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

TOLUENE 2004

This fact sheet provides Canadian soil quality guidelines for toluene for the protection of environmental and human health (Table 1). A scientific supporting document is also available (Environment Canada 2004).

Background Information

Toluene ($C_6H_5CH_3$; CAS 108-88-3) is a clear, colourless liquid at room temperature with a sweet, pungent odour (NIOSH 1973). It is a monocyclic aromatic compound with one hydrogen on the benzene ring substituted by one methyl group. Toluene is a volatile liquid with relatively high vapour pressure (28.4 mm Hg at 25°C) and Henry's law constant (5.94×10^{-3} atm·m^{-3}·mol^{-1}) that is highly flammable and explosive. The solubility of toluene in freshwater is relatively low (347–707 mg·L^{-1} at 25°C), but is high enough to be of environmental concern. Toluene has a low octanol–water partition coefficient (log K_{ow} 2.69 at 25°C) (Mackay et al. 1992), indicating a low fat solubility and consequently low bioaccumulation potential (Environment Canada 2004).

Toluene, ethylbenzene, and the three xylene isomers (*o*-, *m*-, and *p*-xylene) fall into the broad category of volatile organic compounds that are monoaromatic hydrocarbons composed of an alkyl-substituted benzene ring. These compounds, collectively referred to as TEX, are often studied together, with the addition of benzene, because they are all present in gasoline and make up more than 60% of the water soluble fraction (Barbaro et al. 1992).

TEX are products or by-products of petroleum and coal refining. Toluene and xylene are produced as an aromatic mixture with benzene, primarily from catalytic reformate in refineries and secondarily as by-products of olefin manufacture during the cracking of hydrocarbons.

Table 1. Soil quality guidelines for toluene (mg·kg^{-1}).*

	Land use and soil texture							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Surface								
Guideline[a]	**0.37**	**0.08**	**0.37**	**0.08**	**0.37**	**0.08**	**0.37**	**0.08**
SQG_{HH}	0.37	0.08	0.37	0.08	0.37	0.08	0.37	0.08
SQG_E	75	110	75	110	250	330	250	330
Subsoil								
Guideline[a]	**0.37**	**0.08**	**0.37**	**0.08**	**0.37**	**0.08**	**0.37**	**0.08**
SQG_{HH}	0.37	0.08	0.37	0.08	0.37	0.08	0.37	0.08
SQG_E	150	220	150	220	500	660	500	660

Notes: SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.
*Free-phase formation, a circumstance deemed unacceptable by many jurisdictions, occurs when a substance exceeds its solubility limit in soil water. The concentration at which this occurs is dependent on a number of factors, including soil texture, porosity, and aeration porosity. Under the assumptions used for this guideline, at concentrations greater than 660 mg·kg^{-1} in coarse soil, or 680 mg·kg^{-1} in fine soil, formation of free-phase toluene will likely occur. Contact jurisdiction for guidance.
[a]Data are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated *de novo* guideline for this land use.

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. Use of some values listed in Table 1 may not be permitted at the generic level in some jurisdictions. For example, use of subsoil values may result in land use restrictions. The reader should consult the appropriate jurisdiction before application of the values.

Ethylbenzene is primarily produced by the alkylation of benzene with ethylene.

TEX are widely used as solvents in paints, lacquers, adhesives, inks, and cleaning and degreasing agents and in the production of dyes, perfumes, plastics, pharmaceuticals, and pesticides. TEX also make up a significant fraction of crude petroleum. The typical fractions of toluene in the gasolines used in Ontario are 6.7% in regular unleaded and 11.3% in premium unleaded (OMEE 1993b).

The introduction of TEX into the atmosphere is due largely to incomplete combustion of petroleum fuels from motor vehicles and volatilization of TEX-based solvents and thinners. Other natural sources include volcanic gases, forest fires, and vegetation (Isidorov et al. 1990).

TEX are released to soil and water mainly from leaking of underground petroleum storage tanks and landfill sites, accidents and spills during transportation, pesticide applications, and discharges of industrial and municipal wastes (Johnson et al. 1989; Lesage et al. 1990, 1991; DGAIS 1992).

Concentrations of TEX in ambient air vary widely depending on the source and the sampling season. Toluene concentrations ranging from 1.1 $\mu g \cdot m^{-3}$ in rural areas (Dann et al. 1989) to 2600 $\mu g \cdot m^{-3}$ near gas stations in summer (PACE 1987, 1989) have been reported.

In water, the reported toluene concentrations vary from 0.1 $\mu g \cdot L^{-1}$ (NAQUADAT 1992) to 0.5 $\mu g \cdot L^{-1}$ in the Great Lakes (Otson 1987). Lesage et al. (1990) reported 3900 $\mu g \cdot L^{-1}$ of toluene in a shallow aquifer near a chemical waste disposal site at Elmira, Ontario.

Data on concentrations of toluene in soils and sediments are scarce for the Canadian environment. The Ontario Ministry of Environment and Energy has reported that the 98th percentiles of toluene concentrations in rural and old urban parkland soils not impacted by a local point source of pollution are 1.3 and 0.92 $\mu g \cdot kg^{-1}$, respectively (OMEE 1993a).

Environmental Fate and Behaviour in Soil

The major processes that determine the behaviour of TEX in the terrestrial environment are volatilization, sorption, biodegradation, and leaching. TEX do not have hydrolyzable groups and therefore hydrolysis is not an important transformation pathway. Likewise, TEX are not degraded directly by photolysis (Howard 1990; Mackay et al. 1992). In the atmosphere, however, TEX are degraded with a half-life of 3 h to 1 d by reacting with photochemically produced hydroxyl radicals.

Volatilization is a dominant process determining the fate of TEX in the terrestrial environment (Parker and Jenkins 1986; Jin and O'Connor 1990; Anderson et al. 1991). Volatilization depends on temperature, humidity, sorption, and biodegradation processes in soils (Aurelius and Brown 1987; Ashworth 1988). The relatively high vapour pressures and Henry's law constants ($>10^{-3}$ $atm \cdot m^{-3} \cdot mol^{-1}$) of TEX make them subject to rapid volatilization from soils with half-lives ranging from 2.2 to 28 d (Howard 1990; Anderson et al. 1991).

Adsorption reduces the mobility of TEX in soils and affects their biotransformation rate. Soil organic matter, especially humic acids, strongly sorb TEX (El-Dib et al. 1978; Schwarzenbach and Westall 1981; Jury et al. 1987; Jin and O'Connor 1990). TEX are also adsorbed on clay minerals such as bentonite, illite, and kaolinite. Adsorption in soil increases with increasing TEX concentrations, with decreasing pH, and with decreasing moisture content (El-Dib et al. 1978; Chiou et al. 1981; English and Loehr 1991; Rutherford and Chiou 1992). Sorption is low in light textured soils with low organic matter (Garbarini and Lion 1986; English and Loehr 1991).

A variety of soil microorganisms are able to utilize TEX as a source of carbon, and degrade them to CO_2 and water. *Pseudomonas* species are the main degrading bacteria in soils, but other species such as *Arthrobacter* have also been reported to degrade TEX (Utkin et al. 1992). Degradation half-lives usually range from 5 to 10 d and are typically <20 d (Grbić-Galić and Vogel 1987; Chiang et al. 1989; Evans et al. 1991a, 1991b; Haag et al. 1991; Mackay et al. 1992). Degradation may occur in aerobic or anaerobic conditions. In aerobic conditions, the oxygen supply in soil is the major controlling factor (Barker et al. 1989; Chiang et al. 1989; Allen 1991). The availability of nutrients, especially nitrogen, also affects the degradation rate. This rate is higher in upper soil horizons and in unsaturated zones due to greater oxygen supply (Kampbell et al. 1987; Miller et al. 1990; Haag et al. 1991; Edwards et al. 1992). Anaerobic degradation is much slower and may be increased by adding nitrates and sulphates to the soil (Evans et al. 1991a, 1991b; Hutchins 1991; Beller et al. 1992; Edwards et al. 1992).

TEX are moderately soluble in water and may move with percolating waters, either in solution or sorbed to dissolved organic matter. In organic soils, TEX leaching is highest in low organic matter and light texture situations, whereas in mineral soils, it depends on the type of clay and the soil moisture content. Sorption and biodegradation processes reduce TEX mobility in soils.

Bioconcentration

Herman et al. (1991) examined the relationship between K_{ow}, bioconcentration, and toxicity of TEX in algae *(Selenastrum capricornutum)*. A strong positive linear relationship was reported between bioconcentration and K_{ow} ($r^2 = 0.98$) and between bioconcentration and toxicity (EC_{50} for growth reduction) ($r^2 = 0.99$). The sorption rate of these aromatic hydrocarbons by algae was initially rapid and then relatively constant. The 12-h BCF for toluene, expressed as logarithms to the base 10, was 1.99. The 8-d EC_{50} was 9.4 mg·L^{-1} for toluene (Herman et al. 1991).

Although TEX may accumulate in algae (Howard 1990), the relatively low log K_{ow} (< 4.0) of TEX indicates that the bioconcentration potential is generally low (WHO 1985; Nielsen and Howe 1991).

Behaviour and Effects in Biota

Soil Microbial Processes

Anderson et al. (1991) reported that 100 mg·kg^{-1} soil dw of toluene was not toxic to soil microorganisms. Walton et al. (1989) observed depressed soil microbial activity, as measured by CO_2 production, at 1000 mg toluene·kg^{-1} soil dw. However, the effect disappeared 6 d after application, suggesting low potential for long-term impacts.

Vonk et al. (1986) measured short-term oxygen consumption and nitrification in two soils (loam and humic sand) treated with toluene. The NOEC values for respiration and nitrification were 300–1000 and <20 mg·kg^{-1} soil ww, respectively, and did not differ with the soil type. Slooff and Blokzijl (1988) reported that the NOEC for toluene on soil microbial respiration and ammonification ranged from 100 to 1300 mg·kg^{-1}, while for nitrification, the NOEC was <26 mg·kg^{-1}.

Terrestrial Plants

Toluene can enter the plant through the stomata and cuticle and thus damage the plasma membrane. Plant chlorosis and growth inhibition were induced at levels >6 mg·L^{-1} of air, 500 mg·L^{-1} of aqueous medium, and 1000 mg·kg^{1} soil ww (Slooff and Blokzijl 1988).

Currier (1951) exposed tomato, carrot and barley seedlings to 12 mg·L^{-1} of toluene for 30–120 min at 25°C. Inhibition of root formation was found to be 0–75, 50–100, and 0–25% for tomatoes, carrots, and barley, respectively. Hung et al. (1992) reported erratic responses in seed mortality, germination, and seedling vigour when seeds of corn were soaked in toluene for up to 8 h.

In an attempt to establish phytotoxic levels of toluene in soil, Environment Canada conducted seedling emergence tests for both radishes *(Raphanus sativa)* and lettuce *(Lactuca sativa)* in 1995. The lowest concentrations at which adverse effects occurred were 7 and 9 mg toluene·kg^{-1} soil, resulting in a 25% reduction in seedling emergence for radishes and lettuce, respectively. Although these results were used for deriving provisional soil quality guidelines in 1997, the data were suspect due to problems associated with the recovery of toluene from soil and the volatility of the compound (Environment Canada 1995).

Using advanced techniques for determining the toxicity of highly volatile compounds, new plant toxicity tests were conducted by ESG International in 2002. Tests conducted with early northern wheatgrass (*Agropyron dasystachyum*) and alfalfa (*Medicago sativa*) examined the effects of toluene on shoot and root length and dry and wet biomass after 14 days of exposure in both coarse and fine soils. In coarse soils, the most sensitive endpoint for alfalfa was reduction of shoot dry mass, with an IC_{25} value of 234 mg·kg^{-1}, and for northern wheatgrass the most sensitive endpoint was an IC_{25} of 55 mg·kg^{-1} for reduction of root dry mass (ESG 2002). The results for fine soils reported by ESG (2002) were recalculated by Komex (2002) to take into account volatile losses that occur between spiking the sample and introducing the plants 2 hours later. (Similar calculations had already been made by ESG for the data from the coarse soils.) Therefore, the most sensitive estimated effect concentrations in fine soils for alfalfa and northern wheatgrass were an IC_{25} of 120 mg·kg^{-1} for reduction of shoot dry mass, and an IC_{25} of 112 mg·kg^{-1} for reduction of root wet mass, respectively (Komex 2002).

Terrestrial Invertebrates

The lowest reported toluene concentration resulting in adverse effects to soil invertebrates comes from Environment Canada (1995). The earthworm *(Eisenia foetida)* suffered 25% mortality at 44 mg toluene·kg^{-1} soil. Although this study was used for deriving provisional soil quality guidelines in 1997, the same problems associated with the phytotoxicity tests were encountered (Environment Canada 1995).

Toluene caused 100% mortality at a concentration of 2000 mg·kg^{-1} bw per day and a reduced growth rate at <50 mg·kg^{-1} bw per day in 2 to 6-week exposures of *E. foetida* (Hartenstein 1982). Neuhauser et al. (1985) exposed *E. foetida* to toluene on filter paper and reported 48-h LC_{50} values of 75 μg·cm^{-2}. Slooff and Blokzijl (1988) reported a NOEC value of 15–50 mg toluene·kg^{-1} soil dw for *E. foetida*.

Vonk et al. (1986) exposed *E. foetida* to toluene in artificial soil. The 14-d and 28-d LC_{50}s for mortality were reported as 100–180 mg·kg^{-1} soil ww. The 28-d NOEC for mortality was also reported in the same range. The 28-d NOEC for the worms' appearance and for cocoon production were reported at 10–32 and 32–100 mg toluene·kg^{-1} soil, respectively. The change in appearance was believed to be related to the ability of toluene to dissolve fat and damage cell membranes.

Studies commissioned by the CCME in 2001, and using advanced techniques for dealing with volatile compounds, examined the toxicity of toluene to the collembolan (*Onychiurus folsomi*) and the earthworm (*Eisenia andrei*). The LC_{25} for collembolans was 521 mg·kg^{-1} in coarse soil (ESG 2002) and 406 mg·kg^{-1} in fine soil (Komex 2002). A 14-day LC_{25} could not be calculated for earthworms in either coarse or fine soils. In coarse soils, the NOEC and LOEC for adverse effects in earthworms were 80 and 172 mg·kg^{-1}, respectively (ESG 2002). In fine soils, the NOEC and LOEC for adverse effects in earthworms were 172 and 368 mg·kg^{-1}, respectively (Komex 2002).

Livestock and Wildlife

Studies specifically on the toxicological effects of toluene to livestock and wildlife are currently lacking. Studies on experimental animals are covered in the next section.

Human and Experimental Animal Health Effects

The uptake of TEX in animals may occur via many routes, including oral, inhalation, subcutaneous, and dermal (percutaneous) absorption. Skowronski et al. (1989) found percutaneous absorption of toluene to be a major route of exposure in male rats. For the general population, the most significant route of exposure is inhalation from air, particularly from indoor air, with estimated intakes ranging from 10.7 to 16.7 µg·kg^{-1} bw per day. (Health Canada 1996a). Cigarette smoke is by far the greatest source of exposure to toluene for smokers, the total daily intake being up to about 60 µg·kg^{-1} bw per day for adults. Individuals living near hazardous waste sites or contaminated sites where gasoline and oil spills have occurred may be exposed to elevated concentrations of toluene. Toluene is rapidly and efficiently absorbed through the lungs and more slowly and less efficiently through the gastrointestinal tract (Health Canada 1996a). Toluene is distributed to the highly vascularized, lipid-rich tissues, such as the brain, kidney, and liver, but accumulates principally in adipose tissue (Sato 1988). The metabolization of toluene produces benzoic acid, which is subsequently conjugated with glycine to form hippuric acid and excreted in the urine (Ogata et al. 1970). The cytochrome P_{450} mixed function oxidase has been inhibited in the lungs of rats by toluene (Pyykkö et al. 1987).

In most studies on humans, adverse effects of toluene on various neurological function have not been observed following exposure to 375 mg·m^{-3} or less for single periods of 20 min to 3.5 h or repeated exposures of 3–7 h for periods up to 3 d (Health Canada 1996a). Decrease in neurological function, increase in neurological symptoms, and irritation of the respiratory tract following exposure of 16 volunteers to 375 mg·m^{-3} 6 h per day for 4 d have been reported (Andersen et al. 1983). These effects are reversible on cessation of exposure. Adverse effects on visual vigilance have also been reported (Dick et al. 1984).

The acute toxicity of toluene to rats is relatively low. The oral LD_{50} has been reported to be 2.6–7.5 g·kg^{-1} bw (Government of Canada 1992). In a 14-week study in mice, Huff (1990) reported the value of 375 mg·m^{-3} as the lowest concentration of toluene having an effect on male and female mice when administered by inhalation (7.5 and 12% decreases in weight, respectively). Results of studies on chronic toxicity and carcinogenicity of toluene are not consistent (Health Canada 1996a). Some results indicated histopathological effects of the olfactory epithelium or decreased body and brain weights. Toluene is not considered mutagenic in mammalian or microbial systems (Government of Canada 1992). Results of in vitro and in vivo studies indicated that toluene is not genotoxic (Health Canada 1996a). Toluene does not appear to be teratogenic in mice, rats, or rabbits, based on the limited data (Health Canada 1996a). Fetotoxic effects due to continuous inhalation exposure of toluene at 133–2000 ppm (7500 mg·m^{-3}) have been reported (Donald et al. 1991). Neurotoxic effects of toluene have resulted only following exposure to levels greater than those reported here.

Available epidemiological data are inadequate to assess the carcinogenicity and clastogenicity of toluene in humans. Toluene was not found to be carcinogenic following inhalation in rats and mice in a well-conducted bioassay (Huff 1990) and in rats in a less sensitive bioassay (CIIT 1980). The weight of evidence indicates that toluene is not genotoxic in mammalian or microbial systems. Toluene has therefore been classified in Group IV-C, probably not carcinogenic to man (Government of Canada 1992), according to the classification scheme developed for use in the derivation of the guidelines for drinking water quality (Health and Welfare Canada 1989). The oral tolerable daily intake (TDI) was determined as 0.22 mg·kg^{-1} bw per day (Health Canada 1996b). This TDI is based on a study by Huff (1990) that reported a NOEL of 312 mg·kg^{-1} bw per day for increases in relative liver and kidney weight of male rats exposed for 13 weeks by gavage. The tolerable concentration (TC) by inhalation was determined as 3.8 mg·m^{-3} (Health

Canada 1996b). This is based on a clinical study by Andersen et al. (1983) that reported an increase in neurological symptoms and irritation of the respiratory tract in human volunteers exposed to 375 mg·m^{-3} for 6 hours per day over four days. No adverse effects were observed in the volunteers at 150 mg·m^{-3}.

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 assumed for each land use (Table 1). Various modifications to the 1996 protocol that were used in the Canada-wide Standard for Petroleum Hydrocarbons in Soil (CCME 2000) were also applied in the development of these guidelines, including the derivation of guidelines for different soil textures (coarse and fine) and depths (surface soil and subsoil). As defined in the Canada-wide Standard for Petroleum Hydrocarbons, fine-grained soils are those which contain greater than 50% by mass particles less than 75 µm mean diameter (D_{50} < 75 µm). Coarse-grained soils are those which contain greater than 50% by mass particles greater than 75 µm mean diameter (D_{50} > 75 µm). Surface soil refers to the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for terrestrial plant growth, and can extend as deep as 1.5 m. Subsoil is defined as the unconsolidated regolith material above the water table not subject to soil forming processes; this nominally includes vadose zone materials below 1.5 m depth. Detailed derivations of soil quality guidelines for toluene are provided in Environment Canada (2004).

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, 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 where data permit. For industrial land use, an off-site migration check is also calculated where appropriate.

In the case of toluene, there are sufficient data to derive a guideline value for soil contact with plants and invertebrates (Table 2). A nutrient and energy cycling check value was not calculated due to a lack of data. The available dataset was also not sufficient to meet the requirements of the CCME (1996) protocol for calculating the soil and food ingestion guideline; however, the process used to determine tolerable daily intakes for humans was adapted to calculate daily threshold doses for livestock. As bioconcentration of toluene into livestock fodder is not expected to be significant, a guideline was calculated only for the livestock soil ingestion (and not food ingestion) pathway.

Check values for groundwater have been calculated to determine toluene soil concentrations that will be protective of freshwater aquatic life and livestock associated with groundwater discharge to surface water. These groundwater check values are not applied in the determination of the SQG_Es, but should be applied on a site-specific basis (Table 2). An off-site migration check was not calculated for toluene with the rationale that, given the volatility and biodegradability of toluene, it is unlikely that significant amounts would remain after wind or water transport of soil.

Soil Quality Guidelines for Human Health

Human health soil quality guidelines (SQG_{HH}s) for threshold contaminants are usually derived using a TDI (Health Canada) for the most sensitive receptor designated for a land use. Ingestion and dermal contact guidelines were calculated for all surface soils, but these two pathways were considered not applicable in subsoils, unless the ground is disturbed. Indoor vapour inhalation check values were calculated for both surface soils and subsoils. A groundwater check value was calculated to determine toluene soil concentrations that will be protective of drinking water.

The SQG_{HH} is the lowest of the various human health guidelines and check values, and in the case of toluene, the SQG_{HH} for all land uses and soil types is based on the groundwater (drinking water) check (Table 2).

Soil Quality Guidelines for Toluene

The soil quality guidelines are intended to be protective of both environmental and human health and are taken as the lower of the SQG_{HH} and the SQG_E. Where sufficient and adequate data exist for both, the interim soil quality criteria (CCME 1991) can be superseded.

In the case of toluene, the soil quality guidelines are calculated as the SQG_{HH} for all land uses and soil types. Because there are sufficient data to derive an SQG_{HH} and an SQG_E for each land use, the soil quality guidelines represent fully integrated *de novo* guidelines. The interim soil quality criteria for toluene (CCME 1991), and the soil quality guidelines for toluene derived in 1997, are superseded.

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

Table 2a. Soil quality guidelines and check values for toluene (mg·kg^{-1}) in surface soil.

SURFACE SOIL	Land use: Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]
Human health guidelines/check values								
SQG_{HH}	0.37[b]	0.08[b]	0.37[b]	0.08[b]	0.37[b]	0.08[b]	0.37[b]	0.08[b]
Soil ingestion guideline	22 000	22 000	22 000	22 000	82 000	82 000	NA	NA
Soil dermal contact guideline	220 000	220 000	220 000	220 000	790 000	790 000	NA	NA
Soil inhalation guideline	NC	NC	NC	NC	NC	NC	NC	NC
Inhalation of indoor air check (basement)	200	2 600	200	2 600	—	—	—	—
Inhalation of indoor air check (slab-on-grade)	120	2 700	120	2 700	1 400	13 000	1 400	13 000
Off-site migration check	—	—	—	—	—	—	NC[c]	NC[c]
Groundwater check (drinking water)	0.37	0.08	0.37	0.08	0.37	0.08	0.37	0.08
Produce, meat, and milk check	NC[d]	NC[d]	NC[d]	NC[d]	—	—	—	—
Environmental health guidelines/check values								
SQG_E	75[e]	110[e]	75[f]	110[f]	250[f]	330[f]	250[f]	330[f]
Soil contact guideline	75	110	75	110	250	330	250	330
Soil and food ingestion guideline	1 400	1 400	—	—	—	—	—	—
Nutrient and energy cycling check [g]	NC	NC	NC	NC	NC	NC	NC	NC
Off-site migration check	—	—	—	—	—	—	NC[c]	NC[c]
Groundwater check (livestock)	1 800[h]	NC[i]	—	—	—	—	—	—
Groundwater check (aquatic life)	0.10[j]	NC[i]	0.10[j]	NC[i]	0.10[j]	NC[i]	0.10[j]	NC[i]
Interim soil quality criterion (CCME 1991)	0.1		3		30		30	

Notes: NA = calculated guideline >1 000 000 mg·kg^{-1}; 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 a 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 an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated *de novo* guideline for this land use. The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

[b]The SQG_{HH} is the lowest of the human health guidelines and check values.

[c]Given the volatility and biodegradability of toluene, it is unlikely that significant amounts would remain after wind or water transport of soil, and so this pathway was not evaluated.

[d]This check is intended to protect against chemicals that may bioconcentrate in human food. Toluene is not expected to exhibit this behaviour, and so this pathway was not evaluated.

[e]The SQG_E for agricultural land uses is based on the lower of the soil contact guideline and the soil and food ingestion guideline.

[f]The SQG_E is based on the soil contact guideline.

[g]Data are insufficient/inadequate to calculate the nutrient and energy cycling check for this land use.

[h]This environmental groundwater check value is provisional because it is not based on the existing Canadian Water Quality Guideline for the protection of livestock watering for toluene. For details on the derivation, see the scientific supporting document (Environment Canada 2004). This check value is not used in determining the national soil quality guideline, but is provided as a reference for site-specific application.

[i]The environmental groundwater check value has not been determined because calculations show that in 100 years groundwater migration through fine soils will be less than 10 metres. For site-specific calculations where the protection of potable groundwater pathway is active, a hydraulic conductivity of 32 m·y^{-1} should be assumed, if adequate measured data are not available.

[j]This environmental groundwater check value is not used in determining the national soil quality guideline, but is provided as a reference for site-specific application.

Table 2b. Soil quality guidelines and check values for toluene ($mg \cdot kg^{-1}$) in subsoil.

SUBSOIL	Land use							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]	**0.37**[a]	**0.08**[a]
Human health guidelines/check values								
SQG_{HH}	0.37[b]	0.08[b]	0.37[b]	0.08[b]	0.37[b]	0.08[b]	0.37[b]	0.08[b]
Soil ingestion guideline	NC	NC	NC	NC	NC	NC	NC	NC
Soil dermal contact guideline	NC	NC	NC	NC	NC	NC	NC	NC
Soil inhalation guideline	NC	NC	NC	NC	NC	NC	NC	NC
Inhalation of indoor air check (basement)	200	2 600	200	2 600	—	—	—	—
Inhalation of indoor air check (slab-on-grade)	140	2 800	140	2 800	1 500	13 000	1 500	13 000
Off-site migration check	—	—	—	—	—	—	NC[c]	—
Groundwater check (drinking water)	0.37	0.08	0.37	0.08	0.37	0.08	0.37	0.08
Produce, meat, and milk check	NC[d]	NC[d]	NC[d]	NC[d]	—	—	—	—
Environmental health guidelines/check values								
SQG_E	150[e]	220[e]	150[f]	220[f]	500[f]	660[f]	500[f]	660[f]
Soil contact guideline	150	220	150	220	500	660	500	660
Soil and food ingestion guideline	NC	NC	—	—	—	—	—	—
Nutrient and energy cycling check[g]	NC	NC	NC	NC	NC	NC	NC	NC
Off-site migration check	—	—	—	—	—	—	NC[c]	NC[c]
Groundwater check (livestock)	1 800[h]	NC[i]	—	—	—	—	—	—
Groundwater check (aquatic life)	0.10[j]	NC[i]	0.10[j]	NC[i]	0.10[j]	NC[i]	0.10[j]	NC[i]
Interim soil quality criterion (CCME 1991)	0.1		3		30		30	

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 a 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 an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated *de novo* guideline for this land use, derived in accordance with the soil protocol (CCME 1996a). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.

[b]The SQG_{HH} is the lowest of the human health guidelines and check values.

[c]Given the volatility and biodegradability of toluene, it is unlikely that significant amounts would remain after wind or water transport of soil, and so this pathway was not evaluated.

[d]This check is intended to protect against chemicals that may bioconcentrate in human food. Toluene is not expected to exhibit this behaviour, and so this pathway was not evaluated.

[e]The SQG_E for agricultural land uses is based on the lower of the soil contact guideline and the soil and food ingestion guideline.

[f]The SQG_E is based on the soil contact guideline.

[g]Data are insufficient/inadequate to calculate the nutrient and energy cycling check for this land use.

[h]This environmental groundwater check value is provisional because it is not based on the existing Canadian Water Quality Guideline for the protection of livestock watering for toluene. For details on the derivation, see the scientific supporting document (Environment Canada 2004). This check value is not used in determining the national soil quality guideline, but is provided as a reference for site-specific application.

[i]The environmental groundwater check value has not been determined because calculations show that in 100 years groundwater migration through fine soils will be less than 10 metres. For site-specific calculations where the protection of potable groundwater pathway is active, a hydraulic conductivity of 32 $m \cdot y^{-1}$ should be assumed, if adequate measured data are not available.

[j]This environmental groundwater check value is not used in determining the national soil quality guideline, but is provided as a reference for site-specific application.

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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 was presented in "Canadian Environmental Quality Guidelines" (CCME 1999). In 2002-03, new guidelines were developed for toluene, and the fact sheet was revised again.

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For further scientific information, contact:

Environment Canada
National Guidelines and Standards Office
351 St. Joseph Blvd.
Gatineau, QC K1A 0H3
Phone: (819) 953-1550
Facsimile: (819) 953-0461
E-mail: ceqg-rcqe@ec.gc.ca
Internet: http://www.ec.gc.ca/ceqg-rcqe

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