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

XYLENES
2004

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

Background Information

Xylenes ($C_6H_4(CH_3)_2$; CAS 1330-20-7) are monoaromatic hydrocarbons with two methyl groups attached to the benzene ring, and are also known as alkyl benzenes. There are three isomers of xylene, *o*-, *m*-, and *p*-xylene, depending on the position of the methyl group on the benzene ring (1,2-, 1,3-, and 1,4-, respectively). The three xylene isomers have a high vapour pressure (8.8–11.80 kPa at 25°C) and Henry's law constant (436–1115 $Pa{\cdot}m^{-3}/mol^{-1}$) and are subject to rapid volatilization. They also have a high air saturation potential. These characteristics, combined with their low flash point (17.0, 25.0, and 25.0°C, respectively), make them highly flammable. Their solubility in water is low (122–223 $mg{\cdot}L^{-1}$ at 25°C), but is high enough to be of environmental concern. They have moderate octanol–water partition coefficients, 3.15, 3.20, and 3.18 for *o*-xylene, *m*-xylene, and *p*-xylene, respectively (MacKay et al. 1992). This indicates moderate fat solubility and consequently a moderate bioaccumulation potential (Environment Canada 1996).

Toluene, ethylbenzene, and the three xylene isomers (collectively referred to as TEX) fall into the broad category of volatile organic compounds that are monoaromatic hydrocarbons composed of an alkyl-substituted benzene ring. These compounds, with the addition of benzene, are often studied together 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 xylenes are produced as an

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

	Land use and soil texture							
	Agricultural		**Residential/ parkland**		**Commercial**		**Industrial**	
	Coarse	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**
Surface								
Guideline[a]	**11**	**2.4**	**11**	**2.4**	**11**	**2.4**	**11**	**2.4**
SQG_{HH}	11	2.4	11	2.4	11	2.4	11	2.4
SQG_E	95	65	95	65	350	230	350	230
Subsoil								
Guideline[a]	**11**	**2.4**	**11**	**2.4**	**11**	**2.4**	**11**	**2.4**
SQG_{HH}	11	2.4	11	2.4	11	2.4	11	2.4
SQG_E	190	130	190	130	700	460	700	460

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 600 $mg{\cdot}kg^{-1}$ in coarse soil, or 610 $mg{\cdot}kg^{-1}$ in fine soil, formation of free-phase xylenes will likely occur. Contact jurisdiction for guidance.
§ Guideline values apply to the summation of all three xylene isomers.
[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.

aromatic mixture with benzene, primarily from catalytic reformate in refineries and secondarily as by-products of olefin manufacture during the cracking of hydrocarbons. 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 xylenes in gasoline used in Ontario are 6.9% in regular unleaded and 8.0% 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. Xylene concentrations ranging from 0.3 $\mu g{\cdot}m^{-3}$ in rural areas (Dann and Wang 1992) to 22 000 $\mu g{\cdot}m^{-3}$ (Dann and Gonthier 1986) above landfill sites have been reported.

Xylene concentrations in water vary from 0.32 to 1.72 $\mu g{\cdot}L^{-1}$ across Canada (NAQUADAT 1992), and in sludge, 52 $\mu g{\cdot}L^{-1}$ for *o*-xylene and 1417 $\mu g{\cdot}L^{-1}$ for *m*- and *p*-xylene were reported (OMOE 1992).

Data on concentrations of xylenes in soils and sediments are scarce for the Canadian environment. The Ontario Ministry of Environment and Energy has reported that the 98th percentiles of xylene concentrations in rural and old urban parkland soils not impacted by a local point source of pollution are 0.92 and 0.80 $\mu g{\cdot}kg^{-1}$, 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 by reacting with photochemically produced hydroxyl radicals with a half-life of 3 h to 1 d.

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 downward 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.

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 BCFs for xylenes, expressed as logarithms to the base 10, were 2.41, 2.40, and 2.34 for *m*-, *o*-, and *p*-xylene respectively. The 8-d EC_{50} values were 4.4, 3.9, and 4.2 $mg \cdot L^{-1}$ for *m*-, *o*-, and *p*-xylene, respectively (Herman et al. 1991).

Although TEX may accumulate in algae (Howard 1990), the log K_{ow} is <4.0, indicating that the bioconcentration potential is generally low (WHO 1997; Nielsen and Howe 1991).

Behaviour and Effects in Biota

In the following review, the particular isomers of xylene that were tested have been specified where this information was provided by the original authors. In many cases the specific isomers have not been identified, and therefore the term xylene may refer to a mixture of isomers of variable composition.

Soil Microbial Processes

Hutchins (1991) reported that *m*-xylene inhibited the rate of denitrification in soils in a Michigan aquifer. Eisman et al. (1991) studied the toxicity of a fuel mixture containing toluene, *o*-xylene, *n*-octane, cyclohexane, cyclohexene, benzene, and naphthalene using the Microtox Assay *(Photobacterium phosphoreum)*. The concentrations at which bioluminescence was decreased by 50% after an exposure of 5 min were 200 and 456 $\mu g \cdot L^{-1}$ for *o*-xylene and toluene, respectively. For the water-soluble fraction, the 5-min EC_{50} for *o*-xylene and toluene were 21 and 66 $\mu g \cdot L^{-1}$ respectively. Short-term volatility was not a factor as EC_{50}s were consistent for test periods that ranged from 2.5 to 15 min. Anderson et al. (1991) reported that 100 $mg \cdot kg^{-1}$ soil dw of *p*-xylene was not toxic to soil microorganisms.

Terrestrial Plants

Xylene has been used as a selective herbicide in carrot crops and in the control of submersed aquatic weeds. Bruns and Kelly (1974) found no detectable symptoms of injury or reduction in yield for several field crops (alfalfa, tomatoes, dwarf corn, squash, potatoes, and field beans) when xylene was applied at 370, 740, and 1480 $mg \cdot L^{-1}$.

In an attempt to establish phytotoxic levels of xylene 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 32 and 5 mg $xylene \cdot kg^{-1}$ 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 xylene 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 xylene 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} of 421 $mg \cdot kg^{-1}$, and for northern wheatgrass the most sensitive endpoint was an IC_{25} of 90 $mg \cdot kg^{-1}$ for reduction of root wet mass (ESG 2002). The results reported by ESG (2002) for fine soils 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 coarse soils.) Therefore, the most sensitive estimated effect concentrations in fine soils for alfalfa and northern wheatgrass were an IC_{25} of 92 $mg \cdot kg^{-1}$ for reduction of shoot dry mass, and an IC_{25} of 241 $mg \cdot kg^{-1}$ for reduction of root length, respectively (Komex 2002).

Terrestrial Invertebrates

The lowest reported xylene concentration resulting in adverse effects to soil invertebrates comes from Environment Canada. The earthworm *(Eisenia foetida)* suffered 25% mortality at 56 mg $xylene \cdot kg^{-1}$ 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).

Studies commissioned by the CCME in 2001, and using advanced techniques for dealing with volatile compounds, examined the toxicity of xylene to the collembolan (*Onychiurus folsomi*) and the earthworm (*Eisenia andrei*). In coarse soils, the LC_{25} for collembolans was 733 $mg \cdot kg^{-1}$, and the NOEC and LOEC for adverse effects in earthworms were 8 and 78 $mg \cdot kg^{-1}$, respectively (ESG 2002). The results reported by ESG (2002) for fine soils were recalculated by Komex (2002) to take into account volatile losses that occur between spiking the sample and introducing the invertebrates 24 hours later. (Similar calculations had already been made by ESG for the data from the coarse soils.) Therefore, in fine soils the LC_{25} for collembolans was 835 $mg \cdot kg^{-1}$, and the NOEC and LOEC for adverse effects in earthworms were 8 and 78 $mg \cdot kg^{-1}$, respectively (Komex 2002).

Livestock and Wildlife

Studies specifically on the toxicological effects of xylene 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. TEX are absorbed and rapidly distributed throughout an animal's body. They are preferentially stored in adipose tissue, but are also accumulated in the kidneys, liver, and brain. Excretion through urine is the major route of elimination (Chin et al. 1980; Mattia et al. 1991; Skowronski et al. 1989; Turkall et al. 1991).

Technical grade xylene, which is used commercially, contains ethylbenzene and all the three isomers of xylene. In the majority of toxicological studies conducted to date, experimental animals have been exposed to this mixture rather than to the individual isomers. Also, in epidemiological studies, workers have been exposed to technical grade xylene and other solvents. Therefore, available data are insufficient to assess the health risks associated with exposure to the individual isomers. Moreover, in the general environment, the population is more likely to be exposed to xylene than to the individual isomers (Government of Canada 1993).

Xylene has not been carcinogenic following oral administration to rats and mice in a well-conducted bioassay (NTP 1986). The weight of available evidence also indicates that xylene is not genotoxic (Government of Canada 1993). Xylene has been classified, therefore, in Group IV (probably not carcinogenic to humans) of the classification scheme developed by the Bureau of Chemical Hazards (Health and Welfare Canada 1989).

For compounds classified in Group IV, a tolerable daily intake (TDI) is derived on the basis of a NO(A)EL or LO(A)EL in humans or animal species in studies conducted by the most relevant route of exposure divided by an uncertainty factor. For xylene, studies in which volunteers have been exposed are limited principally to those involving short-term repeated exposure of a limited number of subjects to 100 ppm (435 $mg \cdot m^{-3}$) *m*-xylene or greater (Riihimaki and Savolainen 1980; Savolainen 1980; Savolainen et al. 1980; 1982; 1984; 1985; Seppalainen et al. 1989). Owing to these limitations of the available studies in volunteers and the epidemiological studies mentioned above (i.e., the limited power to detect effects and confounding by concomitant exposure to other substances), available data are considered insufficient for development of a TDI on the basis of studies in humans. Health Canada has therefore derived TDI and tolerable concentration (TC) values on the basis of results from animal studies (Government of Canada 1993; Health Canada 1996).

Inhalation is considered to be the most important route of exposure to xylene for the general public. The lowest concentration at which meaningful effects (fetotoxic effects in the absence of maternal toxicity) have been observed following exposure by inhalation to xylene is 500 $mg \cdot m^{-3}$ in a limited study (Ungvary and Tatrai 1985). At this concentration, moderate embryotoxic effects such as a retardation of body weight increase were observed in the offspring of rabbits exposed continuously on days 7 to 20 of gestation to xylene, the composition of which was unspecified. However, it should be noted that in the same study, maternal (unspecified) and fetal (skeletal retardation) toxicity were observed in rats exposed during gestation to 250 $mg \cdot m^{-3}$ (the lowest concentration administered), indicating that they may be a more sensitive species. The available data do not preclude the possibility that a similar pattern to that observed in rabbits might be observed in rats exposed to lower concentrations.

At similar concentrations (492 $mg \cdot m^{-3}$ for 2 h), transient neurobehavioural effects in rats have been observed (Ghosh et al. 1987), and at slightly lower concentrations (50 ppm, 218 $mg \cdot m^{-3}$ for 2 weeks), biochemical effects on the brain, the significance of which is unclear, have been reported in rats (Savolainen and Pfaffli 1980). In the longest-term studies of the effects of xylene following inhalation (i.e., subchronic studies), the lowest concentration at which effects (a transient increase in the liver to body weight ratio) were observed in the limited number of available studies is 320 ppm (1400 $mg \cdot m^{-3}$) in small groups of rats continuously exposed to xylene (composition unspecified; single exposed group) for 90 d (Kyrklund et al. 1987). However, in another adequate study of a range of endpoints, there were no effects in rats or beagle dogs exposed to up to 3500 $mg \cdot m^{-3}$ xylene, 6 h per day, 5 days per week for 13 weeks (Carpenter et al. 1975).

The lowest concentration of the individual xylene isomers reported to induce adverse effects in studies in animal species following inhalation is 150 $mg \cdot m^{-3}$, in which increased implantational loss and decreased placental weight and retardation in skeletal development of offspring in the absence of maternal toxicity was observed following continuous exposure of pregnant rats to *p*-xylene on days 7 to 14 of gestation (Ungvary et al. 1980).

The database on effects of long-term exposure to xylene following ingestion is more complete than that for inhalation. The lowest reported NOEL in the longest term study conducted to date in which xylene has been administered orally (gavage in corn oil) is 250 $mg \cdot kg^{-1}$ bw per day, based on a 5–8% decrease in body weight in male rats observed at the next highest dose (500 $mg \cdot kg^{-1}$ bw per day) in a 2-year bioassay conducted by the National Toxicology Program (NTP 1986). The decrease in body weight was considered to be indicative of slight toxicity. Survival was also reduced at 500 $mg \cdot kg^{-1}$ bw per day in this study; however, some of these deaths were gavage-related. The NOAEL in the only available study of developmental toxicity in which xylene was administered orally was considerably greater than the NOAEL in the NTP bioassay (i.e., 1030 $mg \cdot kg^{-1}$ bw per day) (Marks et al. 1982) and NO(A)ELs for the individual isomers in subchronic studies in which *m*- or *p*-xylene was administered are slightly less than the NOAEL in the 2-year NTP bioassay (i.e., 200 $mg \cdot kg^{-1}$ bw per day) (Hazleton Labs 1988a, 1991b).

The estimated total average daily intake of xylene from various sources for different age groups in the Canadian population ranges from 5.4 to 8.4 $\mu g \cdot kg^{-1}$ bw per day.

Health Canada has derived an oral TDI of 1.5 $mg \cdot kg^{-1}$ bw per day and a provisional TC for inhalation of 0.18 $mg \cdot m^{-3}$ (Government of Canada 1993; Health Canada 1996). The oral TDI is based on a study by Condie et al. (1988) which reported a NOAEL of 150 $mg \cdot kg^{-1}$ bw per day for increases in the liver weight of rats exposed to xylenes administered by gavage over 90 days. The inhalation TC is based on a developmental study by Ungvary and Tatrai (1985) which reported a LOEL of 250 $mg \cdot m^{-3}$ for maternal toxicity and fetal skeletal retardation in rats exposed to xylenes on days 7 to 15 of gestation.

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). 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 for the soil quality guidelines for xylene 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 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 where data permit. For industrial land use, an off-site migration check is also calculated.

In the case of xylene, there are sufficient data to derive a guideline value for soil contact with plants and invertebrates (Table 2). A nutrient and energy cycling check 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 xylene 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 xylene 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 xylenes with the rationale that, given the volatility and biodegradability of xylenes, 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}) for threshold contaminants require a TDI for the most sensitive receptor designated for a land use. Ingestion and dermal contact guidelines were calculated for all surface soils, but these pathways were considered not applicable in subsoils, unless the ground is disturbed.

The CCME recommends the application of various check mechanisms, when relevant, in order to provide a broader scope of protection (Table 2). For xylene, indoor vapour inhalation check values were calculated for both surface soils and subsoils. A groundwater check value was calculated to determine xylene soil concentrations that will be protective of drinking water. An off-site migration check was not calculated because it is unlikely that significant concentrations of xylene would still remain after wind or water transport, due to its high volatility and biodegradability.

The lowest of the various human health guidelines and check values is recommended as the SQG_{HH}. The SQG_{HH} for xylene is therefore based on the groundwater check for the protection of drinking water (Table 2).

Soil Quality Guidelines for Xylenes

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 xylene, 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 (CCME 1991), and the soil quality guidelines for xylene 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 xylenes ($mg \cdot kg^{-1}$) in surface soil.

SURFACE SOIL	Land use							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline	**11[a]**	**2.4[a]**	**11[a]**	**2.4[a]**	**11[a]**	**2.4[a]**	**11[a]**	**2.4[a]**
Human health guidelines/check values								
SQG_{HH}	11[b]	2.4[b]	11[b]	2.4[b]	11[b]	2.4[b]	11[b]	2.4[b]
Soil ingestion guideline	150 000	150 000	150 000	150 000	560 000	560 000	NA	NA
Soil dermal contact guideline	NA	NA	NA	NA	NA	NA	NA	NA
Soil inhalation guideline	NC	NC	NC	NC	NC	NC	NC	NC
Inhalation of indoor air check (basement)	22	320	22	320	—	—	—	—
Inhalation of indoor air check (slab-on-grade)	14	320	14	320	160	1 600	160	1 600
Off-site migration check	—	—	—	—	—	—	NC[c]	NC[c]
Groundwater check (drinking water)	11	2.4	11	2.4	11	2.4	11	2.4
Produce, meat, and milk check	NC[d]	NC[d]	NC[d]	NC[d]	—	—	—	—
Environmental health guidelines/check values								
SQG_E	95[e]	65[e]	95[f]	65[f]	350[f]	230[f]	350[f]	230[f]
Soil contact guideline	95	65	95	65	350	230	350	230
Soil and food ingestion guideline	3 700	3 700	—	—	—	—	—	—
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)	20 000[h]	NC[i]	—	—	—	—	—	—
Groundwater check (aquatic life)	37[j]	NC[i]	37[j]	NC[i]	37[j]	NC[i]	37[j]	NC[i]
Interim soil quality criterion (CCME 1991)	0.1		5		50		50	

Notes: NA = calculated guideline >1,000,000 $mg \cdot kg^{-1}$; 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, 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 xylene, 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. Xylene 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 at the time of derivation there was no Canadian Water Quality Guideline for the protection of livestock watering for xylenes upon which to base it. 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 provisional because at the time of derivation there was no Canadian Water Quality Guideline for the protection of aquatic life for xylenes upon which to base it. For details on the derivation, see Komex (2002). 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 xylenes ($mg \cdot kg^{-1}$) in subsoil.

SUBSOIL	Land use							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline	**11**[a]	**2.4**[a]	**11**[a]	2.4[a]	**11**[a]	**2.4**[a]	**11**[a]	**2.4**[a]
Human health guidelines/check values								
SQG_{HH}	11[b]	2.4[b]	11[b]	2.4[b]	11[b]	2.4[b]	11[b]	2.4[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)	22	320	22	320	—	—	—	—
Inhalation of indoor air check (slab-on-grade)	16	340	16	340	170	1 600	170	1 600
Off-site migration check	—	—	—	—	—	—	NC[c]	NC[c]
Groundwater check (drinking water)	11	2.4	11	2.4	11	2.4	11	2.4
Produce, meat, and milk check	NC[d]	NC[d]	NC[d]	NC[d]	—	—	—	—
Environmental health guidelines/check values								
SQG_E	190[e]	130[e]	190[f]	130[f]	700[f]	460[f]	700[f]	460[f]
Soil contact guideline	190	130	190	130	700	460	700	460
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)	20 000[h]	NC[i]	—	—	—	—	—	—
Groundwater check (aquatic life)	37[j]	NC[i]	37[j]	NC[i]	37[j]	NC[i]	37[j]	NC[i]
Interim soil quality criterion (CCME 1991)	0.1		5		50		50	

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 xylene, 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. Xylene 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 at the time of derivation there was no Canadian Water Quality Guideline for the protection of livestock watering for xylenes upon which to base it. 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 provisional because at the time of derivation there was no Canadian Water Quality Guideline for the protection of aquatic life for xylenes upon which to base it. For details on the derivation, see Komex (2002). 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 xylene, and the fact sheet was revised again.

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