



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

n-HEXANE 2011

This fact sheet provides Canadian soil quality guidelines for n-hexane for the protection of environmental and human health (Table 1). A supporting scientific document is also available (CCME, 2011).

Background Information

n-Hexane (CAS# 110-54-3) is a straight-chain saturated aliphatic hydrocarbon compound (or alkane) with the chemical formula C_6H_{14} . Synonyms for n-hexane include hexane, normal hexane, dipropyl and hexyl hydride. It is a component of the “F1” hydrocarbon fraction defined by CCME (2008). At standard temperature and pressure, n-hexane is a clear and colourless liquid, with a mild petroleum-like odour which is detectable at 65 to 248 ppm (WHO, 2000; NLM, 2005; National Pollutant Inventory Substance Profile, 2005; ATSDR, 1999). n-Hexane is not highly soluble in water (solubility of 9.5 mg/L) and has a log octanol–water partition coefficient (log K_{OW}) of 4.11

(MacKay *et al.*, 2006, Gustafsen *et al.*, 1997), and estimated K_{OC} of 3410 (Gustafsen *et al.*, 1997) indicating a low potential to bioconcentrate (CCME, 1999). In liquid form, n-hexane is less dense than water; vapours are heavier than air. n-Hexane is highly flammable, and vapour/air mixtures are explosive (WHO, 2000). With a Henry’s Law Constant of 1.69 to 1.83 atm·m³/mol, n-hexane is expected to volatilize rapidly from water surfaces (AENV, 2004a).

n-Hexane is a naturally occurring component of crude oil and natural gas. n-Hexane has been reported to comprise approximately 1.1% of gasoline (by weight) and 2.4% of JP-4 fuel oil (Potter and Simmons, 1998); although modern high octane gasolines may contain 3% n-hexane by weight (ATSDR, 1999). n-Hexane is also a component of glues, rubber cement, paints, coatings and adhesives (ATSDR, 1999; NLM, 2005), and is used in low temperature thermometers (NLM, 2005). High purity n-hexane is used as a laboratory reagent (ATSDR, 1999).

Table 1. Soil quality guidelines for n-hexane (mg·kg⁻¹).

	Land use and soil texture							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline^a	0.49	6.5	0.49	6.5	6.5	21	6.5	21
SQG _{HH}	0.49	6.5	0.49	6.5	6.5	21	6.5	21
SQG _E	NC	NC	NC	NC	NC	NC	NC	NC

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

^aData are sufficient and adequate to only calculate an SQG_{HH}, and not an SQG_E. Therefore the recommended soil quality guideline is set as the SQG_{HH} and represents a *de novo* guideline for this land use, derived in accordance with the soil protocol (CCME, 2006).

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. The reader should consult the appropriate jurisdiction before application of the values.

A major use of n-hexane is to extract vegetable oils from crops, including soybeans, canola, flaxseed, peanuts, safflower, corn germ and cottonseed and in the production of defatted products such as defatted soy flour (ATSDR, 1999; WHO, 1991). Hexane concentrations in five brands of extra-virgin olive oil ranged from 19.1 ng/mL to 95.3 ng/mL (Overton and Manura, 1995); mean hexane residues were <0.9 mg/kg in peanut oil and <1.5 mg/kg in sunflower oil (Hautfenne *et al.*, 1987).

Solvents containing n-hexane are also used as cleaning agents or degreasers for the printing, textile, furniture, shoemaking and leather industries (ATSDR, 1999). n-Hexane solvents are used in rubber polymerization, and in the manufacture of polyolefins, elastomers, cosmetics and pharmaceuticals (NLM, 2005, WHO, 1991).

Small amounts of n-hexane may also be produced biogenically by marine phytoplankton (McKay *et al.*, 1996), terrestrial plants (Rinnan *et al.*, 2005) and fungi (Ahearn *et al.*, 1996).

n-Hexane may be present in soils and groundwater contaminated with petroleum hydrocarbons (particularly gasoline), or at the locations of hexane spills. No data were identified for n-hexane concentrations in uncontaminated soils, sediments, groundwater, surface water or drinking water.

n-Hexane concentrations in ambient air vary widely depending on the source and the sampling season. Across Canada, mean ambient n-hexane concentrations have been reported to be $2.03 \pm 2.87 \mu\text{g}/\text{m}^3$, with values ranging from below the detection limit of $0.1 \mu\text{g}/\text{m}^3$ to $242 \mu\text{g}/\text{m}^3$ (OMOE, 2005). Similar results were reported in Ontario, where n-hexane concentrations were between the detection limit of $0.02 \mu\text{g}/\text{m}^3$ and $110 \mu\text{g}/\text{m}^3$ (OMOE, 2005). In Quebec, average annual concentrations were 0.53 to $3.41 \mu\text{g}/\text{m}^3$ (Gouvernement du Quebec, 2002), and in Alberta, 24-hr average concentrations ranged from 0.223 to $25.55 \mu\text{g}/\text{m}^3$ (AENV, 2004b). Ambient n-hexane concentrations are generally lower in rural settings: average annual n-hexane concentrations in Quebec were $0.23 \mu\text{g}/\text{m}^3$ (Gouvernement du Quebec, 2002) with monthly mean values of 0.07 to $0.28 \mu\text{g}/\text{m}^3$ reported at Lac la Flamme (Bottenheim and Shepherd, 1995); monthly mean concentrations ranged from 0.07 to $0.5 \mu\text{g}/\text{m}^3$ at Kejimikujik National Park, Nova Scotia, 0.1 to $0.35 \mu\text{g}/\text{m}^3$ at Egbert, Ontario, and 0.035 to $0.32 \mu\text{g}/\text{m}^3$ at Saturna Island, British Columbia (Bottenheim and Shepherd, 1995).

Higher than average n-hexane concentrations in ambient air have been reported in the vicinity of chemical, food, petroleum, adhesive tape, plastic film, and steel production facilities and near oil sands operations (Environment Canada, 2007).

In a 1991-1992 Canada-wide study, the mean n-hexane concentration in indoor air was found to be $1.2 \mu\text{g}/\text{m}^3$, with a maximum of $124 \mu\text{g}/\text{m}^3$ (Davis and Otson, 1996). The mean n-hexane concentration in indoor air samples collected in Toronto between February and April, 1996, was $5.24 \mu\text{g}/\text{m}^3$ (Otson and Zhu, 1997). In California, a study of office buildings reported a geometric mean n-hexane concentration of $1.9 \mu\text{g}/\text{m}^3$, with indoor to outdoor air ratios ranging from 0.26 to 18 (Daisey *et al.*, 1994). Concentrations can be much higher in poorly-ventilated occupational settings; concentrations exceeding $1750 \mu\text{g}/\text{m}^3$ have been reported at some locations where n-hexane is used (ATSDR, 1999).

Environmental Fate and Behaviour in Soil

The high vapour pressure and Henry's Law constant for n-hexane indicate that it is likely to volatilize rapidly from surficial soils and water surfaces. Adsorption to soil particles is considered moderate, given the relatively low K_{oc} (AENV, 2004b; ATSDR, 1999); however, n-hexane may persist for much longer in deeper soils, particularly if the oxygen content is low or nutrients are limited (ATSDR, 1999). The low water solubility of n-hexane indicates that relatively little will dissolve in surface water or groundwater. n-Hexane is less dense than water and will be present as a light non-aqueous phase liquid at high concentrations (above solubility limits) (Feenstra *et al.*, 1991; Hunt *et al.*, 1988; ATSDR, 1999). n-Hexane contamination, therefore has the potential to be mobile and to spread along the top of the saturated zone.

Volatilization is believed to be much more rapid than chemical or biochemical degradation; however, n-hexane can be converted into primary alcohols, aldehydes and, ultimately, fatty acids (ATSDR, 1999). The biodegradation products from oxidation for n-hexane based on metabolites isolated from a pure culture of *Pseudomonas* are 2-hexanol and 1-hexanol. 1-Hexanol can further degrade to acetate and adipic acid (Heringa *et al.* 1961). Aerobic degradation is often assumed to be higher for low molecular weight aliphatics than heavier hydrocarbons; however, n-hexane vapours in soil have a lower rate of aerobic degradation (first-order decay rate constant of approximately 0.24 d^{-1}) than n-octane or n-decane (Höhener *et al.*, 2003).

n-Hexane degradation rates are affected by numerous factors, including oxygen, soil properties, and microbial communities. In an activated sludge inoculum, n-hexane and 12 other components of gasoline were completely degraded in less than 30 days (Solano-Serena *et al.*, 2000). In a separate experiment, high octane gasoline (100 µl/L or 7,550 µg/L octane at 15°C) including n-hexane (1.36 µL/L or 0.89 mg/L) was incubated with natural flora in groundwater at 13°C. After 192 hours, biodegradation reduced n-hexane concentrations by 46% (Verschuere, 1983; HSDB, 2005).

Biodegradation of n-hexane in surface water or groundwater has been demonstrated in laboratory and field studies, particularly under aerobic conditions (McClay *et al.*, 1995; Rosenberg *et al.*, 1992; ATSDR, 1999). n-Hexane is therefore not expected to persist in most surface water, but may persist in groundwater, particularly under anaerobic or low-nutrient conditions (ATSDR, 1999).

Bioconcentration

n-Hexane is considered unlikely to bioconcentrate and bioaccumulate in aquatic and terrestrial food (AENV, 2004a; ATSDR, 1999). The CCME considers substances with bioconcentration or bioaccumulation factors of less than 5000 (or a log K_{OW} of < 5) unlikely to concentrate or accumulate in aquatic biota (CCME, 1999). Based on the log K_{OC} (3.5) and log K_{OW} (4.11) n-hexane is not expected to bioconcentrate.

Behaviour and Effects in Biota

Soil Microbial Processes

Several types of bacteria have been observed to metabolize n-hexane. Aerobic catabolism is believed to be the dominant mechanism of n-hexane degradation in soils with adequate oxygen (Leahy and Colwell, 1990). However, in some soils oxygen and nutrient concentrations may not be adequate for aerobic degradation.

Rabus *et al.*, (2001) found that certain denitrifying bacteria were able to oxidize n-hexane anaerobically, forming (1-methylpentyl) succinate, which in turn is converted to methyl-branched fatty acids (Wilkes *et al.*, 2002) and eventually CO₂ (Wilkes *et al.*, 2006). Only certain species can metabolize n-hexane (Ehrenreich *et al.*, 2000), indicating that microbial community composition may affect degradation rates. Sulphate-reducing and iron(III)-reducing bacteria have also been shown to anaerobically metabolize alkanes, including n-hexane (Harayama *et al.*, 2004).

A 24-hr exposure to 500 mg/L, n-hexane was toxic to over 20 methyltrophic organisms in a 50 mg suspension of municipal sewage sludge (Gerhold and Malaney, 1966). Oxidation of n-hexane to 2-pentanone and 2-pentanol was also observed (Gerhold and Malaney 1966).

Terrestrial Plants

Phytoremediation has been applied for the remediation of petroleum hydrocarbon contamination; however, n-hexane metabolism in plants has not been studied. Maize growing normally in soil containing petroleum hydrocarbons did not accumulate saturated alkanes (Chaîneau *et al.*, 1997). The presence of plants reduced diesel fuel concentrations in arctic soils, particularly lighter alkanes; however, the plants did not appear to significantly bioaccumulate these compounds (Palmroth *et al.*, 2002).

Exposure to n-hexane vapours has been shown to injure some plant tissues. *Hordeum vulgare* (barley) and *Daucus carota sativus* (carrots) species were fumigated with 4.5 to 6.3 mmol/L (388 to 543 mg/L) and 4.5 to 7.8 mmol/L (388 to 675 mg/L) n-hexane; adverse effects were observed at 1 day and 28 days, respectively (Currier and Peoples, 1954). Exposure to n-hexane vapours resulted in increased leaf permeability. The application of slight pressure on the leaf resulted in darkening, with cell sap filling intercellular spaces; dark areas also appeared in the leaves in the absence of pressure, followed by loss of turgor, complete wilting, and plant death (Currier and Peoples, 1954). Membrane damage has also been observed in ornamental crop species exposed to n-hexane (Vincoli, 1997).

Soaking *Hordeum vulgare* (barley) roots in 0.69 mmol/L (59.46 mg/L) of n-hexane for 0.25 day produced loss of root cell viability, with the apical meristem being most resistant (Currier and Peoples, 1954). As plant roots are more adapted to absorbing polar substances and leaves to absorbing non-polar substances, plant roots may have a greater resistance to hydrocarbon exposure than leaves (Crafts, 1948).

Terrestrial Invertebrates

No specific information was found on metabolism or effects of n-hexane in terrestrial invertebrates in the published literature. Two separate unpublished studies performed at the Centre d'expertise en analyse environnementale du Québec (CEAEQ) on the earthworm *Eisenia Andrei*, showed a 80 and 95% avoidance of the worms to two different soil types both with n-hexane levels of 1.42 ppm, and 0% earthworm mortality at n-hexane levels of 210 ppm (Gaëlle Triffault-Bouchet, CEAEQ, pers. comm.)

Livestock and Wildlife

Studies addressing the toxicological effects of n-hexane in livestock and wildlife are currently lacking. Studies on experimental animals are covered in the next section.

Health Effects in Humans and Experimental Animals

In humans, n-hexane may be absorbed following ingestion, inhalation, and dermal exposure. A significant proportion of inhaled n-hexane is not absorbed and is exhaled as unmetabolized n-hexane (Bus *et al.*, 1982): systemic absorption of n-hexane from human lungs is approximately 17% (Mutti *et al.*, 1984) to 25% (Veulemans *et al.*, 1982). Inhaled n-hexane is rapidly absorbed and distributed throughout the body. In rats, n-hexane is distributed to most tissues including the kidney, liver, lung, brain and testes, as well as peripheral nerves (Baker and Rickert, 1981). The toxicity of n-hexane is attributed to its metabolites, and in particular 2,5-hexanedione, rather than the parent compound (ATSDR, 1999). There are three primary excretion routes for n-hexane: exhalation as unchanged n-hexane in the lungs (Baelum *et al.*, 1998); excretion as metabolic CO₂ in the lungs; and excretion as metabolites in urine (Bus *et al.*, 1982).

Inhalation and oral exposures to n-hexane are known to produce neurological, reproductive, and visual system toxicity. A novel sensori-motor peripheral neuropathy occurring in workers exposed to petroleum-based solvents containing n-hexane was first described in epidemiological studies in the 1960s. The neurotoxic syndrome developed in Japanese sandal making workers (Yamamura, 1969; Yamada, 1964), Italian shoemakers (Abbritti *et al.*, 1976; Mutti *et al.*, 1982), Taiwanese press proofing workers (Wang *et al.*, 1986), and American tungsten carbide milling workers (Sanagi *et al.*, 1980) following exposures from less than a year to 25 years or more. In the 1990s, similar neurotoxic effects were noted among workers in a leather coat and shoe production facility (Oge *et al.*, 1994), a luggage factory (Yuasa *et al.*, 1996), and in automotive repair shops (Harrison *et al.*, 2001). The identification of n-hexane as a causative agent in these cases was complicated by the presence of numerous other compounds, some of which were also neurotoxins.

Rats experimentally exposed to n-hexane via inhalation developed clinical and physiological symptoms of neurotoxicity similar to those seen in cases of occupational neurotoxicity. Similar histopathological changes in peripheral nerves have been observed in humans and experimental animals (Chang *et al.*, 1993).

Detailed toxicokinetic and biochemical studies have correlated the neurotoxicity of n-hexane to the formation of a γ -diketone metabolite (2,5-hexanedione) in both rats and humans (Pyle *et al.*, 1992; DeCaprio *et al.*, 1987; DeCaprio *et al.*, 1983).

Adverse effects on the human optic tract may occur following n-hexane exposure, characterized by blurred vision, maculopathy, and impaired colour discrimination (Chang, 1987). Experimentally exposed animals developed characteristic histopathological changes (i.e., axonal swelling) in the optic tract (Spencer *et al.*, 1980). Abnormal evoked neuronal potentials have been reported in humans exposed to solvents containing n-hexane and in experimental animals exposed to pure n-hexane (Chang, 1987). A possible correlation between n-hexane exposure and potentiation of visual failure in individuals with Leber Hereditary Optic Neuropathy (hereditary loss of vision linked to maternal mitochondria DNA mutations) has been suggested (Carelli *et al.*, 2007); however, further work is required before statements of causality can be made.

The limited data available did not indicate significant reproductive toxic effects in males, or in females at doses that were not maternally toxic. A NOAEL of 200 ppm n-hexane was identified for developmental toxicity based on a subchronic reproductive study in rats (Mast *et al.*, 1988). Multigenerational reproductive and developmental toxicity studies are lacking.

ATSDR and U.S. EPA have evaluated the carcinogenicity of n-hexane. The EPA (U.S. EPA, 2005) concluded there is inadequate information to assess the carcinogenic potential of n-hexane because there are no available animal carcinogenicity studies and only a single human study (Beall *et al.*, 2001), in which workers were chronically exposed to mixtures containing n-hexane and other chemicals.

Neurological toxicity was selected as the most sensitive toxicity endpoint. An extensive database regarding n-hexane neurotoxicity is available. Significant correlations between the dose and duration of n-hexane exposure and the time to onset and severity of neurotoxic effects have been observed in both animal and human studies. n-Hexane exposure produces early paresthesia and impairment of touch and pain sensation, followed by reduced arm reflexes and leg paralysis. Reduced motor nerve conduction velocity (MCV) and mixed nerve conduction velocity (MNCV) have also been measured at doses below those causing overt toxicity (Takeuchi *et al.*, 1980; Takeuchi *et al.*, 1981; Huang *et al.*, 1989; Iwata *et al.*, 1984; Takeuchi *et al.*, 1983; Ono *et al.*, 1982).

Effects associated with n-hexane exposure include seminiferous tubule atrophy in the testes of rats and developmental effects in rats and mice following maternal exposures. The available epidemiological data are inadequate to evaluate doses associated with these endpoints in humans. In experimental animals, the data for effects on males were inadequate for the development of toxicity reference values. For females, the available data suggest reproductive and developmental effects occurred at doses greater than those producing significant neurotoxic effects.

A number of factors were considered in the development of toxicological reference values (TRVs) for n-hexane, including: increased potency of n-hexane in more continuous non-occupational exposure regimes compared to occupational exposures (due to the toxicokinetics of n-hexane and 2,5-hexanedione, and relatively high clearance rates during non-exposure periods); dose- and duration-dependent inhibition and/or induction of n-hexane metabolism to 2,5-hexanedione (possibly via a metabolite of n-hexane); progression of n-hexane toxicity with increasing dose and duration; potentially sensitive subpopulations, such as people with Parkinson's disease; interspecies differences (i.e., rats have greater 2,5-hexanedione excretion rates than humans); and toxicokinetic interactions with other compounds (e.g., co-exposure to linear, branched, and cyclic aliphatic hydrocarbons, aromatics [xylenes, toluene], ketones [methylethylketone, acetone] or alcohols [isopropyl alcohol]).

For the purpose of deriving the SQG for vapour inhalation, a reference concentration (RfC) of 0.7 mg/m³ based on US EPA (2005) was used as a Tolerable Concentration (TC) for inhalation of n-hexane. The lifetime TC for inhaled n-hexane was based on Huang *et al.* (1989) in which rats were exposed to n-hexane (>99% pure) 12 hours per day, seven days per week for 12 weeks. The critical health effect endpoint examined in the Huang *et al.* (1989) study was a neurological endpoint.

The toxicity database for oral exposures to n-hexane was considerably smaller than for inhalation. An interim oral tolerable daily intake (TDI) of 0.1 mg/kg bw per day (Equilibrium, 2008) was used to derive the soil quality guideline for direct contact. The calculated point of departure (POD) value relied on the use of repeated measures data from a meta-analysis of studies (Ono *et al.*, 1979; Ono *et al.*, 1981). A POD value of 8 mg/kg-d based on a 5% reduction in mixed nerve conduction velocity was determined for the derivation of a lifetime oral TDI, after adjustment to an equivalent lifetime exposure. An uncertainty factor of 90 was applied (x 10 for sensitive individuals; x 3 for

interspecies toxicokinetic differences; and x 3 for limitations of the oral dataset, including a small number of data points and the use of repeated measures data).

Guideline Derivation

Canadian soil quality guidelines for different land uses are derived following the process outlined in CCME (2006). Different receptors and exposure scenarios are defined for each land use (Table 1). Modifications to the 2006 protocol used to develop the Canada-wide Standard for Petroleum Hydrocarbons in Soil (CCME 2008) were also applied in the development of these guidelines, including the derivation of guidelines for different soil textures (coarse and fine). 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 (D₅₀< 75 µm). Coarse-grained soils contain greater than 50% (by mass) particles greater than 75 µm mean diameter (D₅₀> 75 µm). Detailed derivations for the soil quality guidelines for n-hexane are provided in the supporting document (CCME, 2011).

Soil Quality Guidelines for Environmental Health

Environmental soil quality guidelines (SQG_E) are based on toxicity studies in 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 n-hexane, there are insufficient data to derive a guideline value for soil contact with plants and invertebrates. The available dataset was also insufficient to meet the requirements of the CCME (2006) protocol for calculating a nutrient and energy cycling check. A provisional soil and food ingestion guideline has been developed for primary consumers. A guideline for secondary consumers was not developed since available data suggest n-hexane does not bioaccumulate in the food chain.

A check value for groundwater has been calculated to determine n-hexane soil concentrations that will be protective for livestock watering and groundwater discharge to surface water. No aquatic life guideline for n-hexane from any jurisdiction could be found, which is a necessary component for deriving the soil quality guideline for the protection of freshwater life. In order to provide some guidance for this pathway, a deviation from the soil protocol (CCME, 2006) was made by deriving an aquatic life Toxicity Reference Value from the limited aquatic toxicity data available (CCME,

2011). The resulting soil quality guideline for the protection of freshwater life is considered provisional, was not used in the determination of the SQG_E , and should be used with discretion. The provisional groundwater check value for livestock was not applied in the determination of the SQG_E , but should be applied on a site-specific basis (Table 2). An off-site migration check was not calculated for n-hexane with the rationale that, given the volatility and biodegradability of n-hexane, 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 for direct contact (ingestion and dermal contact) for threshold contaminants require a TDI for the most sensitive receptor designated for a land use. In the absence of a TDI from Health Canada for n-hexane, an interim TDI was developed for use in the derivation of the soil quality guidelines. Ingestion and dermal contact guidelines were calculated for each of the four land uses specified by CCME (2006). As n-hexane is considered a volatile contaminant, indoor inhalation guidelines were also calculated for each of the four land uses. In the absence of a TC from Health Canada for n-hexane, the US EPA (2005) RfC of 0.7 mg/m^3 was used in the calculations. The relative absorption factors for inhalation, ingestion and dermal contact are assumed to be 100%, by default.

CCME (2006) recommends a multimedia approach to guidelines development in which a default of 20% of the residual tolerable daily intake is allocated to soil. Therefore, a soil allocation factor of 0.2 was applied in the derivation of the guideline.

CCME recommends the application of various check mechanisms, when relevant, in order to provide a broader scope of protection (Table 2). For n-hexane, indoor vapour inhalation check values were calculated for both coarse- and fine-grained soils. In the absence of a tolerable concentration (TC) from Health Canada for n-hexane, the US EPA's RfC was used in the calculation. A relative absorption factor (inhalation:oral) of 100% is assumed by default.

A groundwater check value was calculated to determine n-hexane soil concentrations that would be protective of drinking water. In the absence of a Canadian Drinking Water Guideline for n-hexane, the groundwater check value was developed using a source guidance value for groundwater (SGVG) of 0.23 mg/L (CCME, 2011). The SQVG, calculated solely for the purpose of the groundwater check, includes consideration of multi-

route exposure. An equivalent drinking water ingestion rate of 6.25 L-eq/d was derived by adding the assumed oral ingestion rate (1.5 L/d) and conservative estimates of the equivalent n-hexane ingestion rate via dermal absorption (2.96 L-eq/d) and via inhalation (1.79 L-eq/d) that may occur during bathing and showering.

An off-site migration check was not calculated because it is unlikely that significant concentrations of n-hexane would still remain after wind or water transport, due to its high volatility and biodegradability. Nor was a produce, meat and milk check carried out, since n-hexane exhibits very limited potential for food-web mediated transfer.

The lowest of the various human health guidelines and check values is recommended as the SQG_{HH} . The SQG_{HH} for n-hexane is therefore based on the indoor vapour inhalation check (Table 2).

Soil Quality Guidelines for n-Hexane

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.

Data are sufficient and adequate to only calculate an SQG_{HH} , and not an SQG_E . Therefore the recommended soil quality guideline is set as the SQG_{HH} and represents a *de novo* guideline derived in accordance with the soil protocol (CCME, 2006). There are no pre-existing soil quality guidelines for n-hexane. CCME (1996) provides guidance on potential modifications to the final recommended soil quality guideline when setting site-specific objectives.

For most contaminated sites, the exposure pathways previously described are considered sufficient for developing soil quality guidelines. However, other concerns with respect to n-hexane could include, but are not limited to; free-phase liquid formation, threat of explosion or fire hazards, or exposure of workers in trenches to n-hexane vapours. See CCME (2011) for further discussion.

Table 2. Soil quality guidelines and check values for n-hexane (mg·kg⁻¹).

Guideline ^a	Land use							
	Agricultural		Residential/ parkland		Commercial		Industrial	
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Guideline^a	0.49	6.5	0.49	6.5	6.5	21	6.5	21
Human health guidelines/check values								
SQG _{HH} ^b	0.49	6.5	0.49	6.5	6.5	21	6.5	21
Direct Contact	2,140 ^c	2,140 ^c	2,140 ^c	2,140 ^c	3,250 ^c	3,250 ^c	15,600 ^c	15,600 ^c
Inhalation of indoor air check								
basement	0.75	6.8	0.75	6.8	—	—	—	—
slab-on-grade	0.49	6.5	0.49	6.5	6.5	41	6.5	41
Off-site migration check ^d	—	—	—	—	NA	NA	NA	NA
Groundwater check (drinking water)	21	21	21	21	21	21	21	21
Produce, meat, and milk check ^e	NC	NC	NC	NC	—	—	—	—
Environmental health guidelines/check values								
SQG _E ^f	NC	NC	NC	NC	NC	NC	NC	NC
Soil contact guideline	NC	NC	NC	NC	NC	NC	NC	NC
Soil and food ingestion guideline	75 ^g	75 ^g	—	—	—	—	—	—
Nutrient and energy cycling check ^h	NC	NC	NC	NC	NC	NC	NC	NC
Off-site migration check	—	—	—	—	NA ^c	NA ^c	NA ^c	NA ^c
Groundwater check (livestock)	10,750 ^{gc}	9400 ^{gc}	—	—	—	—	—	—
Groundwater check (aquatic life)	12.3 ⁱ	11.6 ⁱ	12.3 ⁱ	11.6 ⁱ	12.3 ⁱ	11.6 ⁱ	12.3 ⁱ	11.6 ⁱ
Interim soil quality criterion (CCME 1991)	No value		No value		No value		No value	

Notes: NA = not applicable; NC = not calculated; 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.

^aData are sufficient and adequate to only calculate an SQG_{HH}, and not an SQG_E. Therefore the recommended soil quality guideline is set as the SQG_{HH} and represents a *de novo* guideline for this land use, derived in accordance with the soil protocol (CCME, 2006).

^bThe SQG_{HH} is the lowest of the human health guidelines and check values.

^cFree-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 free-phase formation will likely occur at concentrations greater than 315 mg·kg⁻¹ in fine soil and 261 mg·kg⁻¹ in coarse soil. Contact jurisdiction for guidance.

^dGiven the volatility and biodegradability of n-hexane, it is unlikely that significant amounts would remain after wind or water transport of soil, and so this pathway was not evaluated.

^eThis check is intended to protect against chemicals that may bioconcentrate in human food. n-Hexane is not expected to exhibit this behaviour, and so this pathway was not evaluated.

^fThe SQG_E could not be derived because there was insufficient/inadequate data to calculate the required soil contact guideline.

^gProvisional guideline.

^hData are insufficient/inadequate to calculate the nutrient and energy cycling check for this land use.

ⁱThis guideline is considered provisional because there was no Canadian Water Quality Guideline for the Protection of Aquatic Life available for its derivation, as required in CCME (2006). As a substitute, a freshwater life Toxicity Reference Value was estimated based on the limited n-hexane toxicity data available, see CCME (2011) for details. This value is presented for users to consider applying at their own discretion.

References

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For further scientific information, contact:

Environment Canada
National Guidelines and Standards Office
200 Sacré-Cœur Blvd.
Gatineau, QC K1A 0H3
Phone: (819) 953-1550
E-mail: ceqg-rcqe@ec.gc.ca

For additional copies, contact:

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