Environment Canada Environnement Canada

Canadian Environmental Protection Act, 1999
Federal Environmental Quality Guidelines

Tetrabromobisphenol A (TBBPA)

Environment and Climate Change Canada

Publication Date:

May 2016

Introduction

Federal Environmental Quality Guidelines (FEQGs) provide benchmarks for the quality of the ambient environment. They are based solely on the toxicological effects or hazards of specific substances or groups of substances. FEQGs serve three functions: first, they can be an aid to prevent pollution by providing targets for acceptable environmental quality; second, they can assist in evaluating the significance of concentrations of chemical substances currently found in the environment (monitoring of water, sediment and biological tissue); and third, they can serve as performance measures of the success of risk management activities. The use of FEQGs is voluntary unless prescribed in permits or other regulatory tools. Thus FEQGs, which apply to the ambient environment are not effluent limits or "never-to-be-exceeded" values but may be used to derive effluent limits. The development of FEQGs is the responsibility of the Federal Minister of Environment and Climate Change under the *Canadian Environmental Protection Act, 1999* (CEPA) (Canada 1999). The intent is to develop FEQGs as an adjunct to the risk assessment/risk management of priority chemicals identified in the Chemicals Management Plan (CMP) or other federal initiatives. This factsheet describes the FEQGs for water, sediment and mammalian wildlife diet to protect aquatic life and mammalian consumers of aquatic life from adverse effects of tetrabromobisphenol A (TBBPA) (Table 1). This TBBPA factsheet was based largely on the screening assessment report published under Canada's Chemicals Management Plan. It is based on data and information identified up to February 2013 (GC 2013).

Table 1. Federal Environmental Quality Guidelines for Tetrabromobisphenol A (TBBPA).

Water (µg/L)	Sediment* (mg/kg dw)	Mammalian Wildlife diet (mg/kg food ww)**
3.1	0.6	20

* Normalized to 1% organic carbon

** The mammalian wildlife diet guideline is intended to protect mammals that consume aquatic biota. It is the concentration of a TBBPA in aquatic biota, expressed on whole body, wet weight basis that could be eaten by terrestrial or semi-aquatic wildlife.

dw = dry weight; ww = wet weight

Substance Identity

TBBPA (CAS No. 79-94-7) is a brominated flame retardant produced by the bromination of bisphenol A (WHO 1995) and is being considered as a potential substitute for commercial octabromodiphenyl ether (OctaBDE), a brominated flame retardant which has been subject to a global production phase-out (DEFRA 2002). Based on the Screening Assessment Report (SAR), GC (2013) concluded that TBBPA is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. TBBPA meets the criteria for persistence, but not for the bioaccumulation potential as set out in the *Persistence and Bioaccumulation Regulations* (GC 2000). Under anaerobic conditions, TBBPA has been shown to degrade to form bisphenol A (BPA) and BPA has been determined to meet the criteria defined in section 64 of CEPA (GC 2008). FEQGs for BPA are under development.

Uses

No TBBPA was manufactured in Canada in 2000, however amounts in the range of 100 000 to 1 000 000 kg were imported into the country in that year, with all reported uses being as a flame retardant (EC 2001). Recent estimates suggest that TBBPA imports to Canada remain in the same range (GG 2013). TBBPA is primarily used as a flame retardant in flame-retarded epoxy and polycarbonate resins, and to a lesser extent, in acrylonitrile-butadiene-styrene resins and phenolic resins (GC 2013). A major usage of flame-retarded epoxy resins containing TBBPA is in rigid epoxy-laminated printed circuit boards; other uses include glass-reinforced construction panels, motor housings and terminal boards (Danish Environmental Protection Agency 1999). Applications of TBBPA flame-retarded polycarbonate resins include communications and electronics equipment, appliances, transportation devices, sports and recreation equipment, lighting fixtures and signs (WHO 1995). TBBPA may also be incorporated into unsaturated polyesters used in simulated marble floor tiles, bowling balls, furniture parts, sewer pipe coupling compounds, automotive patching compounds and buttons, and for encapsulating electrical devices (Gustafsson and Wallen 1988).

Fate, Behaviour and Partitioning

TBBPA is weakly acidic and can exist in un-ionized (neutral) or ionized forms. The predominant form of TBBPA present in an aquatic system is a function of pH. With a pKa near neutral (GC 2008), at neutral pH about 50% of TBBPA will be in the undissociated form. At lower pH (e.g., <5.5), the un-ionized forms predominate. TBBPA has low to moderate water solubility (0.063 - 4.16 mg/L) that is a function of both temperature and pH, low vapour pressure ($<1.19 \times 10^{-5}$ pascals at $20^{o}C$), and a moderately high K_{OA} (4.5-5.9) (GC 2013). If released into receiving water, TBBPA is expected to mainly partition to sediment (96.4%), with 2.84% remaining in water (GC 2013).

Laboratory and field studies indicate that TBBPA degrades slowly in the environment; complete mineralization of the substance has not yet been demonstrated (GC 2013). In freshwater sediments TBBPA has been shown to degrade under anaerobic conditions to form bisphenol A (BPA) (Ronen and Abeliovich 2000). Biodegradation can also occur during the anaerobic treatment of sewage sludge; however, empirical data to quantify degradation rates are not available. In marine sediments, TBBPA has been found to dehalogenate completely to form BPA (GC 2013).

TBBPA applied to loam soil and sand adsorbs strongly to particulates in both, however, its significant redistribution can occur to a depth of 15 cm (Larsen et al. 2001). This suggests that TBBPA present in applied biosolids would remain at the surface thus reducing the risk of groundwater contamination (GC 2013).

Bioaccumulation and bioconcentration of TBBPA have been demonstrated in several species of fish and aquatic invertebrates (GC 2013). Depending on the organic content in sediments, bioconcentration factors (BCFs) of 240 to 3200 are reported for the freshwater midge, *Chironomus tentans* (GC 2013), indicating that although TBBPA does not meet CEPA bioaccumulation criteria, it can accumulate in the tissue of biota. Concentrations up to 376 µg/kg ww have been measured in organisms at higher trophic levels, such as marine mammals (de Boer et al. 2002).

Ambient Concentrations

Data characterizing concentrations of TBBPA in Canadian environment are limited with no reports of detection in surface water (GC 2013). TBBPA levels measured in bottom sediments from eight locations in Lake Ontario ranged from not detected (DL 0.002 µg/kg dw) to 0.063 µg/kg dw (Quade 2003). Among the samples of sludge collected from 35 Canadian municipal sewage treatment plants in seven provinces between 1994 and 2001, TBBPA was present in 34 samples with concentrations ranging from 2.9 to 46.2 µg/kg dw (Lee and Peart 2002). With the highest concentration in a raw sludge from a treatment plant in Toronto, it was hypothesized that the industrial wastewaters from textiles, furniture, toys and printed circuit board production were likely to be the primary sources of the TBBPA (Lee and Peart 2002). Quade (2003) also measured concentrations of TBBPA in sewage sludge collected from five treatment plants in southern Ontario with concentrations ranging from 9.04 to 43.1 µg/kg dw. In lake trout collected from Lake Ontario, TBBPA derivatives ranged from 0.2 to 1.7 µg/kg ww (Ismail et al. 2006). While levels of TBBPA itself have been below detection in Canadian wildlife (polar bear and snapping turtle) (Chu and Letcher 2013), derivatives of TBBPA (substances which are themselves derived from TBBPA) have been detected at very low levels in the eggs of herring gull (0.08 – 0.56 µg/kg ww) from the Great Lakes (Letcher and Chu 2010).

Mode of Action

The mode of toxic action of TBBPA has not been determined, however, the neutral (undissociated) form is expected to act as a narcotic or baseline toxicant, adversely affecting membrane integrity and function due to its presence and concentration in the membrane (GC 2013). Because ionized forms of TBBPA have lower bioavailability, they are likely to be less toxic. Escher and Sigg (2004) proposed that TBBPA may act as an uncoupler of oxidative and photo-phosphorylation thus making it a potential disruptor of the electron transfer chain which is integral to energy production in cells.

Federal Environmental Quality Guidelines Derivation

Federal Water Quality Guideline

Federal Water Quality Guidelines (FWQGs) are preferably developed using CCME (2007) protocols. In the case of TBBPA, there was a need to develop a predicted no effect concentration (PNEC) for the ecological screening assessment and the FWQG, although there was insufficient chronic toxicity data to meet the minimum data requirements for a CCME Type A or Type B guideline[1]. The FWQGs developed here identify benchmarks for aquatic ecosystems that are intended to protect all forms of aquatic life for indefinite exposure periods. The FWQG applies to both freshwater and marine waters because it cannot be demonstrated that the toxicity differs significantly between these two environments (e.g., due to ionization).

Chronic aquatic toxicity data were identified in the SAR (GC 2013) and data considered acceptable for developing the FWQG are presented in Table 2. Among the freshwater toxicity data the most reliable chronic endpoint of 310 µg/L (35-d lowest observed effect concentration) (LOEC) for fathead minnow (*Pimephales promelas*) was selected for deriving the PNEC. An application factor (AF) of 100 was applied to this chronic toxicity value (CTV) to account for inter- and intra-species variability in sensitivity and extrapolation from laboratory to field conditions. Furthermore, the AF of 100 was considered appropriate because adverse effects of TBBPA were shown to occur at lower concentrations (Table 2). The resulting PNEC of 3.1 µg/L (GC 2013) was adopted as the FWQG for TBBPA (Figure 1).

Table 2. Chronic aquatic toxicity for TBBPA (Source: GC 2013).

Species	Group	Endpoint	Concentration (µg/L)	Reference
Zebrafish *Danio rerio*	■	47-d LOEC (development)	13	Kuiper et al. (2007)
Eastern Oyster (*Crassostrea virginica*)	●	4-d LOEC (shell deposition)	18	Great Lakes Chemical Corporation (1989a)
Common Mussel (*Mytilus edulis*)	●	70-d LOEC (growth)	32	ACCBFRIP (2005a,b)
Midge (*Chironomus tentans*)	●	14-d LOEC (growth)	70	Great Lakes Chemical Corporation (1989b)
Marine Algae *Skeletonema costatum*	▲	3-d EC50 (growth)	90	Walsh et al. (1987)
Copepod (*Acartia tonsa*)	●	5-d EC50 (development)	125	Wollenberger et al. (2005)
Marine Algae (*Thalassiosira pseudonana*)	▲	3-d median effective	130	Walsh et al. (1987)

[1] CCME (2007) provides two approaches for developing water quality guidelines, depending on the availability and quality of the available data. The preferred approach is to use the statistical distribution of all acceptable data to develop Type A guidelines. The second approach is based on extrapolation from the lowest acceptable toxicity endpoint to develop Type B guidelines. For further detail on the minimum data requirements for CCME guidelines see CCME (2007).

		concentration (EC50) (growth)		
Fathead Minnow (*Pimephales promelas*)	■	35-d LOEC (survival)	310	Great Lakes Chemical Corporation (1989c)
Water Flea (*Daphnia magna*)	●	21-d LOEC (reproduction)	980	Great Lakes Chemical Corporation (1989d)

Legend: ■ = Fish; ● = Invertebrate; ▲ = Plant

The FWQG (3.1 µg/L) represents the concentration below which one would expect either no, or only a low likelihood of adverse effects on aquatic life. In addition to this guideline, two other concentration ranges are provided (Figure 1). At concentrations greater than the FWQG of 3.1 µg/L to the CTV of 310 µg/L, there is a moderate likelihood of adverse effects to aquatic life. Concentrations that are greater than 310 µg/L have a higher likelihood of causing adverse effects to aquatic life

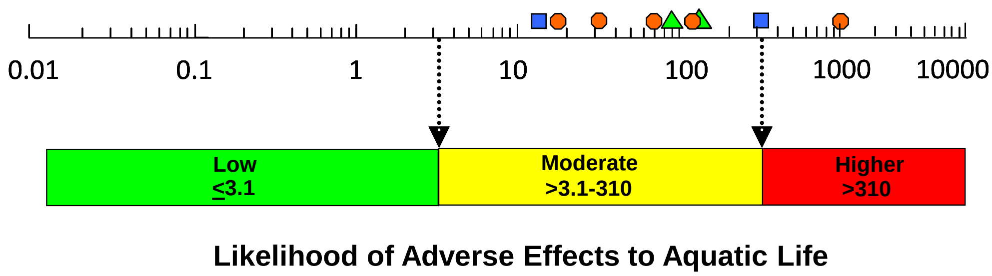

Figure 1. Relative likelihood of adverse effects of TBBPA to aquatic life. The FWQG (3.1 µg/L) and CTV (310 µg/L) are marked by arrows.

Federal Sediment Quality Guideline

The Federal Sediment Quality Guidelines (FSeQG) are intended to protect sediment dwelling biota as well as pelagic animals which bioaccumulate TBBPA from sediments (Table 1). The FSeQG applies to indefinite exposure periods to freshwater sediments, and specifies the concentration of TBBPA found in bulk sediment (dry weight) not expected to result in adverse effects. The guideline may not be appropriate to evaluate the impacts of TBBPA in aquatic plants growing in sediments as there are no published toxicity data for these species.

Sediment toxicity data for TBBPA are limited (Figure 2). Twenty-eight day LOECs for freshwater oligochaete (*Lumbriculus variegates*) based on reduced survival and reproduction, and growth, were 151 and 426 mg/kg dw (dry weight) for sediments with organic carbon (OC) content of 2.5% and 5.9%, respectively ACCBFRIP (2002c,d). A 28-d study for midge (*Chironomus riparius*) reported a LOEC of 250 mg/kg dw, based on emergence ratio, development rate and development time (ACCBFRIP 2005). Similar to SAR (GC 2013), the 28-d LOEC for *L. variegatus* of 151 mg/kg dw for 2.5% OC was selected as the CTV, but the CTV value was normalized to 1% OC in sediment (60 mg/kg dw) and an AF of 100 was applied to account for extrapolation from laboratory to field conditions and inter- and intra-species variations. The resulting value of 0.6 mg/kg dw is the FSeQG (Figure 2).

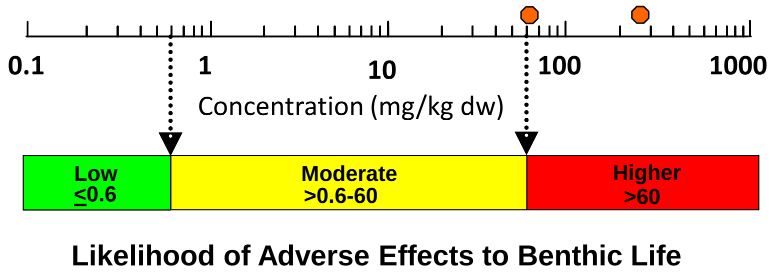

Figure 2. Relative likelihood of adverse effects of TBBPA to benthic life in aquatic sediments. The FSeQG (0.6 mg/kg dw) and CTV (60 mg/kg dw) are marked by arrows.

In addition to the FSeQG value, three concentration ranges were identified to represent low, moderate and higher relative risks of adverse effects to aquatic life (Figure 2). At concentrations equal to or less than the FSeQG (1.6 mg/kg dw), there is low likelihood of adverse effects to aquatic life. At concentrations greater than the FSeQG and the CTV of 16 mg/kg dw, there is a moderate likelihood of adverse effects to aquatic life. At concentrations that are greater than 16 mg/kg dw there is a higher likelihood of causing adverse effects to aquatic life.

Federal Wildlife Dietary Guideline

The Federal Wildlife Dietary Guideline (FWiDG) is intended to protect mammalian consumers of aquatic biota. This is a benchmark concentration of a substance in aquatic biota (whole body, wet weight) that could be consumed by terrestrial or semi-aquatic wildlife. The FWiDG for mammals may not be appropriate to extrapolate the impacts of TBBPA to other terrestrial consumers (e.g., birds or reptiles). Neither birds nor reptiles were evaluated.

The FWiDG is based on the PNEC for TBBPA as developed by GC (2013). There were no toxicological studies with mammalian wildlife species for TBBPA. The PNEC was based on histological evidence of liver toxicity in female offspring of laboratory mice that were only exposed via the maternal route. The lowest NOAEL of 15.7 mg/kg bw/d and the lowest LOAEL of 140.5 mg/kg bw/d of gave a MATC (geometric mean) of 46.97 mg/kg bw/d (Tada et al. 2006). Using this value as the tolerable daily intake rate in CCME (1998) protocol, a safety factor of 10 (GC 2013) (also the minimum safety factor allowed) and adjusted for the largest food intake: body weight (0.24 for American mink) produces the lowest acceptable dietary concentration, in this case, 20 mg/kg diet wet weight.

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List of Acronyms and Abbreviations

AF - application factor
BCF - bioconcentration factor
BPA - bisphenol A
CAS - Chemical Abstracts Service
CCME - Canadian Council of Ministers of Environment
CMP - Chemicals Management Plan
CTV - critical toxicity value
dw - dry weight
EC – Environment Canada
EC50- median effective concentration; concentration in test medium that is estimated to cause a specified toxic effect to 50% of the test organisms
FEQG - Federal Environmental Quality Guideline
FWQG - Federal Water Quality Guideline
FSeQG - Federal Sediment Quality Guideline
FWiDG - Federal Wildlife Dietary Guideline
GC – Government of Canada
K_{OA} - octanol- air partition coefficient
K_{OW} - octanol- water partition coefficient
LOEC - lowest observable effect concentration
LOAEL - lowest observed adverse effect level
MATC - maximum allowable toxicant concentration and is equal to the geometric mean of NOAEL and LOAEL for a test species
NOAEL – no observed adverse effect level
PNEC - predicted no effect concentration
SAR - screening assessment report
TBBPA - tetrabromobisphenol A
TDI - total daily intake
ww - wet weight