Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health

ETHYLENE GLYCOL 1999

This fact sheet provides soil quality guidelines for ethylene glycol in Canada for the protection of environmental health (Table 1). A supporting scientific document is also available (Environment Canada 1996).

Background Information

Ethylene glycol ($C_2H_6O_2$; CAS 107-21-1) is an aliphatic alcohol characterized by two hydroxyl functional groups attached to methyl subunits in an aliphatic chain. Ethylene glycol is a clear, colourless, odourless, relatively nonvolatile, viscous liquid with a melting point of -13°C, a boiling point of 197.6°C, and a flash point of 111–115°C. It has a sweet taste and imparts a warming sensation to the tongue when swallowed. Ethylene glycol has a low vapour pressure of 6.7 Pa (0.05 mm Hg) at 20°C, a low Henry's law constant of 6×10^{-8} $atm \cdot m^{-3} \cdot mol^{-1}$, and a very low octanol–water coefficient ($\log K_{ow}$ -1.36). It is miscible in water and in solvents such as acetone, formaldehyde, glycerol, and acetic acid. It is sparingly soluble in ether and insoluble in benzene, chlorinated hydrocarbons, and oils. It is very hygroscopic and will absorb up to 200% its weight in water at 100% relative humidity. In 1991, total consumption of ethylene glycol in Canada was 135 kt, of which about 60% was used in the production of deicing fluids and antifreeze mixtures (Chinn 1993). An additional 11% was used in the production of polyethylene terephthalate (polyester). Minor uses are in the processing of oil and gas and in the production of solvents, explosives, cellulose film, and glycol esters (Chinn 1993; CPI Product Profiles 1994).

Table 1. Soil quality guidelines for ethylene glycol ($mg \cdot kg^{-1}$).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**960**[a]	**960**[a]	**960**[a]	**960**[a]
SQG_{HH}	NC[b]	NC[b]	NC[b]	NC[b]
Limiting pathway for SQG_{HH}	ND	ND	ND	ND
Provisional SQG_{HH}	NC[c]	NC[c]	NC[c]	NC[c]
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
SQG_E	NC[d]	NC[d]	NC[d]	NC[d]
Limiting pathway for SQG_E	ND	ND	ND	ND
Provisional SQG_E	960	960	960	960
Limiting pathway for provisional SQG_E	Aquatic life	Aquatic life	Aquatic life	Aquatic life
Interim soil quality criterion (CCME 1991)	No value	No value	No value	No value

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.

[a]Data are sufficient and adequate to calculate only a provisional SQG_E.

[b]There is no SQG_{HH} for this land use at this time.

[c]There is no provisional SQG_{HH} for this land use at this time.

[d]Data are insufficient/inadequate to calculate an SQG_E. However, data are sufficient and adequate to calculate a provisional SQG_E.

The guidelines in this fact sheet are for general guidance only. Site-specific conditions should be considered in the application of these values. The values may be applied differently in various jurisdictions. The reader should consult the appropriate jurisdiction before application of the values.

No information was found on levels of ethylene glycol in Canadian soils. Data on ethylene glycol levels in other environmental media are limited to areas near airports. Percy (1992) reported air concentrations of ethylene glycol of 3.2 and 4.1 $mg \cdot m^{-3}$ at an Ontario airport. In surface water, the highest reported ethylene glycol concentration (up to 13 200 $mg \cdot L^{-1}$) was measured in a drainage ditch carrying runoff from a Quebec airport in 1974. More recent measurements, however, suggest that contamination levels at that site have declined since 1974 as concentrations of ethylene glycol ranged from 4.5 to 552 $mg \cdot L^{-1}$ in 1987 (Transport Canada 1988). Other Canadian airports have reported similar concentrations of ethylene glycol ranging from <10 to 643 $mg \cdot L^{-1}$ (Transport Canada 1989a, 1989b, 1990). In groundwater samples collected at one Canadian airport in 1985 and 1986, the maximum recorded ethylene glycol concentration was 415 $mg \cdot L^{-1}$ (Transport Canada 1985, 1987).

Environmental Fate and Behaviour in Soil

The major processes that determine the mobility and distribution of ethylene glycol in the terrestrial environment are leaching, biodegradation, and photolysis.

The low vapour pressure and relatively low Henry's law constant of ethylene glycol suggest that volatilization is not an important fate process in most circumstances (Howard 1990; MacDonald et al. 1992; Nielsen et al 1993). Also, the low K_{ow} and high water solubility of ethylene glycol indicate a low potential for soil and sediment adsorption (Lokke 1984; Abdelghani et al. 1990; Howard 1990; MacDonald et al. 1992; Nielsen et al 1993).

Ethylene glycol is miscible in water and thus is subject to surface transport with surface water and storm water and has a high potential to leach into groundwater (Lokke 1984; Nielsen et al. 1993). Field studies by Transport Canada (1987) showed that a solution of 10% ethylene glycol moved through a silt sand at an average rate of 0.6 $m \cdot d^{-1}$. Of particular concern is the potential for oxygen depletion in water bodies receiving ethylene glycol-contaminated surface waters, storm water, or groundwater. The biodegradation of ethylene glycol can be sufficiently rapid that dissolved oxygen could be depleted in receiving waters to levels that may threaten oxygen-dependent aquatic biota.

Ethylene glycol is known to be susceptible to phototransformation, which is thought to be proportional to light intensity (Atkinson 1985; Cunningham et al. 1985; Freitag et al. 1985).

Biodegradation of ethylene glycol has been reported under aerobic and anaerobic conditions in soils, sediments, and sludge (Gaston and Stadtman 1963; Haines and Alexander 1975; Means and Anderson 1981; Willetts 1981; Dwyer and Tiedje 1983; Howard 1990). Under aerobic conditions, ethylene glycol is degraded by species such as *Pseudomonas* sp. and *Flavobacterium* sp. to glycolate and eventually to carbon dioxide (Haines and Alexander 1975; Willetts 1981). Under anaerobic conditions, it is degraded by anaerobic bacteria such as *Clostridium glycolicum* and converted to ethanoic acid and ethanol (Gaston and Stadtman 1963).

Behaviour and Effects in Biota

Soil Microbial Processes

Few data were found on the effects of ethylene glycol to microbes and microbial processes in soil, but there are several studies carried out in other media. Khoury et al. (1990) reported an average toxic endpoint, IC_{50} (50% reduction in optical density), of 114 300 $mg \cdot L^{-1}$ on heterotrophic soil microorganisms.

Daugherty (1980) reported that the *Pseudomonas aeruginosa* is capable of degrading ethylene glycol, in culture medium, up to 1000 $mg \cdot L^{-1}$, and concentrations >2000 $mg \cdot L^{-1}$ were found to be inhibitory. Stahl and Pessen (1953) reported the inhibitory effect for the same organism at 20 000 $mg \cdot L^{-1}$.

Kilroy and Gray (1992) reported 50% reduction of respiration at 202.36 $mL \cdot L^{-1}$ in a mixture of municipal sludge and synthetic sewage and at 154.79 and 196.65 $mL \cdot L^{-1}$ in factory sludge/synthetic sewage and factory sludge/factory feed, respectively. Klecka and Landi (1985) reported a 50% reduction in microbial respiration at >1000 $mg \cdot L^{-1}$ in incubated activated sludge.

Terrestrial Plants

In an attempt to establish phytotoxic levels of ethylene glycol in soil, Environment Canada conducted seedling emergence tests for both radishes *(Raphanus sativa)* and lettuce *(Lactuca sativa)*. The lowest concentrations at which adverse effect occurred were 5300 and 9000 $mg \cdot kg^{-1}$ soil, resulting in a 25% reduction in seedling emergence for radishes and lettuce, respectively (Environment Canada 1995). Unresolved problems associated with the recovery of ethylene glycol allow these results to be used for calculating provisional soil quality guidelines only.

Reynolds (1977) reported a 50% inhibition of germination of lettuce at 55 $mg \cdot L^{-1}$ in nutrient solution.

Terrestrial Invertebrates

The only available information on the toxic effects of ethylene glycol on terrestrial invertebrates is from Environment Canada. The lowest reported ethylene glycol concentration resulting in adverse effects in the earthworm *(Eisenia foetida)* is 20 000 $mg \cdot kg^{-1}$ soil. At this concentration the earthworm suffered 25% mortality. The same unresolved problems associated with the phytotoxicity tests were encountered, and the results are used for deriving provisional soil quality guidelines only (Environment Canada 1995).

Livestock and Wildlife

Ethylene glycol itself is not toxic, however, its intermediary oxidation products are active toxicants (Black 1983). Ethylene glycol is metabolized by alcohol and aldehyde dehydrogeneses in the liver, and the main metabolites are glycoaldehyde, glycolic acid, glyoxylic acid, and glycolate. Chou and Richardson (1978) observed a direct correlation between urinary glycolate levels and mortality. It is thought that glycolate is the primary toxic metabolite of ethylene glycol.

Symptoms of ethylene glycol toxicity may include weakness, depression, metabolic acidosis, coma, cardiopulmonary collapse, and death in mammals (Environment Canada 1996). In poultry, Riddell et al. (1967) reported drowsiness, ataxia, dyspnea, and torticollis followed by watery droppings, ruffled feathers, recumbency, and death.

Ethylene glycol imparts a sweet or semisweet taste to fluids such as antifreeze and may attract animals to consume them. Ethylene glycol poisoning is common among domestic animals and has been reported in cats, dogs, chickens, ducks, calves, and polar bears (Kersting and Nielsen 1965; Riddell et al. 1967; Black 1983; Amstrup et al. 1989).

Ethylene glycol is a slow-acting poison. Even after massive dose, an animal will be unaffected for 0.5–2 h after exposure (Lakshmipaty and Oehme 1975; Oehme 1983; Beasley 1985; Grauer and Thrall 1986). The toxicity of ethylene glycol varies among species. Cats were reported to be the most susceptible to poisoning (Osweiler et al. 1985). The reported lethal dose for cats is 1.5 $mL \cdot kg^{-1}$ (Black 1983), whereas for dogs it is 4.2–6.6 $mL \cdot kg^{-1}$ bw (Beasley and Buck 1980; Oehme 1983; Grauer and Thrall 1986). Osweiler et al. (1985) reported a lethal dose of 2–4 $mL \cdot kg^{-1}$ bw in cats, 4–5 $mL \cdot kg^{-1}$ bw in dogs, and 7–8 $mL \cdot kg^{-1}$ bw in poultry.

Riddell et al. (1967) reported an LD_{50} of 7.7 $mL \cdot kg^{-1}$ bw in 6-month-old chickens. Schwarzmaier (1941) also reported an LD_{50} at 7.5 $mL \cdot kg^{-1}$ bw in hens. Stowe et al. (1981) reported NOED and LOED values of 1.1 and 2.3 $mL \cdot kg^{-1}$ bw, respectively for the mallard duck. As the dosage was increased, blood and tissue concentrations of ethylene glycol increased and time to death decreased.

Ethylene glycol poisoning in cattle has been reported by Crowell et al. (1979). The toxic dose was reported at 2 $mL \cdot kg^{-1}$ bw, and the symptoms were increased respiration, staggering gait, paraparesis, depression, and, later, recumbency and death.

Ethylene glycol poisoning in polar bears has been reported by Amstrup et al. (1989). Soil, snow, and urine sampled under the dead animal contained high quantities of ethylene glycol (200 $mg \cdot kg^{-1}$ soil) and rhodamine B, a mixture commonly used to mark roads and runways during snow and ice periods. It was concluded that there was enough ethylene glycol in the body to cause the bear's death.

Guideline Derivation

Canadian soil quality guidelines are derived for different land uses following the process outlined in CCME (1996a) using different receptors and exposure scenarios for each land use (Table 1). Detailed derivations for ethylene glycol soil quality guidelines are provided in Environment Canada (1996).

Soil Quality Guidelines for Environmental Health

Environmental soil quality guidelines (SQG_Es) are based on soil contact using data from toxicity studies on plants and invertebrates. In the case of agricultural land use, soil and food ingestion toxicity data for mammalian and avian species are included. To provide a broader scope of protection, a nutrient and energy cycling check is calculated. For industrial land use, an off-site migration check is also calculated.

In the case of ethylene glycol, there are insufficient data to derive any of the environmental health guidelines or check values. However, there are sufficient data to derive a provisional SQG_E based on soil contact of plants and invertebrates (Table 2).

Table 2. Soil quality guidelines and check values for ethylene glycol (mg·kg^{-1}).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**960[a]**	**960[a]**	**960[a]**	**960[a]**
Human health guidelines/check values[b]				
SQG_{HH}	NC	NC	NC	NC
Soil ingestion guideline	NC	NC	NC	NC
Inhalation of indoor air check	NC	NC	NC	NC
Off-site migration check	—	—	—	NC
Groundwater check (drinking water)	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Provisional SQG_{HH}	NC[c]	NC[c]	NC[c]	NC[c]
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
Environmental health guidelines/check values				
SQG_E	NC[d]	NC[d]	NC[d]	NC[d]
Soil contact guideline	1100[a]	1100[a]	1800[a]	1800[a]
Soil and food ingestion guideline	NC[d]	—	—	—
Nutrient and energy cycling check	1700[a]	1700[a]	2000[a]	2000[a]
Off-site migration	—	—	—	NC[d]
Groundwater check (aquatic life)	960[e]	960[e]	960[e]	960[e]
Provisional SQG_E	960[e]	960[e]	960[e]	960[e]
Limiting pathway for provisional SQG_E	Aquatic life	Aquatic life	Aquatic life	Aquatic life
Interim soil quality criterion (CCME 1991)	No value	No value	No value	No value

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health. The dash indicates guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

[a]Data are sufficient and adequate to calculate only a provisional SQG_E.

[b]There are no human health guidelines/check values at this time.

[c]There is no provisional SQG_{HH} for this land use at this time.

[d]Data are insufficient/inadequate to calculate this value for this land use.

[e]Because of the known fate and behaviour of ethylene glycol in the environment, the groundwater check (aquatic life) value has been applied in the determination of the environmental soil quality guideline. This check should be applied to all sites regardless of site-specific characteristics.

The environmental groundwater check has been used to derive an ethylene glycol soil concentration that is protective of freshwater aquatic life associated with groundwater recharge to surface water. Because of the known fate and behaviour of ethylene glycol in the environment, this groundwater check value is applied in the determination of the environmental soil quality guideline. This check should be applied to all sites regardless of site-specific characteristics (Table 2).

Soil Quality Guidelines for Human Health

There are no human health guidelines or check values available at this time (Table 2).

Soil Quality Guidelines for Ethylene Glycol

The soil quality guidelines are the provisional SQG_Es.

CCME (1996b) provides guidance on potential modifications to the final recommended soil quality guideline when setting site-specific objectives.

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This fact sheet was originally published in the working document entitled "Recommended Canadian Soil Quality Guidelines" (Canadian Council of Ministers of the Environment, March 1997, Winnipeg). A revised and edited version is presented here.

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian soil quality guidelines for the protection of environmental and human health: Ethylene glycol (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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