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Canadian Environmental Protection Act, 1999

Federal Environmental Quality Guidelines

Chlorinated Alkanes

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Introduction

Federal Environmental Quality Guidelines (FEQGs) provide benchmarks for the quality of the ambient environment.. They are based solely on the toxicological effects or hazard 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 deciding 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 chlorinated alkanes (CA) (Table 1). This CA factsheet was largely developed in consideration of the screening assessment conducted under Canada's Chemicals Management Plan (GC 2008) with the data and information updated up to April 2010.

Table 1. Federal Environmental Quality Guidelines for Chlorinated Alkanes.

Homologue	Water (µg/L)	Fish Tissue (µg/g lipid)	Sediment* (mg/kg dw)	Mammalian Wildlife Diet (mg/kg food ww)
SCCAs	2.4	2.7	1.8	18
MCCAs	2.4	0.76	5.4	0.54
LCCAs	2.4	–	100[a]	18[b], 770[c]

SCCAs = short chain chlorinated alkanes (C_{10-13})
MCCAs = medium chain chlorinated alkanes (C_{14-17})
LCCAs = long chain chlorinated alkanes ($C_{\geq 18}$)
dw = dry weight; ww = wet weight
*values 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.
[a]C_{18-20} liquid; [b]$C_{>20}$ liquid; [c] $C_{>20}$ solid

Substance Identity

Chlorinated alkanes (CAs), also referred to as chlorinated paraffins, are chlorinated hydrocarbons (n-alkanes) that can have carbon chain lengths from 10 to 38 and chlorine content from 30 to 70% by weight (GC 2008). CAs with carbon chains containing 10-13 carbon atoms are termed "short chain CAs" (SCCAs), those with 14-17 carbon atoms are called "medium chain CAs" (MCCAs) and those with carbon chains having 18 or more carbon atoms are called "long chain CAs" (LCCAs). LCCAs fall into two categories based on their chain length: (i) $C_{18–20}$ and $C_{>20}$ liquid LCCAs (referred as liquid LCCAs) and (ii) $C_{>20}$ solid LCCAs (GC 2008). Chlorination of the n-alkane feedstock yields extremely complex mixtures, owing to the many possible positions for chlorine atom substitution, and n-alkanes may contain branched alkanes and aromatics. Standard analytical methods do not permit their separation and identification (GC 2008). In the case of MCCAs, these mixtures consist of $C_{14–17}$ alkanes with typically 4–9 chlorines (i.e., ~40–60% chlorine by weight). For LCCAs, there is a wider range of possible chlorine percentages due to the wider range of carbon chain lengths. The average chlorine content of the liquid products is 30–54% and of the $C_{>20}$ solids is 70–72%. The risk assessment (GC 2008) concluded that CAs containing up to 20 carbon atoms are entering or may enter 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 and thus meets the criteria under section 64 of CEPA. CAs were added to Schedule 1 (List of Toxic Substances) of CEPA on September 29, 2011. Furthermore, these CAs meet the criteria for persistence and bioaccumulation potential as set out in *Persistence and Bioaccumulation Regulations* and were recommended for addition to the Virtual Elimination List (GC 2008).

Uses

There are no known natural sources of CAs. The major sources of release of CAs into the Canadian environment are likely the formulation and manufacturing of products containing CAs, such as polyvinyl chloride (PVC) plastics, and use in metalworking fluids (GC 2008). The possible sources of releases to water from manufacturing include spills, facility wash-down and drum rinsing/disposal. CAs in metalworking or metal cutting fluids may also be released to aquatic environments from drum disposal, carry-off and spent bath. These releases are collected in sewer systems and may end up in the effluents of sewage treatment plants.

Total reported annual usage of CAs in Canada (production + imports – exports) was approximately 3000 tonnes in 2000 and 2001 (GC 2008). Pioneer Chemicals Inc. (formerly ICI Canada), Cornwall, Ontario, was the only Canadian producer of CAs and it is currently not producing CAs. The plant previously produced MCCAs and LCCAs with a chlorine content of up to 56% under the trade name Cereclor (Camford Information Services 2001). The capacity for production was 5.0, 5.0, 8.5 and 8.5 kilotonnes in 1997, 1998, 1999 and 2000, respectively; the corresponding imports to Canada in these years were 2.0, 2.0, 1.7 and 1.8 kilotonnes, respectively. MCCAs accounted for a large majority of CAs usage in Canada, followed by smaller proportions of SCCAs and LCCAs. Nearly all reported usage of SCCAs in Canada is in metalworking applications. Minor uses are as a flame retardant in plastics and rubber. The majority of uses for MCCAs are in plastics and as lubricating additives. Minor uses are as an additive in sealants and caulking, in rubber and paints and as a flame retardant in plastics or rubber. The major uses of LCCAs are in lubricating additives, metalworking fluids and paints. Minor uses are in plastics and as flame retardants, engine oil, fabric adhesive and rock drilling fluid (GC 2008).

Fate, Behaviour and Partitioning in the Environment

Atmospheric half-lives of many CAs are estimated to be greater than 2 days (GC 2008) and partitioning from water to air or from moist soils to air depends on environmental conditions and prevailing concentrations in each compartment (Drouillard et al. 1998a). Short chain CAs of lower chlorine content undergo aerobic biodegradation more quickly than long chain CAs of similar chlorine contents (Omori et al. 1987; Allpress and Gowland 1999). The water solubility of $C_{10–12}$ CAs is estimated in the range of 400–960 μg/L (Drouillard et al. 1998b). The solubility of C_{10} and C_{13} CA mixtures is estimated in the range of 6.4–2370 μg/L, whereas the empirical data suggest that the water solubility of SCCAs may be on the lower side of this range (BUA 1992). The water solubility of CAs varies with both carbon chain length and degree of chlorination; increasing with increasing degree of chlorination up to five chlorine substituents (GC 2008). For MCCA (C_{16}; 52% chlorine by weight), solubility values of 10 μg/L in freshwater and 4 μg/L in seawater are reported (Campbell and McConnell 1980). No measured water solubility values are available for the $C_{18–20}$ LCCAs, whereas the estimated values range between 0.017-6.1 μg/L (UK Environment 2009). Two measured values available for C_{25} with 42% and 43% chlorine are 3.0 and 6.6 μg/L, respectively (UK Environment 2009).

SCCAs with 50–60% chlorine have predicted log K_{OA} values from 9 to 11 (Muir 2010). The values for MCCAs range from 11-15 (Muir 2010) and LCCA values are even higher (GC 2008). Log K_{OA} values of this magnitude imply high partitioning to organic matter. The predicted log K_{OC} values for SCCAs and MCCAs range from 3.66 to 7.14 and 4.53 to 6.75, respectively, with values for LCCAs expected to be even higher. These high K_{OC} values imply that when transported in river water or wastewater streams, MCCAs and LCCAs will be predominantly adsorbed to particles and will experience very high removal rates from the aqueous phase in high particulate organic carbon environments, such as wastewater treatment plants (GC 2008).

SCCAs have been detected in Arctic biota and lake sediments in the absence of significant sources of SCCAs in this region, which indicates that long-range atmospheric transport of SCCAs is occurring. SCCA and MCCA residues have been detected in Canadian lake sediments deposited over 25 years, suggesting that their half-lives in sediment are greater than 1 year. Computer modelling of SCCAs has shown that they would achieve their highest concentrations in sediment and soil (Muir et al. 2001) and that the fate of SCCAs in soil is important for understanding the environmental fate of these compounds. No LCCAs data are available for Canadian sediments; however, based on their physical/chemical properties, which are similar to those of MCCAs, LCCAs are expected to be persistent in sediments (GC 2008).

Muir (2010) compared SCCA homologue data in sediment versus bottom feeding fish (flounder and sculpin) from the same area and observed that the C_{13} chloro-n-alkanes are less bioavailable than the shorter chain length SCCAs. There was also an indication that the less chlorinated chain lengths (e.g., $C_{10}C_{l5}$, $C_{11}C_{l5}$) were underrepresented, most likely due to biotransformation. This transformation might occur in sediment-dwelling invertebrates preyed upon by the fish as well as in the fish (Muir 2010). Moreover, Fisk et al. (1998) showed that C_{12}–C_{16} chloro-n-alkanes were biotransformed in aerobic sediments and by oligochaetes, and that the susceptibility to degradation in sediments decreased with increasing chlorine content.

Bioconcentration factors (BCFs) for SCCAs vary dramatically among different species of biota. Data reviewed by GC (1993a) identified relatively low BCF values in freshwater and marine algae (<1–7.6), whereas values were up to 7816 ww in rainbow trout (*Oncorhynchus mykiss*) and 5785–138 000 ww in the common mussel (*Mytilus edulis*). More recently, SCCAs were found in all components of the food chain in Lake Ontario. The BAF (L/kg lipid) for plankton was 5×10^4 while BAFs for fish ranged from 1×10^5 for alewife (*Alosa pseudoharengus*) to 1×10^7 for sculpin (*Cottus cognatus*) (Houde et al. 2008). MCCAs and liquid LCCAs have significant potential to bioaccumulate in aquatic food webs (GC 2008). Houde et al. (2008) found MCCAs in all components of the Lake Ontario food chain and BAFs (L/kg lipid) for fish ranged from 3.2×10^6 for lake trout (*Salvelinus namaycush*) to 2.5×10^7 for sculpin (*Cottus cognatus*). Field BAFs for liquid LCCAs are lacking and model data for nearly half of the $C_{18\text{-}20}$ congeners examined had BAF≥5000 whereas none of the $C_{>20}$ congeners examined had modelled BAF≥5000 (GC 2008).

Ambient Concentrations

SCCAs have been detected in Canadian Arctic sediments (1.6 to 257 ng/g dw) from remote northern lakes (Tomy et al. 1999; Stern and Evans 2003); sewage treatment plant effluents (59-448 ng/L) from southern Ontario (Muir et al. 2001); surface waters (0.041-0.606 ng/L), near harbour areas of Lake Ontario sediments (5.9 to 290 ng/g dw) and fish (4.6 to 34 ng/g ww) (Muir et al. 2001, 2002; Houde et al. 2008); and in marine mammals (95-785 ng/g ww) from the Arctic (110- 770 ng/g ww) and the St. Lawrence River (370–1360 ng/g ww) (Tomy et al. 2000).

Metcalfe-Smith et al. (1995) reported $C_{14–17}$ MCCA concentrations in effluent from the MCCAs/LCCAs manufacturing plant on the St. Lawrence River at Cornwall, Ontario, to be 12.7 µg/L. In water samples collected from various sites in Lake Ontario, MCCAs concentrations ranged from <0.0001 to 0.0008 ng/L (Houde et al. 2008). Total MCCAs in a sediment core from Lake St. Francis downstream of Cornwall, Ontario were reported at 0.75–1.2 µg/g dw (Muir et al. 2002). No MCCA measurements are available for Lake Ontario sediments. Concentrations of MCCAs in Lake Ontario fishes were: lake trout 24 ng/g ww; alewife 35 ng/g ww; slimy sculpin 108 ng/g ww; rainbow smelt 109 ng/g ww (Houde et al. 2008). No data on environmental concentrations in Canada exist for LCCAs.

Mode of Action

For aquatic organisms the mechanism of acute toxicity of SCCAs and MCCAs is suggested to be narcosis based on loss of startle response and skin darkening in various fish species (Fisk et al. 1999; Cooley et al. 2001). The mechanism of toxicity for LCCA is likely to be similar to MCCAs and it is suggested that none of the LCCAs would be expected to be directly toxic to fish via a waterborne exposure to concentrations at or below the water solubility (UK Environment 2009), though they could be taken up through the food. Cooley et al. 2001 suggested that toxicity was inversely related to carbon chain length, at least within the SCCA.

Table 2. Toxicity endpoints for aquatic life exposed to CAs considered in the derivation of the Federal Water Quality Guideline. The lowest endpoints for individual species selected for the SSD (Figure 1) are marked with an asterisk.

Species	Group	Endpoint	Concentration (µg/L)	Reference
SCCAs				
Mussel (*Mytilus edulis*)	●	84d MATC (growth)	4.6*	Thompson and Shillabeer (1983)
Water Flea (*Daphnia magna*)	●	21d MATC (mortality)	6.7*	Thompson and Madeley (1983a)
Mysid shrimp (*Mysidopsis bahia*)	●	28d NOEC (growth, dev., mort)	7.3*	Thompson and Madeley (1983b)
Japanese medaka (*Oryzias latipes*)	■	20d MATC (development)	23*	Fisk et al. (1999)
Rainbow trout (*Oncorhynchus mykiss*)	■	60d LOEC (growth)	40*	Madeley and Maddock (1983)
Algae (*Skeletonema costatum*)	△	4d EC_{50} (growth)	42.3*	Thompson and Madeley (1983c)
MCCAs				
Water Flea (*Daphnia magna*)	●	21d MATC (mortality)	13.4	Thompson et al. (1997a)
Algae (*Selenastrum capricornutum*)	△	3d NOEC (growth)	49*	Thompson et al. (1997b)
Bleak (*Alburnus alburnus*)	■	14d NOEC (mortality)	125*	Bengtsson et al. (1979)
Mussel (*Mytilus edulis*)	●	60d NOEC (mortality)	220	Madeley and Thompson (1983a)
Japanese medaka (*Oryzias latipes*)	■	20d NOEC (development)	1600	Fisk et al. (1999)
Rainbow trout (*Oncorhynchus mykiss*)	■	60d NOEC (growth, mort.)	4500	Madeley and Maddock (1983)
LCCAs				
Water Flea (*Daphnia magna*)	●	21d LOEC (reproduction, mort.)	68	Frank (1993)
Mussel (*Mytilus edulis*)	●	60d NOEC (mortality)	1330	Madeley and Thompson (1983b)
Rainbow trout (*Oncorhynchus mykiss*)	■	60d NOEC (mortality)	>4000	Madeley and Maddock (1983)

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

Federal Environmental Quality Guidelines Derivation

Federal Water Quality Guideline

Toxicity data to develop the FWQG for chlorinated alkanes were primarily obtained from the SARs (GC 1993a, 2008). Data were examined for quality and completeness. These data were further evaluated by reviewing the original literature and any additional data encountered were also assessed. Because the data for individual CAs groups were limited (Table 2), the lowest acceptable endpoint for individual species was selected either for SCCAs, MCCAs, or LCCAs to develop the FWQG. Acceptable endpoints range from no- or low-level to medium-level effects. The final dataset included toxicity measures for six species for SCCAs and two for MCCAs. No toxicity data could be selected for the LCCAs because the species for which the toxicological data were available were already captured for SCCAs or MCCAs (e.g., *Daphnia magna*) and/or had weaknesses in data because of the difficulty in preparing dissolved concentrations, especially when preparing "water-soluble" fractions (GC 1993a,b; UK Environment 2009). For example, exposure of mussels (*Mytilus edulis*) and rainbow trout (*Oncorhynchus mykiss*) to $C_{18–26}$ (with 43% and 70% chlorine) LCCAs for 60 days caused no mortalities at concentrations far above the water solubility of the compounds (Madeley and Thompson 1983a,b). Because the toxicity value for *Daphnia magna* for LCCAs is within the range of SCCAs and MCCAs toxicity, the FWQG developed using SCCAs and MCCAs toxicity data would be also applicable to LCCAs.

The aquatic toxicity data presented in Table 2 indicate a general trend of decreasing toxicity with increasing chain length of CAs. Invertebrates appear to be the most sensitive to CAs followed by fish and plants. Among invertebrates, the most sensitive species is mussel (*Mytilus edulis*), followed by water flea (*Daphnia magna*) and mysid shrimp (*Mysidopsis bahia*). Among fish, the Japanese medaka (*Oryzias latipes*) was the most sensitive species. Among plant/algal species, *Skeletonema costatum* was more sensitive than *Selenastrum capricornutum*. The available data also suggest that SCCAs are more hazardous than MCCAs and LCCAs (Table 2).

The Federal Water Quality Guidelines (FWQGs) developed herein identify benchmarks for aquatic ecosystems that are intended to protect all forms of aquatic life for indefinite exposure periods. They are applicable to both freshwater and marine systems because the dataset included both the freshwater and marine species. The acceptable data identified for developing the CAs guideline consist of three fish species, four invertebrate species, and two plant species. Although the persistence of CAs in water may be limited under field conditions by factors such as binding to suspended solids and volatility in water, aquatic organisms may experience long-term exposure. Aquatic organisms may be chronically exposed to CAs if they inhabit the waters receiving input from multiple sources or multiple applications.

FWQGs are preferably developed using CCME (2007) protocols. In the case of CAs, the combined toxicity dataset (discussed above) meet the CCME (2007) data requirements for a Type A guideline[1]. Each species for which appropriate toxicity data was available was ranked according to sensitivity, and its centralized position on the species sensitivity distribution (SSD) was determined. Several cumulative distribution functions (CDFs) were fitted to the data using regression methods and the best model was selected based on consideration of goodness-of-fit and model feasibility. The log normal model provided the best fit of the models tested and the 5^{th} percentile of the SSD is 2.4 µg/L (Figure 1), with lower and upper confidence limits of 1.1 and 5.3 µg/L, respectively.

[1] CCME Type A guidelines are derived using a species sensitivity distribution (SSD) approach when there are adequate data to satisfactorily fit a SSD curve. For further detail on the minimum data requirements for Type A guidelines see CCME (2007).

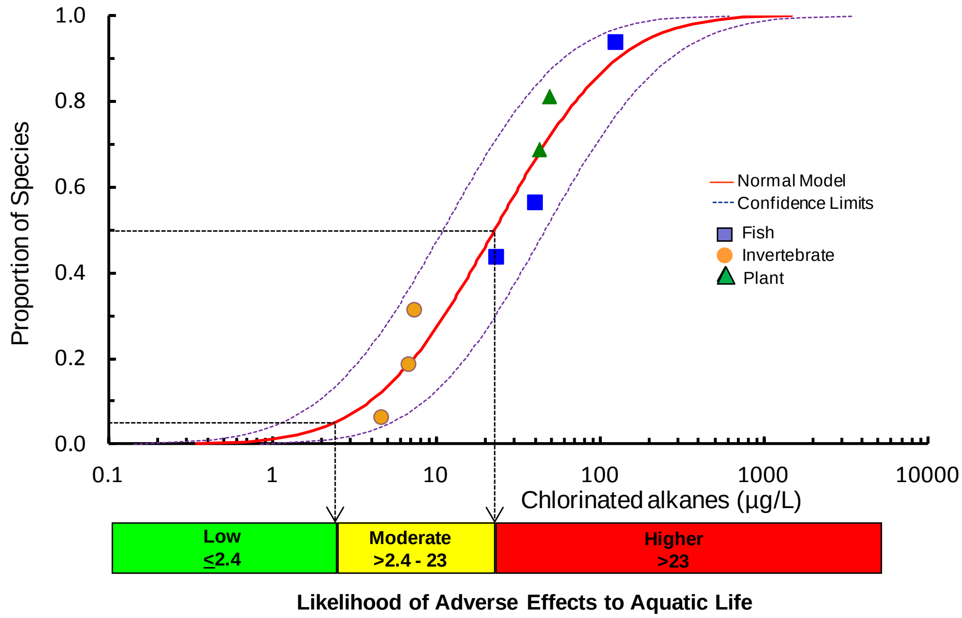

Figure 1. Species sensitivity distribution (SSD) for the chronic toxicity of chlorinated alkanes and associated effect levels for aquatic life.

The recommended FWQG is 2.4 µg/L and applies to SCCAs, MCCAs and LCCAs individually. The guideline 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 for use in risk management. At concentrations between >5th and 50th percentile of the SSD (>2.4-23 µg/L) there is a moderate likelihood of adverse effects to aquatic life. Concentrations greater than the 50th percentile (>23 µg/L) have a higher likelihood of causing adverse effects. Risk managers may find these additional concentration ranges useful in defining short-term or interim risk management objectives for a phased risk management plan. The moderate to higher concentration range may also be used in setting less protective interim targets for waters that are already highly degraded or where there are socio-economic considerations that preclude the ability to meet the federal water quality guideline.

Federal Fish Tissue Guideline

The Federal Fish Tissue Guidelines (FFTGs) are benchmarks for aquatic ecosystems that are intended to protect fish themselves from direct adverse effects (Table 1). FFTGs supplement water quality guidelines in that they provide a different metric to assess potential adverse effects. FFTGs apply to both freshwater and marine fish species, and specify the concentration of CAs in whole body fish tissue (wet weight - ww) not expected to result in adverse effects to the fish themselves. They may not be appropriate to evaluate the impacts of CAs found in unrepresented aquatic biota (amphibians, invertebrates or plants in this case).

There have been few studies that correlated tissue concentrations with adverse effects in fish. In medaka eggs and larvae exposed via the water, the NOEC and LOEC were 100 and 1000 µg/g whole body for a C_{10} SCCA, which were converted to 345 and 3448 µg/g lipid respectively assuming a lipid content of 2.9% of medaka (Elonen et al. 1998). Similarly for C_{12} NOEC and LOEC values were 245 and 2138 µg/g lipid based on narcosis-induced lethality (Fisk et al. 1999). Sublethal effects of the same CAs used by Fisk et al. (1999) were studied by Cooley et al. (2001) in rainbow trout exposed via the diet for 21or 85 d. Fish exposed to a single, low concentration for 85 d were considered no effect exposures. At the higher concentrations there were no effects on weight or liver somatic index, but fish showed signs typical of narcosis. Histologically there were effects at a geometric mean SCCA concentration of 1.35 µg/g whole fish or 27.1 µg/g lipid assuming a median value of 5% lipid (Arnot and Gobas 2006). Using an application factor of 10, results in a FFTG of 2.7 µg/g lipid.

For MCCPs, Fisk et al. (1999) using waterborne exposures found that peak concentrations of C_{14} in eggs and larvae of medaka were 110 and 84 µg/g whole body wet weight respectively, which we converted to 3800 and 2900 µg/g lipid "no effect" concentrations. As above, Cooley et al. (2001) found histological effects in livers of rainbow trout at much lower concentrations, that is, 0.378 µg/g whole body. Converting that to a lipid basis gave a critical value of 7.6 µg/g lipid. Dividing by a safety factor of 10 gives a guideline value of 0.76 µg/g lipid.

There were insufficient data to calculate fish tissue residue guidelines for LCCPs.

Federal Sediment Quality Guidelines

The Federal Sediment Quality Guidelines (FSeQG) developed for CAs (SCCAs and MCCAs) are intended to protect sediment dwelling animals as well as pelagic animals which bioaccumulate CAs from sediments (Table 1). FSeQGs apply to indefinite exposure periods to freshwater and marine sediments, and specify the concentration of CAs found in bulk sediment (dry weight) not expected to result in adverse effects. They may not be appropriate to evaluate the impacts of CAs in sediments to plants.

Only limited sediment toxicity data exist for MCCAs. No reliable sediment toxicity data exist for SCCAs and LCCAs. The data used for developing the sediment PNECs (referred as ENEVs in SAR) are used here (GC 2008), but the data were adjusted to 1% organic carbon instead of 2% organic carbon for SCCAs and LCCAs and 5% organic carbon for MCCAs in the SAR (Figure 2). An equilibrium partitioning approach (Di Toro et al. 1991) was used to calculate a chronic LOEC of 18 mg/kg dw for SCCAs (8.9 µg/L for *Daphnia* 21-d LOEC multiplied by the K_{oc} and 1% organic carbon – see GC 2008) and 1020 mg/kg dw for liquid $C_{18–20}$ LCCAs (same *Daphnia* endpoint) for sediment containing 1% organic carbon. Data acceptable for the development of a sediment quality guideline for MCCAs were limited to three species, *Hyalella azteca*, *Lumbriculus variegates* and *Chironomus riparius*. *Hyalella azteca* was the most sensitive species, with a LOEC of 54 mg/kg dw for sediment containing 1% organic carbon content.

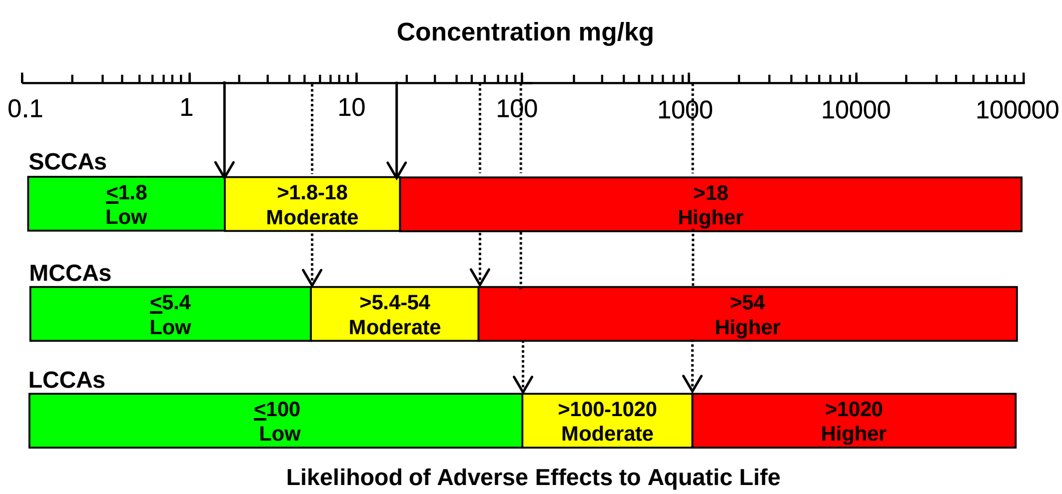

Figure 2. Relative likelihood of adverse effects of chlorinated alkanes to benthic organisms in aquatic sediments (mg/kg dry weight). The FSeQGs and LOECs for SCCAs, MCCAs and LCCAs are marked by arrows.

The FSeQG for SCCA, the chronic value (LOEC) of 18 mg/kg dw was divided by an application factor (AF) of 10 to yield a sediment quality guideline value of 1.8 mg/kg dw of sediment (Figure 2). An AF of 10 was chosen because of the paucity of data. The FSeQG for MCCAs was developed by dividing the LOEC value of 54 mg/kg dw by an AF of 10 to yield a sediment quality guideline value of 5.4 mg/kg dw of sediment (Figure 2). An AF of 10 was chosen because of the paucity of data. The FSeQG for liquid LCCAs

($C_{18–20}$) was derived by dividing the chronic LOEC of 1020 mg/kg dw by an AF of 10 to yield the sediment quality guideline value of 100 mg/kg dw of sediment (Figure 2). Similar to SCCAs and MCCAs, an AF of 10 was chosen because of the paucity of data. Because of the unavailability of toxicity data, PNEC could not be derived for the liquid $C_{>20}$ LCCAs (GC 2008). Adverse effects on benthic organisms are not expected to occur at levels equal to or less than the FSeQGs of 1.8, 5.4 and 100 mg/kg for SCCAs, MCCAs and LLCAs ($C_{18–20}$), respectively (Figure 2).

In addition to the FSeQGs, three concentration ranges were identified to represent low, moderate and higher relative risks of adverse effects to aquatic life to aid in the risk management of CAs (Figure 2). At concentrations equal to or less than the FSeQG, there is low likelihood of adverse effects to aquatic life. At concentrations greater than the FSeQG and the LOEC (18, 54 and 1020 mg/kg for SCCAs, MCCAs and LCCAs, respectively), there is a moderate likelihood of adverse effects to aquatic life. Concentrations that are greater than LOECs have a higher likelihood of causing adverse effects to aquatic life. Similar to water, risk managers may find these additional concentration ranges useful in risk management planning. Also, the moderate to higher concentration ranges may also be used in setting less protective interim targets for waters that are already highly degraded or where there are socio-economic considerations that preclude the ability to meet the FSeQG.

Federal Wildlife Dietary Guidelines

The Federal Wildlife Dietary Guidelines (FWiDGs) are intended to protect non-human mammalian consumers of aquatic biota. These are benchmark concentrations of substances in aquatic biota (whole body, wet-weight) that are consumed by terrestrial and semi-aquatic wildlife. The FWiDGs may not be appropriate to extrapolate the impacts of CAs to other terrestrial consumers (e.g., birds or reptiles).

The FWiDGs for CAs are all based on studies with rats that were fed contaminated diets for 90 days (see summary by Serrone et al. 1987). The CCME (1998) protocol for tissue residues was followed to the extent possible given the paucity of data. This procedure uses published tolerable daily intakes (TDI) or calculates it as the geometric mean of the no observed and the lowest observed adverse effect concentrations (NOAEL/LOAEL). Where only the LOAEL was available, the NOAEL was estimated (CCME 1998). The TDI is then converted to a dietary concentration by dividing by the food intake to body weight ratio. While several species-specific values may be calculated, in practice, the FWiDG is determined by the mink food intake. Details of the calculations are given in Table 3. There were no studies on birds that could be used for guideline derivation.

Table 3. Federal Wildlife Dietary Guidelines calculations for CA homologues.

Homologue	Endpoint	Test conc (mg/kg bw/d)	TDI (mg/kg bw/d)	Mink food intake:bw	Application Factor	FWiDG (mg/kg diet ww)
SCCAs	13-week LOAEL[a]	100[a]	42.2	0.24	10	18
MCCAs	13-week NOAEL/ LOAEL[b]	0.4/4.2[b]	1.3	0.24	10	0.54
$C_{18\text{-}20}$ liquid LCCAs	-	-	-	-	-	-
$C_{>20}$ liquid LCCAs	13 week LOAEL[c]	100[c]	42.2	0.24	10	18
$C_{>20}$ solid LCCAs	13 week NOAEL/ LOAEL[d]	900/3750[d]	1837	0.24	10	770

SCCAs = short chain chlorinated alkanes ($C_{10\text{-}13}$); MCCAs = medium chain chlorinated alkanes ($C_{14\text{-}17}$); LCCAs = long chain chlorinated alkanes ($C_{>18}$)
[a]IRDC 1984; [b]Poon et al. 1995; [c]Serrone et al. 1987, Bucher et al. 1987; [d]Serrone et al. 1987

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List of Acronyms and Abbreviations

AF - application factor
BAF - bioaccumulation factor

BCF - bioconcentration factor
BMF - biomagnification factor
CAs - chlorinated alkanes
CCME - Canadian Council of Ministers of Environment
CEPA - Canadian Environmental Protection Act
CDF - cumulative distribution function
CMP - Chemicals Management Plan
CTV - critical toxicity value
EC_{50} - effect concentration
ENEV - estimated no effect value
FEQG - Federal Environmental Quality Guideline
FSeQG - Federal Sediment Quality Guideline
FFTG - Federal Fish Tissue Guideline
FWiDG - Federal Wildlife Dietary Guideline
FWQG - Federal Water Quality Guideline
K_{OA} - octanol:air partition coefficient
K_{OC} - organic carbon sorption coefficient
K_{OW} - octanol:water partition coefficient
LCCAs - long chain chlorinated paraffins (18 or more carbon atoms)
LOAEL - lowest observable adverse effect level
LOEC - lowest-observed-effect concentration
MATC - maximum acceptable toxicant concentration and is equal to the geometric mean of the NOEL and LOEL for a test species
MCCAs - medium chain chlorinated paraffins (14-17 carbon atoms)
NOAEL – no observable adverse effect level
NOEC - no-observed-effect concentration
PNEC – predicted no effect concentration
PVC - polyvinyl chloride
SCCAs - short chain chlorinated paraffins (10-13 carbon atoms)
SSD - species sensitivity distribution
TDI - tolerable daily intake