Canadian Water Quality Guidelines for the Protection of Aquatic Life

DDAC

Didecyl dimethyl ammonium chloride (DDAC) ($C_{22}H_{48}NCl$), a quaternary ammonium compound (QAC) with strong cationic properties, has a CAS number of 7173-51-5 and molecular weight of 361.5. It is used in disinfectant, molluscicide, and antisapstain formulations produced as a water soluble salt in an aqueous solution at 80% a.i. DDAC has low vapour pressure (Solomon 1990). It is completely miscible with water and *n*-octanol; therefore, the octanol–water partition coefficient is not defined (Nixon 1998). Soil adsorption tests have indicated that DDAC has a high capacity for soil adsorption and is essentially immobile in soil. Reported log soil adsorption coefficient (K_{oc}) values range from 5.64 (sand) to 6.20 (silty clay loam) (ABC Laboratories Inc. 1989a). Production yields a product 80% DDAC (20% ethanol, water) termed a manufacturer's use product. The pH of "manufacturer's use" DDAC (i.e., Bardac 2280) at room temperature is 7.81. It is a colourless liquid free from visible foreign matter at 20°C with a density of 0.870 $g{\cdot}mL^{-1}$ and a flashpoint of 29.5°C (Wildlife International Ltd. 1997).

DDAC is registered in Canada for use as a molluscicide (full registration), in formulated disinfectants (full registration), in recirculating cooling towers (full registration), and as an antisapstain (temporary registration). Antisapstain formulations containing DDAC were used at 37 of 50 mills surveyed in British Columbia in 1996, represented largely by Kop-Coat NP-1 and F-2 (Environment Canada 1998a). On an active ingredient basis, 454 400 kg of DDAC was used by lumber mills for antisapstain purposes in 1996, decreasing from 581 561 kg used in 1993 (Environment Canada 1998a). DDAC is, as a result, one of the most heavily used pesticides in British Columbia (Environment Canada 1995).

The mode of action of DDAC has not been systematically studied in any aquatic organism and is not well understood. Because DDAC is a surfactant, a mode of action can be attributed to binding to the cell surface causing cell membrane disruption and protein denaturation, leading to cell death. The end result is tissue damage of those areas directly exposed to DDAC. This is most likely to occur at high concentrations. In contrast, however, Wood et al. (1996) found no external disruptions to fish gill lamellae using scanning electron microscopy. The slope of the acute dose–response curve of DDAC is very steep (Farrell et al. 1998), suggesting an all-or-none type of lethal effect.

When considering the environmental fate and persistence of DDAC, two key physicochemical properties are exposed: one is the lipophilic alkyl moiety, the other is the cationic moiety, which, because of its association with chloride, renders to the molecule its capacity to be hydrophilic.

DDAC has been shown to be highly adsorptive to sediments (log K_{oc} values range from 5.64 to 6.20) (ABC Laboratories 1989a) and suspended sediments in the water column. Although DDAC sorbs strongly and rapidly to sediments, clay materials, and other negatively charged surfaces, biodegradation does occur. Biotransformation is expected to be the main route of dissipation of DDAC in the environment (Agriculture Canada et al. 1989). Ruiz Cruz and Dobarganes Garcia (1979) demonstrated the degradation of QACs in unacclimated river water. From an initial QAC concentration of 5 $mg{\cdot}L^{-1}$, lag periods and half-lives ranged from <1 to several days. The half-life of the 12 carbon alkyl chain DDAC was reported as 2.1 d. As the rate of degradation decreases with increasing alkyl chain length (Boethling 1984), DDAC would be expected to degrade in similar fashion, if not more rapidly.

DDAC has been reported to be nonvolatile (Agriculture Canada et al. 1989; Toxicology/Regulatory Services 1997), stable to hydrolysis in the water column (ABC Laboratories 1989b), and stable to the effects of photolysis (ABC Laboratories 1989c).

DDAC is not expected to bioaccumulate significantly. In addition, a study examining the bioconcentration and

Table 1. Water quality guidelines for the protection of aquatic life for DDAC (Environment Canada 1998b).

Aquatic life	Guideline value ($\mu g{\cdot}L^{-1}$)
Freshwater	1.5*
Marine	NRG†

*Interim guideline.
†No recommended guideline.

elimination of DDAC and its residues by bluegill sunfish *(Lepomis macrochirus)* (Springborn Laboratories Inc. 1990a) reported that the mean steady state BCF for the 28-d exposure to DDAC was 38 for edible portions (muscle/skin), 140 for inedible portions (viscera/carcass), and 81 for whole body tissues.

As DDAC is not known to be naturally occurring, all DDAC in the environment is assumed to be from anthropogenic sources. Such sources could include spills and other unpermitted discharges, permitted discharges from commercial facilities using the chemical, and discharges from products treated with DDAC (Henderson 1992). Levels of DDAC in leachate from treated packages of lumber at a British Columbia wood-processing site were reported to be 73.2 and 65.8 mg·L^{-1} after the first two rainfall events, 6.0 mg·L^{-1} after the seventh rainfall event, and averaged 15.9 mg·L^{-1} over 15 rainfall events. The concentration of DDAC in the leachate continued to decrease, likely due to continued dilution and sorbing of DDAC to clays and silts on the ground surface, as it migrated across the yard before being discharged to the Fraser River at a concentration of 1.06 mg·L^{-1} (Mendoza and Krahn 1992). A study including ambient levels in the Fraser River demonstrated the high adsorption tendency of DDAC to sediments as levels fell from 449 µg·L^{-1} at the point of discharge to 119 µg·L^{-1} 1 m from discharge, to 11 µg·L^{-1} 5 m from discharge, and finally to <10 µg·L^{-1} (detection limit) 10 m from discharge (Szenasy 1998). This was the only report found to discuss ambient levels of DDAC in surface water.

Analysis of sediment samples from receiving waters immediately downstream from four lumber mills on the Fraser River, British Columbia, yielded concentrations of DDAC ranging from 0.57 to 1.26 µg·g^{-1} dw. The percent moisture for these samples ranged from 44 to 62% (Szenasy 1998).

Water Quality Guideline Derivation

The interim water quality guideline for DDAC for the protection of freshwater life was developed based on the CCCME protocol (CCME 1991). For more information, see the supporting document (Environment Canada 1998b).

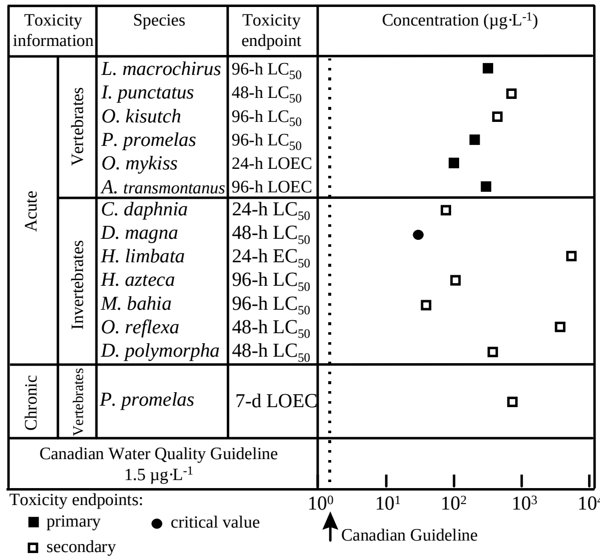

Figure 1. Select freshwater toxicity data for DDAC.

Freshwater Life

Toxicity data of DDAC to freshwater biota were available for fish, invertebrates, and two species of plants. The available data from 10 species of fish reported values ranging from a 24-h LOEL of 100 µg Bardac 2280 (80% a.i.)·L^{-1} for the swimming performance of rainbow trout *(Oncorhynchus mykiss)* (Wood et al. 1996) to a 96-h LC_{50} of 2.81 mg·L^{-1} for rainbow trout (Liu 1990). The only study found to examine chronic toxicity of DDAC involved fathead minnow larvae exposed for 7 d in a static renewal test. The LOEC and MATC were reported to be 0.75 and 0.53 mg Calgon H-130 (50% a.i.)·L^{-1}, respectively, with mortality and growth observations as the endpoints (Resource Analysts Inc. 1990).

DDAC toxicity data located for nine species of invertebrates ranged from a 48-h LC_{50} of 0.037 mg Bardac 2280·L^{-1} for *Daphnia magna* (Farrell et al. 1998) to a 48-h LC_{50} of 6.12 mg Calgon H-130·L^{-1} for the mussel *Obliquaria reflexa* (Waller et al. 1993).

A single study that examined the effects of DDAC exposure on the growth of green alga (*Chlorella* sp.) and duckweed *(Spirodella oligorhiza)* was found. Both species had reduced growth after a 3-d exposure to 10^{-5} molar (*M*) (~3.62 mg a.i.·L^{-1}) DDAC (Walker and Evans 1978).

The lowest concentration causing a toxic effect was a 48-h LC_{50} of 30 µg Bardac 2280·L^{-1} for *D. magna* (Farrell et al. 1998). This value was calculated using the raw data from Farrell et al. (1998) and a three-parameter logistic model ($\alpha < 0$) (Caux and Moore 1997). The guideline was derived by multiplying this 48-h LC_{50} by the safety factor of 0.05 (CCME 1991). The safety factor was used to account for differences in sensitivity to the substance associated with different species, test endpoints, test durations, and test conditions. This calculation results in an interim water quality guideline of 1.5 µg·L^{-1} for DDAC for the protection of freshwater life (Environment Canada 1998b).

Marine Life

Insufficient data were found to derive a water quality guideline for DDAC for the protection of marine life according to the protocol (CCME 1991).

Acute toxicity of DDAC to marine biota were available for fish and invertebrates. Springborn Laboratories Inc. (1994a) reported a 96-h LC_{50} of 0.940 mg Bardac 2280·L^{-1} for the sheepshead minnow *(Cyprinodon variegatus)*, and Farrell et al. 1998 reported a 96-h LC_{50} of 2.05 mg Bardac 2280·L^{-1} for the starry flounder *(Platichthys stellatus)*. The former also reported an 96-h EC_{50} of 0.13 mg Bardac 2280·L^{-1} for the Eastern oyster *(Crassostrea virginica)* (Springborn Laboratories Inc. 1994b) and a 96-h LC_{50} of 0.069 mg Bardac 2280·L^{-1} for *Mysidopsis bahia* (Springborn Laboratories Inc. 1990b). No information was located on the acute toxicity of DDAC to marine plants, or on the chronic toxicity of DDAC to any marine organisms.

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