APPENDIX A

Technical Data for HHRA Generic Assessment Criteria

VIRIDOR New England Energy from Waste Project

APPENDIX A

Contaminants of Concern – Derivation of Generic Assessment Criteria

Generic Assessment Criteria (GAC) derived using the Environment Agency's CLEA model are defined as screening tools for the generic quantitative risk assessment of chronic exposure to contaminants in soil (Defra and Environment Agency, 2004). They represent "trigger values", indicators to a risk assessor that above this level soil concentrations may pose a possibility of significant harm to human health (Defra, 2009b), although further investigation and evaluation of risk will usually be required.

The GAC used in this report for the Human Health Risk Assessment of contaminant levels in soil are primarily a mixture of soil guideline values (SGVs) recently published by the Environment Agency and GAC derived by Land Quality Management and the Chartered Institute for Environmental Health (LQM/CIEH) following the same principles (Nathanail et al., 2009).

Where a published Soil Guideline Value (SGV) or LQM/CIEH GAC is not available for the contaminants of concern SLR has derived de novo Generic Assessment Criteria (GACs) to assess the risk from deposited particulate material. GACs have been derived using CLEA model v1.05 (released by the Environment Agency in September 2009).

SLR GAC have been generated following the approaches recommended in the Environment Agency reports SR2-4 (Environment Agency, 2009a,b,c) Physico-chemical input parameters for the CLEA model were selected from Environment Agency/Defra publications (e.g. SR7, Environment Agency, 2009d), where available, and other authoritative data sources[1].

Generation of GACs for individual contaminants of concern and selection of the source data input to the CLEA model are detailed below. CLEA UK record sheets detailing the model input and output for calculation of the GAC are presented in Appendix B.

[1] For example, CRC Handbook of Chemistry and Physics, IUPAC-NIST Solubility Series and US Environmental Protection Agency databases.

1.0 THALLIUM

Thallium is an acute poison that can be lethal at low doses with effects on the gastrointestinal tract, cardiovascular and nervous systems. Long-term low dose exposure leads to similar but milder symptoms. The reproductive system appears to be susceptible to the toxic effects of thallium. Human toxicological data following long term low-level exposure are scarce as there are very few data on the effects of chronic occupational exposure to thallium.

The selected HCV for oral exposure (TDI_{oral}) is based on the USEPA oral reference dose (RfD) for thallium sulphate reported in IRIS (USEPA, 1990). The RfD is based on a 90-day study in rats which determined a no observed adverse effect level (NOAEL) of 0.25 $mg.kg^{-1}$ $bw.day^{-1}$ for increases in the incidence of alopecia, lacrimation and exophthalmos, together with increased serum aspartate aminotransferase, lactate dehydrogenase and sodium levels and decreased glucose levels. The RfD was derived by application of an uncertainty factor of 3000 (including 10 for subchronic to chronic extrapolation, 10 for intraspecies extrapolation, and 10 to account for species variability) plus a factor of 3 to account for lack of reproductive and chronic toxicity data. This gives an oral RfD of 8 $\times 10^{-5}$ $mg.kg^{-1}$ $bw.day^{-1}$ for thallium sulphate which is corrected to 6.5 $\times 10^{-5}$ $mg.kg^{-1}$ $bw.day^{-1}$ thallium as it is assumed that thallium is responsible for the compound's observed toxicity.

The selected HCV for inhalation exposure (TDI_{inh}) is based on 1% of the Workplace Exposure Limit (WEL) of 0.1 $mg.m^{-3}$ detailed in the 2007 Edition of HSE's EH40 document[2]. A TDI_{inh} of 3.0 $x10^{-4}$ $mg.kg^{-1}$ $bw.day^{-1}$ is derived based on the assumption that a 70 kg adult inhales $20m^3$ of air daily (Environment Agency, 2009c).

The main route of exposure to thallium is from food and an estimated mean daily intake (MDI) of thallium from food of 2 $\mu g.day^{-1}$ is reported in the HSDB profile of thallium compounds[3]. The same source reports an estimated daily thallium intake from air for a 70 kg adult of 3.4 ng.

HCVs, MDI and physico-chemical data input to the CLEA-UK model for thallium are detailed in Table 1-1 below with reference to the source of the data.

Table 1-1
Thallium Toxicological and Physico-Chemical Input Parameters for CLEA v1.05

Parameter	Value	Reference
TDI_{oral}	0.065 $\mu g.kg^{-1}$ $bw.d^{-1}$	IRIS Database (USEPA, 1990)
TDI_{inh}	0.3 $\mu g.kg^{-1}$ $bw.d^{-1}$	1% WEL (EH40, HSE 2007)
MDI_{oral}	2 $\mu g.d^{-1}$	HSDB
MDI_{inh}	3.4 $x10^{-3}$ $\mu g.d^{-1}$	HSDB
Aqueous solubility	3.9 $x10^{4}$ $mg.L^{-1}$	WHO EHC 182 (IPCS, 1996)
Kd	19 $L.kg^{-1}$	ATSDR, 1992
Dermal absorption factor	0.1	CLEA default for inorganics
Soil-Plant availability correction	5	CLEA Report (EA, 2009)

[2] http://www.hse.gov.uk/coshh/table1.pdf

[3] Hazardous Substances Data Bank [Thallium compounds] available August 2009 at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Parameter	Value	Reference
Internal plant distribution correction factors (fint) – 0.5		
Soil-plant concentration factor (CF) – Fresh Weight		
Green vegetables CF	0.004 (DW)	Baes et al. 1984
Root vegetables CF	0.004 (DW)	Baes et al. 1984
Tuber vegetables CF	0.004 (DW)	Baes et al. 1984
Herbaceous fruit CF	0.004 (DW)	Baes et al. 1984
Shrub fruit CF	0.004 (DW)	Baes et al. 1984
Tree fruit CF	0.004 (DW)	Baes et al. 1984
Soil-dust transport factor	0.5	CLEA default
Bioaccessible fraction	1	Default, assuming 100% bioavailability

The CLEA model v1.05 calculates GAC of 2.7 $mg.kg^{-1}$ thallium in soil for a 'residential with plant uptake' exposure scenario and 4.6 $mg.kg^{-1}$ for an allotment scenario. CLEA record sheets for calculation of the thallium GAC are provided in Appendix B.

Table 1-2
Generic Assessment Criteria for Thallium

Land Use	GAC ($mg.kg^{-1}$ dry weight soil)
Residential with home-grown produce	2.7
Allotment	4.6

References

ATSDR (1992) Toxicological profile for thallium. Agency for Toxic Substances and Disease Registry, Atlanta

Baes CF III, Sharp RD, Sjoreen AL & Shor RW (1984) A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture. ORNL-5786. Oak Ridge National Laboratory, Tennessee

Environment Agency (2009) Updated Technical Background to the CLEA Model. Science Report SC050021/SR3

IPCS (1996) Thallium. Environmental Health Criteria Document No 182. International Programme on Chemical Safety, WHO, Geneva.

USEPA (1990) IRIS Integrated risk assessment system, thallium sulfate, US Environmental Protection Agency. Available [August 2009] at http://www.epa.gov/iris/subst/0111.htm

2.0 CHROMIUM

The toxicity of chromium depends upon its oxidation state. Hexavalent chromium is more toxic than the trivalent form, which is considered to be an essential element. Chromium-containing substances of various chemical compositions and chromium oxidation states have been shown to cause sensitisation, or to produce reactions (skin or respiratory effects) in already sensitised people. Chromium(VI) is a known human carcinogen via inhalation, and has been shown to have mutagenic potential (Defra and Environment Agency, 2002a,b).

The derivation of generic assessment criteria for chromium is described briefly as the Environment Agency has previously published health criteria values (HCVs) in TOX 4 (Defra & EA, 2002a), which are still recommended for use until they are replaced by new reports during late 2009. The EA has also previously published an SGV for chromium (Defra & EA, 2002b) using a previous version of CLEA and LQM/CIEH has recently recommended GAC (Nathanail et al., 2009). However, the LQM/CIEH values are intended for use only where laboratory speciation of chromium has been undertake. Input parameter values and approaches used in the derivation of the previous SGVs and LQM/CIEH assessment criteria has heavily influenced the derivation of the GAC detailed below using CLEA v1.05. Input parameter values are summarised in Table 2.1-1, with reference to source material.

2.1 Parameter Values Input to CLEA v1.05

Table 2.1-1 below presents a summary of the parameters used in the CLEA v1.05 software to derive GAC for chromium.

Table 2.1-1
Chromium Toxicological and Physico-Chemical Input Parameters for CLEA v1.05

Model Parameter	Input value	Reference/comment
HCVoral (TDI)	3 $\mu g.kg^{-1}$ $bw.day^{-1}$	TOX 4 (Defra & EA, 2002a)
HCVinh (Index Dose)	0.001 $\mu g.kg^{-1}$ $bw.day^{-1}$	TOX 4 (Defra & EA, 2002a)
Oral MDI	13 $\mu g.day^{-1}$	TOX 4 (Defra & EA, 2002a)
Inh MDI	NR	Not relevant as Cr is considered as non-threshold contaminant by inhalation
Water Solubility	2.3 $x10^{6}$ $mg.L^{-1}$	LQM/CIEH, (Nathanail et al., 2009)
Kd	18 $cm^{3}.g^{-1}$	LQM/CIEH, (Nathanail et al., 2009)
Dermal Absorption Factor	0	CLEA default for inorganics
Soil-Plant availability correction	5	CLEA Report (EA, 2009)
Internal plant distribution correction factors (fint) – 1.0		
Soil-plant concentration factor (CF) – Fresh Weight		
Green vegetables CF	2.0 $x10^{-4}$	LQM/CIEH, (Nathanail et al., 2009)
Root vegetables CF	1.0 $x10^{-4}$	LQM/CIEH, (Nathanail et al., 2009)
Tuber vegetables CF	1.0 $x10^{-4}$	LQM/CIEH, (Nathanail et al., 2009)
Herbaceous fruit CF	0.09	LQM/CIEH, (Nathanail et al., 2009)
Shrub fruit CF	3.0 $x10^{-4}$	LQM/CIEH, (Nathanail et al., 2009)

Tree fruit CF	0.09	LQM/CIEH, (Nathanail et al., 2009)
Soil-dust transport factor	0.5	LQM/CIEH, (Nathanail et al., 2009)
Bioaccessible fraction	1	Default, assuming 100% bioavailability

2.2 Generic Assessment Criteria for Chromium Using CLEA v1.05

Generic Assessment Criteria (GAC) derived using the CLEA model are defined as screening tools for the generic quantitative risk assessment of chronic exposure to contaminants in soil (Defra and Environment Agency, 2004). They represent "trigger values", indicators to a risk assessor that above this level soil concentrations may pose a possibility of significant harm to human health (DEFRA, 2008), although further investigation and evaluation of risk will usually be required.

2.2.1 Chromium Generic Assessment Criteria for Residential Land Use and Allotments

GAC for chromium for residential land use and allotment scenarioss were derived using the Environment Agency's recently released CLEA v1.05 model (described in Environment Agency, 2009b) and are summarised in Table 2.2-1 below (see Appendix for CLEA v1.05 output record sheets).

As in the derivation of the previous (and now withdrawn SGV, Defra & EA, 2002b) it is assumed that chromium is present as the more toxic form, Cr(VI) and 'total chromium' measured in soil should be compared to these GAC; it is acknowledged that this is a highly conservative approach.

As for the arsenic SGVs and the BaP CCs derived in the previous section of this report, GAC for chromium have been derived by comparing oral+dermal exposure to $TDSI_{oral}$. This is because of the very small contribution to exposure that inhalation makes for non-volatile compounds and the fact that the ID_{inh} is orders of magnitude lower than the TDI_{oral} and would therefore make a disproportionate contribution in the derivation of assessment criteria for soil.

The 'residential with homegrown produce' GAC has also been adopted for the allotment scenario[4]. It should be noted that this assessment criteria is only marginally higher than the median background concentration of 39.3 mg/kg reported for chromium in soil in England and Wales (EA & Defra, 2002b) and is judged to be adequately protective of the health of a young child.

Table 2.2-1
Generic Assessment Criteria for Chromium

Land Use	GAC ($mg.kg^{-1}$ dry weight soil)
Residential with home-grown produce	45
Allotment	45

References

[4] Allotment GAC generated by CLEA v1.05 is 7.8 $mg.kg^{-1}$; this concentration is considered impractical for use in risk assessment as it is considerably lower than background levels in Uk soil

Defra and Environment Agency (2002a) Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Chromium, R&D Publication TOX 4.

Defra and Environment Agency (2002b) Soil Guideline Values for Chromium Contamination. R&D Publication SGV4

Environment Agency (2009) Updated Technical Background to the CLEA Model. Science Report SC050021/SR3

Nathanail CP, McCaffrey C, Ashmore M, Cheng YY, Gillett A, Ogden R & Scott D (2009) The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd Edition). Land Quality Press, Nottingham

3.0 LEAD

3.1 Identity, Sources and Background Concentrations

Lead is a naturally occurring element and the most common of the heavy metals. It is widely distributed in the earth's crust, air and water and occurs in a number of ores with galena (lead sulphide, PbS) being the most important (Defra & EA, 2002a). Industrial/commercial uses of lead include lead-acid batteries, ammunition, cable sheathing, sheet lead and solder. The use of lead in petrol, paint and pipes has now been phased out (HPA, 2007).

Elevated soil concentrations of lead can result from natural and anthropogenic sources. Naturally high levels of lead due to mineral deposits, often exacerbated by mining activities, exist in a number of areas across the UK. Soil is a significant sink for anthropogenic lead and its initial route of entry is often via the atmosphere (HSDB, 2009). Atmospheric lead levels have fallen as lead has been removed from petrol and has been replaced by emissions from industry and the burning of fossil fuels in terms of significance. The vast majority of atmospheric lead is present in an inorganic form and this report focuses on inorganic lead.

In addition to atmospheric fallout, solid wastes such as sewage sludge, leaded paints and industrial sources can all contribute to lead in soil (DEFRA & EA, 2002a).

McGrath & Loveland (1992) report a median background value of 40 $mg.kg^{-1}$ dw for total lead in all soil types in the UK (5692 samples). Median and 'upper hinge' values for the various soil types range from 32-145 and 62-403 $mg.kg^{-1}$ for sandy and peaty soils, respectively. Davies (1995) reports that normal surface (0-15 cm) soil lead content lies between 15 and 106 $mg.kg^{-1}$, with a geometric mean of 42 $mg.kg^{-1}$.

3.2 Behaviour in the Soil Environment

Two oxidation states of lead (Pb(II) and Pb(IV)) are stable but the environmental chemistry of lead is dominated by the plumbous ion, Pb2+ (Davies 1995). Lead is relatively immobile in soil and has been found to accumulate in the top horizons within the soil profile, especially in soils with at least 5% organic matter or a pH >5 (Davies, 1995; HSDB, 2009). There is also little evidence that it is readily lost from soil profiles by leaching. Lead binds strongly to clay minerals, organic matter (especially high molecular weight humic acids) and has a strong affinity for sulphur (Davies 1995). When soluble forms of lead are released to soil, it is expected to convert slowly to more insoluble forms such as lead sulphate, sulphide, oxide and phosphate salts (HSDB, 2009).

Studies have identified soil pH and cation exchange capacity as the main soil properties involved in the immobilisation of lead and concluded that soil organic matter is more important in this process than precipitation as the carbonate or sorption by hydrous oxides (Davies, 1995). Concentrations of lead in soil solution reach a minimum between pH 5 and 6 due to the formation of lead-organic complexes under these conditions (HSDB, 2009). Lead's residence time in so long that it can be regarded as permanent (Davies, 1995).

3.3 Toxicity of Lead and Health criteria values

3.3.1 Toxicology

The toxicity of lead has been well studied and there are a number of reports summarising health effects resulting from exposure to lead (e.g. ATSDR, 2007; WHO, 2003, HPA, 2007 & Defra & EA, 2002a). The distribution of lead within the human body has been found to be independent of the route of absorption; it is transported via red blood cells and is distributed among blood, bone and soft tissue (Defra and EA, 2002a). However, toxicity most frequently results from ingestion or inhalation and rarely from dermal or ocular exposure (HPA, 2007). Lead is primarily considered to be a chronic or cumulative toxin and few adverse health effects are observed following an acute exposure at lower doses (HPA, 2007).

The most sensitive targets for lead toxicity are the developing nervous system, the haematological and cardiovascular systems, and the kidney but the multi-modular action of lead on biological systems is such that it may potentially affect any system or organ in the body (ATSDR, 2007). HPA (2007) have reported that chronic lead exposure may lead to anaemia, headaches, irritability, tiredness, muscle weakness, paralysis, renal and hepatic injury and gastrointestinal disturbances. In children, chronic exposure may lead to cognitive deficit, manifested as a decrease in IQ.

Lead is of particular concern as it presents specific risks to the health of young children, who are the sensitive receptor considered in the generation of UK soil guideline values. This is thought to be because lead is partially absorbed by the same mechanism as calcium and calcium is better absorbed in children than adults as their growth demands more calcium (RIVM, 2008).

Traditionally the effects of lead have been described in relation to blood lead levels and most standards of health and exposure have been defined in terms of blood lead level, generally in terms of μg lead dL^{-1} blood. Lead interferes with haem synthesis and exposure to lead may lead to anaemia due to reduced haemoglobin production and shortened lifespan of erythrocytes. Reduced haemoglobin synthesis has been observed in adults and children at 40-50 μg dL^{-1}, although inhibition of haemoglobin sufficient to cause clinically observable anaemia has been reported at blood lead levels of 80-100 μg dL^{-1} (HPA, 2007).

Chronic exposure to lead leading to blood concentrations of 50-200 μg dL^{-1} may cause chronic effects to the kidney, i.e. chronic nephropathy characterised as a reduction in glomerular filtration rate, sparse nuclear inclusion bodies and irreversible atrophy of the proximal and distal tubules (HPA, 2007). Lead also exhibits effects on the human cardiovascular system and there are indications of increased hypertension at blood lead levels greater than 37 μg dL^{-1} (WHO, 2003). Reproductive effects have been observed following long-term exposure to lead and gonadal dysfunction has been associated with blood lead levels of 40-50 μg dL^{-1} (WHO, 2003). Reproductive dysfunction may also occur in females occupationally exposed to lead.

Several lines of evidence demonstrate that both the central and peripheral nervous systems are the principal targets for lead toxicity (WHO, 2003). These include subencepholpathic neurological and behavioural effects in adults but the major concern regarding lead toxicity is considered to be the cognitive and neuro-behavioural deficits observed in children exposed to lead. Epidemiological studies have shown an inverse relationship between blood lead concentrations above 10 μg dL^{-1} and IQ; an increase from 10 to 20 μg dL^{-1} is associated with a deficit of 2 IQ

points (HPA, 2007). However, it important to note that no threshold has been identified for the effects of lead on IQ (ATSDR, 2007; HPA, 2007) and the lowest blood lead concentration reported to cause such an effect was 5.6 µg dL^{-1}.

Inorganic lead compounds are classified as probably carcinogenic to humans (IARC Group 2A) based on limited evidence of an increased risk of cancer in workers following occupational exposure (IARC, 2004; HPA, 2007). The International Agency for Research on Cancer (IARC, 2004) has assessed potential mechanisms for leads observed carcinogenicity and concluded that there is little evidence that lead interacts directly with DNA. The genetic effects of lead appear to be mediated in part by the modulation of reactive oxygen species and the interactions with proteins, including those involved in DNA repair.

3.3.2 Selection of Health Criteria Values and Mean Daily Intakes

Health criteria values (HCVs) and mean daily intakes (MDIs) have been selected based on the principles outlined in the Environment Agency's technical guidance on toxicology (EA, 2009a) and where possible, HCVs were adopted from UK sources. HCVs for lead have not previously been recommended in the form of intake doses for human health risk assessment (HHRA) of contaminated land in the UK and the previous soil guideline value (SGV) for lead was based on empirical observation of the relationship between soil lead concentrations and blood lead levels. Recently, the Environment Agency has indicated that the new SGV for lead will be calculated using the CLEA model and will therefore be based on intake doses (for consistency with other contaminants and in order to better facilitate site specific risk assessment) but it is currently unclear whether these will be in the form of index doses or tolerable daily intakes (TDI) for oral/dermal and inhalation exposure pathways.

The 'HCV' previously recommended for use in HHRA of contaminated land is a blood lead level of 10 µg dL^{-1}, which is applicable to the blood of both adults and children and should take account of exposure from all routes and sources (Defra & EA, 2002a). The report containing this recommendation, TOX 6, also states that "expert groups generally consider that there may be no threshold for the neurotoxic action of lead and therefore the 10 µg dL^{-1} value would be associated with the additional requirement that exposures from all sources should be as low as reasonably practicable (ALARP)" (Defra & EA, 2002a).

3.3.3 Health Criteria Values

The ATSDR (2007) has not recommended minimal risk levels (MRLs) for lead as they consider there to be no clear threshold for some of the more sensitive effects of lead on humans that some studies suggest subtle neurobehavioural effects in children at very low blood lead levels. Similarly, the USEPA (2004) has not recommended a reference dose (RfD) or reference concentration (RfC) because the sensitive health effects caused by lead "may occur at blood lead levels so low as to be essentially without a threshold".

The only dietary intake value for lead recommended by an authoritative body is the provisional tolerable weekly intake (PTWI) of 25 µg.kg^{-1} recommended by JECFA[5] in 1987 (WHO, 1987). This equates to a tolerable daily intake (TDI) of 3.6 µg.kg^{-1} bw.day^{-1} and was based on dietary balance studies which showed that infants fed 3-4 µg Pb kg^{-1} bw.day^{-1} did not increase their blood lead and were in negative balance for lead. The PTWI of µg.kg^{-1} was reconsidered and retained by JECFA in 1993 and 1999 (WHO, 1993, 2000a) with the observation that a dietary intake of 1 µg.kg^{-1}

[5] Joint FAO/WHO Expert Committee on Food Additives

bw.day^{-1} would result in an increase in lead in blood of 1 µg dL^{-1} and that this relationship was valid during a long-term exposure period (in utero + 10 years) (WHO, 2000a). JECFA considered that consumption of the PTWI of 25 µg.kg^{-1} would lead to a blood lead concentration of 5.7 µg.dL^{-1} for a 10 kg child and that this blood lead level was below that generally associated with effects on intellectual performance.

The JECFA PTWI is used by the WHO in setting guideline values for lead in drinking water (WHO, 2003) and by the Dutch RIVM in deriving the lead Intervention Value (IV) for the HHRA of contaminated land (VROM, 2001; RIVM, 2001). Significantly, a TDI of 3.6 µg.kg^{-1} bw.day-1, based on the JECFA PTWI, is used by the UK Food Standards Agency (FSA) in risk assessment of lead in food (e.g. assessment of dietary lead intake in 2006 UK Total Diet Study; FSA, 2009) and this value is recommended here for use as the TDIoral for the calculation of soil assessment criteria. Although there is no acknowledged threshold for the neurotoxicological effects of lead the 'TDI approach' is adopted here as there is an obvious need to consider exposure from sources of exposure other than soil and the use of a TDI rather an index dose (ID) is considered to be more conservative as the background intake is subtracted from the TDI to generate a tolerable daily soil intake (TDSI) for the calculation of soil assessment criteria.

WHO revised air quality guidelines (WHO, 2000b) recommended that the annual average lead level in air should not exceed 0.5 µg.m^{-3} based on an objective of 98% of the population having a blood lead concentration of less than 10 µg.dL^{-1}, in which case the median blood lead value would not be more than 5.4 µg.dL^{-1}. This value of 0.5 µg.m^{-3} was set as a UK National Air Quality Objective (AQO) to be achieved by 2004. A more stringent AQO of 0.25 µg.m^{-3} was to be met by 2008 and this is the value recommended for lead in air by the UK Expert Panel on Air Quality Standards (EPAQS) (DETR, 1998). An inhalation TDI (TDIinh) of 0.07 µg.kg^{-1} bw.day^{-1} is recommended based on the AQO of 0.25 µg.m^{-3}, assuming a 70 kg adult inhales 20m^3 per day.

3.3.4 Mean Daily Intake

Based on the results of chemical analysis of food samples taken during the 2006 UK Total Diet Study, the FSA estimated the UK population dietary exposure to lead as 6 µg.day^{-1}. TOX 6 (Defra & EA, 2002a) details the estimation of a similar intake originating from lead in drinking water, leading to an overall oral MDI of 12 µg.day^{-1}.

Airborne lead concentrations have decreased considerably since the introduction of unleaded petrol. In 1996 the average airborne lead concentration at nine urban sites was 93 ng.m^{-3} (Defra & EA, 2002a) while in 2007 the annual average lead concentration at seventeen urban sites across the UK was 15 ng.m^{-3} (DEFRA, 2009), Using the 2007 urban data results in a daily respiratory intake of about 0.3 µg.day^{-1} (based upon daily respiratory volume of 20m^3); this corresponds to 0.004 µg.kg^{-1} bw.day^{-1} for a 70 kg adult.

HCVs and MDIs for lead selected for input to the CLEA v1.05 model for the calculation of soil assessment criteria are detailed overleaf in Table 3.3-1.

Table 3.3-1
Health Criteria Values and Mean Daily Intake for Inorganic Lead

Parameter	Value

Parameter	Value
TDI_{oral}	3.6 µg.kg^{-1} bw.day^{-1}
TDI_{inh}	0.07 µg.kg^{-1} bw.day^{-1}
MDI_{oral}	12 µg.day^{-1}
MDI_{inh}	0.3 µg.day^{-1}

3.4 Physico-Chemical Input Values for Lead

Physico-chemical data were selected based on the principles outlined in the Environment Agency's CLEA report (EA, 2009b) which recommends the use of values routinely used by scientists within the field and from peer-reviewed databases. Physico-chemical input parameters for lead used to populate the CLEA v1.05 model were selected from authoritative peer-reviewed data handbooks (e.g. CRC Handbook of Chemistry and Physics; Lide, 2005) and the primary scientific literature.

3.4.1 Soil-Water Partition Coefficient, Kd

As reported in Section 3.2 it is commonly stated that lead is highly sorbed by soil and is generally considered to be immobile. HSDB (2009) report that log Kd values ranged from 2.2 to 7.6 for 9 soils with a mean value of 3.5 (equivalent to a Kd of ~3,200 cm^3.g^{-1}). Kd is soil-type dependent and the report for the PRISM model for plant uptake (Thorne et al., 2005) details Kd values of 2.7-27,000 cm^3.g^{-1} for sand; 990-270,000 for loam and 5.5-54,000 for clay. A 'reference value' of 1000 cm^3.g^{-1} for loam is recommended by Thorne et al (2005) and this Kd value is considered to be the most authoritative[6] and is therefore selected as input to CLEA v1.05.

3.4.2 Water Solubility

Lead compounds have varying solubility in water, with WHO (1995) reporting that the inorganic salts of lead, such as lead sulfide and the oxides of lead, are generally poorly soluble in water although the nitrate and, to a much lesser degree, the chloride are water soluble. Water solubility values for various lead compounds are detailed below in Table 3.4-1:

Table 3.4-1
Aqueous solubility of inorganic lead compounds (Lide, 2005)

Compound	Solubility in Water (mg.L^{-1})[7]
Lead oxide/sulphide	Insoluble
Lead chloride	1.08 x10^4
Lead nitrate	5.97 x10^5

The CRC Handbook (Lide, 2005) also details the aqueous solubility of inorganic compounds at various temperatures and the solubility of lead nitrate is reported as 473.5 g.L^{-1} at 10ºC (converted to 2.96 x105 mg.L^{-1} Pb2+). This value is selected as it is detailed in an authoritative, peer-reviewed data handbook and represents the highest solubility of the lead cation (Pb2+) from a simple salt and is also presented at the ambient soil temperature recommended in the CLEA technical guidance.

6 Thorne et al (2005) is used as the source of the Kd used in the calculation of the new mercury and selenium SGVs.
7 Aqueous solubility at 25ºC

3.4.3 Dermal Absorption Factor

Dermal absorption of lead is generally quite low (HPA, 2007). The ATSDR (2007) report studies with human volunteers that measured lead absorption of ≤0.3% following application of radio-labelled lead acetate and a dermal absorption factor of 0.003 is adopted here.

3.4.4 Plant Uptake Factors

Plant roots can take up contaminants from soil and the contaminants can then move to other compartments within the plant including the fruit, which may be consumed by people harvesting them. Different plants will take up and translocate contaminants to varying extents and the degree of uptake will also vary from contaminant to contaminant and depend on the soil conditions. The CLEA model predicts the chemical concentration in edible portions of fruits and vegetables from the relationship between the soil and plant known as the soil-to-plant concentration factor (CF).

The generic approach to estimate uptake of inorganic chemicals within the CLEA model is consistent with the approach used by the FSA within PRISM Version 2, a model designed to model the transport of radionuclides in the terrestrial foodchain (Thorne et al., 2005). The model distinguishes between broad categories of plants rather than individual species or varieties. In the default modelling approach with CLEA v1.05, a single generic soil-to-root concentration factor is adopted for an inorganic chemical based on Kd (the soil-water partition coefficient) and a proportionality constant, the 'soil-plant availability correction', guideline values for which are provided in the CLEA report (EA, 2009b). Transport of inorganic elements within the plant from the root zone to edible fruits etc. is estimated by correcting the calculated value of CR for the fraction reaching the internal plant system (fint). Therefore, the CLEA model requires four different fint values to account for the different internal plant partitioning behaviour. Input values for lead for the distribution fractions reaching different plants compartments were taken from the CLEA Report (EA, 2009b) and the PRISM Model Report (Thorne et al, 2005).

As indicated above, the CLEA model's treatment of the relationship between soil and plant concentrations is relatively complex and the choice of input parameters for estimating this relationship is very important. An alternative approach to generic modelling of root uptake and distribution between different plant compartments is the use of empirical soil-plant concentrations measured for different food plants corresponding to the CLEA plant categories.

Generally, only a small proportion of lead in soil is thought to be available for uptake in plants (Kataba-Pendias, 2001). A literature review was undertaken to identify suitable plant uptake data for lead. A number of papers were identified that demonstrated the uptake of lead by a number of plant species with the most significant uptake observed for root vegetables, such as carrots, and lettuce (Samse-Peterson et al, 2002; Pendergrass and Butcher, 2006). Tomato and bean plants were observed to mainly accumulate metals in their roots with little being translocated to the fruits (Cobb et al, 2000). No soil-to-plant concentration factors were identified for a number of the CLEA food plant categories during this review and the conservative approach was taken of adopting the maximum values recorded for uptake in above ground fruit or vegetables as input to the CLEA model for all above ground plant types.

Similar results were derived from the CLEA model using both the internal generic model based on PRISM and the selected soil-plant concentration factors[8]. The use of soil-plant concentration factors was selected as they are based on experimental measurements, which are preferred to modelled values.

3.4.5 Parameter Values Input to CLEA v1.05

Table 3.4-2 below presents a summary of the parameters used in the CLEA v1.05 software to derive GAC for inorganic lead.

Table 3.4-2
Lead Toxicological and Physico-chemical Input Parameters for CLEA v1.05

Model Parameter	Input value	Reference
HCV_{oral} – TDI[9]	3.6 $\mu g.kg^{-1}$ $bw.day^{-1}$	Based on WHO (1982) PTWI of 25 $\mu g.kg^{-1}$ bw. This value is used in UK food risk assessment (e.g. FSA, 2009)
HCV_{inh} – TDI	0.07 $\mu g.kg^{-1}$ $bw.day^{-1}$	Based on 70 kg adult inhaling 20 m^3 per day and EPAQs air quality guideline of 0.25 $\mu g.m^{-3}$, recommended as annual average (DETR, 1998).
Oral MDI	6.0 µg.day-1	2006 Total Diet Study (FSA, 2009)
Inh MDI	0.3 $\mu g.day^{-1}$	Calculated from Defra (2009) air quality archive - overall average from NPL Metals Data for UK in 2007 was 15 $ng.m^{-3}$.
Water Solubility	2.96 $x10^5$ $mg.L^{-1}$	Pb proportion of lead nitrate solubility (473.5 g L^{-1} at 10 ºC – Lide, 2005)
Kd	1000 cm3.g-1	Table 38 (Thorne et al, 2005)
Dermal Absorption Factor	0.003	Danish EPA
Soil-Plant availability correction	5	SR3 (EA, 2009b)
Internal plant distribution correction factors (fint)		
Root-Shoot f_{int}	0.2	Thorne et al (2005). 20% of soil absorbed lead is translocated to shoots, the rest remains in the roots.
Root-Root f_{int}	0.8	Thorne et al (2005). 20% of soil absorbed lead is translocated to shoots, the rest remains in the roots.
Root-Tuber f_{int}	0.8	Thorne et al (2005). 20% of soil absorbed lead is translocated to shoots, the rest remains in the roots.

[8] Allotment GAC calculated as 260 $mg.kg^{-1}$ using generic model and 250 $mg.kg^{-1}$ using selected experimental soil-plant concentration factors.
[9] Lead may be considered to be a non-threshold contaminant and therefore represented by an index dose. However the WHO recommendation for safe intake is presented as a 'provisional tolerable weekly intake' and consideration of the HCV as a TDI and subsequent subtraction of MDI is a more conservative approach.

Model Parameter	Input value	Reference
Root-Fruit f_{int}	0.06	Thorne et al (2005). Observation reported of grain:stem:root ratios of approx. 1:2:13 in grain on dry weight basis.
Soil-plant concentration factor (CF)		
Green vegetables CF	0.0038	Samse-Peterson et al (2002); highest reported value for lettuce/beans
Root vegetables CF	0.05	Samse-Peterson et al (2002); highest reported value for carrot with peel
Tuber vegetables CF	0.003	Samse-Peterson et al (2002); highest reported value for potato with peel
Herbaceous fruit CF	0.0038	Samse-Peterson et al (2002); assumed equal to green vegetables
Shrub fruit CF	0.0038	Samse-Peterson et al (2002); assumed equal to green vegetables
Tree fruit CF	0.0038	Samse-Peterson et al (2002); assumed equal to green vegetables
Soil-dust transport factor	0.5	CLEA default. SR3 (EA, 2009b)
Bioaccessible fraction (soil)	1	Default, assuming 100% bioavailability
Bioaccessible fraction (dust)	1	Default, assuming 100% bioavailability

3.5 Deriving Generic Assessment for Lead Using CLEA V1.05

GAC derived using the CLEA model are defined as screening tools for the generic quantitative risk assessment of chronic exposure to contaminants in soil (Defra and Environment Agency, 2004). They represent “trigger values”, indicators to a risk assessor that above this level soil concentrations may pose a possibility of significant harm to human health (Defra, 2008), although further investigation and evaluation of risk will usually be required.

3.5.1 Lead Generic Assessment Criteria for Residential Land Use and Allotments

GAC for inorganic lead for residential land use and allotment scenarios were derived using the Environment Agency’s recently released CLEA v1.05 model (described in Environment Agency, 2009b) and are summarised in Table 3.5-1 below (See Appendix for CLEA v1.05 output record sheets).

Table 3.5-1
Residential GAC for Inorganic Lead

Land Use	GAC ($mg.kg^{-1}$ dry weight soil)
Residential with home-grown produce	290
Residential without home-grown produce	340
Allotment	250

For the 'residential with home-grown produce' scenario the dominant exposure pathway from soil is the direct ingestion of soil/soil-derived dust, with consumption of homegrown produce and attached soil and dermal exposure making much smaller contributions (background oral exposure makes a significant contribution of ~20% for all exposure scenarios). For the 'residential without home-grown produce' scenario the dominant exposure pathway is ingestion of soil/soil-derived dust. Unsurprisingly, the dominant exposure pathway for a 'high end' consumer of homegrown produce considered by the allotment scenario is consumption of produce with attached soil with a smaller contribution from direct ingestion of soil. Pathway contributions to exposure calculated by the CLEA model are presented in Table 3.5-2 below.

Table 3.5-2
Pathway Contribution to Exposure

	% Contribution by Pathway		
Exposure Pathway	**Residential with home-grown produce**	**Residential without home-grown produce**	**Allotment**
Ingestion of soil & dust	65.26	77.48	13.79
Consumption of home-grown produce & attached soil	12.84	-	67.19
Dermal exposure	1.01	1.19	0.21
Inhalation of vapour	-	-	-
Inhalation of dust	0.21	0.25	0.01
Oral background	20.47	20.84	18.80
Inhalation background	0.21	0.25	0.01

It should be noted that GAC generated using CLEA v1.05 and the associated technical guidance are designed to be protective of long-term (i.e. chronic) exposure to contaminants and are considered to also be adequately protective of acute exposure for most contaminants.

3.6 Comparison with 2002 SGV

In 2002 Defra and the Environment Agency (2002b) published soil guidelines (SGVs) for lead of:

- 450 $mg.kg^{-1}$ for residential with/without plant uptake; and
- 750 $mg.kg^{-1}$ for commercial/industrial

These SGVs were derived using empirical relationships between environmental lead exposure and blood lead concentrations for children and adults, respectively and these values therefore take some account of the bioavailability of lead in soil. However, these SGVs were withdrawn in 2008 and are no longer recommended for use in the risk assessment of contaminated land.

3.7 Conclusions and Recommendations

Generic assessment criteria for inorganic lead derived by SLR using CLEA v1.05 are:

- 290 $mg.kg^{-1}$ for residential with home-grown produce;
- 340 $mg.kg^{-1}$ for residential without home-grown produce; and
- 250 $mg.kg^{-1}$ for allotments.

These GAC are to be used for the generic quantitative risk assessment (GQRA) of contaminated land and represent “trigger values” that indicate to a risk assessor that above this level soil concentrations may pose a possibility of significant harm to human health (DEFRA, 2008) and that further investigation and evaluation of risk will be required.

These generic assessment criteria calculated using CLEA v1.05 are lower than the previous SGV and values recommended by other national bodies and are therefore considered to be adequately conservative and protective of human health.

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APPENDIX B

CLEA v1.05 Record Sheets

CLEA Software Version 1.05

Report generated	01-Oct-09
Report title	Residenital Generic Assessment Criteria
Created by	SLR Consulting at SLR

RESULTS

		Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?	
		oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal
1	Thallium	2.74E+00	1.27E+04	2.74E+00	1.00	0.00	1.00	NR	Yes	No
2	Chromium	4.52E+01	NR	NR	1.00	0.00	NR	NR	No	No
3	Lead	3.25E+02	2.20E+03	2.90E+02	0.89	0.11	1.00	#VALUE!	No	No
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	Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?	
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		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
1	Thallium	98.6	1.4	0.0	100.0	2.74E+00	NR	1.37E+00	1.17E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-03	1.13E-03	2.31E-03	6.37E-04	1.82E-03	1.72E-03
2	Chromium	98.5	1.5	0.0	100.0	4.52E+01	NR	2.26E+01	1.92E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.04E-03	4.52E-03	4.52E-03	4.07E+00	1.36E-02	4.07E+00
3	Lead	100.0	0.0	0.0	100.0	2.90E+02	NR	1.45E+02	1.23E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E-01	1.49E+00	1.83E-01	6.40E-02	1.83E-01	1.73E-01
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	Soil Distribution				Media Concentrations												
	Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
	%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
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		Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
		Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
1	Thallium	2.04E-05	1.68E-06	1.05E-05	6.46E-08	0.00E+00	1.13E-04	2.06E-07	31.26	2.58	16.06	0.10	0.00	0.00	49.90	0.10
2	Chromium	3.35E-04	1.93E-03	0.00E+00	1.06E-06	0.00E+00	7.31E-04	0.00E+00	11.17	64.45	0.00	0.00	0.00	0.00	24.38	0.00
3	Lead	2.15E-03	4.23E-04	3.32E-05	6.83E-06	0.00E+00	6.75E-04	1.82E-05	65.26	12.84	1.01	0.21	0.00	0.00	20.47	0.21
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	Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
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		Oral Health Criteria Value (µg kg^{-1} BW day^{-1})		Inhalation Health Criteria Value (µg kg^{-1} BW day^{-1})		Oral Mean Daily Intake (µg day^{-1})	Inhalation Mean Daily Intake (µg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
1	Thallium	TDI	0.065	TDI	0.3	2	0.0034	NR	NR	NR	NR	NR	0.1	0.5	1	1	1
2	Chromium	TDI	3	ID	0.001	13	NR	NR	NR	NR	NR	NR	0	0.5	1	1	1
3	Lead	TDI	3.6	TDI	0.07	12	0.3	NR	NR	NR	NR	NR	0.003	0.5	1	1	1
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	Oral Health Criteria Value (µg kg^{-1} BW day^{-1})		Inhalation Health Criteria Value (µg kg^{-1} BW day^{-1})		Oral Mean Daily Intake (µg day^{-1})	Inhalation Mean Daily Intake (µg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
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		Soil-to-water partition coefficient ($cm^3\ g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg\ L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
1	Thallium	1.90E+01	NR	3.90E+04	0.004 dw	0.004 dw	0.004 dw	0.004 dw	0.004 dw	0.004 dw
2	Chromium	1.80E+01	NR	2.30E+06	0.0002 fw	0.0001 fw	0.0001 fw	0.09 fw	0.0003 fw	0.09 fw
3	Lead	1.00E+03	0.00E+00	2.96E+05	0.0038 dw	0.05 dw	0.003 dw	0.0038 dw	0.0038 dw	0.0038 dw
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	Soil-to-water partition coefficient ($cm^3 g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
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CLEA Software Version 1.05

Report generated 02-Oct-09

Report title Allotment Generic Assessment Criteria

Created by SLR Consulting at SLR

RESULTS

		Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?	
		oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal
1	Thallium	4.60E+00	3.69E+05	4.60E+00	1.00	0.00	1.00	NR	Yes	No
2	Chromium	7.84E+00	NR	NR	1.00	0.00	NR	NR	No	No
3	Lead	2.49E+02	6.38E+04	2.48E+02	1.00	0.00	1.00	#VALUE!	No	No
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	Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?	
	oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal
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		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
1	Thallium	98.6	1.4	0.0	100.0	4.60E+00	NR	NA	7.83E-08	0.00E+00	NA	0.00E+00	0.00E+00	1.77E-03	1.89E-03	3.86E-03	1.07E-03	3.05E-03	2.89E-03
2	Chromium	98.5	1.5	0.0	100.0	7.84E+00	NR	NA	1.33E-07	0.00E+00	NA	0.00E+00	0.00E+00	1.57E-03	7.84E-04	7.84E-04	7.05E-01	2.35E-03	7.05E-01
3	Lead	100.0	0.0	0.0	100.0	2.48E+02	NR	NA	4.22E-06	0.00E+00	NA	0.00E+00	0.00E+00	9.05E-02	1.28E+00	1.56E-01	5.47E-02	1.57E-01	1.48E-01
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	Soil Distribution				Media Concentrations												
	Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
	%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
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		Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
		Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
1	Thallium	9.18E-06	1.88E-05	4.57E-06	3.73E-09	0.00E+00	1.13E-04	2.06E-07	14.12	28.84	7.03	0.01	0.00	0.00	49.99	0.01
2	Chromium	1.56E-05	2.25E-03	0.00E+00	6.36E-09	0.00E+00	7.31E-04	0.00E+00	0.52	75.10	0.00	0.00	0.00	0.00	24.38	0.00
3	Lead	4.95E-04	2.41E-03	7.40E-06	2.02E-07	0.00E+00	6.75E-04	1.82E-05	13.79	67.19	0.21	0.01	0.00	0.00	18.80	0.01
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	Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
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		Oral Health Criteria Value	(µg kg^{-1} BW day^{-1})	Inhalation Health Criteria Value	(µg kg^{-1} BW day^{-1})	Oral Mean Daily Intake (µg day^{-1})	Inhalation Mean Daily Intake (µg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
1	Thallium	TDI	0.065	TDI	0.3	2	0.0034	NR	NR	NR	NR	NR	0.1	0.5	1	1	1
2	Chromium	TDI	3	ID	0.001	13	NR	NR	NR	NR	NR	NR	0	0.5	1	1	1
3	Lead	TDI	3.6	TDI	0.07	12	0.3	NR	NR	NR	NR	NR	0.003	0.5	1	1	1
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	Oral Health Criteria Value (µg kg^{-1} BW day^{-1})		Inhalation Health Criteria Value (µg kg^{-1} BW day^{-1})		Oral Mean Daily Intake (µg day^{-1})	Inhalation Mean Daily Intake (µg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
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		Soil-to-water partition coefficient ($cm^3\ g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg\ L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
1	Thallium	1.90E+01	NR	3.90E+04	0.004 dw	0.004 dw	0.004 dw	0.004 dw	0.004 dw	0.004 dw
2	Chromium	1.80E+01	NR	2.30E+06	0.0002 fw	0.0001 fw	0.0001 fw	0.09 fw	0.0003 fw	0.09 fw
3	Lead	1.00E+03	0.00E+00	2.96E+05	0.0038 dw	0.05 dw	0.003 dw	0.0038 dw	0.0038 dw	0.0038 dw
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	Soil-to-water partition coefficient ($cm^3\ g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg\ L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
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APPENDIX C

CLEA Dioxin Worksheet_Infant

PCDDs, PCDFs and dioxin-like compounds worksheet for a user defined land use scenario

This worksheet should be used only in conjunction with *Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil, Science Report SC050021 / Dioxins SGV*

For each congener/compound, enter the site-specific representative soil concentration and the calculated exposure factor from the CLEA software in the respective grey and yellow boxes. Enter the oral TDSI for the age classes considered in the green box. The Hazard Index is the ratio of the total soil exposure to the oral TDSI.

Substance	Soil concentration		Exposure factor			TEF		Average Daily Exposure	Contribution to ADE
	ng kg^{-1} DW		mg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil	pg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil		-		pg WHO-TEQ kg^{-1} BW day^{-1}	%
2,3,7,8-TCDD	5.25E-05	x (	1.10E-11	1.10E-02	) x	1	=	5.76E-07	12.9
1,2,3,7,8-PeCDD	5.79E-05	x (	1.05E-11	1.05E-02	) x	1	=	6.11E-07	13.7
1,2,3,4,7,8-HxCDD	3.40E-05	x (	1.02E-11	1.02E-02	) x	0.1	=	3.47E-08	0.8
1,2,3,6,7,8-HxCDD	7.86E-05	x (	1.02E-11	1.02E-02	) x	0.1	=	8.02E-08	1.8
1,2,3,7,8,9-HxCDD	6.80E-05	x (	1.02E-11	1.02E-02	) x	0.1	=	6.94E-08	1.6
1,2,3,4,6,7,8-HpCDD	3.80E-04	x (	9.87E-12	9.87E-03	) x	0.01	=	3.75E-08	0.8
OCDD	5.70E-04	x (	9.78E-12	9.78E-03	) x	0.0003	=	1.67E-09	0.0
2,3,7,8-TCDF	1.09E-03	x (	1.20E-11	1.20E-02	) x	0.1	=	1.30E-06	29.3
1,2,3,7,8-PeCDF	2.36E-04	x (	1.09E-11	1.09E-02	) x	0.03	=	7.75E-08	1.7
2,3,4,7,8-PeCDF	3.26E-04	x (	1.09E-11	1.09E-02	) x	0.3	=	1.07E-06	24.0
1,2,3,4,7,8-HxCDF	2.09E-04	x (	1.03E-11	1.03E-02	) x	0.1	=	2.16E-07	4.8
1,2,3,7,8,9-HxCDF	1.50E-04	x (	9.96E-12	9.96E-03	) x	0.1	=	1.49E-07	3.4
1,2,3,6,7,8-HxCDF	2.52E-05	x (	9.96E-12	9.96E-03	) x	0.1	=	2.51E-08	0.6
2,3,4,6,7,8-HxCDF	1.68E-04	x (	1.03E-11	1.03E-02	) x	0.1	=	1.74E-07	3.9
1,2,3,4,6,7,8-HpCDF	2.93E-04	x (	9.96E-12	9.96E-03	) x	0.01	=	2.91E-08	0.7
1,2,3,4,7,8,9-HpCDF	4.50E-05	x (	9.96E-12	9.96E-03	) x	0.01	=	4.48E-09	0.1
OCDF	1.53E-04	x (	9.84E-12	9.84E-03	) x	0.0003	=	4.53E-10	0.0
PCB-77		x (			) x	0.0001	=		#VALUE!
PCB-81		x (			) x	0.0003	=		#VALUE!
PCB-126		x (			) x	0.1	=		#VALUE!
PCB-169		x (			) x	0.03	=		#VALUE!
PCB-105		x (			) x	0.00003	=		#VALUE!
PCB-114		x (			) x	0.00003	=		#VALUE!
PCB-118		x (			) x	0.00003	=		#VALUE!
PCB-123		x (			) x	0.00003	=		#VALUE!
PCB-156		x (			) x	0.00003	=		#VALUE!
PCB-157		x (			) x	0.00003	=		#VALUE!
PCB-167		x (			) x	0.00003	=		#VALUE!
PCB-189		x (			) x	0.00003	=		#VALUE!

Total WHO-TEQ ADE	**4.46E-06**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
TDSI	**1.00E+00**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
Hazard Index	**0.00**	

APPENDIX C

CLEA Dioxin Worksheet_Child

PCDDs, PCDFs and dioxin-like compounds worksheet for a residential land use scenario

This worksheet should be used only in conjunction with *Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil, Science Report SC050021 / Dioxins SGV*

For each congener/compound, enter the site-specific representative soil concentration in the respective grey box. The Hazard Index is the ratio of the total soil exposure to the oral TDSI.

Substance	Soil concentration		Exposure factor		TEF		Average Daily Exposure	Contribution to ADE
	ng kg^{-1} DW		pg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil		-		pg WHO-TEQ kg^{-1} BW day^{-1}	%
2,3,7,8-TCDD	5.25E-05	x	1.04E-02	x	1	=	5.47E-07	13.4
1,2,3,7,8-PeCDD	5.79E-05	x	1.04E-02	x	1	=	6.01E-07	14.7
1,2,3,4,7,8-HxCDD	3.40E-05	x	9.78E-03	x	0.1	=	3.32E-08	0.8
1,2,3,6,7,8-HxCDD	7.86E-05	x	9.78E-03	x	0.1	=	7.69E-08	1.9
1,2,3,7,8,9-HxCDD	6.80E-05	x	9.78E-03	x	0.1	=	6.65E-08	1.6
1,2,3,4,6,7,8-HpCDD	3.80E-04	x	8.94E-03	x	0.01	=	3.40E-08	0.8
OCDD	5.70E-04	x	8.72E-03	x	0.0003	=	1.49E-09	0.0
2,3,7,8-TCDF	1.09E-03	x	1.01E-02	x	0.1	=	1.10E-06	26.9
1,2,3,7,8-PeCDF	2.36E-04	x	1.01E-02	x	0.03	=	7.17E-08	1.8
2,3,4,7,8-PeCDF	3.26E-04	x	1.01E-02	x	0.3	=	9.89E-07	24.2
1,2,3,4,7,8-HxCDF	2.09E-04	x	9.61E-03	x	0.1	=	2.00E-07	4.9
1,2,3,7,8,9-HxCDF	1.50E-04	x	9.61E-03	x	0.1	=	1.44E-07	3.5
1,2,3,6,7,8-HxCDF	2.52E-05	x	9.61E-03	x	0.1	=	2.42E-08	0.6
2,3,4,6,7,8-HxCDF	1.68E-04	x	9.61E-03	x	0.1	=	1.61E-07	4.0
1,2,3,4,6,7,8-HpCDF	2.93E-04	x	8.97E-03	x	0.01	=	2.62E-08	0.6
1,2,3,4,7,8,9-HpCDF	4.50E-05	x	8.97E-03	x	0.01	=	4.04E-09	0.1
OCDF	1.53E-04	x	8.82E-03	x	0.0003	=	4.06E-10	0.0
PCB-77		x	1.29E-02	x	0.0001	=		
PCB-81		x	1.29E-02	x	0.0003	=		
PCB-126		x	1.29E-02	x	0.1	=		
PCB-169		x	1.29E-02	x	0.03	=		
PCB-105		x	1.29E-02	x	0.00003	=		
PCB-114		x	1.29E-02	x	0.00003	=		
PCB-118		x	1.29E-02	x	0.00003	=		
PCB-123		x	1.29E-02	x	0.00003	=		
PCB-156		x	1.29E-02	x	0.00003	=		
PCB-157		x	1.29E-02	x	0.00003	=		
PCB-167		x	1.29E-02	x	0.00003	=		
PCB-189		x	1.29E-02	x	0.00003	=		

Total WHO-TEQ ADE	**4.08E-06**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
TDSI	**1.00E+00**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
Hazard Index	**4.1E-06**	

APPENDIX C

CLEA Dioxin Worksheet_Adult

PCDDs, PCDFs and dioxin-like compounds worksheet for a user defined land use scenario

This worksheet should be used only in conjunction with *Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil, Science Report SC050021 / Dioxins SGV*

For each congener/compound, enter the site-specific representative soil concentration and the calculated exposure factor from the CLEA software in the respective grey and yellow boxes. Enter the oral TDSI for the age classes considered in the green box. The Hazard Index is the ratio of the total soil exposure to the oral TDSI.

Substance	Soil concentration		Exposure factor			TEF		Average Daily Exposure	Contribution to ADE
	ng kg^{-1} DW		mg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil	pg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil		-		pg WHO-TEQ kg^{-1} BW day^{-1}	%
2,3,7,8-TCDD	5.25E-05	x (	2.15E-12	2.15E-03	) x	1	=	1.13E-07	14.0
1,2,3,7,8-PeCDD	5.79E-05	x (	2.03E-12	2.03E-03	) x	1	=	1.18E-07	14.7
1,2,3,4,7,8-HxCDD	3.40E-05	x (	1.65E-12	1.65E-03	) x	0.1	=	5.62E-09	0.7
1,2,3,6,7,8-HxCDD	7.86E-05	x (	1.65E-12	1.65E-03	) x	0.1	=	1.30E-08	1.6
1,2,3,7,8,9-HxCDD	6.80E-05	x (	1.65E-12	1.65E-03	) x	0.1	=	1.12E-08	1.4
1,2,3,4,6,7,8-HpCDD	3.80E-04	x (	1.15E-12	1.15E-03	) x	0.01	=	4.36E-09	0.5
OCDD	5.70E-04	x (	1.01E-12	1.01E-03	) x	0.0003	=	1.74E-10	0.0
2,3,7,8-TCDF	1.09E-03	x (	2.27E-12	2.27E-03	) x	0.1	=	2.46E-07	30.6
1,2,3,7,8-PeCDF	2.36E-04	x (	1.99E-12	1.99E-03	) x	0.03	=	1.41E-08	1.8
2,3,4,7,8-PeCDF	3.26E-04	x (	1.99E-12	1.99E-03	) x	0.3	=	1.94E-07	24.2
1,2,3,4,7,8-HxCDF	2.09E-04	x (	1.59E-12	1.59E-03	) x	0.1	=	3.32E-08	4.1
1,2,3,7,8,9-HxCDF	1.50E-04	x (	1.18E-12	1.18E-03	) x	0.1	=	1.77E-08	2.2
1,2,3,6,7,8-HxCDF	2.52E-05	x (	1.18E-12	1.18E-03	) x	0.1	=	2.98E-09	0.4
2,3,4,6,7,8-HxCDF	1.68E-04	x (	1.59E-12	1.59E-03	) x	0.1	=	2.67E-08	3.3
1,2,3,4,6,7,8-HpCDF	2.93E-04	x (	1.18E-12	1.18E-03	) x	0.01	=	3.46E-09	0.4
1,2,3,4,7,8,9-HpCDF	4.50E-05	x (	1.18E-12	1.18E-03	) x	0.01	=	5.32E-10	0.1
OCDF	1.53E-04	x (	1.08E-12	1.08E-03	) x	0.0003	=	4.97E-11	0.0
PCB-77		x (			) x	0.0001	=		#VALUE!
PCB-81		x (			) x	0.0003	=		#VALUE!
PCB-126		x (			) x	0.1	=		#VALUE!
PCB-169		x (			) x	0.03	=		#VALUE!
PCB-105		x (			) x	0.00003	=		#VALUE!
PCB-114		x (			) x	0.00003	=		#VALUE!
PCB-118		x (			) x	0.00003	=		#VALUE!
PCB-123		x (			) x	0.00003	=		#VALUE!
PCB-156		x (			) x	0.00003	=		#VALUE!
PCB-157		x (			) x	0.00003	=		#VALUE!
PCB-167		x (			) x	0.00003	=		#VALUE!
PCB-189		x (			) x	0.00003	=		#VALUE!

Total WHO-TEQ ADE	**8.04E-07**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
TDSI	**1.00E+00**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
Hazard Index	**0.00**	

APPENDIX C

CLEA Dioxin Worksheet_Farmer

PCDDs, PCDFs and dioxin-like compounds worksheet for a user defined land use scenario

This worksheet should be used only in conjunction with *Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil, Science Report SC050021 / Dioxins SGV*

For each congener/compound, enter the site-specific representative soil concentration and the calculated exposure factor from the CLEA software in the respective grey and yellow boxes. Enter the oral TDSI for the age classes considered in the green box. The Hazard Index is the ratio of the total soil exposure to the oral TDSI.

Substance	Soil concentration		Exposure factor			TEF		Average Daily Exposure	Contribution to ADE
	ng kg^{-1} DW		mg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil	pg kg^{-1} BW day^{-1} per ng kg^{-1} DW soil		-		pg WHO-TEQ kg^{-1} BW day^{-1}	%
2,3,7,8-TCDD	5.25E-05	x (	2.86E-12	2.86E-03	) x	1	=	1.50E-07	13.8
1,2,3,7,8-PeCDD	5.79E-05	x (	2.75E-12	2.75E-03	) x	1	=	1.59E-07	14.6
1,2,3,4,7,8-HxCDD	3.40E-05	x (	2.36E-12	2.36E-03	) x	0.1	=	8.04E-09	0.7
1,2,3,6,7,8-HxCDD	7.86E-05	x (	2.36E-12	2.36E-03	) x	0.1	=	1.86E-08	1.7
1,2,3,7,8,9-HxCDD	6.80E-05	x (	2.36E-12	2.36E-03	) x	0.1	=	1.61E-08	1.5
1,2,3,4,6,7,8-HpCDD	3.80E-04	x (	1.86E-12	1.86E-03	) x	0.01	=	7.07E-09	0.6
OCDD	5.70E-04	x (	1.73E-12	1.73E-03	) x	0.0003	=	2.96E-10	0.0
2,3,7,8-TCDF	1.09E-03	x (	2.98E-12	2.98E-03	) x	0.1	=	3.23E-07	29.6
1,2,3,7,8-PeCDF	2.36E-04	x (	2.70E-12	2.70E-03	) x	0.03	=	1.91E-08	1.8
2,3,4,7,8-PeCDF	3.26E-04	x (	2.70E-12	2.70E-03	) x	0.3	=	2.64E-07	24.2
1,2,3,4,7,8-HxCDF	2.09E-04	x (	2.30E-12	2.30E-03	) x	0.1	=	4.81E-08	4.4
1,2,3,7,8,9-HxCDF	1.50E-04	x (	1.89E-12	1.89E-03	) x	0.1	=	2.84E-08	2.6
1,2,3,6,7,8-HxCDF	2.52E-05	x (	1.89E-12	1.89E-03	) x	0.1	=	4.78E-09	0.4
2,3,4,6,7,8-HxCDF	1.68E-04	x (	2.30E-12	2.30E-03	) x	0.1	=	3.87E-08	3.5
1,2,3,4,6,7,8-HpCDF	2.93E-04	x (	1.89E-12	1.89E-03	) x	0.01	=	5.54E-09	0.5
1,2,3,4,7,8,9-HpCDF	4.50E-05	x (	1.89E-12	1.89E-03	) x	0.01	=	8.53E-10	0.1
OCDF	1.53E-04	x (	1.79E-12	1.79E-03	) x	0.0003	=	8.24E-11	0.0
PCB-77		x (			) x	0.0001	=		#VALUE!
PCB-81		x (			) x	0.0003	=		#VALUE!
PCB-126		x (			) x	0.1	=		#VALUE!
PCB-169		x (			) x	0.03	=		#VALUE!
PCB-105		x (			) x	0.00003	=		#VALUE!
PCB-114		x (			) x	0.00003	=		#VALUE!
PCB-118		x (			) x	0.00003	=		#VALUE!
PCB-123		x (			) x	0.00003	=		#VALUE!
PCB-156		x (			) x	0.00003	=		#VALUE!
PCB-157		x (			) x	0.00003	=		#VALUE!
PCB-167		x (			) x	0.00003	=		#VALUE!
PCB-189		x (			) x	0.00003	=		#VALUE!

Total WHO-TEQ ADE	**1.09E-06**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
TDSI	**1.00E+00**	**pg WHO-TEQ kg^{-1} BW day^{-1}**
Hazard Index	**0.00**	