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Soil Guideline Values for ethylbenzene in soil

Project SC050021 / ethylbenzene 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 ethylbenzene in soil.

SGVs and the 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. Ethylbenzene*. (Environment Agency, 2009d).

Supplementary information on ethylbenzene is also available (Environment Agency, 2008, 2009e).

All notes in the SGVs series, the introductory guide and further supplementary information can be downloaded from our website (<http://www.environment-agency.gov.uk/clea>).

Ethylbenzene

Ethylbenzene (CAS No. 100-41-4) – sometimes known as ethylbenzol or phenylethane – is a naturally occurring aromatic hydrocarbon compound, with an ethyl hydrocarbon group substituted on a benzene ring (IPCS, 1996; ATSDR, 2007). It is a colourless, volatile liquid (at room temperature and pressure) with a sweet, petrol-type odour (IPCS, 1996). Ethylbenzene has a low aqueous solubility, but is readily miscible with most organic solvents (IPCS, 1996); its solubility varies in the presence of other petroleum products (TPHCWG, 1998; ATSDR, 2007).

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.

Ethylbenzene forms naturally in forest fires and is a constituent of crude oil (IPCS, 1996). The most common method used to manufacture ethylbenzene is the Friedel–Crafts alkylation of benzene with ethene in the presence of an aluminium chloride catalyst (IPCS, 1996; ECB, 2005).

Ethylbenzene is also produced in the fractionation of crude oil and in the xylene manufacturing process (IPCS, 1996; ECB, 2005; ATSDR 2007). It is a component of “mixed xylenes”, representing around 15–20 percent of its composition (IPCS, 1997; ECB, 2005).

Total annual production of ethylbenzene in the European Union (excluding petroleum refining) is estimated to be approximately 5.28 million tonnes (ECB, 2005).

The primary use of ethylbenzene (excluding use in petrol) is in the production of styrene (IPCS, 1996; ECB, 2005; ATSDR, 2007); approximately 95–99.8 per cent is used in this way (ECB, 2005). A small fraction is used as an intermediate in the production of other chemicals (ECB, 2005). Other minor uses include as a solvent in paints, varnishes and rubbers, and as a constituent of asphalt and naphtha (IPCS, 1996; ATSDR, 2007).

Ethylbenzene is used as a petrol additive to improve the octane rating (ECB, 2005). The average concentration of ethylbenzene in petrol is around 2–3 per cent (MAFF, 1995; CONCAWE, 1997). Annual consumption of petrol across the EU (1990–1994) was about 120 million tonnes with an average of 2 percent ethylbenzene this equates to approximately 2.2 million tonnes of ethylbenzene consumed per year in petrol (ECB, 2005).

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 ethylbenzene and its compounds is reviewed in *Contaminants in soil: updated collation of toxicological data and intake values for humans*. Ethylbenzene (Environment Agency, 2009d) and only a brief summary is presented here.

The principal target organs for the toxicity of oral and inhaled ethylbenzene are the liver and kidneys.

Health Criteria Values for ethylbenzene are summarised in Table 1. The inhalation tolerable daily intake (TDI) is derived from the Tolerable Concentration in Air of 0.77 mg m^{-3} proposed by the Dutch Natural Institute for Public Health and the Environment (RIVM). This value is the most precautionary of three numerically very similar expert group proposals reviewed in Environment Agency (2009d).

The oral TDI in Table 1 is based on the no-observed adverse effect level (NOAEL) of ethylbenzene in rats given oral doses of 136 mg kg^{-1} bodyweight (bw) day^{-1} , five days per week for six months. Three expert groups used this NOAEL to derive an oral HCV of $100 \text{ } \mu\text{g kg}^{-1}$ bw day^{-1} , and this is recommended as the oral TDI (Environment Agency, 2009d).

Table 1

Recommended Health Criteria Values and estimated background adult intakes for ethylbenzene (Environment Agency, 2009d)

Parameter	Ethylbenzene
$\text{TDI}_{\text{oral}}, \mu\text{g kg}^{-1} \text{ bw day}^{-1}$	100
$\text{MDI}_{\text{oral}}, \mu\text{g day}^{-1}$	5
$\text{TDI}_{\text{inh}}, \mu\text{g kg}^{-1} \text{ bw day}^{-1}$	220
$\text{MDI}_{\text{inh}}, \mu\text{g day}^{-1}$	130

bw = bodyweight

MDI = mean daily intake

TDI = tolerable daily intake

No authoritative assessments of the health risks posed by dermal exposures to ethylbenzene have been identified (Environment Agency, 2009d). In the absence of a dermal HCV, both dermal and oral exposure will be compared against the oral HCV (Environment Agency, 2009c).

An inhalation mean daily intake (MDI) of $130 \text{ } \mu\text{g day}^{-1}$ is estimated for background exposure to ethylbenzene from its presence in ambient air.

Background oral exposure to ethylbenzene from its presence in food and water is considered to be low. Ethylbenzene was not found in most of the foodstuffs analysed by the then Ministry of Agriculture, Fisheries and Food (MAFF), although concentrations were

reported in carcass meat, offal, meat products, poultry, fish and nuts (MAFF, 1995).

The oral MDI of $5 \text{ } \mu\text{g day}^{-1}$ occupies only a very small fraction of the oral TDI (Environment Agency, 2009d).

Sources not included in the MDI estimations include: ethylbenzene in mainstream cigarette smoke; and in air at localised areas of higher concentrations such as petrol stations and areas of industrial solvent manufacture/storage and use.

Exposure assessment

Occurrence in soil

Ethylbenzene occurs in crude oil and is formed as a by-product from the combustion of natural materials (IPCS, 1996; ATSDR, 2007). These natural sources are considered to be small compared with anthropogenic sources (ATSDR, 2007).

Ethylbenzene is volatile, upon release to air the majority will partition into the atmosphere (ECB, 2005; ATSDR, 2007). A large proportion of the ethylbenzene released to the environment occurs during the production and processing of styrene or other solvents in which it is used (ECB, 2005; ATSDR, 2007). As a constituent of fuel, it is also emitted during storage and refuelling, and from the operation of motor vehicles and power stations (ECB, 2005; ATSDR, 2007). Furthermore, it can be released during combustion in waste incinerators (ECB, 2005).

A review of the literature identified no data regarding background levels of ethylbenzene in UK soils. A similar conclusion was drawn by Paterson *et al.* (2003) in work commissioned by the Scottish Environment Protection Agency (SEPA).

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

As there are no reports of significant background concentrations of ethylbenzene in soil, it would be expected that concentrations of ethylbenzene in uncontaminated areas would be low. Ethylbenzene concentrations in soil may be highly elevated as a result of localised spills of petroleum products and during historical production/processing of styrene or "mixed xylenes", and poor management practice.

Ethylbenzene is often a component of complex and weathered mixtures of hydrocarbon compounds and may exist in soils as a degradation by-product.

Behaviour in the soil environment

Recommended values for chemical data used in the exposure modelling of ethylbenzene are provided in Table 4. Further information about the selection of chemical properties for ethylbenzene can be found in Environment Agency (2008). *Supplementary information for the derivation of SGVs for ethylbenzene*

(Environment Agency, 2009e) provides additional information about the review and recommendations for the soil-to-plant concentration factors for ethylbenzene. Ethylbenzene is considered by most authoritative organisations to be moderately mobile in the soil environment (IPCS, 1996; ECB, 2005; ATSDR 2007).

Upon release into soil, ethylbenzene will tend to sink through the unsaturated zone until it reaches the saturated zone (Environment Agency, 2003). It has a low aqueous solubility and will tend to collect at the water table as a light non-aqueous phase liquid (LNAPL) if present in sufficient concentrations (IPCS, 1996).

Ethylbenzene can easily leach from soil given its aqueous solubility, molecular weight and octanol–water partition coefficient (K_{ow}) (Environment Agency, 2003). Ethylbenzene has a low to moderate tendency to sorb to SOM (reflected by its soil-to-water partition coefficient, K_{oc}) (IPCS, 1996; ECB, 2005; ATSDR 2007). Nonetheless, adsorption to soil will increase as SOM increases and this can influence ethylbenzene's potential to leach. The sorption potential also varies with changes in other soil properties (e.g. number of available adsorption sites, porosity and water content) and environmental conditions (e.g. temperature) (Environment Agency, 2003; ATSDR, 2007).

Ethylbenzene will volatilise readily from surface soil given its vapour pressure, air–water partition coefficient and K_{oc} , but less rapidly than benzene and toluene (TPHCWG, 1998; Environment Agency, 2003) and this is the most important of the transport processes (IPCS, 1996; ECB, 2005; ATSDR, 2007). Upon volatilisation into the atmosphere, it is degraded by photo-oxidation reactions (IPCS, 1996; Environment Canada, 2004; ECB, 2005; ATSDR, 2007). This photo-oxidation reaction is thought to contribute to smog formation (IPCS, 1996).

Ethylbenzene 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 SOM (ethylbenzene will adsorb to the SOM), or high moisture content (it will have to diffuse through the water in the first instance) (Environment Agency, 2003). The rate of volatilisation will also decrease at greater depths (IPCS, 1996; ECB, 2005; ATSDR, 2007).

Key aspects of ethylbenzene behaviour in the soil environment will be influenced by the presence of other compounds. The solubility and volatility of ethylbenzene are reported to decrease when present with other hydrocarbon compounds and after weathering of the compounds has taken place (TPHCWG, 1998).

Ethylbenzene in soil is also subject to microbial degradation under both aerobic and anaerobic conditions; the former is typically much more rapid (ATSDR, 2007). Biodegradation rates are dependent on several factors including: the type and population of microbes present; soil temperature; initial concentration of ethylbenzene; soil oxygen content; and the potential

presence of other electron receptors¹ (Environment Agency, 2000a, 2003; ATSDR, 2007).

There are limited data regarding the degradation half-life values of ethylbenzene. The reported range of half-life values for ethylbenzene in soil range from 0.14 to 231 days under aerobic conditions², and 2.47 to 1,155 days under anaerobic conditions² (Environment Agency, 2003) based on a first-order rate constant. Mackay *et al.* (2006) cited a range of aerobic degradation half-life values for ethylbenzene in soil from 3 to 10 days. ECB (2005) reported that no data were available from biodegradation tests of ethylbenzene in soil that could be used in a risk assessment.

A report prepared for the US Environmental Protection Agency (USEPA) describes a number of degradation 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).

Modelling the partitioning of volatile organic compounds (VOCs) such as ethylbenzene from 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 illustrate 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 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

¹ 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 ethylbenzene 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)

² These reported half-lives may also include other loss processes besides biodegradation.

the derivation of SGVs for ethylbenzene. 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.

Ethylbenzene is moderately hydrophobic based on its K_{oc} (Environment Agency, 2009e). The uptake of ethylbenzene into plants from soil therefore has the potential to occur directly through passive root uptake or indirectly following volatilisation of ethylbenzene from the soil and subsequent vapour phase sorption onto plant surfaces. On entering the leaves, ethylbenzene may be lost through transpiration or metabolised. Resulting metabolites may be retained in the leaves as bound residues, incorporated into structures, or transpired. Ethylbenzene has also been reported to accumulate in oil-containing plant structures such as the waxy layers of leaves and fruit (Environment Agency, 2009e).

Available studies indicate that ethylbenzene can cause damaging effects in some plants. Data are not widely documented, although reduced root length and mass have been reported as adverse effects (Environment Agency, 2009e).

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

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

A review of the literature found no data relevant to estimating the concentration of ethylbenzene in household dust from any sources, including soil. The default value of 0.5 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

The SGVs for ethylbenzene 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 ethylbenzene 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 at the SGV for the residential and the allotment land uses is presented in Table 3. The ADE/HCV ratios for oral and inhalation exposures are also presented. Modelling suggests that:

- the inhalation of indoor vapour and the consumption of homegrown produce are the most significant exposure pathway at the SGV for the residential land use (contributing approximately 55 per cent and 40 per cent, respectively, of total exposure). However, because the inhalation HCV is more than twice the oral HCV, the dominant exposure pathway driving the risk for this land use is the consumption of homegrown produce;
- the consumption of homegrown produce is the most significant exposure pathway at the SGV for allotment land use and is the pathway driving the risk;
- the exposure via dermal pathways is negligible, contributing less than 1 per cent of total exposure at the SGVs for both land uses;
- the inhalation of dust is not an important exposure pathway.

Using the CLEA model to calculate an SGV for the commercial land use scenario results in an exceedance of the saturated vapour concentration of ethylbenzene at a concentration much lower than the combined assessment criterion. At the lower saturation limit, the vapour pathway contributes almost 65 per cent of total exposure for ethylbenzene. 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 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 limits (the vapour limit) of $2.84 \times 10^3 \text{ mg kg}^{-1} \text{ DW}$.

Analytical limits of detection⁴ for ethylbenzene depend on the analytical technique used and range from 0.0005 to $0.010 \text{ mg kg}^{-1} \text{ DW}$, with limits of quantification⁵ ranging from 0.0025 to $0.050 \text{ mg kg}^{-1} \text{ DW}$. Limits of detection and quantification can vary due to the range, sensitivity, set-up of the instrumentation being used and the sample matrix. MCERTS⁶ accredited analytical methods for testing for ethylbenzene in soil are available.

³ 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.

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

⁵ The amount present of a substance that can be measured quantitatively.

⁶ Environment Agency's Monitoring Certification Scheme

Table 2

The Soil Guideline Values for ethylbenzene presented in this table should only be used in conjunction with the information contained in this technical 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. Ethylbenzene* (Environment Agency, 2009d).

Land use	Soil Guideline Value (mg kg ⁻¹ DW) ^{1,2,3,4,5}
	Ethylbenzene
Residential	350
Allotment ⁶	90
Commercial ⁷	2.8 × 10 ³

Notes

- ¹ Based on a sandy loam soil as defined in Environment Agency (2009a) and 6% soil organic matter (SOM). At a lower SOM, SGVs may not be sufficiently protective.
- ² Generic assessment criteria for ethylbenzene will vary according to SOM for all land uses.
- ³ Figures are rounded to one or two significant figures.
- ⁴ SGVs assume that free phase contamination is not present.
- ⁵ SGVs based on a sub-surface soil to indoor air correction factor of 10.
- ⁶ In applying the rules for non-soil background to the allotment SGV, the inhalation background ADE is limited to being no larger than the contribution of the inhalation soil ADE.
- ⁷ SGV for commercial land use capped at the lower of the vapour and aqueous saturation

Ingestion of drinking-water contaminated from on-site soil sources is not an exposure pathway included in the CLEA model (Environment Agency, 2009b). Environment Agency (2000b) and WRAS (2002) identify petroleum hydrocarbon compounds, including ethylbenzene, as having the potential to permeate certain types of plastic water pipes. Pipe permeation is especially likely to occur 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 the contaminant mixture present, the water content of the soil, the distribution between the soil, air and vapour phases (mobility and K_{oc}), 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 ethylbenzene at the level of the residential and 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 potential for free phase product should be assessed at the preliminary stage of risk assessment when formulating the outline conceptual model as outlined within Defra and Environment Agency (2004). For example, maps may show the presence of tanks or anecdotal information may indicate that spills might have occurred at the site. 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;
- ethylbenzene is present in isolation and not in a mixture with other compounds.

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.

It is highly unusual for ethylbenzene 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, 1998; ATSDR, 2007). The assessor should consider the effects of other substances on the mobility of ethylbenzene 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 ethylbenzene in the mixture (TPHCWG, 1999, Environment Agency, 2003).

The phytoavailability of ethylbenzene 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 some are dependent on the K_{ow} of ethylbenzene (that is, the degree to which ethylbenzene 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 ethylbenzene is available for plant uptake 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 SGVs (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 ethylbenzene that will partition into the soil vapour phase, including SOM (sorption to organic matter retards volatilisation). When the inhalation of indoor air is the risk driving pathway, 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).

As noted above, soil organic matter content may affect the vapour inhalation and plant uptake pathways significantly. SGVs are based on a SOM content of 6 per cent. At a lower SOM, they may not be sufficiently protective.

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

	ADE:HCV ratio	
	Residential	Allotment
Oral ADE to HCV ratio at SGV	0.62	1.0
Inhalation ADE to HCV ratio at SGV	0.38	0
	Contribution to exposure according to land-use (%) ^{1,3}	
Exposure pathway	Residential	Allotment
Ingestion of soil and indoor dust ²	1.7	0.2
Consumption of homegrown produce and attached soil	38.5	99.2
Dermal contact (indoor)	0	NA
Dermal contact (outdoor)	0.9	0.1
Inhalation of dust (indoor)	0	NA
Inhalation of dust (outdoor)	0	0
Inhalation of vapour (indoor)	53.5	NA
Inhalation of vapour (outdoor)	0	0.1
Oral background	0.2	0.3
Inhalation background	5.2	0.1

Notes¹ Values rounded to one decimal place.² Treated as one pathway (see Environment Agency, 2009b).³ 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

NA = not applicable (This exposure pathway is not included in the generic land use.)

Table 4
Recommended physical-chemical data for ethylbenzene (at 10°C unless stated)

Chemical property	Ethylbenzene	Reference
Air–water partition coefficient, $\text{cm}^3 \text{cm}^{-3}$	0.139	Environment Agency (2008)
Dermal absorption fraction, dimensionless	0.1	Environment Agency (2009b)
Diffusion coefficient in air, $\text{m}^2 \text{s}^{-1}$	7.04×10^{-6}	Environment Agency (2008)
Diffusion coefficient in water, $\text{m}^2 \text{s}^{-1}$	5.31×10^{-10}	Environment Agency (2008)
Octanol–water partition coefficient (log), dimensionless	3.15	Environment Agency (2008)
Organic carbon–water partition coefficient (log), $\text{cm}^3 \text{g}^{-1}$	2.65	Environment Agency (2008)
Relative molecular mass, g mol^{-1}	106.17	Environment Agency (2008)
Soil–water partition coefficient, $\text{cm}^3 \text{g}^{-1}$	NA	
Vapour pressure, Pa	553	Environment Agency (2008)
Water solubility, mg L^{-1}	180	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	As discussed above.
Soil-to-plant concentration factor, $\text{mg kg}^{-1} \text{FW plant per mg kg}^{-1} \text{DW soil}$		
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 ¹	To be modelled	Environment Agency (2009e)
Shrub fruit produce ¹	To be modelled	Environment Agency (2009e)
Tree fruit produce	To be modelled	Environment Agency (2009e)

Notes ¹ 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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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.

The CLEA Guidance is non-statutory. It does not purport to interpret the policies or procedures of the Environment Agency and shall not operate as a statutory licence, waiver, consent or approval from the Environment Agency. Nothing in the CLEA Guidance shall prejudice, conflict with or affect the exercise by the Environment Agency of its statutory functions, powers, rights, duties, responsibilities, obligations or discretions arising or imposed under the Environment Act 1995 or any other legislative provision enactment, bye-law or regulation.

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.