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## Soil Guideline Values for mercury in soil

### Science Report SC050021 / Mercury 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 elemental, inorganic and monomethylated forms of mercury 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. Mercury* (Environment Agency, 2009d). Supplementary information on mercury is also available (Environment Agency, 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>).

### Mercury and its compounds

In its elemental form, mercury (CAS No. 7439-97-6) is a dense, silvery white metal, which is a volatile liquid at room temperature (ATSDR, 1999). Mercury readily forms amalgams with a variety of other metals including sodium and zinc, although not with the lighter transition metals such as iron (Greenwood and Earnshaw, 1997).

Mercury forms inorganic compounds in both the  $\text{Hg}^{\text{I}}$  and  $\text{Hg}^{\text{II}}$  valent states (Greenwood and Earnshaw, 1997). Mercuric chloride (CAS No. 7487-94-7) has the chemical formula  $\text{HgCl}_2$  and is commonly used for experimental

studies on the toxicology and environmental behaviour of inorganic mercury (ATSDR, 1999).

A large number of organomercury compounds are also known and can be synthesised by the action of sodium amalgam or Grignard reagent<sup>1</sup> and  $\text{HgCl}_2$  with halogenated hydrocarbons (Greenwood and Earnshaw, 1997).

Mercury is most commonly encountered in the environment in elemental form, as inorganic mercuric ( $\text{Hg}^{\text{II}}$ ) compounds, or as monomethylmercury compounds with the general formula,  $\text{CH}_3\text{HgX}$ .<sup>2</sup> The most important source of mercury is the naturally occurring mineral, cinnabar ( $\text{HgS}$ ).

Monomethylated mercury compounds are most likely to be found in soil as a result of natural microbial transformation of inorganic mercury (ATSDR, 1999; Environment Canada, 2002). Toxicological studies have focused on methylmercury chloride (CAS No. 115-09-3) to represent organomercury compounds. Its chemical properties are used in this technical to be representative of monomethyl mercury compounds more generally (ATSDR, 1999).

Mercury has been used by man since ancient times and was known to the Egyptians, Chinese and Indians (Steinnes, 1995; Kabata-Pendias and Mukherjee, 2007). Global production fell markedly during the 20th century, with new mercury production in the European Union between 550–680 tonnes in 1999 (Kabata-Pendias and Mukherjee, 2007). During the latter years of the 20th century, mercury was used primarily in the recovery of gold and silver from ores and in the manufacture of fulminate (explosive salt) and vermilion (red pigment) (Steinnes, 1995).

<sup>1</sup> Alkyl or aryl magnesium halide

<sup>2</sup> X represents common anions including chloride, nitrate, sulphate and sulphide.

It was also used in agriculture, alkaline batteries, chloralkali plants, dental fillings, paints, pharmaceuticals, thermometers, and in electrical apparatus. Many of these applications have now been phased out in western countries (Steinnes, 1995; ATSDR, 1999; Kabata-Pendias and Mukherjee, 2007).

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

The principal target organs for the toxic effects of mercury are the central nervous system (CNS), the brain and the kidneys.

HCVs for elemental, inorganic and monomethyl mercury compounds are summarised in Table 1. They are derived separately for each chemical form of mercury to take into account differences in exposure, kinetics and toxicity.

Elemental mercury is volatile and well absorbed following inhalation, whereas absorption following oral ingestion is extremely limited. The main target of repeated inhalation exposure to elemental mercury is the CNS. Long-term and repeated occupational exposure to concentrations of  $20 \mu\text{g m}^{-3}$  produced mild effects on the CNS and provided the basis for the tolerable concentration in air of  $0.2 \mu\text{g m}^{-3}$  recommended for the derivation of the inhalation tolerable daily intake (TDI). Although the paucity of oral and dermal toxicity data precludes the derivation of an oral TDI for elemental mercury, a high degree of toxicity is unlikely.

**Table 1**

Recommended Health Criteria Values and estimated background adult intakes for elemental, inorganic and methylmercury compounds (Environment Agency, 2009d)

Parameter	Elemental Hg	Inorganic Hg <sup>2+</sup> †	Methyl Hg <sup>++</sup>
TDI <sub>oral</sub> , $\mu\text{g kg}^{-1} \text{ bw day}^{-1}$	not derived	2	0.23
MDI <sub>oral</sub> , $\mu\text{g day}^{-1}$	negligible	1	0.5
TDI <sub>inh</sub> , $\mu\text{g kg}^{-1} \text{ bw day}^{-1}$	0.06	(0.06) #	(0.23) ##
MDI <sub>inh</sub> , $\mu\text{g day}^{-1}$	0.05	—	—

Notes: † As the water solubility and bioavailability of mercurous (Hg<sup>I</sup>) compounds are much less than those of mercuric chloride, such compounds are likely to be less toxic and therefore the oral TDI applies to all inorganic compounds of mercury.

‡ Specifically excluded is dimethyl mercury, a highly volatile and toxic compound.

# Extrapolated from data for elemental mercury

## Based on route-to-route extrapolation of the TDI<sub>oral</sub> for methylmercury

bw = bodyweight

MDI = mean daily intake

TDI = tolerable daily intake

Single or repeated oral ingestion of inorganic mercury compounds has been linked to kidney toxicity in reported human cases. Similarly in rats, repeated oral administration of mercuric chloride for six months resulted in kidney damage with a no-observed adverse effect level (NOAEL) of  $0.16 \text{ mg kg}^{-1} \text{ bw day}^{-1}$  (as adjusted for continuous exposure). The tolerable dose from this rat study is recommended for the derivation of the oral TDI. There are no inhalation toxicity data from which to derive an inhalation TDI for inorganic mercury compounds. However, it would not be unreasonable to apply the inhalation TDI for elemental mercury to all inorganic forms.

The brain is the key target for the toxic effects of ingested methylmercury. Epidemiological studies indicate that developmental neurotoxicity may occur at maternal doses in the order of  $1 \mu\text{g kg}^{-1} \text{ bw day}^{-1}$  and the oral TDI has been derived to guard against such an effect. There are no inhalation toxicity data from which to derive an inhalation TDI for methylmercury but, based on its absorption and ultimate toxic mechanism, it would be appropriate to extrapolate from the oral TDI in this case.

No expert group derivations of HCVs for dermal exposure were identified for elemental, inorganic or monomethylated compounds of mercury, and dermal toxicity data are very limited (Environment Agency, 2009d). There are nevertheless indications that inorganic mercury and monomethylated compounds can be absorbed through skin. In the absence of a dermal HCV, in deriving SGVs dermal exposure has been compared to the oral HCV in line with Environment Agency (2009c).

The adult inhalation MDI for mercury from ambient air is estimated at  $0.05 \mu\text{g day}^{-1}$ , most of which will be in the elemental form. The adult MDI<sub>oral</sub> for inorganic and monomethylated mercury compounds from food and water combined are about 1.0 and  $0.5 \mu\text{g day}^{-1}$  respectively (Environment Agency, 2009d).

## Exposure assessment

### Occurrence in soil

Almost all commercial production of mercury comes from the sulphide ore, cinnabar, which results from hydrothermal mineralisation associated with volcanic activity (Steinnes, 1995; Kabata-Pendias and Mukherjee, 2007). Mercury abundance in the Earth's crust is very low being in the range  $0.02$  to  $0.06 \text{ mg kg}^{-1}$ , although it is likely to be more concentrated in argillaceous sediments and in coal (Kabata-Pendias and Mukherjee, 2007).

Anthropogenic activity is a major source of aerial emissions of mercury and a significant contributor to soil contamination (Steinnes, 1995; ATSDR, 1999). Most of the mercury in air is present as elemental mercury vapour: 90–99% according to EC (2001); over 95% according to ATSDR (1999); and 75% according to IPCS (1990), which assumed 5% occurred as inorganic

mercury and 20% as methylmercury. The main sources of contamination have been mining and smelting, burning of fossil fuels, industrial production of sodium hydroxide and chloride, and waste incineration although mercury also occurs in trace amounts in fertilisers used on farmland (Steinnes, 1995).

The UK Soil and Herbage Survey (SHS) is a comprehensive survey of the concentrations of major contaminants in soils and herbage across the UK. The UK SHS found total mercury concentrations in the range 0.07 to 1.22 mg kg<sup>-1</sup> for rural soils, with a mean value of 0.13 mg kg<sup>-1</sup> (Environment Agency, 2007). Urban soils were found to contain higher total mercury concentrations ranging from 0.07 to 1.53 mg kg<sup>-1</sup>, with a mean of 0.35 mg kg<sup>-1</sup> (Environment Agency, 2007).

### Behaviour in the soil environment

Recommended values for chemical data used in the exposure modelling of mercury and its compounds are shown in Table 6. Further information about the selection of chemical properties and the derivation of the soil-to-plant concentration factors for inorganic and methylated compounds of mercury can be found in *Supplementary information for the derivation of SGV for mercury and its compounds* (Environment Agency, 2009e).

Inorganic mercury may occur in three different valent states in soil depending on factors including redox potential, pH, soil organic matter (SOM) content and chloride ion concentration (Schlüter, 1993; Steinnes, 1995; Kabata-Pendias and Mukherjee, 2007).

Elemental mercury (Hg<sup>0</sup>) is stable in the presence of

#### Distribution of mercury in soil

In the late 1950s, an unknown quantity of mercuric nitrate and elemental mercury was released into East Fork Poplar Creek from a government facility in Oak Ridge, Tennessee. Total mercury concentrations in the floodplain soil along the creek were 0.5–3,000 mg kg<sup>-1</sup>, with an estimated total mass of 77,000 kg. Investigations in the late 1980s found that 85–88 per cent of the mercury was present as mercury sulphide, 6–9 per cent as elemental mercury and only 0.02 per cent as methylmercury (ATSDR, 1999).

sulphide species under strongly reducing conditions, but at increasing redox potential, it will precipitate as mercury sulphide. It is also formed by microbial transformation from Hg<sup>II</sup> and, due to its volatility, is an important component in the cycling of mercury between soil and air (Schlüter, 1993; Steinnes, 1995). Several studies have shown that the volatilisation of mercury increases with increasing soil moisture content (Steinnes, 1995; Kabata-Pendias and Mukherjee, 2007).

Although mercury can form inorganic compounds in the Hg<sup>I</sup> valent state (Hg<sub>2</sub><sup>+</sup>), the Hg<sup>II</sup> valent state is much

more stable in the soil environment and is the form normally encountered (Schlüter, 1993; Steinnes, 1995).

Due to its strong tendency to form complexes with other anions (such as Cl<sup>-</sup>, OH<sup>-</sup>, and S<sup>2-</sup>) and humic matter, the mercuric cation (Hg<sup>2+</sup>) is rarely found in soil solution under natural conditions and the major fraction is bound in soil minerals, or adsorbed to either inorganic mineral surfaces or to organic matter (Steinnes, 1995; ATSDR, 1999). Yin *et al.* (1996) observed in experimental studies that soil adsorption decreased significantly above pH 5 as a result of increasing amounts of dissolved organic matter and the tendency for mercury to complex strongly to organic carbon.

Inorganic mercury can be methylated by abiotic and microbial processes in soil systems and is the primary source of methylmercury compounds in soil (Schlüter, 1993; Steinnes, 1995; ATSDR, 1999; Environment Canada, 2002). In surface soils, about 1–3 per cent of total mercury is in the methylated form with the rest predominantly as Hg<sup>II</sup> compounds (Kabata-Pendias and Mukherjee, 2007).

Dimethyl mercury is a highly toxic and volatile compound, and is readily lost from soil to air. Monomethylated mercury compounds (CH<sub>3</sub>HgX) are also volatile and, due to their relatively high mobility compared with inorganic forms, they are the most important mercury species for environmental pollution (Schlüter, 1993; ATSDR, 1999). They are also sorbed to soils; for example, methylmercury chloride is most strongly adsorbed in soils at around pH 7 (Steinnes, 1995).

The phytoavailability and toxicity of mercury in soil–plant systems depends on its form in, and sorption to, soil with simple salts and elemental mercury causing the greatest hazard because of the potential to generate toxic vapours (Kabata-Pendias and Mukherjee, 2007). Plants differ in their ability to take up mercury and can develop a tolerance to high concentrations on contaminated sites, with corresponding elevated concentrations in edible parts compared with natural soils (Kabata-Pendias and Mukherjee, 2007).

Several studies have reported the accumulation of mercury in plant roots, although translocation within the plant to other parts including shoots and seeds will also occur (Schlüter, 1993; ATSDR, 1999; Kabata-Pendias and Mukherjee, 2007; Environment Agency, 2009e). Monomethylated mercury compounds may have higher transport rates than other forms of mercury, but there is currently insufficient evidence in the literature to quantify this effect (Schlüter, 1993; Environment Agency, 2009e).

Sartorelli *et al.* (2003) investigated the dermal absorption of inorganic mercury. Mercury concentrations in penetrated fluids were found to be below detection limits when studying the skin absorption of mercuric chloride from a loamy soil, although absorption was observed from a buffered solution.



Dermal absorption of inorganic mercury from soil is not expected to be significant and the default value for the dermal absorption fraction ( $ABS_d$ ) of 0 for inorganic chemicals has been used (ATSDR, 1999; USEPA, 2004; Environment Agency, 2009d).

There is insufficient information to evaluate the dermal absorption of monomethyl mercury from soil although absorption of dimethylmercury was reportedly very significant (ATSDR, 1999). The default value for the dermal absorption fraction ( $ABS_d$ ) for organic chemicals of 0.1 has been used (Environment Agency, 2009b).

A review of the literature found no data that could be used to provide a generalised mercury soil-to-dust transport factor. In the absence of a contaminant specific soil-to-dust transport factor, the default value of  $0.5 \text{ g g}^{-1} \text{ DW}$  has been used (Environment Agency, 2009b).

## Soil Guideline Values

Soil Guideline Values for the three different chemical forms of mercury 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).

SGVs for the three chemical forms of mercury differ significantly from each other for two reasons.

- Human toxicology differs for each of the three main forms, with elemental mercury and methylmercury the most toxic by the inhalation and oral routes respectively.
- Elemental mercury and monomethylmercury forms are much more volatile than inorganic mercury and therefore vapour inhalation is more likely to contribute to exposure.

The proportion of exposure attributable to each individual pathway for each standard land use is summarised in Tables 3, 4 and 5. However, elemental mercury is not included for the allotment and commercial land use because the SGV is capped at the saturation limit.

Modelling suggests that for inorganic and methylmercury:

- the ingestion of soil and indoor dust is the most significant exposure pathway for the residential and commercial and use.
- the consumption of homegrown produce is the most significant exposure pathway for the allotment land use.

The SGVs for elemental mercury consider only the inhalation route. Vapour intrusion into buildings is the most important exposure pathway. Absorption of

elemental mercury following oral ingestion is extremely limited and a high degree of toxicity is therefore unlikely (Environment Agency, 2009d).

Using the CLEA model to calculate an SGV for elemental mercury for the allotment and commercial land use scenarios results in an exceedance of the saturated vapour concentration of elemental mercury at a concentration much lower than the estimated inhalation assessment criterion. At the lower saturation limit, the vapour pathway contributes nearly 15 and 65 per cent of total exposure for the allotment and commercial land use respectively. 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 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 saturation limit (vapour) of  $26 \text{ mg kg}^{-1} \text{ DW}$ .

The vapour intrusion pathway can be significantly affected by a number of factors including soil properties, building design and the potential for preferential pathways through the soil and into the building. The uncertainties in modelling exposure via the intrusion of vapour into buildings are described in CIRIA (in press) and Environment Agency (2009b). Should the SGV be exceeded and the inhalation of indoor air be the risk driving pathway, further assessment such as soil vapour monitoring may be appropriate. Further information regarding this can be found in CIRIA (in press).

The contribution to exposure from dust is a minor pathway for elemental mercury for the residential scenario.

SGVs for inorganic mercury consider the oral, dermal and inhalation exposure routes. However, because of the use of the generic default value for the dermal absorption fraction (0), the modelled overall contribution from dermal exposure is zero.

SGVs for methylmercury consider the oral, dermal and inhalation routes.

Environment Agency (2009d) quotes a statement from WHO (2006) that "... in the case of women of childbearing age, it should be borne in mind that [methylmercury] intake should not exceed the PTWI [provisional tolerable weekly intake of  $1.6 \text{ } \mu\text{g kg}^{-1} \text{ bw}$ ], in order to protect the embryo and foetus". The SGVs for the residential and allotment land uses, which are based on a child aged 0 to 6 years, are also protective of an adult of childbearing age.

Using the CLEA model to calculate an SGV for methylmercury for the commercial land use scenario results in an exceedance of the saturated vapour concentration of methylmercury for the combined assessment criteria. However, the vapour inhalation pathway represents less than five percent of the total exposure at the lowest saturation limit and therefore the

SGV presented in Table 2 has not been adjusted to account for the vapour saturation limit.

**Table 2**

The Soil Guideline Values for mercury 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. Mercury* (Environment Agency, 2009d).

Land use	Soil Guideline Value (mg kg <sup>-1</sup> DW) <sup>1,2</sup>		
	Elemental Hg <sup>4</sup>	Inorgani c Hg <sup>2+</sup>	Methyl Hg <sup>+4</sup>
Residential	1.0	170	11
Allotment	26 <sup>3</sup>	80	8
Commercial	26 <sup>3</sup>	3,600	410

<sup>1</sup> Based on a sandy loam soil (Environment Agency, 2009b) and 6% SOM.

<sup>2</sup> Figures are rounded to one or two significant figures.

<sup>3</sup> SGV is based on the vapour saturation limit.

<sup>4</sup> For the purposes of modelling the vapour inhalation pathway, elemental mercury and methylmercury are treated as organic.

Analytical limits of detection<sup>3</sup> for total mercury depend on the analytical technique used and range from 0.1 to 2.0 mg kg<sup>-1</sup> DW, with limits of quantification<sup>4</sup> ranging from 0.5 to 10 mg kg<sup>-1</sup> DW. MCERTS (the Environment Agency's Monitoring Certification Scheme) accredited analytical methods for testing total mercury in soil are available.

Analytical limits of detection for elemental mercury are about 0.02 mg kg<sup>-1</sup> DW with a limit of quantification of about 0.1 mg kg<sup>-1</sup> DW.

Whilst analytical methods are available for testing methylmercury in soil, there are a limited number of commercially available techniques. It is not anticipated that routine analysis for methylmercury is undertaken, however, we recognise that there may be circumstances where methylmercury may be present in soil as a result of industrial contamination and risk assessors should consider this as part of their preliminary risk assessment (Defra and Environment Agency, 2004) including the need to analyse for it.

For general surface contamination and to simplify the assessment, the SGVs for inorganic mercury can normally be compared with chemical analysis for total mercury content because the equilibrium concentrations of elemental and methylmercury compounds are likely to be very low.

Although unlikely to form naturally in near-surface soils, assessors should consider carefully whether there is any evidence for elemental mercury to have been introduced into the soil by anthropogenic activity. This should be completed at the preliminary stage of risk assessment when formulating the outline conceptual model, as outlined within Defra and Environment Agency (2004). For example, elemental mercury may be present as a result of the historical use of the land by processes that used amalgams such as for millinery or chloralkali production. Should elemental mercury be present, it may be visually identifiable in the soil, if in sufficient concentrations. It is expected that elemental mercury will only be analysed for directly on a few sites.

Site-specific consideration should be given to peaty or flooded soils, or soils amended with sewage sludge, as these more reducing soil conditions may trigger increased methylation. In such cases, separate speciation of mercury may also be required.

The availability of mercury to garden produce depends on a number of complex factors. The soil-to-plant concentration factors are based on a geometric mean value calculated from a review of experimental studies (Environment Agency, 2009e). In circumstances where the SGV is exceeded and the consumption of produce is a significant pathway, assessors may wish to consider the likely forms of mercury in the soil. Factors such as pH and soil organic matter (SOM) should also be considered in any evaluation of the likelihood of exposure via this pathway. The form of mercury in the soil affects the amount of the mercury available to the plant. Soil adsorption of mercury may decrease above pH 5 and therefore there is the potential that more mercury will be available for plant uptake. Where appropriate, further investigation (including the sampling and chemical analysis of edible parts of fruits and vegetables) could be undertaken to establish site specific plant concentration factors.

<sup>3</sup> The amount of a substance that can be detected, but not quantitatively measured.

<sup>4</sup> Amount present of a substance that can be quantitatively measured

**Table 3**

Contribution to total exposure for the relevant pathways expressed as a percentage, calculated by the CLEA model for the residential with the consumption of homegrown produce land use.

Exposure pathway	ADE to HCV Ratios		
	Elemental mercury	Inorganic mercury	Methyl mercury
Oral ADE to HCV ratio at SGV	NR	0.93	0.82
Inhalation ADE to HCV ratio at SGV	1.00	0.07	0.18
<b>Contribution to total exposure<sup>1</sup> for the residential land use (%)</b>			
	Elemental mercury	Inorganic mercury	Methyl mercury
Ingestion of soil and indoor dust <sup>2</sup>	NR	66.7	36.1
Consumption of homegrown produce and attached soil	NR	30.1	16.3
Dermal contact (indoor)	NR	0	0.7
Dermal contact (outdoor)	NR	0	17.9
Inhalation of dust (indoor)	0	0.2	0.1
Inhalation of dust (outdoor)	0	0	0
Inhalation of vapour (indoor)	94.9	0	17.0
Inhalation of vapour (outdoor)	0	0	0
Oral background	NR	3.0	12.0
Inhalation background	5.1	0	0

Notes <sup>1</sup> Rounded to one decimal place

<sup>2</sup> Treated as one pathway (see, Environment Agency, 2009b)

ADE = Average Daily Exposure

HCV = Health Criteria Value

NR = Not relevant for elemental mercury as discussed in text above



**Table 4**

Contribution to total exposure for the relevant pathways expressed as a percentage, calculated by the CLEA model for the allotment land use.

Exposure pathway	ADE to HCV Ratios	
	Inorganic mercury	Methyl mercury
Oral ADE to HCV ratio at SGV	1.0	0.99
Inhalation ADE to HCV ratio at SGV	0	0.01
	<b>Contribution to total exposure<sup>1,3</sup> for the allotment land use (%)</b>	
	Inorganic mercury	Methyl mercury
Ingestion of soil and indoor dust <sup>2</sup>	8.0	6.9
Consumption of homegrown produce and attached soil	89.2	76.8
Dermal contact (indoor)	NA	NA
Dermal contact (outdoor)	0	3.4
Inhalation of dust (indoor)	NA	NA
Inhalation of dust (outdoor)	0	0
Inhalation of vapour (indoor)	NA	NA
Inhalation of vapour (outdoor)	0	0.6
Oral background	2.8	12.2
Inhalation background	0	0

Notes <sup>1</sup> Rounded to one decimal place

<sup>2</sup> Treated as one pathway (see, Environment Agency, 2009b)

<sup>3</sup> Elemental mercury is not presented as the SGV is capped at the 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 5**

Contribution to total exposure for the relevant pathways expressed as a percentage, calculated by the CLEA model for the commercial land use.

Exposure pathway	ADE to HCV Ratios	
	Inorganic mercury	Methyl mercury
Oral ADE to HCV ratio at SGV	0.83	0.96
Inhalation ADE to HCV ratio at SGV	0.17	0.04
	<b>Contribution to total exposure<sup>1,3</sup> soil for the commercial land use (%)</b>	
	Inorganic mercury	Methyl mercury
Ingestion of soil and indoor dust <sup>2</sup>	98.5	79.5
Consumption of homegrown produce and attached soil	NA	NA
Dermal contact (indoor)	0	5.3
Dermal contact (outdoor)	0	7.8
Inhalation of dust (indoor)	0.6	0.5
Inhalation of dust (outdoor)	0	0
Inhalation of vapour (indoor)	0	3.1
Inhalation of vapour (outdoor)	0	0.7
Oral background	0.9	3.1
Inhalation background	0	0

Notes <sup>1</sup> Rounded to one decimal place

<sup>2</sup> Treated as one pathway (see, Environment Agency, 2009b)

<sup>3</sup> Elemental mercury is not presented as the SGV is capped at the 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 6**

Recommended chemical data for elemental mercury, inorganic mercury and methylmercury (at 10°C unless stated)

Chemical property	Elemental Hg		Inorganic Hg <sup>2+</sup>		Methyl Hg <sup>+</sup>	
Air-water partition coefficient, dimensionless	0.117	Estimated by Clapeyron relationship from the Henry's Law constant at 25°C	NA		<sup>†</sup> 9.00 × 10 <sup>-6</sup>	Recommended literature value
Dermal absorption fraction, dimensionless	NR		0	Environment Agency (2009b)	0.1	Environment Agency (2009b)
Diffusion coefficient in air, m <sup>2</sup> s <sup>-1</sup>	6.34 × 10 <sup>-6</sup>	Estimated by Heinsohn and Cimbala method (2003)	NA		8.61 × 10 <sup>-6</sup>	Estimated by FSG method
Diffusion coefficient in water, m <sup>2</sup> s <sup>-1</sup>	2.00 × 10 <sup>-9</sup>	Estimated by Hayduk and Laudie method (1974)	NA		8.61 × 10 <sup>-10</sup>	Estimated by Hayduk and Laudie method
Octanol–water partition coefficient (log), dimensionless	0.62	Recommended literature value	NA		1.7	Recommended literature value
Organic carbon–water partition coefficient (log), cm <sup>3</sup> g <sup>-1</sup>	4.16 <sup>#</sup>	Estimated from soil–water partition coefficient	NA		1.9	Calculated using non-hydrophobic relationship with the octanol–water partition coefficient
Relative molecular mass, g mol <sup>-1</sup>	200.59	Recommended literature value	NA		251.1	Recommended literature value
Soil–water partition coefficient, cm <sup>3</sup> g <sup>-1</sup>	NA		500	Recommended literature value	NA	
Vapour pressure, Pa	0.07028	Recommended literature value	NA		1.13 (25°C)	Recommended literature value
Water solubility, mg L <sup>-1</sup>	0.056 (25°C)	Recommended literature value	74,000 (20°C)	Recommended literature value	100 (21°C)	Recommended literature value
Soil-to-dust transport factor, dimensionless	0.5	Environment Agency (2009b)	0.5	Environment Agency (2009b)	0.5	Environment Agency (2009b)
Sub-surface soil to indoor air correction factor	1	Environment Agency (2009b)	1	Environment Agency (2009b)	1	Environment Agency (2009b)
<i>Soil-to-plant concentration factor, mg kg<sup>-1</sup> FW plant per mg kg<sup>-1</sup> soil</i>						
Green vegetable produce	NR		3.8 × 10 <sup>-3</sup>	Recommended literature value	<sup>†</sup> 3.8 × 10 <sup>-3</sup>	Recommended literature value
Root vegetable produce	NR		6.9 × 10 <sup>-3</sup>	Recommended literature value	<sup>†</sup> 6.9 × 10 <sup>-3</sup>	Recommended literature value
Tuber vegetable produce	NR		4.3 × 10 <sup>-3</sup>	Recommended literature value	<sup>†</sup> 4.3 × 10 <sup>-3</sup>	Recommended literature value
Herbaceous fruit produce	NR		1.0 × 10 <sup>-3</sup>	Recommended literature value	<sup>†</sup> 1.0 × 10 <sup>-3</sup>	Recommended literature value
Shrub fruit produce	NR		1.1 × 10 <sup>-3</sup>	Recommended literature value	<sup>†</sup> 1.1 × 10 <sup>-3</sup>	Recommended literature value
Tree fruit produce	NR		1.0 × 10 <sup>-3</sup>	Extrapolated from other produce categories	<sup>†</sup> 1.0 × 10 <sup>-3</sup>	Extrapolated from other produce categories

Notes: <sup>#</sup> Value estimated from soil–water partition coefficient for inorganic compounds of mercury at a fraction of organic carbon of 0.0348 (equivalent to 6% SOM).<sup>†</sup> K<sub>aw</sub> experimental value at Cl<sup>-</sup> ionic strength of 0.2 × 10<sup>-3</sup> mol.<sup>†</sup> Insufficient data to derive separate plant uptake factors for methylmercury compounds from soil solution and therefore data for inorganic compounds have been adopted.

FW = fresh weight

NA = not applicable because the CLEA model does not require these values in the derivation of assessment criteria for inorganic / organic chemicals.

NR = not relevant as oral pathways are not considered

## References

- ATSDR, 1999. *Toxicological Profile for mercury*. Atlanta, GA: US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Available from: <http://www.atsdr.cdc.gov/toxprofiles/tp46-p.pdf> [accessed 3 February 2009].
- CIRIA, in press. *The VOCs Handbook: Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination*. Unpublished Project No. RP766. London: Construction Industry Research and Information Association.
- DEFRA and ENVIRONMENT AGENCY, 2004. *Model procedures for the management of land contamination*. Contaminated Land Report 11. Bristol: Environment Agency.
- EC, 2001. *Ambient air pollution by mercury (Hg) position paper*. Brussels: European Commission. Available at: [http://ec.europa.eu/environment/air/pdf/pp\\_mercury.pdf#page=18](http://ec.europa.eu/environment/air/pdf/pp_mercury.pdf#page=18)
- ENVIRONMENT AGENCY, 2007. *UK Soil and Herbage Pollutant Survey. Report No. 7: Environmental concentrations of heavy metals in UK soil and herbage*. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009a. *Using Soil Guideline Values*. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009b. *Updated technical background to the CLEA model*. Science Report SC050021/SR3. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009c. *Human health toxicological assessment of contaminants in soil*. Science Report SC050021/SR2. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009d. *Contaminants in soil: updated collation of toxicological data and intake values for humans. Mercury*. Science Report SC050021/SR TOX7. Bristol: Environment Agency.
- ENVIRONMENT AGENCY, 2009e. *Supplementary information for the derivation of SGV for mercury and its compounds*. Bristol: Environment Agency.
- ENVIRONMENT CANADA, 2002. *Canadian tissue residue guidelines for the protection of consumers of aquatic life: methylmercury*. Report 1-4. Ottawa: Environment Canada.
- GREENWOOD, N.N. and EARNSHAW, A., 1997. *Zinc, cadmium and mercury*. In *Chemistry of the Elements* (2nd edn.), Chapter 29, pp. 1201–1226. Oxford: Butterworth-Heinemann.
- HAYDUK, W., LAUDIE, H., 1974. Prediction of diffusion coefficients for non-electrolysis in dilute aqueous solutions. *Journal of the American Institute of Chemical Engineers*, 20, 611-615.
- HEINSOHN, R.J. and CIMBALA, J.M., 2003. *Indoor Air Quality Engineering: Environmental Health and Control of Indoor Air Pollutants*. CRC Press
- IPCS, 1990. *Methylmercury*. Environmental Health Criteria No. 101. Geneva: WHO, International Programme on Chemical Safety. Available at: <http://www.inchem.org/documents/ehc/ehc/ehc101.htm>
- KABATA-PENDIAS, A. and MUKHERJEE, A.B., 2007. *Trace Elements from Soil to Human*. Berlin: Springer-Verlag.
- SARTORELLI, P., MONTOMOLI, L., SISINNI, A.G., BARABESI, L., BUSSANI, R., CHERUBINI, D.I. and SIMPLICIO, F., 2003. Percutaneous penetration of inorganic mercury from soil: an *In Vitro* study. *Bulletin of Environmental Contamination and Toxicology*, 71, 1091-1099.
- SCHLÜTER, K., 1993. *Soil and groundwater research report IV. The fate of mercury in soil: A review of current knowledge*. Brussels: European Commission.
- STEINNES, E., 1995. *Mercury*. In *Heavy Metals in Soils* (2nd edn.) (ed. B.J. Alloway). London: Blackie Academic & Professional.
- USEPA, 2004. *Risk assessment guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*. Final Report EPA/540/R/99/005. Washington, DC: US Environmental Protection Agency.
- WHO, 2006. *Evaluation of certain food additives and contaminants*. Sixty-seventy report of the Joint FAO/WHO Expert Committee on Food Additives, WHO Technical Report Series 940. Geneva: World Health Organization. Available from: <http://www.who.int/ipcs/publications/jecfa/reports/trs940.pdf> [Accessed 3 February 2009].
- YIN, Y., ALLEN, H.E., LI, Y., HUANG, C.P. and SANDERS, P.F., 1996. Adsorption of mercury (II) by soil: effects of pH, chloride, and organic matter. *Journal of Environmental Quality*, 25, 837-844.

## Publication Information

This technical note presents information from Science Project SC050021.

**Project manager:** Jo Jeffries, Science, Head Office

This work was funded by the Environment Agency's Science Department, which provides scientific knowledge, tools and techniques to enable us to protect and manage the environment as effectively as possible.

**Published by:** Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS32 4UD.

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### Research Contractor:

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### Dissemination Status:

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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.

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