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## Soil Guideline Values for toluene in soil

### Science Report SC050021 / toluene SGV

This technical note is one in a series that describe Soil Guideline Values (SGVs) for individual, or groups of similar, chemicals to assist in the assessment of risks from land contamination.

SGVs are an example of generic assessment criteria (Defra and Environment Agency, 2004) and can be used in the preliminary evaluation of the risk to human health from long-term exposure to chemicals in soil. Specifically, this note provides SGVs for toluene in soil.

The SGVs and additional advice found here should be used only in conjunction with the introductory guide to the series entitled *Using Soil Guideline Values* (Environment Agency, 2009a), the framework documents *Updated technical background to the CLEA model* (Environment Agency, 2009b) and *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c), and *Contaminants in soil: updated collation of toxicological data and intake values for humans. Toluene* (Environment Agency, 2009d). Supplementary information on toluene is also available (Environment Agency, 2008, 2009e).

All notes in the SGV series, the introductory guide and further supplementary information can be downloaded from our website

(<http://www.environment-agency.gov.uk/clea>).

### Toluene

Toluene (CAS No. 108-88-3), the common name for methylbenzene, is a naturally occurring aromatic hydrocarbon with a sweet, benzene-like odour. Natural sources include forest fires; it is also present in low concentrations in crude oil (IPCS, 1985; ATSDR, 2000; ECB, 2003).

Pure toluene is a clear, colourless, volatile liquid (at room temperature and ambient pressure) which is highly flammable and explosive in air. It is moderately soluble in water, but is miscible with most organic solvents (IPCS, 1985; ATSDR, 2000; ECB, 2003).

Benzene, toluene, ethylbenzene and xylene are often referred to collectively as BTEX because they have closely related chemical structures, and have similar fate and transport properties. They are often used together in industrial and petroleum products, and commonly occur together in the environment as a result of related pollution.

Purified toluene may contain benzene at levels of up to 0.01 per cent, while industrial grade toluene may contain benzene at levels of up to 25 per cent (IPCS, 1985).

Toluene is a commercially important chemical produced throughout the world in enormous quantities (IPCS, 1985). The annual consumption of toluene across the EU was estimated to be 2.8 million tonnes (excluding use in petrol). Toluene is produced both in the isolated form and as a component of mixtures, approximately 80% is used in industry as an intermediate in the production of other substances (ECB, 2003).

A major use of toluene is as a petrol additive to improve octane rating (ATSDR, 2000). The average concentration of toluene in UK fuels is 5 to 11 per cent (CONCAWE, 1997; UKPIA, 2005). The annual petrol consumption rate for the EU (1990 to 1994) was 120 million tonnes with an average of 11% toluene, which equates to approximately 13 million tonnes of toluene consumed per year in petrol (ECB, 2003).

It is also used as a raw material in the manufacture of a large number of chemicals such as benzene, xylene, phenol, toluene diisocyanate, benzoic acid, benzaldehyde, xylene, toluene sulfonylchloride, and other derivatives of toluene (IPCS, 1985; ECB, 2003).

Toluene is used as an intermediate or as a solvent in the manufacture of numerous products including household aerosols, paint, varnishes, adhesives, glue, explosives, dyes, detergents, pesticides, wood preservatives, pharmaceuticals, nail polish, cosmetics, stain removers, fabric dyes and in some printing and leather tanning processes (IPCS, 1985; ATSDR, 2000; ECB, 2003).

## Potential harm to human health

The principles behind the selection of Health Criteria Values (HCVs), and the definition of concepts and terms used, are outlined in *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c). Specific information on the toxicity of toluene is reviewed in *Contaminants in soil: updated collation of toxicological data and intake values for humans. Toluene* (Environment Agency, 2009d) and only a brief summary is presented here.

Toxicity to the central nervous system (CNS) is the main human health concern following medium- to long-term inhalation exposure. Although there is a lack of human studies of oral toxicity, nervous system toxicity has been observed in animal studies following ingestion.

Health Criteria Values for toluene are summarised in Table 1. The recommended inhalation tolerable daily intake (TDI) is based on CNS effects seen in workers exposed to toluene.

Toxicity data from repeated oral exposure are not available for humans. The recommended oral TDI in Table 1 is based on increased liver weights seen in 13-

**Table 1**

Recommended Health Criteria Values and estimated background adult intakes for toluene (Environment Agency, 2008d)

Parameter	Toluene
TDI <sub>oral</sub> , $\mu\text{g kg}^{-1} \text{ bw day}^{-1}$	223
MDI <sub>oral</sub> , $\mu\text{g day}^{-1}$	10
TDI <sub>inh</sub> , $\mu\text{g kg}^{-1} \text{ bw day}^{-1}$	1,400
MDI <sub>inh</sub> , $\mu\text{g day}^{-1}$	520

bw = bodyweight

MDI = mean daily intake

TDI = tolerable daily intake

week experimental mice studies.

No authoritative assessments of the health risks posed by dermal exposures to toluene have been identified (Environment Agency, 2009d). In view of the slower absorption of toluene through the skin than via the gastrointestinal tract, and the absence of an indication of any notable first-pass detoxification metabolism following oral absorption, Environment Agency (2009d) concludes that it would not seem unreasonable to assume that the oral HCV value could be used for a conservative screening of dermal risk (that is, dermal exposure could be compared with the oral TDI).

Background inhalation exposure to toluene from its presence in ambient air is low relative to toxicity and the inhalation mean daily intake (MDI) occupies only a very small fraction of the inhalation TDI.

Toluene was present in most of the food stuffs analysed by the then Ministry of Agriculture, Fisheries and Food (MAFF), with the highest concentrations found in milk and beverages (MAFF, 1995). However, background oral exposure to toluene from its presence in food and water is low and the oral MDI similarly occupies only a very small fraction of the oral TDI (Environment Agency, 2009d).

Sources not taken into account in the MDI estimations include toluene in mainstream cigarette smoke, and toluene in air at localised areas of higher concentrations such as petrol stations and areas of industrial solvent manufacture/storage.

## Exposure assessment

### Occurrence in soil

Although toluene occurs naturally as a result of forest fires and is found in low concentrations in crude oil, these sources are small compared with anthropogenic inputs into the environment (ECB, 2003). Most soils will contain very little, if any, toluene as a result of natural processes or diffuse pollution.

### Volatilisation of toluene in soil

Rapid initial rates of BTEX volatilisation from soil have been reported, but removal via volatilisation from a sorbed or dissolved phase at depth can take considerably longer. For example, 90 per cent of toluene released to surface soils has been shown to volatilise within 24 hours, while the level of the same contaminant fell by less than 3 per cent in a year at depths of 1–1.3 metres below ground (ATSDR, 2000).

Toluene is commercially manufactured by a variety of different petroleum distillation conversion processes (ECB, 2003). It can enter the environment at production sites, but also during distribution and use (ECB, 2003). Highly elevated concentrations in soil can occur as a result of localised spills of petroleum and solvent products from historical use and poor management practice (which often results in persistent contamination over a wide area). Toluene is often a component of complex and weathered mixtures of hydrocarbon compounds, and may exist in soil as a degradation by-product.

IPCS (1985) estimated that about 86 per cent of the toluene produced is eventually released to the environment. Although almost all of this toluene is discharged directly into the atmosphere, small amounts are released through land disposal of sludges and petroleum wastes (ATSDR, 2000).

A review of the literature identified no data regarding background levels of toluene in UK soils. A similar conclusion was drawn by Paterson *et al.* (2003) in work commissioned by the Scottish Environment Protection Agency (SEPA). Neither ATSDR (2000) nor IPCS (1985) located any international studies of toluene levels in

urban or rural soils. According to Wolverhampton City Council (personal communication, 2009), average background concentrations of toluene in glacial drift deposits on a large housing estate in an urban area of the West Midlands were below the detection limit of  $1 \mu\text{g kg}^{-1}$ .

ECB (2003) reported average toluene concentrations in unspecified soils in the Netherlands of  $0.001 \text{ mg kg}^{-1}$ , while seven samples from uncontaminated sites in Florida, USA, reported results below the detection limit of  $<0.04 \mu\text{g kg}^{-1}$ .

### Behaviour in the soil environment

Recommended values for chemical data used in the exposure modelling of toluene are provided in Table 4. Further information about the selection of chemical properties can be found in Environment Agency (2008). *Supplementary information for the derivation of SGVs for toluene* (Environment Agency (2009e) provides additional information about the review and recommendations for the soil-to-plant concentration factors for toluene.

Toluene is considered by most authoritative organisations to be mobile in the soil environment (IPCS, 1985; ATSDR, 2000).

Upon release into soil, toluene will tend to sink through the unsaturated zone until it reaches the saturated zone (Environment Agency, 2003). It is a light non-aqueous phase liquid (LNAPL) and will tend to collect at the water table if present in sufficient concentrations.

Toluene can easily leach from soil given its aqueous solubility, molecular weight and octanol–water partition coefficient ( $K_{ow}$ ) (Environment Agency, 2003). However, leaching is also controlled by its ability to adsorb to soil organic matter (SOM). Toluene has a moderate tendency to adsorb to SOM (reflected by its organic carbon–water partition coefficient,  $K_{oc}$ ). The sorption potential varies with changes in soil properties (e.g. soil organic matter, number of available adsorption sites and porosity) and environmental conditions (e.g. temperature) (IPCS, 1985; ATSDR, 2000).

Toluene will volatilise readily from surface soil given its high vapour pressure, high air–water partition coefficient and moderate  $K_{oc}$  (ATSDR, 2000; Environment Agency, 2003). Volatilisation from the soil to air is the most important of the transport processes for toluene, though the rate of volatilisation will decrease at greater depths (IPCS, 1985; ATSDR, 2000). Toluene will volatilise more readily from soils with a high air-filled porosity such as sands and gravels (Environment Agency, 2003). Volatilisation will be retarded in soils with a high soil organic matter as toluene will adsorb to organic matter (Environment Agency, 2003). It will also volatilise more slowly from water logged soils or those with a high moisture content because the rate of diffusion through water is much slower than in air (Environment Agency, 2003).

Toluene in soil is also subject to microbial degradation under both aerobic and anaerobic conditions; the former is typically much more rapid, with toluene expected to degrade readily under most aerobic environmental conditions (IPCS, 1985; ATSDR, 2000). Biodegradation

rates are dependent on factors including: the presence of sunlight; the type of microbes present; soil temperature; initial concentration of toluene; soil oxygen content; and potential presence of electron acceptors<sup>1</sup> (Environment Agency, 2000a, 2003).

ECB (2003) reports degradation half-lives for toluene in soil of 2–93 days<sup>2</sup> and proposes a conservatively derived aerobic half-life of 90 days for use in the estimation of soil concentrations. ATSDR (2000) reports typical degradation half-lives in the order of 1–7 days<sup>2</sup> in the soil environment. Davis and Madsen (1996) concluded that toluene concentrations in soil of greater than  $250 \text{ mg kg}^{-1}$  are likely to inhibit degradation processes, probably due to its inherent toxicity to the microbial population (though the extent of this effect was not reported).

A report prepared for the US Environmental Protection Agency (USEPA) describes a number of half-life studies based on laboratory investigations. These are not discussed here as the optimised conditions mean that the half-lives and thus degradation potential are not comparable with a real soil environment. Half-lives from groundwater studies are also not discussed as oxygen is often the rate limiting parameter for biodegradation. Results may therefore not be applicable to aerobic soils (USEPA, 1999).

The variation of biodegradation half-lives reported in soil and the physical-chemical parameters of toluene indicate that it would be removed rapidly upon entry into soil. However, site-specific conditions and the presence of other contaminants should be taken into account as, in some situations, toluene will remain in the soil longer than anticipated (Alvarez and Vogel, 1991).

Toluene contamination is often associated with spills of petroleum products. Key aspects of its environmental behaviour will be influenced by the presence of other compounds. The solubility and volatility of toluene are reported to decrease when present with other hydrocarbon compounds and after weathering of the compound has taken place (TPHCWG, 1998).

Modelling the partitioning of volatile organic compounds (VOCs) such as toluene from the soil to ambient or indoor air is subject to a number of simplifications and limitations (CIRIA, in press). Many environmental models, including the CLEA model, predict chemical concentrations in soil systems using simple linear partitioning models. CIRIA (in press) reports empirical data from a large number of site investigations in the US and UK which illustrates that this approach is conservative for many petroleum hydrocarbons across different situations and soil types.

Although the reasons for the difference between empirical and theoretical calculations is the subject of

<sup>1</sup> Electron acceptors are compounds which are capable of accepting electrons during oxidation–reduction reactions. Microbes obtain energy by transferring electrons from electron donors such as toluene to an electron acceptor (Environment Agency, 2000a). Typical electron acceptors found in soil include dissolved oxygen, nitrate, sulphate, iron, manganese and carbon dioxide (Environment Agency, 2000a)

<sup>2</sup> Assuming a first-order rate constant.



continued debate (CIRIA, in press), reported factors include sampling technique, biodegradation in the vapour phase, and natural ground heterogeneity. As soil vapour is transported upwards towards the building, biodegradation of petroleum hydrocarbons commonly occurs which can significantly affect the amount of vapour that will enter the building. Among other factors, this is dependent on the oxygen availability in the unsaturated zone (CIRIA, in press).

Using simple linear partitioning, the concentrations of petroleum hydrocarbons in the soil gas can be over-predicted by at least a factor of 10 (and up to a factor of 1,000) (Environment Agency, 2009b; CIRIA, in press).

Given the likely level of overprediction reported in empirical studies, it is not unreasonable to include a sub-surface soil to indoor air correction factor of 10 in the derivation of SGVs for toluene. This is the lower end of the range of over-predictions reported and, therefore, sufficiently conservative to be appropriate to use in a generic screening value.

Toluene is moderately hydrophobic based on its  $K_{ow}$  (Environment Agency, 2009e). The uptake into plants from soil therefore has the potential to occur directly through passive root uptake or indirectly following volatilisation of toluene from the soil and subsequent vapour phase sorption onto plant surfaces. When toluene enters the transpiration stream, it is likely to be transported to leaves and shoots. On entering the leaves, toluene may be transpired or retained in the leaves as bound residues. Surveys of toluene concentrations in plants have found that, following uptake of gaseous toluene, it tends to accumulate in oil-containing plant structures such as the waxy layers of leaves and fruit (Environment Agency, 2009e).

Available studies indicate that toluene can cause damaging effects in plants; these are dependent on the soil type, toluene concentration in soil, and plant species (Environment Agency, 2009e). Reduced seedling emergence and vigour, reductions in shoot and root growth, and chlorosis have been reported as symptoms of toluene phytotoxicity (Environment Agency, 2009e).

In the absence of sufficient data to specify soil-to-plant concentration factors for toluene, Environment Agency (2009e) recommends that the generic CLEA models for calculating soil-to-plant concentration factors are used in the derivation of SGVs.<sup>3</sup>

A review of the literature did not identify any studies for quantifying the dermal absorption fraction for toluene and therefore the default value of 0.1 proposed by Environment Agency (2009b) for all organic compounds was used in the derivation of the SGVs.

A review of the literature found no data relevant to the concentration of toluene in soil-derived household dust. There are a number of potential sources of toluene from products used in the home and therefore toluene is likely

to be present in indoor dust. But even if data were available regarding the level of toluene in household dust, it would be difficult to distinguish the observed enrichment of toluene in indoor dust derived from non-soil sources in the home and that from the soil. The default value of  $0.5 \text{ g g}^{-1}$  dry weight (DW) for the soil-to-dust transport factor was used in the derivation of the SGVs (Environment Agency, 2009b). This is considered to be a sufficiently conservative assumption.

### Soil Guideline Values

Soil Guideline Values for toluene are presented according to land use in Table 2. For residential and allotment land uses, SGVs are based on estimates representative of exposure of young children because they are generally more likely to have higher exposures to soil contaminants. Further information on the default exposure assumptions used in the derivation of SGVs can be found in *Updated technical background to the CLEA model* (Environment Agency, 2009b).

The SGVs for toluene given in Table 2 are based on a consideration of the oral, dermal and inhalation routes of exposure. The toxicological effects are considered to be systemic and the combined assessment criteria are presented.

The percentage of exposure attributable to each individual relevant pathway for the residential and allotment land use is presented in Table 3. The ADE/HCV ratios for oral and inhalation exposures are also presented. Modelling suggests that:

- the inhalation of vapours indoors is the most significant exposure pathway at the SGV (representing more than 50 per cent) for the residential land use. However because the HCV for inhalation exposure is much higher than that for oral exposure, the dominant exposure pathway driving the risk for the residential land use SGV is the consumption of homegrown produce;
- the consumption of homegrown produce is the most significant exposure pathway at the SGV for the allotment land use and is the pathway driving the risk;
- the exposure via dermal pathways is negligible, contributing less than 1% of total exposure for the residential and allotment land uses;
- the inhalation of dust is not an important exposure pathway. This is due to the high vapour pressure and Henry's Law constant of toluene, and its moderate preference to adsorb to soil organic matter.

Using the CLEA model to calculate an SGV for the commercial land use scenario results in an exceedance of the saturated vapour concentration for toluene at a concentration much lower than the combined assessment criterion. At the lower saturation limit, the vapour pathway contributes nearly 65 per cent of total exposure. At soil concentrations above the lower saturation limit there is potential for free phase contamination to be present. The CLEA model does not account for oral or dermal exposure via direct contact

<sup>3</sup> In the absence of suitable models for shrub fruit and herbaceous fruit (Environment Agency, 2009b), exposure from ingestion of shrub and herbaceous fruits was not included in the derivation of the SGVs.

with, or inhalation exposure from vapours arising from, free phase chemicals and may under estimate the risk to health at higher soil concentrations. The SGV has therefore been set equal to the lower of the aqueous and vapour saturation limit of 4,400 mg kg<sup>-1</sup> DW.

Analytical limits of detection<sup>4</sup> for toluene are dependent on the analytical technique used and range from 0.001 to 0.005 mg kg<sup>-1</sup> DW, with limits of quantification<sup>5</sup> ranging from 0.005 to 0.025 mg kg<sup>-1</sup> DW. Limits of detection and quantification can vary due to the range, sensitivity, set-up of the instrumentation being used and the sample matrix. MCERTS<sup>6</sup> accredited analytical methods for testing for toluene in soil are available.

**Table 2**

The Soil Guideline Values for toluene presented in this table should only be used in conjunction with the information contained in this briefing note and with an understanding of the exposure and toxicological assumptions contained in *Updated technical background to the CLEA model* (Environment Agency, 2009b), *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c) and *Contaminants in soil: updated collation of toxicological data and intake values for humans. Toluene* (Environment Agency, 2009d).

Land use	Soil Guideline Value (mg kg <sup>-1</sup> DW) <sup>1,2,3,4,5</sup>
	Toluene
Residential	610
Allotment	120
Commercial <sup>6</sup>	4.4 × 10 <sup>3</sup>

- Notes
- <sup>1</sup> Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% SOM. At a lower SOM, SGV may not be sufficiently protective.
  - <sup>2</sup> Generic assessment criteria for toluene will vary according to SOM for all land uses.
  - <sup>3</sup> Figures are rounded to one or two significant figures.
  - <sup>4</sup> SGVs assume that free phase contamination is not present.
  - <sup>5</sup> SGVs based on a sub-surface soil to indoor air correction factor of 10.
  - <sup>6</sup> SGVs presented are based on the vapour saturation limit.

Ingestion of drinking-water contaminated from on-site sources is not an exposure pathway included in the CLEA model (Environment Agency, 2009b). Toluene can be tasted in water at a concentration of between 0.04 and 1 mg L<sup>-1</sup> (ATSDR, 2000). Environment Agency

(2000b) and WRAS (2002) identify petroleum hydrocarbon compounds including toluene as having the potential to permeate certain types of plastic water pipes, especially where there is prolonged contact with heavily contaminated soils including the presence of free phase. Permeation is dependent on factors such as the chemical characteristics of toluene or the mixture present, the water content of the soil, the distribution between the soil, air and vapour phases (mobility and K<sub>oc</sub>), length of exposure and temperature (DWI, 1997).

RIVM (1995) proposed a method of estimating pipe permeation, although this is highly uncertain and the assessment will depend on the type of pipe work found, water usage and the soil concentration immediately adjacent to the pipe wall.

It is unlikely that soil concentrations of toluene at the level of the residential or allotment SGVs will pose a significant additional risk to health from this pathway. However, where contamination is found or is suspected close to buried water services, the risk assessor should consider its implications carefully and, where necessary, investigate the likelihood of contamination of the water supply.

The SGVs in Table 2 should be applied cautiously where free phase contamination is suspected (e.g. by taking into account visual and olfactory observations) and its potential presence at the surface should be considered qualitatively as part of the risk assessment. In such cases, alternative methodologies, such as those which model vapours from non-aqueous phase liquids (NAPLs), or a consideration of dermal contact with NAPLs may be more suitable (Environment Agency, 2009f).

The generic conceptual exposure models used to derive SGVs (as described in Environment Agency, 2009b) assume that:

- the source term is infinite;
- the source term is not itself reduced by biological or chemical degradation;
- toluene is present in isolation as a pure compound and not in a mixture.

Assessors undertaking a Detailed Quantitative Risk Assessment (DQRA) (Defra and Environment Agency, 2004) may wish to consider the applicability of these assumptions on a site-specific basis. The actual degradation half-life of a chemical in soil is highly site-specific and dependent on a number of influences including soil temperature, oxygen availability, microbial population and the presence of other contaminants. Biodegradation is reported to be reduced at concentrations over 250 mg kg<sup>-1</sup> (Davis and Madsen, 1996).

It is highly unusual for toluene to occur in isolation in a contaminated soil, although fate and transport calculations (such as those used by the CLEA model) normally assume single component behaviour. Its environmental behaviour will be influenced by the presence of other compounds in the mixture (TPHCWG,

<sup>4</sup> The amount of a substance that can be detected, but not measured quantitatively.

<sup>5</sup> The amount present of a substance that can be measured quantitatively.

<sup>6</sup> Environment Agency's Monitoring Certification Scheme.

1998; ATSDR, 2000). The assessor should consider the effects of other substances on the mobility of toluene as part of a Detailed Quantitative Risk Assessment. For example, when the inhalation of vapour is a key pathway, assessors may wish to use Raoult's Law to determine the effective vapour concentration of toluene in the mixture (TPHCWG, 1999, Environment Agency, 2003).

The phytoavailability of toluene to garden produce depends on a number of complex factors. The soil-to-plant concentration factors used in the derivation of the SGVs are calculated from generic algorithms (detailed in Environment Agency, 2009b) for a generic scenario and are dependent on the  $K_{ow}$  of toluene (that is, the degree to which toluene partitions between water and plant lipids). In circumstances where the SGV is exceeded and the consumption of produce is a significant pathway, assessors may wish to adjust for the site-specific measured SOM. A higher SOM will mean that less toluene is available for plant uptake into the plant because it remains sorbed to the soil.

Assessors undertaking a Detailed Quantitative Risk Assessment could also carry out further investigation (including the sampling and chemical analysis of edible parts of fruits and vegetables) to determine site-specific plant concentration factors. Herbaceous and shrub fruit produce groups have not been modelled in the derivation of SGV (Environment Agency, 2009b). In cases where these predominate the total fruit and vegetables consumed from a site, further consideration is necessary. However, the sampling and chemical analysis of edible parts of fruits and vegetables is unlikely to be an easy task.

Environment Agency (2009b) highlights some uncertainties in the Johnson and Ettinger algorithms used to estimate the concentrations within indoor air. It is recognised that the concentration of petroleum hydrocarbons within the building may be overestimated using this approach.

A number of factors contribute significantly to the amount of toluene that will partition into the soil vapour phase. When the inhalation of indoor air is the pathway driving the risk, assessors undertaking a Detailed Quantitative Risk Assessment could carry out further assessment such as soil vapour monitoring. Further guidance and information can be found in CIRIA (in press).

Exposure from dermal contact and direct soil ingestion pathways may be important in scenarios where the vapour pathway is actively or passively managed by, for example, the building design. Further discussion of these pathways can be found in Environment Agency (2009b).

**Table 3**

Contribution to total exposure for the relevant pathways as calculated by the CLEA software

	<b>ADE:HCV ratio</b>	
	<b>Residential</b>	<b>Allotment</b>
Oral ADE:HCV ratio at SGV	0.81	1.00
Inhalation ADE:HCV ratio at SGV	0.19	0
	<b>Contribution to exposure<sup>1,3</sup> according to land use (%)</b>	
<b>Exposure pathway</b>	<b>Residential</b>	<b>Allotment</b>
Ingestion of soil and indoor dust <sup>2</sup>	1.0	0.1
Consumption of homegrown produce and attached soil	36.0	99.4
Dermal contact (indoor)	0	0
Dermal contact (outdoor)	0.5	0.1
Inhalation of dust (indoor)	0	0
Inhalation of dust (outdoor)	0	0
Inhalation of vapour (indoor)	55.8	0
Inhalation of vapour (outdoor)	0	0.1
Oral background	0.1	0.3
Inhalation background	6.6	0.1

**Notes**<sup>1</sup> Rounded to one decimal place.<sup>2</sup> Treated as one pathway (see Environment Agency, 2009b).<sup>3</sup> Percentage contributions not presented for a commercial land use as the commercial SGV presented is at the vapour saturation limit.

ADE = Average Daily Exposure

HCV = Health Criteria Value



**Table 4**

Recommended chemical data for toluene (at 10°C unless stated)

Chemical property	Toluene	
Air–water partition coefficient, dimensionless	1.15E-01	Environment Agency (2008)
Dermal absorption fraction, dimensionless	0.1	Environment Agency (2009b)
Diffusion coefficient in air, $\text{m}^2 \text{s}^{-1}$	7.78E-06	Environment Agency (2008)
Diffusion coefficient in water, $\text{m}^2 \text{s}^{-1}$	5.88E-10	Environment Agency (2008)
Octanol–water partition coefficient (log), dimensionless	2.73	Environment Agency (2008)
Organic carbon–water partition coefficient (log), $\text{cm}^3 \text{g}^{-1}$	2.31	Environment Agency (2008)
Relative molecular mass, $\text{g mol}^{-1}$	92.14	Environment Agency (2008)
Soil–water partition coefficient, $\text{cm}^3 \text{g}^{-1}$	NA	
Vapour pressure, Pa	1,730	Environment Agency (2008)
Water solubility, $\text{mg L}^{-1}$	590	Environment Agency (2008)
Soil-to-dust transport factor, $\text{g g}^{-1} \text{DW}$	0.5	Environment Agency (2009b)
Sub-surface soil to indoor air correction factor, dimensionless	10	Recommended in this report.
Soil-to-plant concentration factor, $\text{mg kg}^{-1} \text{FW per mg kg}^{-1} \text{DW}$		
Green vegetable produce	To be modelled	Environment Agency (2009e)
Root vegetable produce	To be modelled	Environment Agency (2009e)
Tuber vegetable produce	To be modelled	Environment Agency (2009e)
Herbaceous fruit produce	To be modelled <sup>1</sup>	Environment Agency (2009e)
Shrub fruit produce	To be modelled <sup>1</sup>	Environment Agency (2009e)
Tree fruit produce	To be modelled	Environment Agency (2009e)

Notes <sup>1</sup> Algorithms are not presented in Environment Agency (2009b) for herbaceous and shrub fruit. Exposure from these pathways was therefore not considered in the derivation of the SGVs.

DW = dry weight

FW = fresh weight

NA = not applicable



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## Legal Status and Disclaimer

The CLEA Guidance incorporates the following

- 1) *Science Report SC050021/SR2: Human health toxicological assessment of contaminants in soil.*
- 2) *Science Report SC050021/SR3: Updated technical background to the CLEA model.*
- 3) *Science Report SC050021/SR4: CLEA Software (Version 1.04) Handbook.*
- 4) *CLEA Software version 1.04 (2009)*
- 5) *Toxicological reports and SGV technical notes*

The CLEA Guidance can help suitably qualified assessors to estimate the risk that a child or adult may be exposed to a soil concentration on a given site over a long period of exposure that may be a cause for concern to human health. The CLEA Guidance does not cover other types of risk to humans, such as fire, suffocation or explosion, or short-term and acute exposures. Nor does it cover risks to the environment or the pollution of water.

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The CLEA guidance describes the soil concentrations above which, in the opinion of the Environment Agency, there may be concern that warrants further investigation and risk evaluation for both threshold and non-threshold substances. These levels are a guide to help assessors estimate risk. It does not provide a definitive test for telling when risks are significant.

Regulators are under no obligation to use the CLEA Guidance.