediment, aquatic biota, and/or soil) that are recommended to protect, enhance, and restore designated uses of the environment. These concentrations provide benchmarks for the interpretation of environmental monitoring data and serve as the scientific basis for determining interim management objectives and performance indicators to measure progress in virtual elimination strategies. EQGs are intended for use by Canadian provincial, territorial, and federal agencies as well as private/corporate stakeholders to assess environmental quality problems and to manage competing uses of resources. These national numerical environmental quality guidelines are important tools in comprehensive ecosystem management but they are not intended to preclude the need for site-specific considerations and approaches. Thus, it should be noted that the use of the guidelines will require consideration of local conditions.
As a class of compounds, polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are considered 'toxic' substances as defined in Section 11 of the *Canadian Environmental Protection Act*. Additionally, they meet the specifications for Track 1 substances under the Toxic Substance Management Policy because they are toxic, persistent, bioaccumulative, and concentrations in the environment primarily result from human activities. As such they are slated for virtual elimination from the Canadian environment (Environment Canada 1997). In recognition of these characteristics, the CCME requisitioned its Task Group on Water Quality Guidelines to prepare Canadian Environmental Quality Guidelines (EQGs) for PCDD/Fs.

Materials and Methods

Ambient water quality guidelines (WQGs) and sediment quality guidelines (SQGs) for the protection of freshwater and marine/estuarine biota, and tissue residue guidelines (TRGs) for the protection of wildlife consumers of freshwater and marine/estuarine biota are developed according to formal protocols approved by the CCME (CCME 1991, 1995, 1998). For their respective media, these protocols establish a lowest-observable-effect-level from which a no-observable-effect-level is estimated. To develop EQGs for PCDD/Fs, a detailed technical review, current as of December 1998, was carried out for the seventeen 2,3,7,8-substituted congeners. Production, sources, and pathways for entering the environment were detailed; levels of PCDD/Fs in the tissues of biota in Canada were documented in extensive tables to facilitate comparisons among regions and species. In addition, available data on the environmental fate and persistence of these substances were evaluated and summarised to identify the compartments most at risk of being contaminated. Most importantly, a comprehensive assessment of the toxicity of PCDD/Fs to aquatic life (plants, invertebrates, amphibians, and fish) and wildlife (mammals and birds) was undertaken to evaluate the environmental hazards posed by these chemicals. Together, this information was used, in accordance with the formal protocols, to derive numerical EQGs on a toxic equivalents (TEQs) basis.

Results and Discussion

Data Evaluation

Although slated for virtual elimination, significant sources of PCDD/Fs continue to exist in Canada of which municipal waste incinerators are most notable. Examination of fate and behaviour processes revealed that bed sediments may represent long term sources of PCDD/Fs to the aquatic food web as bioaccumulation from the organic fraction of the sediments is an important path of uptake of PCDD/Fs for some aquatic organisms (e.g., carp, *Cyprinus carpio*). The geometric mean biota-sediment accumulation factors (BSAFs) for 2,3,7,8-T_4CDD are 0.3 and 0.14 for species resident in Canadian freshwater and marine/estuarine systems, respectively. Lipid-normalized bioconcentration factors ($BCFs_{lipid}$) recorded for 2,3,7,8-T_4CDD were the highest of all congeners, with a geometric mean of 175 245 for species resident in Canada. Accumulation from food may be the primary source of PCDD/Fs for some species (e.g., lake trout, *Salveinus namaycush*) but not for others (e.g., carp and guppies, *Poecilia reticulata*). Moreover, PCDD/Fs seem unusual in that they do not appear to biomagnify like other halogenated aromatics with comparable hydrophobicities. The greatest biomagnification factors (BMFs) reported were 32 and 76 for herring gulls (*Larus argentatus*) and mink (*Mustela vison*), respectively. More research on accumulation rates and processes is needed to obtain a clearer understanding of PCDD/F movement through the food chain.

PCDD/Fs are thought to elicit most, if not all, of their toxicity via the aryl hydrocarbon (*Ah*) receptor, a protein conserved across mammals, birds, and fish. A multitude of toxic and biologic responses to PCDD/F exposure have been described in the scientific literature and include: mortality (often delayed), decreased body weight gain, decreased feed consumption, thymic atrophy, histopathologic effects, immunotoxicity, developmental and reproductive effects, biochemical effects, neurotoxicity, and carcinogenesis. PCDD/Fs are also known to disrupt the endocrine system which could have serious repercussions on sexual development. Clearly, it is

unlikely that the complete spectrum of effects would be observed in any single species but the data indicate that PCDD/Fs and related compounds elicit the same qualitative pattern of responses within each species. For the purposes of developing Canadian EQGs, toxic responses of aquatic biota (plants, invertebrates, amphibians, and fish), and mammals and birds (preferable wildlife) to PCDD/Fs exposure through water, sediment, and/or diet were reviewed and evaluated according to quality standards outlined in the protocols. To account for differing concentrations and toxicity among the various congeners, exposure concentrations were converted to a toxic equivalent (TEQ) basis. The most recent toxic equivalent factors (TEFs) for mammalian, avian, and fish species developed by the World Health Organization (van den Berg et al. 1998) were applied.

Guideline Derivation

The goal of Canadian WQGs is to protect all forms of aquatic life and all aquatic life cycles during an indefinite exposure to water. According to formal protocol, Canadian WQGs are derived preferably from the most sensitive lowest-observable-adverse-effect level (LOEL) from a chronic exposure study on a native Canadian species, multiplied by a safety factor (CCME 1991). Where data are limited, interim guidelines are deemed preferable to no guidelines.

The CCME has developed a formal protocol to derive numerical sediment quality guidelines (SQGs) for both freshwater and marine (including estuarine) sediments to protect aquatic life associated with bed sediments (CCME 1995). This protocol relies on the National Status and Trends Program (NSTP) approach (with modifications) and the Spiked-Sediment Toxicity Test (SSTT) approach (Long and Morgan 1990; CCME 1995). Subsequent to an evaluation of the toxicological information, Canadian SQGs (also referred to as 'full' SQGs) are recommended if information exists to support both approaches. Generally, the lower of the two values derived using either the NSTP approach or SSTT approach is recommended. If insufficient information exists to derive interim guidelines using either the modified NSTP approach or the SSTT approach, guidelines from other jurisdictions are evaluated and may be provisionally adopted in the short-term as interim SQGs. Interim Canadian SQGs (ISQGs) are recommended if information is available to support only one approach. The guidelines may also be derived to reflect predictive relationships that have been established between the concentration of the chemical in sediments and any environmental factor or condition (e.g., characteristics of the sediment, such as the concentration of organic carbon; characteristics of the overlying water column, such as hardness) involved in modifying the expression of the toxicity of the chemical. For both WQGs and SQGs for PCDDs and PCDFs, an equilibrium partitioning model was applied to cross-check guideline values across media.

For substances such as PCDD/Fs that are persistent and bioaccumulative, an important route of exposure for wildlife in aquatic ecosystems is the consumption of contaminated aquatic prey species such as fish. In order to address this route of exposure, tissue residue guidelines (TRGs), which are maximum concentrations of chemical substances in aquatic biota, are developed to protect, restore, and sustain wildlife that consume aquatic biota in freshwater, estuarine, and marine ecosystems. TRGs can apply to tissue residues in dietary species including fish, shellfish, invertebrates, or aquatic plants that are consumed by wildlife (e.g., piscivores, insectivores, and herbivores). For the derivation of the Canadian TRG, the lowest tolerable daily intake (TDI) levels for PCDD/Fs were divided by the highest food intake rate to body weight ratios (FI:BW) of a variety resident wildlife species to calculate reference concentrations (RCs) (CCME 1998). The lowest RC among available mammalian and avian species is adopted as the TRG for PCDD/Fs.

The guideline refers to the concentration due to PCDD/Fs measured in an aquatic organism on a wet weight basis that is not expected to result in adverse effects on wildlife.
The EQGs for PCDD/Fs are currently undergoing peer review; details of the approach and final, numerical guideline values will be presented.

Acknowledgements

The authors would like to extend our thanks to the many contributors and reviewers of the dioxin and furan EQGs document; their efforts greatly improved the quality of this work.

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