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

TRICHLOROETHYLENE 2006

This fact sheet provides Canadian soil quality guidelines for trichloroethylene (TCE) for the protection of environmental and human health (Table 1). A supporting scientific document is also available (CCME 2005).

Canadian Soil Quality Guidelines for the protection of environmental health for trichloroethylene were originally developed in 1997 (CCME 1997). This fact sheet updates the TCE ecological assessment using information available to November 2004. In addition, calculations of TCE soil quality guidelines protective of human health have been added and reflect the recent Health Canada deliberations on human toxicological thresholds for TCE. Guidelines in this fact sheet were calculated using the most recent (2003) draft of the CCME protocol for the derivation of Canadian Soil Quality Guidelines.

Background Information

Trichloroethylene (C_2HCl_3; CAS 79-01-6) is a clear, colourless, non-viscous liquid with a characteristic, slightly sweet odour and is a powerful solvent for a large number of natural and synthetic substances (McNeill 1979; Schaumburg 1990). It has a molecular weight of 131.40 and is a volatile liquid at room temperature (boiling point 86.7 °C) with a higher density (1.4649 $g \cdot mL^{-1}$ [20 °C]) and lower surface tension (0.029 $N \cdot m^{-1}$) than water.

Under conditions of normal use, TCE is considered nonflammable and is moderately stable, but requires the addition of stabilizers (up to 2% v/v) in commercial grades. In the absence of stabilizers, it is slowly oxidized by air or photolyzed by light.

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

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline (Coarse and Fine Soils)[a]	**0.01**	**0.01**	**0.01**	**0.01**
SQG_{HH} (Coarse and Fine Soils)	0.01	0.01	0.01	0.01
Limiting pathway for SQG_{HH}	SQG_{DW}[d]	SQG_{DW}[d]	SQG_{DW}[d]	SQG_{DW}[d]
SQG_E				
Coarse Soils[b]	0.05	0.05	0.05	0.05
Fine Soils[c]	0.16	0.16	0.16	0.16
Limiting pathway for SQG_E	SQG_{AL}[e]	SQG_{AL}[e]	SQG_{AL}[e]	SQG_{AL}[e]
Interim soil quality criterion (CCME 1991)	0.1	5	50	50

Notes: SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.

[a] This guideline value may be less than the common limit of detection for trichloroethylene in some jurisdictions. Contact jurisdiction for guidance.
[b] Coarse Soils: Soils which contain greater than 50% by mass particles greater than 75 μm mean diameter ($D_{50} > 75$ μm).
[c] Fine Soils: Soils which contain less than 50% by mass particles greater than 75 μm mean diameter ($D_{50} < 75$ μm).
[d] SQG_{DW}: Soil quality guideline for human ingestion of groundwater as drinking water.
[e] SQG_{AL}: Soil quality guideline for the protection of groundwater for aquatic life.

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.

TCE is encountered as a soil and particularly groundwater contaminant in Canada, owing to its extensive use as a degreasing solvent and subsequent release to the environment. TCE has a high vapour pressure (8.0–9.9 kPa at 20–25 °C) and volatility, as well as a relatively high Henry's law coefficient (dimensionless Henry's constant = 0.36 at 25°C). TCE vapour is heavier than air. TCE is moderately soluble in water (solubility = 1,100–1,400 $\mu g \cdot L^{-1}$). It has a moderately low octanol–water partition coefficient (log K_{OW} = 2.4).

As a result of these properties, TCE may be present in significant concentrations in both the dissolved and vapour phases. Human exposure to TCE may occur through the ingestion of contaminated drinking water, and through occupational or residential exposures, especially based on inhalation and/or dermal absorption.

The major use of TCE in Canada is vapour degreasing and cold cleaning of fabricated metal parts, which is closely associated with the automotive and metals industries (ATSDR 1991; CIS 2002). Health Canada (2004) estimated that about 90% of total domestic use of TCE is used in metal degreasing applications. Minor uses include the production of adhesives and co-polymers, household and industrial dry cleaning, textile manufacturing, cleaning of electronic components, petroleum industry processes involving refining catalysts, paint removers, coatings, vinyl resins, and laboratory reagent/solvent applications. In the vast majority of these uses, TCE is not destroyed, but dispersed into the environment. The total domestic demand is nearly exclusively used for replacing emission losses and for distribution in end products. Until 1985, TCE was produced in Canada at two plants, both in Shawinigan, Quebec; all TCE in Canada is now imported (CIS 2002).

There are only limited data available regarding releases of TCE to the Canadian environment, however, since nearly all of the nationwide usage of TCE is dispersive, the potential release of TCE to the Canadian environment can be estimated as nearly equal to the Canadian net domestic consumption (for example, 2.4 kt in 2001) (CIS 2002). It is estimated from National Pollutant Release Inventory data that TCE releases in Canada in 2002 through emissions, spills or effluent discharges totaled around 0.75 kt.

Mean levels of TCE in air from 11 Canadian cities ranged from 0.07 to 0.98 $\mu g \cdot m^{-3}$, with a maximum concentration of 19.98 $\mu g \cdot m^{-3}$ (Dann and Wang 1992). TCE levels near 12 Canadian homes were reported to range from non-detectable to 2 $\mu g \cdot m^{-3}$ (OMOE 1988). At a rural monitoring site in Canada, mean TCE concentrations of 0.19 $\mu g \cdot m^{-3}$ were measured, with a maximum concentration of 0.46 $\mu g \cdot m^{-3}$ (Dann and Wang 1992). Average TCE levels of 0.04–0.05 $\mu g \cdot m^{-3}$ were detected in Arctic air (Khalil and Rasmussen 1983; Hov et al. 1984). TCE levels in air above hazardous waste and landfill sites, as well as near industrial point sources, can be much higher than those in ambient rural or urban air. For example, levels as high as 1,460 $\mu g \cdot m^{-3}$ have been recorded 0.5 km from a TCE production and storage site in the United States (U.S. EPA 1977).

Concentrations of TCE in indoor air in approximately 750 homes from across Canada were up to 165 $\mu g \cdot m^{-3}$, with an overall mean value of 1.4 $\mu g \cdot m^{-3}$ (Otson *et al*. 1992). In two homes tested, it was reported that showering with well water containing extremely high levels of TCE (40 $mg \cdot L^{-1}$) increased levels of TCE in bathroom air from <0.5 to 68 $mg \cdot m^{-3}$ in less than 30 minutes (Health Canada 2004).

Reported levels of TCE in surface waters of Canada, as reported in various studies, ranged from below 0.001 to 90 $\mu g \cdot L^{-1}$ (Kaiser and Valdmanis 1979; Kaiser et al. 1983; Kaiser and Comba 1983; Strachan and Edwards 1984; COARGLWQ 1986; Kaiser and Comba 1986a,b; Lum and Kaiser 1986). A survey in 2000 of 68 First Nations community water supplies, including both surface waters and groundwater, found no detectable concentrations of TCE at a detection limit of 0.5 $\mu g \cdot L^{-1}$ (Yuen and Zimmer 2001). In Ontario and Quebec, several monitoring studies have detected TCE in leachates from various landfills at levels ranging from 0.29 to 67 $\mu g \cdot L^{-1}$ (Barker 1987; Lesage et al. 1989).

The highest levels of TCE in groundwater are associated with leaching from specific sources, such as landfill waste disposal sites. The highest concentrations of TCE in water in Canada have been recorded in groundwater near waste disposal sites and can reach as high as 21,900 $\mu g \cdot L^{-1}$ (Golder Associates Ltd. 1989). High levels of TCE have also been detected in groundwater at and surrounding a contaminated industrial site at levels of 13,200 and 490 $\mu g \cdot L^{-1}$, respectively (UMA 1992a). In 2000, concentrations of TCE exceeding the guideline for Canadian drinking water quality (which was 50 $\mu g \cdot L^{-1}$ at that time) were detected in private wells in Beckwith Township, Ontario; the source of the TCE was an abandoned landfill site. In 1997, high levels of TCE were detected in an aquifer under the Valcartier military base in Quebec, and three years later in private wells in Shannon, a town close to the Valcartier base. A study conducted in 2001 found that concentrations of TCE near the source at Valcartier were as high as 13,500 $\mu g \cdot L^{-1}$, while maximum concentrations at the boundary between the base and town of Shannon were from 260 to 340 $\mu g \cdot L^{-1}$ (Lefebvre et al. 2003). In 1995, a survey of TCE occurrence across Canada was conducted for 481 municipal/communal and 215 private/domestic groundwater supplies, It was found that 93% of sites had non-detectable levels (detection limits varied from 0.01 to 10 $\mu g \cdot L^{-1}$), 3.6% had a maximum concentration of <1 $\mu g \cdot L^{-1}$, 1.4% had a maximum of 1-10 $\mu g \cdot L^{-1}$, 0.43% had a maximum of 10-100 $\mu g \cdot L^{-1}$ and 1.3% had a maximum of >100 $\mu g \cdot L^{-1}$ (Raven Beck Environmental Ltd. 1995; Health Canada 2005).

Few data exist on the levels of TCE in Canadian sediments. Following a 1985 spill, TCE levels in bottom sediments of the St. Clair River ranged from below the detection limit (0.01 $\mu g \cdot kg^{-1}$) to as high as 1.1×10^5 $\mu g \cdot kg^{-1}$ (COARLGLWQ 1986).

Soil samples collected throughout Ontario from undisturbed old urban and rural parklands not impacted by local point sources of pollution were analyzed for a variety of chemicals to determine average background concentrations known as "Ontario Typical Range" (OTR_{98}) (OMEE 1993), corresponding to the 98th percentile concentration. For TCE, the OTR_{98} values are 0.63 $ng \cdot g^{-1}$ (6.3×10^{-4} $mg \cdot kg^{-1}$) and 0.028 $ng \cdot g^{-1}$ (2.8×10^{-5} $mg \cdot kg^{-1}$) for old urban parkland and rural parkland respectively.

Soil at a former chemical warehouse and distribution facility in Vancouver was found to have TCE concentrations ranging from trace to 4.5 $mg \cdot kg^{-1}$ (Golder Associates Ltd. 1989). Discharge from floor drains at a propellant plant in Manitoba to a regional roadside ditch resulted in soil concentrations of TCE ranging from 140 to 1000 $mg \cdot kg^{-1}$. Other reported localized soil contamination occurred beside solvent burn-off areas, where TCE concentrations ranged from 0.1 to 890 $mg \cdot kg^{-1}$ (UMA 1992b).

Environmental Fate and Behaviour in Soil

Much of the TCE released to soil surfaces will volatilize to the atmosphere. Where TCE penetrates the soil surface before evaporation, however, significant accumulation of the chemical in saturated and unsaturated zones may result (Schwille 1988). In most cases, TCE will enter the soil as an undiluted solution from spills or leaking storage tanks, as leachate from landfill sites, or by wet deposition in rain and snow from the atmosphere (Muraoka and Hirata 1988). It is highly mobile in the subsurface environment and is susceptible to leaching (Schwille 1988).

Concentrated or continuous discharges of TCE to surface and groundwaters can lead to the formation of free product accumulations (non-aqueous phase liquids: NAPLs) due to the density and relatively low water solubility of TCE (Schwille 1988). TCE has a higher specific gravity than groundwater or surface water and free-phase accumulations of TCE tend to sink down until retarded by the underlying substratum. Releases of TCE at concentrations approaching or in excess of solubility limits, therefore, can result in the presence of a dense non-aqueous phase liquid (DNAPL). The half-life of TCE in soil as determined by the level two fugacity model is around 1,700 h (Mackay et al. 1993).

Transport processes in the soil include gaseous and liquid diffusion, gaseous and liquid dispersion as pure liquid or as solute in water, and advection throughout the head spaces within porous soils (Peterson et al. 1988; Cho and Jaffé 1990). The major routes of transport within the soil occur via the vapour phase or in the liquid phase via vertical migration until an impenetrable layer is encountered (Peterson et al. 1988; Schwille 1988; Smith et al. 1990). Pools of TCE may be retarded by saturated zones, but the limited solubility of TCE will allow some direct transport of pure TCE droplets associated with the water phase of aquifers.

The ability of soils to retain TCE is governed by partitioning to organic matter or sorption onto mineral surfaces. TCE partitioning to soil organic matter will be the dominant mechanism of soil retention even at soil organic carbon contents as low as 0.1% (Stauffer and MacIntyre 1986; Ong and Lion 1991). Partitioning to organic matter within soils is a function of the hydrophobicity of TCE. Partitioning processes are influenced by moisture content, soil composition, type and amount of organic matter, and to a slight degree pH (Stauffer and MacIntyre 1986; Grathwhol 1990). Water tends to suppress TCE adsorption by competitively sorbing to clay surfaces (Rao et al. 1989) providing a polarized shield to TCE. TCE increasingly partitions to soil with increasing soil organic matter content (Garbarini and Lion 1986; Seip et al. 1986; Stauffer and MacIntyre 1986).

In groundwater, biodegradation may be the most important transformation process for TCE, although it does not appear to occur rapidly. Various aerobic and anaerobic biodegradation studies in the field and laboratory found TCE to be resistant or only slowly biodegraded with half-lives of several months to years (Roberts et al. 1982; Rott et al. 1982; Wilson et al. 1983a; 1983b; 1986; Wakeham et al. 1983). Other studies noted more rapid biodegradation, depending on the local conditions, induction, and artificial nutrient enrichment with half-lives on the order of a few months (Tabak et al. 1981; Parsons et al. 1984; Wilson and Wilson 1985; Barrio-Lage et al. 1988). These results indicate that TCE in groundwater can undergo biodegradation, but at removal rates much slower than would occur where volatilization is possible.

The major biodegradation products of TCE in groundwater are dichloroethylene, chloroethane, and vinyl chloride (Smith and Dragun 1984; Vogel and McCarty 1985; Baek and Jaffe 1989).

There is little evidence to suggest substantial bioaccumulation of TCE in living tissues. Both the moderate *n*-octanol/water partition coefficient of TCE and various field studies from different trophic levels indicate that bioaccumulation of TCE is a minor process (Pearson and McConnell 1975; Dickson and Riley 1976; Kawasaki 1980; Barrows et al. 1980). Bioaccumulation factors measured ranged from <3 for muscle tissue of marine and

freshwater birds to approximately 100 for fish livers (Pearson and McConnell 1975).

According to ATSDR (1997), TCE has been detected in small amounts in fruits and vegetables, suggesting a potential for limited phytoaccumulation. Laboratory studies with carrot and radish plants and radioactively labeled TCE (Schroll et al. 1994) lead to calculations of bioconcentration factors (BCFs) in the range of 4.4 to 63.9. As noted by the authors, however, these may not have represented true soil-plant BCFs, since the experiment indicated that uptake occurred mainly through the foliage as opposed to the roots in these plants, with subsequent translocation throughout the plant tissues.

Behaviour and Effects in Biota

TCE has been declared "toxic" according to the Canadian Environmental Protection Act. It was found to enter the Canadian environment in significant quantities, cause adverse effects in plants due to high atmospheric concentrations, and have significant potential for contamination of groundwater and groundwater recharged surface water (Government of Canada 1993).

Microbial Processes

Effects of chronic exposure to TCE on microbial communities may include decreased microbial culture vitality, lowered ability to utilize substrate, and inhibited enzyme activity. Marinucci and Chervu (1985) reported that in mixed cultures, complete inhibition of microbial activity occurred at concentrations of 5,000 $mg \cdot kg^{-1}$ in soil and 1 x 10^6 $\mu g \cdot L^{-1}$ in water. Reductions in soil microbial biomass, measured as ATP content, were reported as acute effects occurring at 10,000 $\mu g \cdot L^{-1}$ (Kanazawa and Filip 1986). Fliermans et al. (1988) suggested that in contaminated environments, the biological tolerance of TCE generally appears to be in the range of 200,000 – 300,000 $\mu g \cdot L^{-1}$. Inamori et al. (1989), reported a 50% reduction in the soil microbial consumption of dissolved oxygen at 330,000 $\mu g \cdot L^{-1}$. Very tolerant organisms, like *Rhodococcus erythropolis,* can survive and partially degrade TCE at concentrations of up to 1000 $mg \cdot L^{-1}$ (Ewers et al. 1990).

Terrestrial Plants

Several previous studies of TCE effects on plants in spiked soil experiments (Environment Canada 1995; Pestemer and Ausburg 1989; Kordel et al. 1984; Ballhorn et al. 1984) did not adequately account for the rapid losses from soil of TCE during preparation of test soils and during the exposure period, as a result of the high volatilization rate. Thus, plant effects data relevant to TCE exposures via soil or groundwater are very sparse.

TCE may exert phytotoxic effects as an airborne contaminant. Native Canadian fir trees (*Abies alba*), non-native tree species Norway spruce (*Picea abies*) and European beech (*Fagus silvatica*), and other trees growing in regions with low SO_2 and NO_X concentrations have exhibited increasing incidence of chlorosis, necrosis, and premature needle and leaf loss over the last two decades in the Northern Hemisphere, especially Germany, Finland, and North America (Frank 1989; 1991). This tree damage has been attributed to exposure to chlorinated ethenes, namely TCE and tetrachloroethylene, rather than classic air pollutants such as acid precipitation, NO_X, SO_2, or O_3 (Frank 1989; Figge 1990; Frank et al. 1991; Frank et al. 1992a; 1992b). TCE and tetrachloroethylene are converted by photochemical reaction to highly reactive intermediates (radicals) which are believed to cause the damage (Frank 1989). The ambient TCE concentrations in damaged forest areas range from below the detection limit (0.1 $\mu g \cdot m^{-3}$) to 0.7 $\mu g \cdot m^{-3}$. However, it was shown that air concentrations can undergo rapid and extreme fluctuations, depending on the local meteorological conditions (Ohta et al. 1977; Frank et al. 1991).

Terrestrial Invertebrates

The survival of the earthworm *Eisenia foetida (=andrei)* exposed to TCE was reported by Environment Canada (1995). Applied nominal TCE concentrations ranged from 0 to 7,321 $mg \cdot kg^{-1}$ and the measured concentrations ranged from 0 to 440 $mg \cdot kg^{-1}$, indicating significant volatile losses during the exposure period. The measured concentrations were assumed to be a better estimate of exposure concentrations than the nominal values. Values for the NOEC, LC_{25}, LC_{50} and LOEC, based on measured concentrations, were 60, 79, 106 and 159 $mg \cdot kg^{-1}$, respectively.[1]

Livestock and Wildlife

TCE may be taken up by wildlife by three main routes: dermal absorption from contaminated air and/or soil; oral ingestion of contaminated soils; and inhalation of contaminated air. Inhalation is expected to be a minor route of exposure for wildlife; however, subsurface areas

[1] At the LOEC in this study, 100% mortality of earthworms was observed. Therefore, the LC_{25} and LC_{50} were estimated by interpolating between the NOEC and LOEC.

contaminated by high concentrations of TCE (e.g., in the case of spills or industrial discharges) may act as a localized source of high inhalation and dermal exposure for certain wildlife, especially burrowing mammals, reptiles, and amphibians. Similarly, certain burrowing animals and grazing ungulates may ingest contaminated soil during daily activities, especially during foraging. There are no available direct soil contact exposure data for vertebrates.

No information on the toxicity of TCE to avian or mammalian wildlife was found. However, in a 2-year study in which rats and mice were orally exposed to 500 and 1000 $mg \cdot kg^{-1}$ bw per day, respectively, the survival of male rats and mice was significantly reduced, and toxic nephrosis was found in both rats and mice (NTP 1982, 1986). A subchronic NOEL of 793 $mg \cdot kg^{-1}$ bw per day was reported in a 6-month study in which mice were exposed to drinking water containing TCE (ATSDR 1989).

Humans

The mammalian oral toxicology of TCE has been recently reviewed by Health Canada (2004), who identified an oral tolerable daily intake and cancer unit risk for TCE in support of the revised guideline for Canadian drinking water quality for TCE.

TCE is rapidly and extensively absorbed by all routes of environmental exposure—ingestion, inhalation, and skin contact (U.S. EPA 2001). Significant inter- and intra-species variability in TCE absorption following all routes of exposure has been well documented (Health Canada 2004). Once absorbed, TCE is distributed via the circulatory system throughout the body, where it can accumulate in fat and other tissues. Studies in humans have found TCE or its metabolites in most major organs and tissues. Primary sites of distribution include the lungs, kidneys, liver, and central nervous system (Health Canada 2004). Many of the resulting metabolites of TCE in humans (e.g., trichloroacetic acid, dichloroacetic acid, chloral hydrate, and trichloroethanol, among others) are thought to be responsible for much of the toxic effect of TCE (ATSDR 1997).

Both cancer and non-cancer endpoints are significant in the toxicological evaluation of TCE. Health Canada (2004) classifies TCE as Group II (probably carcinogenic to humans). This classification has been confirmed by the International Agency for Research on Cancer (IARC 1995), who list TCE as Group 2A (probably carcinogenic to humans).

The ability of TCE to cause neurotoxic effects is well established. In general, TCE produces a "solvent narcosis" that may be related to effects on membrane fluidity and may include anesthetic effects. TCE was formerly used as a general anesthetic and induces this effect at about 2,000 ppm (ATSDR 1997).

Health Canada (2004) calculated a tolerable daily intake (TDI) for oral exposure for non-cancer effects of 0.00146 $mg \cdot kg^{-1}$ bw per day. The critical study (Dawson et al. 1993) on which this TDI was based was a developmental study in which female rats were exposed to TCE in their drinking water before and/or during pregnancy. This study yielded a LOAEL of 0.18 $mg \cdot kg^{-1}$ bw per day, based on an increased incidence of fetal heart defects in the young of dams exposed to TCE at this level before and during pregnancy. The Health Canada (2004) TDI is higher than the oral reference dose (RfD) for non-cancer effects calculated by the U.S. EPA (2001) of 0.0002 $mg \cdot kg^{-1}$ bw per day; however, it is based on a more sensitive toxicological endpoint. The RfD calculated by the U.S. EPA was based on a dose of 1 $mg \cdot kg^{-1}$ bw per day (at which adverse liver effects were observed in two species after subchronic dosing) divided by a composite uncertainty factor of 5000. This RfD has since been withdrawn by the U.S. EPA.

Health Canada (2004) focuses on developing a Guideline for Canadian Drinking Water Quality for TCE, and did not consider inhalation studies in detail or calculate an inhalation tolerable concentration (TC). The inhalation TC used in this derivation was 40 $\mu g \cdot m^{-3}$, based on the RfC of the same value in U.S. EPA (2001), although the U.S. EPA RfC has since been withdrawn. The RfC was based on a consideration of non-cancer effects on the central nervous system, kidney, liver, and endocrine system in inhalation studies. A subchronic LOAEL of 38 $mg \cdot m^{-3}$ for central nervous system effects in two occupational studies (also supported by central nervous system effects in rats and liver effects in mice) was selected. This concentration was divided by a composite uncertainty factor of 1000 to obtain the RfC of 40 $\mu g \cdot m^{-3}$ (U.S. EPA 2001). Health Canada intends to review the inhalation toxicity of TCE in 2005/06.

Health Canada (2004) reviewed the available TCE cancer studies and selected kidney tumours as the endpoint on which to base their cancer risk assessment. National toxicology program studies (NTP 1988; 1990) were used to calculate unit risks for tubular cell adenomas and adenocarcinomas of the kidneys in four strains of rats following oral exposure to TCE for 103 weeks. A study by Maltoni et al. (1986), in which rats were exposed to TCE by inhalation for 104 weeks, was used to calculate unit risks for renal tubular adenocarcinomas in rats. Using the pooled unit risks for kidney tumours in the male rats from the cancer potency assessment, an amortized unit risk was

calculated by Health Canada (2004) and converted to a human equivalence value as 8.11 x 10^{-4} (mg·kg^{-1} bw per day)$^{-1}$. For this derivation, a risk-specific dose was calculated, for an excess cancer Risk Level of 10^{-6}, to be 0.00123 mg·kg^{-1} bw per day.

For cancer endpoints and inhalation exposures, Health Canada (1996) has published an inhalation TC_{05} for TCE of 82 mg·m^{-3}, based on their assessment of TCE as a Group II carcinogen (probably carcinogenic to humans). A TC_{05} is the concentration of a chemical expected to cause a 5% incidence of cancer. The TC_{05} may be extrapolated to a risk-specific concentration (RsC) evaluated at an excess cancer risk of 10^{-6} by dividing by 50,000 to give an RsC of 0.00164 mg·m^{-3}. Health Canada intends to review the inhalation toxicity of TCE in 2005/06.

Guideline Derivation

Canadian soil quality guidelines are derived for different land uses. The 2005 TCE guidelines have been developed according to the protocol described by the CCME (CCME 1996; reprinted in 1999, and subsequently revised in 2003 with acceptance of the latest revisions anticipated in 2005).

Soil Quality Guidelines for Environmental Health

The environmental soil quality guidelines (SQG_E) for TCE are derived using the available toxicological data to determine the threshold level of effects for key ecological receptors. Exposure of plants or soil invertebrates from direct soil contact is the primary derivation procedure for environmental guidelines for residential/parkland, commercial and industrial land uses. Another procedure, exposure from contaminated soil and food ingestion, may be considered for certain land uses if there is adequate data. For agricultural land use, if both derivation procedures are used, the lowest-value result is considered the environmental soil quality guideline.

No new data have been produced since 1999 on the toxicity of TCE to plants or soil invertebrates, based on exposures in soil. The data are insufficient to calculate a guideline using a weight-of-evidence approach. Because the available data marginally meet requirements for guidelines derivation using more simple approaches, a provisional SQG_{SC} was calculated using LOEC data produced by Environment Canada (1995) for lettuce and radish seedling emergence and for earthworm mortality (Table 2).

A soil quality guideline based on wildlife or livestock ingestion (SQG_I) was not calculated for TCE, in light of (i) the expected limited tendency of TCE to persist in surface soils or be taken up into plants, (ii) the degree of uncertainty about soil-plant BAFs, and (iii) the minimum data requirements not being met for designation of a wildlife daily threshold effects dose. In addition to this, TCE release sites are expected to occur primarily in commercial and industrial settings. While there is some potential for soil contamination in agricultural settings, the primary mechanism would likely be off-site migration from an adjacent industrial site, or landfill. In such cases, the off-site migration of TCE would best be examined by a more focused site-specific risk assessment, followed by the appropriate risk management actions.

The environmental groundwater check has been used to derive a TCE soil concentration that is intended to be protective of freshwater aquatic life associated with groundwater recharge to surface water. This groundwater check value was applied in the determination of the environmental soil quality guideline (SQG_E: Table 2). The freshwater life groundwater check value was calculated for both coarse and fine soils, and is the same for all land uses.

The overarching concern is off-site migration to an adjacent water body that could support aquatic life in the absence of the contamination. The on-site land-use designation, therefore, is less important than the actual site hydrogeology, potential for groundwater fluxes to surface water bodies, and the distance of any ecologically important surface water bodies from the TCE contaminated soil.

Soil Quality Guidelines for Human Health

TCE can cause both cancer and non-cancer effects. Guidelines were calculated separately for cancer and non-cancer effects, and the lower of the guidelines calculated was retained for each exposure pathway (Table 2). All equations and parameter values were from CCME (2003) unless otherwise noted.

For estimated exposures, background soil concentrations of TCE were assumed to be negligible. While TCE has certainly been detected in soil in the Canadian environment, its presence in soil is likely limited to local areas where this chemical has been used or released.

For inhalation exposures, the Government of Canada (1993) considers 0.0014 mg·m^{-3} to be representative of typical concentrations of TCE in indoor air in Canada, based on the mean value from an unpublished study of 750 homes from 10 provinces across Canada. This value was used in the calculation of the soil quality guideline based on inhalation (SQG_I).

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

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline [a] **(**Coarse and Fine Soils)	**0.01**	**0.01**	**0.01**	**0.01**
Human health guidelines/check values				
SQG_{HH} (Coarse and fine soils)	0.01	0.01	0.01	0.01
Direct contact	28	28	100	1,700
Inhalation of indoor air				
Coarse soils[b]	0.036 (0.058)[d]	0.036 (0.058)[d]	0.11	0.11
Fine soils[c]	0.37 (0.55)[d]	0.37 (0.55)[d]	0.92	0.92
Protection of potable water				
Coarse and fine soils	0.01	0.01	0.01	0.01
Produce, meat and dairy products check	0.028	0.14	—	—
Off-site migration check	—	—	—	NC[e]
Environmental health guidelines/check values				
SQG_E				
Coarse soils[b]	0.05	0.05	0.05	0.05
Fine soils[c]	0.16	0.16	0.16	0.16
Soil contact	3[f]	3[f]	50[f]	50[f]
Soil and food ingestion	NC[g]	—	—	—
Protection of freshwater life				
Coarse soils[b]	0.05	0.05	0.05	0.05
Fine soils[c]	0.16	0.16	0.16	0.16
Nutrient and energy cycling check	NC	NC	NC	NC
Off-site migration check	—	—	—	NC[e]
Interim soil quality criterion (CCME 1991)	0.1	5	50	50

Notes: NC = not calculated; 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] This guideline value may be less than the common limit of detection for trichloroethylene in some jurisdictions. Contact jurisdiction for guidance.

[b] Coarse Soils: Soils which contain greater than 50% by mass particles greater than 75 μm mean diameter ($D_{50} > 75$ μm).

[c] Fine Soils: Soils which contain less than 50% by mass particles greater than 75 μm mean diameter ($D_{50} < 75$ μm).

[d] First value is for slab-on-grade construction; value in parentheses is for construction with a basement.

[e] Calculation of this value is not required for volatile compounds.

[f] Provisional guideline.

[g] Data are insufficient/inadequate to calculate the soil and food ingestion guideline for this land use.

The estimated daily intakes of TCE for Canadian toddlers and adults used to calculate the soil quality guidelines in this report are 0.53 and 0.41 $\mu g \cdot kg^{-1}$ bw per day, for toddlers and adults, respectively. These values are based on the upper end of the ranges provided in Government of Canada (1993).

The soil allocation factor (SF) is the relative proportion which it is allowable for soil to constitute in the total exposure from various environmental pathways (air, soil, food, water, consumer products). By default, SF is set to 0.2, based on the assumption that a given chemical may be present in all five of the above-noted environmental media. CCME (2003) allows SF to be increased in cases where the chemical in question is unlikely to be in all the five media. Since TCE can be present in all the five media (air, soil, food, water, consumer products), the SF was set at a value of 0.2.

Values for the absorption factors for gut, lung, and skin can reflect less than complete adsorption of an applied exposure concentration or mass. However, a value other than 1.0 (100%) is only required if the corresponding exposure limit was based on toxicological data derived from an absorbed, rather than administered dose. The oral and inhalation exposure limits used in this document were based on administered dose (Health Canada 2004, and U.S. EPA 2001), and accordingly the absorption factors for these routes was set at 1.0. For dermal absorption, Poet et al. (2000) found that a maximum of 4.25% was absorbed from water-borne TCE under a patch after 2 hours exposure (a patch reduces evaporation). For soil, the maximum absorbed was 0.8%. Health Canada (2003) suggest a dermal absorption factor for TCE of 10%. In this document, the Health Canada (2003) guidance was followed, and the dermal absorption factor was set at 0.1.

Soil Quality Guidelines for TCE

According to the formal CCME protocol (CCME 1996), both environmental (SQG_E) and human health (SQG_{HH}) soil quality guidelines are developed for four land uses: agricultural, residential/parkland, commercial and industrial. The lowest value generated by the two approaches for each of the four land uses is recommended by the CCME as the Canadian Soil Quality Guideline.

Revised SQG_E for TCE based on direct soil contact and protection of soil invertebrates and plants are similar to values provisionally proposed under the 1999 revision to the TCE SQG. The SQG_{SC} values are 3 $mg \cdot kg^{-1}$ for agricultural and residential/parkland land uses and 50 $mg \cdot kg^{-1}$ for commercial and industrial settings. Freshwater life protective check values are much lower than this (0.05 and 0.16 $mg \cdot kg^{-1}$ in coarse and fine soils, respectively), and protection goals are expected to be far more stringent at TCE-contaminated sites where there is a potential for groundwater-mediated transport of TCE to adjacent water bodies with aquatic life.

For humans, the SQG_{HH} associated with direct soil ingestion was calculated to be 16, 59 and 400 $mg \cdot kg^{-1}$ for exposures in an agricultural or residential/parkland, commercial, or industrial setting, respectively. The acceptable soil concentrations for TCE for indirect exposure pathways are estimated to be several orders of magnitude lower than this. The most stringent of the indirect pathways is the protection of potable groundwater, with a guideline value of 0.01 $mg \cdot kg^{-1}$ for both soil types and all four land uses.

The environmental soil quality guidelines (SQG_E) that have been derived for TCE for all of the four land uses, based on potential for groundwater mediated transfer to adjacent water bodies that contain aquatic life are 0.05 $mg \cdot kg^{-1}$ in coarse textured soils and 0.016 $mg \cdot kg^{-1}$ in fine-textured soils.

The human health soil quality guideline (SQG_{HH}) that has been derived is 0.01 $mg \cdot kg^{-1}$ for both soils types and all four land uses.

The Canadian Soil Quality Guideline for trichloroethylene for the protection of environmental and human health is: 0.01 $mg \cdot kg^{-1}$ for both soils types and all four land uses.

It is noted that vinyl chloride is a potential degradation product of TCE, and may be more toxic (and a more potent carcinogen) than TCE. Accordingly, it is imperative that an assessment of vinyl chloride concentrations be made whenever TCE is present in the environment.

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