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Thiess Services Pty Ltd

Report for Orica Villawood Remediation Project

Air Health Risk Assessment
July 2010



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Abbreviations

Terms

ADI	Acceptable Daily Intake
EP&A	Environment Planning and Assessment
CHS	Chester Hill Stockpile
COPC	Chemicals of Potential Concern
DTD	Direct Thermal Desorption
ECS	Emission Control System
FSB	Feed Soil Building
HI	Hazard Index
HQ	Hazard Quotient
MEI	Maximum Exposed Individual
RAP	Remediation Action Plan
RfD	Reference Dose
SF	Slope Factor
SSF	Secure Storage Facility
UR	Unit Risk

Organisations

NHMRC	National Health and Medical Research Council
USEPA	United States Environment Protection Agency
WHO	World Health Organisation

Chemicals

DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DDX	DDD + DDE + DDT
MAH	Monocyclic Aromatic Hydrocarbons (benzene, toluene, ethylbenzene, xylenes)
PAH	Polycyclic Aromatic Hydrocarbons
PCE	Perchloroethylene (also tetrachloroethylene)



TCE	Trichloroethylene
DCA	Dichloroethane
DCE	Dichloroethylene
TCA	Trichloroethane
VC	Vinyl Chloride



1. Introduction

1.1 Overview

GHD Pty Ltd (GHD) was commissioned by Thiess Services (Thiess) to undertake a health risk assessment (HRA) of air emission impacts from works associated with proposed on site remediation of the Orica site at Villawood, NSW.

The site is located at 2 Christina Road, Villawood, NSW (refer to Figure 1). Thiess propose to remediate approximately 25 000 m³ of contaminated soil, and require to submit a Development Application (DA) under part 3A of the EP&A Act to NSW Department of Planning. The objective of this HRA is to support the DA to evaluate the potential health risks to offsite receptors from air emissions during the proposed site works.

This assessment focuses only on health risk impacts from contaminated dust and vapour, to existing offsite receptors during the works. Assessment of impacts due to dust and odour has been undertaken by PAE Holmes (PAEH). PAEH also undertook air dispersion modelling of dust and vapour from the site, which was relied on to estimate health risks.

Health risks to future site users post-development and potential impacts to groundwater, due to residual contaminants in soil, are subject to separate assessment, and are not considered here.

1.2 Risk Assessment Methodology

Human health risk assessment is a scientific process whereby chemical-specific toxicological data from animals or humans is combined with estimates of potential exposure, to enable predictions whether the chemical in question poses an unacceptable risk to human health. Risk is the probability (or likelihood) that an adverse health effect (e.g. respiratory irritation, liver cancer), will occur following exposure to a particular chemical at a particular dose.

Risk assessments have been used by regulatory agencies across the world for many years to assess impact to and protect public health. In the last few decades, risk assessments have been used to develop standards in a number of environmental areas, including pesticide residues in foodstuffs, drinking water guidelines and ambient air standards.

Risk assessment methodology can also be used to evaluate the hazards associated with emissions from manufacturing facilities and industrial processes and site remediation activities (such as at the Orica site). An important outcome of a risk assessment is identification of risk management recommendations designed to minimise exposure and corresponding health risk to people that may be exposed.

For air assessments in NSW the regulatory guideline to follow is *Approved methods for the Modelling and Assessment of Air pollutants in New South Wales, department of Environment and Conservation (NSW), 2005*. This document contains a list of impact assessment criteria for many toxicants, and generally is to be met using a 1 hour averaging time. However, Section 7.3.1 of the guideline states:



Where a number of toxic and carcinogenic air pollutants are emitted in significant amounts, demonstrating compliance with impact assessment criteria may not adequately demonstrate the protection of human health...Health risk assessment is particularly useful for the assessment of multiple chemicals and exposure through multiple pathways (e.g. inhalation, ingestion or dermal adsorption).

The guideline indicates that risk assessment should broadly follow the framework presented by EnHealth, *Guidelines for assessing human health risks from environmental hazards, 2004*. The risk assessment process consists of the following components:

- ▶ Hazard Identification

Review of data and information regarding the industrial processes and the types of chemicals emitted from a particular site. The hazard identification step is designed to determine which chemicals have the potential to affect adversely human health. These chemicals will ultimately be the primary focus of the risk assessment.

- ▶ Hazard Assessment (also known as Toxicity Assessment)

Evaluation of the relationship between the amount of chemical received (the dose) and the onset of an adverse health effect resulting from the exposure. Chemical-specific toxicity criteria developed by internationally recognised environmental regulatory agencies (e.g. USEPA, WHO) for both carcinogenic and non-carcinogenic chemicals typically provide the basis for the toxicity assessment.

- ▶ Exposure Assessment

This step results in an estimation of the amount of chemical an individual may be exposed to (i.e. the frequency of exposure and duration) as a result of their specific location, lifestyle, and exposure profile. Typically a combination of generic (default) and site-specific exposure assumptions are used to estimate a person's total exposure.

- ▶ Risk Characterisation and Evaluation

The risk characterisation provides a qualitative or quantitative estimate of the likelihood of an adverse health effect developing following exposure to a specific chemical or emission source. The results of the risk characterisation are typically used to identify the most appropriate site management decisions for a particular site or facility. This process can require making value judgements based on a range of scientific, social and economic information.



2. Hazard Identification

2.1 Site Description

The site is located at 2 Christina Road, Villawood, NSW (refer to Figure 1). The site designated as Lot 1 in Deposited Plan (DP) 634604, is approximately 12.6 Ha in size.

The site has historically been operated by a number of owners including the Commonwealth government, Taubmans, and most recently Orica, in manufacturing a range of chemicals including chlorobenzene, DDT and pharmaceutical chemicals. Detailed site investigation works have been undertaken between 2000 and 2007 by SHE Pacific Pty Ltd, URS Pty Ltd, CH2MHill and HLA.

2.2 Site Remediation Plan

A detailed Remediation Action Plan (RAP) was written by HLA-Envirosciences Pty Ltd (HLA, 2007), and recently amended by AECOM (June 2010). The RAP amendment was undertaken when proposed zone specific reuse criteria in the 2007 RAP were replaced by site wide reuse criteria in the 2010 RAP.

Thiess propose to undertake onsite remediation of contaminated soils using a direct thermal desorption (DTD) unit. A number of zones have been identified in the site investigations that require remediation. These zones are summarised in Table 1 and are shown in Figure 2.

In addition to the excavation zones, there are two additional sources to be treated:

- ▶ Chester Hill Stockpile: a stockpile from a nearby site which contains chlorinated hydrocarbons, including trichloroethylene (TCE), trichloroethane (TCA), ethylene dichloride (EDC), carbon tetrachloride (CTC) and other minor compounds; and
- ▶ Secure Storage Facility (SSF): a building located on the north east corner of the site which contains soils with elevated DDX (a sub-set of organochloride pesticides related to DDT), EDC, chlorobenzenes and other minor compounds.



Table 1 Summary of Source Zone

Zone	Source ID	Volume (m ³)	Area (m ²)	Depth	Comments
9	S1	1 000	930	1 m	
1a, 1b, 2	S8, S9	3 840	7 685	0.5 m	Surface section of Zone 1b
1b	S8, S9	2 200	625	3.5 m	Deep section Zone 1b
8	S12	5 000	3 240	1.5 m	
7	S16	1 000	780	1.3 m	
5 (1)	S26	500	410	1.2 m	Part 1 of Zone 5
5 (2)	S25	1 000	930	1 m	Part 2 of Zone 5
Chester Hill stockpile	S9	2 000	-	-	
Secure Storage Facility	SSF	10 000	-	-	

Note: these volumes are based on the 2007 RAP which exceed volumes in the 2010 RAP by about 8%.

The first stage is to excavate Zone 9 (S1), which will become the location of the emission control system (ECS) for the feed soil building (FSB). The FSB will be an extended version of the existing secure storage facility (SSF) to the south. Once the FSB is established, the remaining zones will be excavated and moved to the FSB for temporary storage, where they will be blended with the soil from the SSF and fed to the DTD.

The detailed staging process for the project provided by Thiess is presented in Appendix F. For further details on the stages of remediation refer to Section 3.1.

2.3 Sources of Emissions

Emissions of contaminants from vapour and dust occur during excavation and handling of contaminated soils. The excavation zones and schedules are listed in Section 3.1. In addition to these sources there are two additional sources of emissions:

- ▶ The stack discharge from the feed soil building emissions control system; and
- ▶ The Direct Thermal Desorption (DTD) unit.

For each of the excavation sources, vapour and dust is emitted resulting either from mechanical operations or from fugitive emissions (fugitive dust and diffusive vapour). Dust is expected to contain chemicals adsorbed to the particles, which may be inhaled or deposited in soil in neighbouring areas where receptors could be exposed through direct contact or ingestion of home-grown produce.

Refer to Section 3 for detailed information on chemical emission rates.



2.4 Chemicals of Potential Concern

A health risk assessment by URS (2007) and recently revised by URS in 2010 was conducted to derive remediation criteria for reuse of soil on the site and to identify the chemicals of potential concern (COPC) at the site. The COPC identified on the site which are contained in the proposed remediation zones are:

- ▶ VOCs
 - Hexachlorobenzene;
 - 1,2-Dichloroethane;
 - Chloroform;
 - Carbon tetrachloride;
 - Trichloroethylene (TCE);
 - Tetrachloroethylene (PCE);
 - Chlorobenzene;
 - 1,4-Dichlorobenzene;
 - 1,2,3-trichloropropane;
 - 1,1-Dichloroethane;
 - 1,1-Dichloroethylene;
 - 1,2-(cis)-Dichloroethylene;
 - 1,1,1-Trichloroethane;
 - Vinyl Chloride;
- ▶ MAHs
 - Benzene;
 - Toluene;
 - Xylenes;
- ▶ OCPs
 - a-HCH (a-BHC);
 - b-HCH (b-BHC);
 - d-HCH (d-BHC);
 - g-HCH (Lindane);
 - Dieldrin;
 - DDX (DDT/DDD/DDE);
- ▶ Endosulfan II;
- ▶ Mercury;
- ▶ Naphthalene; and
- ▶ Carcinogenic Polycyclic Aromatic Hydrocarbons (Carc. PAHs).



3. Identification and Quantification of Emission Estimates

3.1 Remediation Zones and Staging

The site has been divided into remediation zones, as described in the RAP (AECOM, 2010), and summarised in Section 2.2. The scheduled project works is to occur over 50 weeks, although works associated with excavation or treatment of contaminated soil is scheduled to occur over a 36 week period.

A detailed schedule of works provided by Thiess, is presented in Appendix F.

With regards to works on excavation and treatment of contaminated soil, the schedule proposed by Thiess is presented in Table 2 (see also Figure 2 for locations of zones on the site).

Table 2 Proposed Schedule of Works

Week	Item	No of days	Volume of soil (m ³)
1	Excavate Zone 9 and transport to FSB	2	1 000
11	Excavate Chester Hill stockpile and transport to FSB	4	2 000
11-12	Excavate Zone 1a, 1b (top), 2 and transport to FSB	8	3 840
12-13	Excavate 1b (bottom) and transport to FSB	5	2 200
17-18	Excavate Zone 8 and transport to FSB	10	5 000
20	Excavate Zone 7 and transport to FSB	2	1 000
20	Excavate Zone 5 (part 1) and transport to FSB	1	500
20	Excavate Zone 5 (part 2) and transport to FSB	2	1 000
11-36	DTD operation, including excavation of SSF and mixing/screening operations with contaminated soil	156	25 760

Note: these volumes are based on the 2007 RAP which exceed volumes in the 2010 RAP by about 8%.

Thiess proposes that excavation works will occur at a rate of 500 m³ per day, where a day consists of 10 hours between 7 am and 5 pm. Excavation works would occur six days per week. Both the rate of work and work hours are conservative because they are greater than expected in reality. Excavations would be carried out using a 25 tonne excavator and it is expected that only one zone (or zone group) will be excavated at any one time. The only parallel sources of contaminated emissions would be the excavation of a soil zone, and emissions from the FSB and DTD.

The DTD would operate 24 hours per day, six days per week, with one day a week off-line for maintenance. Emissions from the FSB will occur during operation of the DTD. Minimum feed to the DTD would be is around 165 m³ soil per day.



The FSB emissions will occur at the same time as the operation of the DTD as the mixing and excavating of the SSF and treatment stockpiles occurs during this period. Note the FSB emissions will be discharged through the ECS which will be constructed where Zone 9 is located after first stage of excavation.

There are a number of other operations at the site which may generate dust emissions. These include:

- ▶ Excavation of clean material;
- ▶ Placement of treated soil; and
- ▶ Breakup of concrete.

This health risk assessment does not include emissions for these activities as dust is not expected to be contaminated. However, these dust emissions have been considered by PAEH for the assessment of total dust exposure.

3.2 Contamination Emission Sources

There are a number of different types of emission sources during the remediation project. These are summarised as follows.

Excavations

Most of the soil in the identified contamination zones consist of clay like fill material. During excavation activities, mechanical movements of soil would cause dust emissions. Chemicals adsorbed on dust particles disperse through the air to neighbouring areas where they may be inhaled or deposited on the ground. In addition to dust, trapped volatile gases are released into the atmosphere during excavation. Furthermore, excavation also exposes fresh contaminated soil surfaces (in base of pit and along walls), allowing further volatilisation.

Thiess have advised that the excavation rate of potentially contaminated soil is 500 m³/day. Excavation works will occur during 10 hour working shifts (7 am to 5 pm), six days per week.

All excavated soil that is to be treated will be moved to the Feed Soil Building (FSB) where it will be stockpiled, and mixed / screened just prior to treatment.

A summary of all the excavation dimensions are presented in Appendix A.

Chester Hill Stockpile (CHS)

The Chester Hill Stockpile contains the contaminated soil which is to be treated by the DTD plant. Volatile emissions as well as dust will be released from the stockpile when excavated and moved to the FSB. The stockpile is covered and will only be partially exposed during the excavation works.

Secure Storage Facility (SSF)

The main contaminant in the SSF soil is DDX. The building will be extended and will be designated as FSB when the emission control system is operational. The stockpiled soil will be treated in the DTD over the duration of the project and will be proportionally mixed with excavated soil within the FSB. Vapour will be emitted during excavation and screening processes in the FSB.



Feed Soil Building (FSB)

The FSB houses excavated soil to be treated, as well as the mixing and screening process of contaminated soils prior to treatment. The FSB contains an Emission Control System (ECS) which captures most of the dust and volatiles are passed through a carbon-bed filter. The Removal Efficiency (RE) of the carbon beds and dust filters is expected to be 99%. For conservatism modelling has been undertaken assuming a minimum RE of 95%. The remaining vapours are discharged through the ECS stack adjacent to the building. The FSB incorporates the SSF and would capture any dust and vapours during excavation of this material.

The mixing and screening operations are proposed to take place 24 hours per day, six days a week to coincide with the operation of the DTD.

Direct Thermal Desorber (DTD)

The DTD thermal oxidiser operates at high temperatures (above 980°C) and destroys most organics through combustion, with a minimum efficiency of 99.9999%. For conservatism, modelling has been undertaken assuming a combustion efficiency of 99.999%. The DTD would operate 24 hours per day six days per week, with one day a week offline for maintenance.

3.3 Dust Emission Rates

Dust emissions from all stockpiles and excavation activities have been estimated by PAEH and implemented in their air dispersion model. The results of their dust emission rate estimates are presented in their report (PAEH, 2010).

The resulting dust ground level concentrations (GLCs) and deposition rates (DRs) are scaled for each COPC adsorbed onto dust particles, based on each source and the measured soil concentrations for that source (refer to Section 3.5 for further detail).

Dust mitigation measures have been assumed to occur during all site works, which would reduce dust emissions by 70% based on no controls (pers. com. John Hunt of Thiess, 2010).

3.4 Volatile Chemical Emission Rates

The calculations for emissions of volatiles are presented in Appendix C. Two types of emission calculations have been used to estimate the emissions of volatiles from excavations and from stockpiles. These are described as follows.

3.4.1 Vapour Diffusion Estimation

When a chemical is exposed at surface soil, (i.e. floor or wall of excavation pit, or surface of stockpile), volatilisation into the atmosphere occurs. Emissions through volatilisation for surface contamination was estimated using a variant on Johnson & Ettinger's volatilisation model (1991). This equation is presented in the Risk Based Corrective Action (RBCA) for Petroleum Release (ASTM, 1995) and is as follows:

$$VF = \frac{C_{air}}{C_s} = \frac{2W\rho_s}{U_{air}\delta_{air}} \sqrt{\frac{D_s^{eff}H}{\pi[\theta_{ws} + k_s\rho_s + H\theta_{as}]}} \tau \times 10^3 \quad (3.1)$$



Where: VF = Volatilisation Factor (ambient air concentration / soil bulk concentration)
(mg/m³)/(mg/kg)

W = Width of source area parallel to wind (cm)
 U_{air} = Wind speed above ground mixing zone (cm/s)
 δ_{air} = Ambient air mixing zone height (cm)
 ρ_s = Soil bulk density (dry) (g/cm³)
 H = Henry's Law constant (cm³-H₂O/cm³-air)
 θ_{as} = Volumetric fraction of air in soil (air porosity)
 θ_{ws} = Volumetric fraction of water in soil (water porosity)
 τ = Averaging time for vapour flux – residence time for exposure for fresh surfaces (s)
 k_s = Soil-Water sorption coefficient
 D_s^{eff} = Effective diffusivity in soil (cm²/s)
 10³ = Conversion factor (cm³.kg/m³.g)

$$k_s = f_{oc} \times K_{oc} \quad (3.2)$$

Where: f_{oc} = Fraction of organic carbon in soil (-)
 K_{oc} = Carbon-water sorption coefficient (g-H₂O/g-C)

$$D_s^{eff} = D^{air} \frac{\theta_{as}^{3.33}}{\theta_T^2} + \frac{D^{air}}{H} \frac{\theta_{ws}^{3.33}}{\theta_T^2} \quad (3.3)$$

Where: D^{air} = Diffusion coefficient in air (cm²/s)
 D^{wat} = Diffusion coefficient in water (cm²/s)
 θ_T = Total porosity = θ_{as} + θ_{ws}

The ambient air concentration is calculated by multiplying the volatilisation factor (VF) by the soil bulk concentration C_s.

Through a mass balance the vapour flux may be estimated. Note that conversion of appropriate units is necessary.

$$F = \frac{C_{air} U_{air} \delta_{air}}{W} \quad (3.4)$$

Where: F = Chemical vapour flux (mg/m²/s)
 C_{air} = Ambient air concentration (mg/m³)
 W = Width of source area parallel to wind (m)
 U_{air} = Wind speed above ground mixing zone (m/s)
 δ_{air} = Ambient air mixing zone height (m)



$$E = F \times A / 1000 \quad (3.5)$$

Where: E = Total vapour emission rate (g/s)
A = Excavation Area (m²)

Equation 3.1 incorporates a three-phase partitioning relationship which is specific to organics, and does not include separate phase scenario (i.e. when pore water concentration exceeds water solubility limits). In these situations, the three-phased equation highly over predicts the soil-vapour concentration. Under these circumstances, vapour follows Raoult's Law, rather than the three-phase partitioning equations. This has been addressed by generalising Equation 3.1 into the following equation:

$$C_{air} = \frac{2WC_s}{U_{air}\delta_{air}} \sqrt{\frac{D_s^{eff} \rho_s C_{sa}}{\pi \tau C_s}} \quad (3.6)$$

$$\text{Where: } C_s = \frac{C_{sa} [\theta_{ws} + k_s \rho_s + H\theta_{as}]}{H\rho_s} \quad (3.7)$$

$$\text{And } C_{sa} = \frac{C_s H \rho_s}{[\theta_{ws} + k_s \rho_s + H\theta_{as}]} \quad (3.8)$$

C_{sa} (g/m³) is the soil-gas concentration, and is calculated using the three-phase partitioning equation 3.8, which incorporates the bulk soil concentration (C_s).

C_{sa} may be replaced by Raoult's Law and the Ideal-Gas Law for the situation where the pore water exceeds solubility limits and a separate phase is formed. This equation is presented as follows:

$$C_{sa} = \frac{P.MW}{R.T} \times 10^3 \quad (3.9)$$

Where: C_{sa} = Soil-gas concentration (g/m³)
P = Chemical vapour pressure (mmHg)
MW = Chemical molecular weight (g/mol)
R = Ideal Gas Law (62.363 L.mmHg.K⁻¹.mol⁻¹)
T = Temperature (298 K)

The lower of C_{sa} from equations 3.8 and 3.9 determines which phases the soil-gas is in equilibrium with, that is:

- ▶ If C_{sa} from equation 3.8 is less than 3.9, then three phases are present and soil-gas is in equilibrium with the dissolved phase; and
- ▶ If C_{sa} from equation 3.9 is less than 3.8, then separate phase is present and soil-gas is in equilibrium with product.

The lower of C_{sa} from equations 3.8 and 3.9 is used in equations 3.6 and 3.7 to calculate C_{air} , and in turn emission rate (E) through equations 3.4 and 3.5.

3.4.2 Vapour Cloud Estimation

When soil is excavated, trapped soil vapour is released into the atmosphere. The amount of vapour released is estimated as the total volume of soil-gas present in the soil to be excavated, multiplied by the soil-gas concentration. The soil-gas concentration is estimated using the same method presented in



Section 3.4.1 for diffusion emissions, using the lower value of C_{sa} from equations 3.8 (three-phase equilibrium) and 3.9 (separate phase).

The total emission rate and vapour flux during excavation is calculated as follows:

$$E = C_{sa} \times V \times \theta_{as} \quad (3.10)$$

Where:

E	=	Soil-gas emission rate (g/s)
V	=	Soil volumetric excavation rate (m ³ /s)
C _{sa}	=	Soil gas concentration (g/m ³) – calculated from 3.8 or 3.9

3.4.3 Key Calculation Assumptions

The key assumptions used in the calculation of the chemical emission rates are as follows (as advised by Thiess):

- Geotechnical properties (densities and porosities) for insitu soil consists mainly of clay fill material, with moisture content around 12% dry weight. Stockpiled materials have allowed for a bulking factor of 15%, with slightly less for the Chester Hill stockpile and the SSF. The stockpile has been standing for some time resulting in some compaction and the material in the SSF was compacted when it was placed. The summary of geotechnical properties and calculations are presented in Appendix B;
- All excavation works occur in sequence as presented in Table 2 with expected duration of works. The total excavation duration is 34 days, based on 500 m³ (insitu) soil per day. These works will be spread over 36 weeks. Excavation works occur between 7 am and 5 pm, six days per week;
- The FSB (and ECS) and DTD Plant will operate for 156 days (6 day week). These emissions will occur concurrently to emissions from excavation works;
- Emissions within the FSB are based on proportional blending between stockpiled soil in the SSF and excavated soil, i.e. soil from SSF based on an excavation rate of 64 m³/day, and treatment stockpiles based on an excavation rate of 101 m³/day (total of 165 m³/day);
- In addition to the excavation and treatment of contaminated soil, there are other site activities that will occur during these activities. It is assumed that these activities will not contribute to emissions of contaminated dust or vapour, and have not been considered in this assessment. PAEH is assessing the contribution of these activities to total dust emission for the proposed project;
- PAEH has modelled each emission source using a unit emission rate (1 g/s for excavation volumes, 1 g/s for stacks) (refer to Section 6.4.2);
- Emission rates from each source zone have been calculated as described in Sections 3.4.1 and 3.4.2. These calculations are presented in Appendix C;
- The averaging time used in the calculation of vapour emissions from floor and wall emission is the average exposure time of a freshly exposed surface, also referred to as the residence time. It is assumed that walls will be excavated / sliced in 2 m increments. An example of this calculation is presented in Appendix A; and
- The air dispersion modelling results from PAEH for each source are based on unit emission rates (discussed above). Ground level concentrations (GLCs) are scaled based on source concentrations for each chemical of potential concern. The source concentrations for each source are discussed in Section 3.5.



3.5 Chemical Concentrations in Soil

Weighted mean concentrations for each remediation zone based on the revised RAP (AECOM, 2010) have been assessed. For conservatism the highest mean concentration for any excavations zone for all COPCs has been applied to all excavation zones. CHS and the SSF are also presented. For the FSB and DTD, the highest mean concentration for any source has been used. These data have been supplied by Thiess and are summarised in Table 3.

Concentrations for PAHs have been based on carcinogenic Toxic Equivalency Factors (Fitzgerald, 1998).



Table 3 Applied Soil Concentrations Per Source (mg/kg)

Chemical	Max Mean Excavation Zones (1, 3)	Chester Hill Stockpile ^(2, 3)	SSF, FSB, DTD ⁽⁴⁾
Hexachlorobenzene	19	nd	19
1,2-Dichloroethane (EDC)	nd	13.5	50
Chloroform	nd	8.71	8.71
Carbon tetrachloride	nd	23.5	23.5
TCE	nd	148	148
PCE	6.4	nd	6.4
Chlorobenzene	63	nd	143
Benzene	0.54	nd	0.54
Toluene	8.9	nd	8.9
Xylenes	nd	nd	10
1,4-Dichlorobenzene	3.1	nd	84
1,2,3-trichloropropane	0.34	nd	0.34
a-BHC	140	nd	140
b-BHC	123	nd	123
d-BHC	20	nd	20
g-BHC (lindane)	138	nd	138
dieldrin	29	nd	29
DDX	6740	nd	6740
endosulfan II	943	nd	943
mercury (total organic)	0.43	nd	0.43
Naphthalene	0.11	nd	0.11
Benzo(a)pyrene - TEQ	0.5	nd	0.5
1,1-Dichloroethane	nd	1.87	1.87
1,1-Dichloroethylene	nd	1.01	1.01
1,2-(cis)-Dichloroethylene	nd	5.6	5.6
1,1,1-Trichloroethane	nd	23.7	23.7
Vinyl Chloride	3.4	nd	3.4

Notes:

nd Not detected in soil

1) Applied to all excavation zones for vapour and dust

2) Applied to Chester Hill stockpile (CHS) for vapour

3) Source 8 and 9 combines excavations and CHS for dust emission. The maximum concentrations between both sources have been used.

4) Based on maximum of excavation zones, CHS and soil from SSF.



3.6 Feed Soil Building and Emission Control System

As described in Section 3.4.3, the emission rates from the FSB are based on the emissions from excavation of the soil in the SSF and the treatment stockpiles within the building. Emissions are passed through a carbon bed and dust filters with a minimum RE of 99%. For conservatism modelling has been undertaken assuming an RE of 95%. Excavation rates from the SSF and treatment stockpiles have been proportioned based on an excavation rate of 64 m³/day for the SSF, and excavation rate of 101 m³/day for the treatment stockpiles (total of 165 m³/day). Operations occur 24 hours per day, six days per week to match the feed requirements for the DTD Plant. Emissions are discharged through the ECS stack.

The emission rates from the ECS stack are presented in Appendix C

3.7 DTD Plant

The emission rates from the DTD plant are conservatively based on the highest mean soil concentrations from all zones where:

- Destruction efficiency is $\geq 99.999\%$; and
- Treatment rate is 35 t/hr.

The exception is mercury which is assumed to pass through with 0% RE, because the actual RE is uncertain.

DTD operations occur 24 hours per day, six days per week, with one day per week offline for maintenance.

The emission rates from the stack are summarised in Table 4.

Table 4 Summary of Emission Rates from the DTD plant

Chemical	DTD Emission Rate (g/s)
Hexachlorobenzene	1.85×10^{-6}
1,2-dichloroethane (EDC)	4.86×10^{-6}
Chloroform	8.47×10^{-7}
Carbon tetrachloride	2.28×10^{-6}
TCE	1.44×10^{-5}
PCE	6.22×10^{-7}
Chlorobenzene	1.39×10^{-5}
Benzene	5.25×10^{-8}
Toluene	8.65×10^{-7}
Xylenes	9.72×10^{-7}
1,4-Dichlorobenzene	8.17×10^{-6}
1,2,3-Trichloropropane	3.31×10^{-8}



Chemical	DTD Emission Rate (g/s)
a-BHC	1.36×10^{-5}
b-BHC	1.20×10^{-5}
d-BHC	1.94×10^{-6}
g-BHC (lindane)	1.34×10^{-5}
Dieldrin	2.82×10^{-6}
DDX	6.55×10^{-4}
Endosulfan II	9.17×10^{-5}
Mercury (total organic)	4.18×10^{-3}
Naphthalene	1.07×10^{-8}
Benzo(a)pyrene - TEQ	4.86×10^{-8}
1,1-Dichloroethane	1.82×10^{-7}
1,1-Dichloroethylene	9.82×10^{-8}
1,2 (cis)-Dichloroethylene	5.44×10^{-7}
1,1,1-Trichloroethane	2.30×10^{-6}
Vinyl Chloride	3.31×10^{-7}



4. Hazard Assessment

4.1 Introduction

The toxicity assessment consists of an evaluation of the potency of a chemical in relation to defined adverse health effects associated with exposure to that chemical. This assessment has been based on dose-response information which relate exposure (or dose) to the appearance of an adverse health effect (or response) in either experimental animals or (for some chemicals) in human populations.

4.2 Toxicity Criteria

The National Health and Medical Research Council (NHMRC), the World Health Organisation (WHO), the USEPA and other scientific organisations have reviewed the toxicological literature and have developed dose-response (toxicity) criteria for a number of chemicals to which humans may be exposed. Toxicity criteria are required in the risk assessment to quantify the health risks based on the likelihood of developing an adverse health effect as a result of exposure to a specific chemical. Toxicity criteria based on human exposure data are preferred over data from other sources. However, due to limitations in human data, the results of animal studies often serve as the basis of toxicity criteria. For this reason, toxicity criteria which are based on animal studies often incorporate safety factors to account for the inherent uncertainties in the extrapolation from animal to humans.

The toxicity criteria used for carcinogenic chemicals are described as slope factors (SF) for exposure via oral or dermal routes, and as unit risks (UR) for the inhalation route. The SF or UR is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime (USEPA, 1989). These criteria are used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen. The actual risk for these chemicals may be less than that presented herein.

The toxicity criteria for non-carcinogenic chemicals are described as reference doses (RfD) or Acceptable Daily Intake (ADI) for exposure via oral or dermal routes, and as reference concentrations (RfC) or Guideline Values (GV) for the inhalation route. The RfD or RfC is an estimate of the long-term averaged daily dose for which no observable medium to long-term health effects occur (i.e. chronic and sub-chronic health effects).

The toxicity criteria of the COPC associated with emissions from the site are summarised in Table 5. The toxicity criteria used for carcinogenic compounds are described as SF for exposure via oral or dermal routes, and as UR for the inhalation route. For the threshold (non-carcinogen) chemicals, the toxicity criteria are presented as an RfD (or ADI) for exposure via oral or dermal routes, and as an RfC (or Guideline Value) for the inhalation route.

A detailed toxicity profiles for the chemicals of potential concern are presented in Appendix E.

Table 5 Toxicity Criteria for the Chemicals of Potential Concern

Chemical	Carcinogenic		Non-Carcinogenic	
	Inhalation UR ($\mu\text{g}/\text{m}^3$) ⁻¹	Oral SF (mg/kg/d) ⁻¹	Inhalation RfC ($\mu\text{g}/\text{m}^3$)	Oral RfD (mg/kg/d)
Hexachlorobenzene	4.6×10^{-4} ⁽³⁾	1.6 ⁽³⁾	2.8 ⁽⁴⁾	0.0008 ⁽³⁾
1,2-Dichloroethane	2.8×10^{-6} ⁽¹⁾	0.02 ⁽²⁾	-	-



Chemical	Carcinogenic		Non-Carcinogenic	
Chloroform	4.2×10^{-7} ⁽¹⁾	0.031 ⁽⁴⁾	98 ⁽⁶⁾	0.07 ⁽²⁾
Carbon tetrachloride	1.5×10^{-5} ⁽³⁾	0.13 ⁽³⁾	6.1 ⁽¹⁾	0.0012 ⁽²⁾
Trichloroethylene	4.3×10^{-7} ⁽¹⁾	3.9×10^{-3} ⁽⁴⁾	-	-
Tetrachloroethylene	-	-	250 ⁽¹⁾	0.014 ⁽²⁾
Chlorobenzene	-	-	500 ⁽¹⁾	0.12 ⁽²⁾
Benzene	6×10^{-6} ⁽¹⁾	0.035 ⁽²⁾	-	-
Toluene	-	-	260 ⁽¹⁾	0.22 ⁽²⁾
Xylenes	-	-	870 ⁽¹⁾	0.179 ⁽²⁾
1,4-Dichlorobenzene	-	-	1000 ⁽¹⁾	0.0107 ⁽²⁾
1,2,3-Trichloropropane	-	30 ⁽³⁾	0.3 ⁽³⁾	0.004 ⁽³⁾
a-HCH	1.8×10^{-3} ⁽³⁾	6.3 ⁽³⁾	-	-
b-HCH	5.3×10^{-4} ⁽³⁾	1.8 ⁽³⁾	-	-
d-HCH	- ⁽⁹⁾	- ⁽⁹⁾	-	-
g-HCH (Lindane)	3.1×10^{-4} ⁽⁴⁾	1.1 ⁽⁴⁾	-	0.0003 ⁽²⁾
Dieldrin	4.6×10^{-3} ⁽³⁾	16 ⁽³⁾	-	0.0001 ⁽²⁾
DDT/DDD/DDE	9.7×10^{-5} ^(3,7)	0.34 ^(3,7)	-	0.02 ^(2,7)
Endosulfan II	-	-	-	0.006 ^(3,8)
Mercury	-	-	1 ⁽¹⁾	0.00047 ⁽²⁾
Naphthalene	-	-	3 ⁽³⁾	0.02 ⁽³⁾
Carc. PAHs ⁽¹¹⁾	0.087 ⁽¹⁾	0.5 ⁽¹⁰⁾	-	-
1,1-Dichloroethane	1.6×10^{-6} ⁽⁴⁾	5.7×10^{-3} ⁽⁴⁾	-	0.2 ⁽⁴⁾
1,1-Dichloroethylene	-	-	200 ⁽³⁾	0.05 ⁽³⁾
1,2-Dichloroethylene	-	-	60 ⁽⁴⁾	0.02 ^(3,5)
1,1,1-Trichloroethane	-	-	5000 ⁽³⁾	2 ⁽³⁾
Vinyl Chloride	8.8×10^{-6} ^(3,12)	1.5 ^(3,12)	100 ⁽³⁾	0.003 ⁽³⁾

Notes:

1. WHO (2000)
2. ADWG (NHMRC, 2004)
3. USEPA Integrated Risk Information System (IRIS)
4. California EPA – Regional Screening Levels (2010)
5. Based on trans isomer
6. ATSDR – Toxicological Profile for Chloroform, September 2007
7. Based on DDT, more toxic of DDD/DDE/DDT
8. Based on Endosulfan I
9. Based on the more stringent of a-, b- g- HCH
10. WHO Water Quality Guidelines (2005)
11. PAH Toxic Equivalency based on toxicity of benzo(a)pyrene
12. Based on the developmental toxicity for child to adult exposure



5. Exposure Assessment

5.1 Introduction

The exposure assessment describes the selection of potentially exposed populations, exposure pathways, and assumptions included in the calculation of potential health risk. The exposure assessment is used to evaluate the extent and magnitude of exposure to offsite receptors in the vicinity of the Orica site. The results of the exposure assessment, when combined with chemical-specific toxicity criteria, are used to assess the potential health risks for each population of interest.

Exposure assessment involves several fundamental steps:

- ▶ Identification of the various population groups (or receptors) that may be exposed;
- ▶ Identification of the exposure scenarios (i.e. transport media and the exposure pathways); and
- ▶ Exposure estimation (i.e. estimating the exposure concentrations of COPC in the media; and the dose or intake by the receptor).

The last step is described in detail in the following chapter.

5.2 Populations of Interest

In assessing health risks, it is important to identify all groups of people that may be exposed to the chemicals of potential concern. In the context of exposure to emissions from the site, off-site residents have been identified as being the population group of greatest interest. Other populations of interest include industrial and commercial workers and public open space.

The area of interest (for modelling purposes) was defined as a 2.8 km x 2.8 km area. Figure 1 presents the locations of the nearby human receptors. The following landuses have been identified surrounding the site:

- ▶ North: immediately north is industrial land, with residential property about 500 m from the site boundary. Chester Hill High School is located about 500 m from the site boundary on the east side of Miller Road;
- ▶ South: immediately south is industrial land, with residential property 700 m from the site boundary, south of Biloela Street;
- ▶ East: Abott Park and residential properties are located directly across Miller Road; and
- ▶ West: industrial land up to Woodville Road.

The residential areas located east and northeast represent those areas with the greatest exposure potential.



5.3 Exposure Scenarios

The chemicals associated with emissions from the site can be transported for variable distances in the air before coming into contact with offsite receptors. Exposure may occur by inhalation of air, or by secondary routes via deposition of these chemicals on the soil, water or crops.

The NSW DECCW has published *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DECC, 2005). In Section 7.3 of this document it indicates that health risk assessment can be undertaken in accordance with *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessment* (CAPCOA, 2003). This program was formerly the Californian Air Pollution Control Officers Association (CAPCOA) HRA96 program, which has been used in many assessments for estimating exposure and health risk from exposure to chemicals in air. The program considers the potential exposure via a multi-pathway exposure profile, however, it was designed for evaluating the health impacts from industrial facilities and estimates health risk for a human receptor exposed for a 70 year duration. The duration for the remediation process will be less than 2 years, and therefore, it has been determined that this software cannot directly be used for this particular assessment.

Instead, the algorithms from the program have been implemented in a spreadsheet and modified to account for the difference in the operation duration (refer to Appendix G for further explanation of the algorithm modifications).

For this assessment, the following exposure pathways have been determined to be potentially complete and have been selected for quantitative evaluation:

- ▶ Inhalation;
- ▶ Soil ingestion;
- ▶ Dermal absorption; and
- ▶ Ingestion of home grown produce.

Other potential exposure pathways of interest, such as meat, surface water and fish ingestion, were not included in this assessment, since they were not considered to be complete pathways or minor in comparison to the primary exposure pathways.

The consumption of produce from homegrown gardens has been included in this risk assessment to account for risks to those residents which may have small vegetable gardens. However, it should be noted that plant uptake of organics is based on empirical equations and may be considered to be highly uncertain.

5.4 Exposure Estimation

The exposure estimation includes the following steps:

1. Estimation of the chemical concentrations in the media from which receptors are likely to be exposed (the exposure media).

Direct measurement of the exposure concentrations (e.g. in ambient air, soil or home grown produce) is preferred, but it is not possible to sample concentrations based on a proposed facility or in this case a proposed remediation project. Hence, models are frequently used to provide an estimation of chemical concentration in the exposure media for incorporation in the risk assessment.



The air dispersion model AUSPLUME was used to provide an estimation of the ground level air concentrations of COPC associated with emissions from the site and the deposition rate of these constituents at various receptor locations. The air dispersion model is discussed in Section 6.

The CAPCOA HRA96 program includes models and techniques for estimating chemical concentrations in the secondary exposure media (i.e. soil) using established algorithms and assumptions. The algorithms and assumptions used in HRA96 are provided in the CAPCOA guidelines (CAPCOA, 1993). These algorithms were implemented in a spreadsheet and modified to account for the shorter facility duration of operation (refer to Appendix G for further detail).

2. Estimation of chemical intake rates from different exposure media. Dose estimation involves consideration of:
 - The contact rate, and frequency and duration of exposure; and
 - The total rate of chemical intake based on the concentration of COPC in the exposure media.

The CAPCOA HRA96 program includes a set of built-in default exposure assumptions. These default assumptions include parameters such as body weight, soil ingestion rate, exposure frequency and duration. The HRA96 program provides an estimation of intake doses for different exposure pathways using the algorithms and assumptions provided in the CAPCOA guidelines (CAPCOA, 1993).

It should be noted that the methodology for estimating health risk through inhalation pathway in CAPCOA is consistent with the recent release of the USEPA document *Risk Assessment Guidelines for Superfund, Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA, 2009).

All other exposure parameters used in the CAPCOA HRA96 program have been adopted in this risk assessment. These are generally similar to those used in Australia.

The program allows for assessment of the contribution from dietary intake of homegrown produce. The dietary intake contribution of homegrown produce with respect to the “normal” diet in the Sydney region was estimated to be 5%. Put another way, approximately 5% of all foodstuffs eaten are considered to come from backyard gardens. This assumption is based on the New South Wales and Australian-specific data from the Australian Bureau of Statistics document entitled “Home Produce of Selected Foodstuffs, Australia, Year Ended, April, 1992”, indicating the proportion of homes with a vegetable garden was 28% and the proportion of homegrown produce consumed was 5% of the diet.



6. Air Dispersion Modelling

6.1 General

A computer modelling program is used to estimate the transport dispersion and deposition of emissions from the Orica site. Potential impacts from the proposed remediation activities on the surrounding area have been assessed using AUSPLUME Version 6. AUSPLUME is an advanced Gaussian dispersion model developed on behalf of the Victorian EPA and is based on the United States Environment Protection Agency's Industrial Source Complex (ISC) model. It is widely used throughout Australia and is regarded as a state-of-the-art model. It is the model recommended in the NSW DECCWs Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales.

The air dispersion modelling was conducted by PAE Holmes (PAEH). A complete description of the modelling and results is presented in their report (PAEH, 2010). The following discussion is a summary of this report.

6.2 Meteorology

Meteorological data from Bankstown Airport was used in this assessment. On an annual basis the predominant winds blow from west and south. In spring the north and southerlies are predominant. In summer the south and east southeast winds are most frequent. In autumn and winter winds from west to east are most common.

The dispersion model used for this assessment, AUSPLUME, requires information about the dispersion characteristics of the area. In particular, data are required on wind speed, wind direction, temperature, atmospheric stability class and mixing height. Atmospheric stability was determined using cloud cover data. Mixing height was determined using a scheme defined by Powell (1976) for daytime conditions and an approach described by Venkatram (1980) for night time conditions.

6.3 Receptor Locations

6.3.1 General

AUSPLUME requires the user to specify the locations at which Ground Level Concentrations (GLCs) and Deposition Rates (DRs) are to be calculated, the so-called receptors. Location arrays can be specified using either a uniform rectangular (Cartesian) grid or a radial (polar) grid. Discrete receptors can also be specified for particular points of interest.

6.3.2 Cartesian Receptor Grid

The region of interest for the risk assessment was specified to be up to 2.8 km north-south and 2.8 km east-west with the Orica site in the centre. A 2.8 km x 2.8 km grid, aligned to Australian Map Grid (AMG) was defined, extending from 312 700 m E to 315 500 m E, and from 6 248 200 m N to 6 251 000 m N. Receptor intervals were set at 200 m.



6.4 Source Geometry

6.4.1 General

AUSPLUME allows for four types of emission source: stack (elevated point release) volume, area and open pit. Volume sources were used to estimate emissions from excavation and waste placement areas and stockpiles.

The following sections describe the source configurations used in the models.

6.4.2 Excavation Zones

The source zones (excavation locations) are summarised in Table 6.

Table 6 Villawood Area Source Locations

Source ID	Remediation Zones	Centroid (AMG)
S1	Zone 9	314224 6249396
S8	Zone 1a,1b,2	314247 6249172
S9	Zone 1a,1b,2	314282 6249237
S12	Zone 8	314282 6249296
S16	Zone 7	314316 6249375
S25	Zone 5(2)	314047 6249384
S26	Zone 5(1)	313998 6249432

Modelling of vapour emissions in AUSPLUME for each of these sources have been based on 1 g/s for the entire source volume. Emissions have been modelled intermittently, with 1 g/s from the hours of 7 am to 5 pm during site operations, and 0 g/s outside operation time.

The output GLCs are scaled for each chemical according to predicted source emission rates (as discussed in Section 3.4.3).

6.4.3 DTD / ECS

The DTD unit consists of a minimum 14.9 m stack with a maximum 1.2 m inner diameter. The ECS will be adjacent to the FSB. Vapour and dust would be captured in the emissions control system consisting of one and possible more carbon bed filters, and then dispersed through a minimum 21 m stack with a maximum 1.3 m inner diameter. The stack characteristics are presented in Table 7.

Table 7 Stack Source Characteristics

Stack	DTD	ECS
Stack Coordinates (AMG)	314210 6249344	314224 6249396
Stack Height	14.9 m	21.5 m



Stack	DTD	ECS
Inner Diameter	1.2 m	1.3 m
Exit Temperature	60 C	20 C
Exit Velocity	18.3 m/s	15.0 m/s
Base elevation	33 m	35 m

6.5 Dust Emissions and Particle Size Distribution

Dust emission modelling was conducted by PAEH, which predicted dust GLC as well as deposition rates for particles. The mass distribution of Total Suspended Particulate (TSP) with size was characterised by PAEH to three fractions, namely:

- ▀ ≤ 2.5 mm;
- ▀ $2.5 \leq 10$ mm;
- ▀ > 10 mm.

Total dust impact was calculated based on a weighted factor for each of the particle sizes, based on their particle size distribution of mass. The particle size distribution is presented in Table 8.

It should be noted that particles greater than 10 mm in size are less likely to enter the lungs as particles of this size become trapped within the nasal cavities. When estimating health risks through the inhalation pathway, the size fraction > 10 μm has not been included in the estimation of chemical concentration in breathable air. This particle size fraction, however, has been included when estimating DRs, since all particles sizes contribute to risks through oral ingestion and direct contact.

Table 8 Particle Site Distribution Characteristics

Size Fraction (μm)	Mass Distribution
≤ 2.5	0.0468
$2.5 \leq 10$	0.344
> 10	0.6092

Air dispersion modelling for dust does not incorporate emission mitigation controls. To account for dust mitigation measures (such as spraying), a 70% reduction (as advised by Thiess) has been applied to the results of the dust GLCs and DRs.

For a more detailed description of the dust emission modelling, refer to PAEH report (PAEH, 2010).

6.6 Dispersion Model Results

The air dispersion modelling results were used as input to the risk calculations for the specified grid (2.8 km x 2.8 km). Volatile emissions were based on a unit emission rates for each source. Simulations were run using an all hours average (24 hour mean) for chronic health risk calculations.

The dispersion model estimates chemical concentrations across the grid area, based on unit emission rates. For volatiles, these results were scaled based on the calculated emission rates for each COPC



(refer to Section 3.4). TSP GLCs and DRs were scaled for each chemical as described above in Section 6.5.

PAEH have also modelled emission using one hour average as described in *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DECC, 2005), and compared to GLC design concentrations. The results of these comparisons may be used to assess potential acute based exposure to emissions. Refer to the PAEH (2010) report for further information.



7. Risk Characterisation

7.1 Introduction

Risk characterisation is the final step in the risk assessment process, where information regarding human exposure patterns, chemical-specific toxicity criteria, and dispersion of airborne chemicals is combined together to assess the potential risks for the receptors of interest. Having assessed the potential exposure to these chemicals, and having determined their toxicity, the risk associated with each source and each chemical can be estimated. For this project, risk characterisation involves the comparison of risk levels predicted by the modified CAPCOA model with acceptable risk levels that have been referred to in NSW.

It should be noted that the methodology for estimating health risk through inhalation pathway in CAPCOA is consistent with the recent release of the USEPA document *Risk Assessment Guidelines for Superfund, Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA, 2009).

To determine the potential health risk associated with environmental chemicals, it is standard practice to evaluate both carcinogenic (cancer causing) and non-carcinogenic effects. This risk assessment presents estimated chronic health risks for both carcinogens and non-carcinogens.

7.1.1 Carcinogenic Chemicals

For receptors exposed to carcinogens, risks are defined as the increase in incremental lifetime risk of cancer based on exposure to a specific chemical or emission source. Cancer risk is calculated using the following equations:

$$\text{Risk} = C \times UR \quad (\text{inhalation pathway}) \quad (7.1)$$

or

$$\text{Risk} = CDI \times SF \quad (\text{non-inhalation pathways}) \quad (7.2)$$

Where:	Risk	=	Incremental lifetime risk of cancer
	C	=	Average Ground Level Air Concentration ($\mu\text{g}/\text{m}^3$)
	UR	=	Unit Risk Factor ($\mu\text{g}/\text{m}^3$) ⁻¹
	CDI	=	Chronic Daily Intake (mg/kg/day)
	SF	=	Slope Factor (sometimes called Cancer Potency Factor) (mg/kg/day) ⁻¹

A formal policy in NSW regarding the level of acceptable cancer risk from airborne contaminants is published by the NSW DECC, *Approved Methods for the Assessment of Air Pollutants in New South Wales*, (NSW DECC, 2005), Section 7.3. The guideline states:

- ▶ Cancer risks less than 1 in 1 million (1×10^{-6}) are acceptable;
- ▶ Cancer risks between 1 in 1 million (1×10^{-6}) and 1 in 10 thousand (1×10^{-4}) require best practice for air toxics to achieve acceptable risks; and
- ▶ Cancer risks greater than 1 in 10 thousand (1×10^{-4}) are not acceptable.



7.1.2 Threshold Chemicals

For chemicals assessed using a threshold approach (i.e. non-carcinogens), risks are defined using a chronic “Hazard Quotient” approach, which compares the estimated exposures with levels previously defined to be acceptable. Threshold risk differs from cancer risks in that they are not probabilities, but are evaluated as a simple ratio.

Non-cancer risks are defined using the following equations:

$$HQ = \frac{C}{RfC} \quad (\text{inhalation pathway}) \quad (7.3)$$

or

$$HQ = \frac{CDI}{RfD} \quad (\text{non-inhalation pathways}) \quad (7.4)$$

Where:	HQ	=	Hazard Quotient
	C	=	Average Ground Level Air Concentration ($\mu\text{g}/\text{m}^3$)
	RfC	=	Chronic Reference Concentration ($\mu\text{g}/\text{m}^3$)
	CDI	=	Chronic Daily Intake (mg/kg/day)
	RfD	=	Chronic Reference Dose (mg/kg/day)

A Hazard Quotient of less than 1 indicates that adverse health effects are not likely to occur. The sum of HQs for each chemical and exposure route is defined as the Hazard Index (HI). An HI of less than 1.0 indicates that adverse health effects are unlikely to occur from exposure to all chemicals. HQs or HIs greater than 1.0 do not indicate that significant risks are present, but rather that additional evaluation should be performed to better define the level of risk.

A formal policy in NSW regarding the non-cancer risk from airborne contaminants is published by the NSW DECC, *Approved Methods for the Assessment of Air Pollutants in New South Wales*, (NSW DECC, 2005), Section 7.3. The guideline states:

- HI less than 0.2 are acceptable;
- HI between 0.2 and 10 require best practice for air toxics to achieve acceptable risks; and
- HI greater than 10 are not acceptable.

7.2 Receptor Groups

This risk assessment model has enabled the risk to be calculated for the gridded receptor locations. The exposure routes included in the calculation of risk were inhalation, dermal contact, soil ingestion and ingestion of homegrown produce.

7.3 Estimation of Cancer and Non-Cancer Risks

For the multi-pathway risk assessment, the total of the inhalation and non-inhalation incremental risk of cancer was calculated for the gridded receptor locations. Likewise, the non-cancer hazard quotients for inhalation and non-inhalation were totalled.



Noncancer HIs are based on the cumulative simultaneous exposure, and therefore it is not appropriate to add all the exposures from all sources together as excavations of contaminated zones will occur sequentially rather than simultaneously. Exposure will occur to a single excavation zone simultaneously with the DTD and ECS. For inhalation of vapour and dust from excavation sources, weighted HIs were calculated by weighting the HIs based on the time for each excavation zone, compared to the total time to excavate all contamination sources. The weightings for each source are presented in Table 9. Details of each emission source are discussed in Section 2.2.

Table 9 Weighting for Non-simultaneous Inhalation Noncancer HIs

Source	Days Operation	Weighting Fraction
S1	2	0.059
S8	8.5	0.250
S9	8.5	0.250
S12	10	0.294
S16	2	0.059
S25	2	0.059
S26	1	0.029
Total	34	1

7.4 Results of Health Risk Calculations

A summary table of total health risk results associated with exposure from all COPC emitted from all sources from the site is presented in Appendix D. Contour plots of the cancer risk and noncancer HI is presented in Figure 3 and 4 respectively. The contributions to risk, at the offsite maximum exposed individual (MEI), from each source and chemical is presented in Table 10 and Table 11 for cancer and non-cancer, respectively.

The MEI is located in the residential properties east of the site, bordering on Miller Road and Abott Park (AMG 314 500E, 6 249 200N).



Table 10 Source Contribution to Cancer Risk at Offsite MEI (315400E, 6249200N)

Source	Hexachloro- benzene	1,2- Dichloroethane	Chloroform	Carbon Tetrachloride	Trichloro- ethylene	Benzene	Bis(2-chloroethyl) ether	a-BHC	b-BHC	d-BHC	g-BHC (lindane)	Dieldrin	DDX	Benzo(a)pyrene - TEQ	1,1- Dichloroethane	vinyl chloride	Total Risk
Inhalation																	
Excavations / Vapour																	
S1	1.5E-12	-	-	-	-	1.7E-13	-	1.9E-11	5.2E-12	6.7E-12	3.2E-12	5.4E-12	2.7E-12	4.4E-13	-	7.4E-12	5.1E-11
S8	1.5E-11	1.8E-12	3.4E-13	5.5E-11	8.2E-12	1.3E-12	-	1.8E-10	5.0E-11	6.4E-11	3.1E-11	5.2E-11	2.6E-11	4.3E-12	3.7E-13	4.4E-11	5.3E-10
S9	1.9E-11	2.4E-12	4.5E-13	7.2E-11	1.1E-11	1.7E-12	-	2.4E-10	6.5E-11	8.4E-11	4.0E-11	6.8E-11	3.4E-11	5.6E-12	4.8E-13	5.7E-11	7.0E-10
S12	2.1E-11	-	-	-	-	2.1E-12	-	2.6E-10	7.2E-11	9.3E-11	4.4E-11	7.5E-11	3.7E-11	6.1E-12	-	8.8E-11	7.0E-10
S16	2.3E-12	-	-	-	-	2.6E-13	-	2.8E-11	7.8E-12	1.0E-11	4.8E-12	8.1E-12	4.0E-12	6.6E-13	-	1.2E-11	7.8E-11
S25	8.0E-13	-	-	-	-	8.8E-14	-	9.8E-12	2.7E-12	3.5E-12	1.7E-12	2.8E-12	1.4E-12	2.3E-13	-	3.9E-12	2.7E-11
S26	2.4E-13	-	-	-	-	2.9E-14	-	2.9E-12	8.0E-13	1.0E-12	5.0E-13	8.4E-13	4.2E-13	6.8E-14	-	1.4E-12	8.2E-12
SUBTOTAL	6.0E-11	4.2E-12	7.9E-13	1.3E-10	1.9E-11	5.6E-12	-	7.4E-10	2.0E-10	2.6E-10	1.3E-10	2.1E-10	1.1E-10	1.7E-11	8.5E-13	2.1E-10	2.1E-09
Inhalation																	
Excavations / Dust																	
S1	5.5E-15	-	-	-	-	2.1E-18	-	1.6E-13	4.1E-14	2.3E-14	2.7E-14	8.4E-14	4.1E-13	2.8E-14	-	1.9E-17	7.8E-13
S8	1.1E-15	4.6E-18	4.5E-19	4.3E-17	7.8E-18	4.0E-19	-	3.1E-14	8.0E-15	4.4E-15	5.2E-15	1.6E-14	8.0E-14	5.3E-15	3.7E-19	3.7E-18	1.5E-13
S9	7.4E-15	3.2E-17	3.1E-18	3.0E-16	5.4E-17	2.7E-18	-	2.1E-13	5.5E-14	3.1E-14	3.6E-14	1.1E-13	5.5E-13	3.7E-14	2.5E-18	2.5E-17	1.0E-12
S12	3.3E-15	-	-	-	-	1.2E-18	-	9.5E-14	2.4E-14	1.4E-14	1.6E-14	5.0E-14	2.5E-13	1.6E-14	-	1.1E-17	4.6E-13
S16	6.8E-16	-	-	-	-	2.5E-19	-	1.9E-14	5.0E-15	2.8E-15	3.3E-15	1.0E-14	5.0E-14	3.4E-15	-	2.3E-18	9.5E-14
S25	2.0E-16	-	-	-	-	7.3E-20	-	5.7E-15	1.5E-15	8.1E-16	9.6E-16	3.0E-15	1.5E-14	9.8E-16	-	6.7E-19	2.8E-14
S26	7.7E-17	-	-	-	-	2.9E-20	-	2.2E-15	5.7E-16	3.2E-16	3.8E-16	1.2E-15	5.8E-15	3.8E-16	-	2.6E-19	1.1E-14
SUBTOTAL	1.8E-14	3.7E-17	3.6E-18	3.4E-16	6.2E-17	6.8E-18	-	5.3E-13	1.4E-13	7.5E-14	8.9E-14	2.8E-13	1.4E-12	9.1E-14	2.9E-18	6.2E-17	2.6E-12
Inhalation																	
DTD																	
	4.6E-12	7.4E-14	1.9E-15	1.9E-13	3.3E-14	1.7E-15	-	1.3E-10	3.4E-11	1.9E-11	2.3E-11	7.0E-11	3.4E-10	2.3E-11	1.6E-15	1.6E-14	6.5E-10
Inhalation																	
FSB/ECS																	
	1.0E-11	3.6E-11	2.0E-12	3.4E-10	5.1E-11	1.3E-12	-	9.5E-11	2.6E-11	3.4E-11	1.6E-11	3.1E-11	1.6E-11	2.1E-12	2.2E-12	5.4E-11	7.2E-10
Direct Contact																	
Excavations / Dust Deposition																	
S1	1.0E-09	-	-	-	-	2.5E-13	-	1.1E-08	2.9E-09	1.6E-09	2.0E-09	6.9E-09	7.5E-08	3.2E-12	-	1.0E-10	1.0E-07
S8	1.8E-10	2.3E-13	4.8E-13	3.7E-12	3.1E-12	1.6E-14	-	6.8E-10	1.7E-10	9.9E-11	1.2E-10	5.7E-10	1.3E-08	1.9E-13	9.8E-15	1.3E-11	1.5E-08
S9	1.2E-09	1.5E-12	3.2E-12	2.4E-11	2.0E-11	1.1E-13	-	4.5E-09	1.1E-09	6.6E-10	7.7E-10	3.8E-09	8.5E-08	1.3E-12	6.5E-14	8.7E-11	9.8E-08
S12	4.7E-10	-	-	-	-	3.6E-14	-	1.5E-09	3.8E-10	2.2E-10	2.6E-10	1.3E-09	3.3E-08	4.2E-13	-	3.3E-11	3.7E-08
S16	1.3E-10	-	-	-	-	3.2E-14	-	1.5E-09	3.7E-10	2.1E-10	2.5E-10	8.8E-10	9.6E-09	4.1E-13	-	1.3E-11	1.3E-08
S25	3.3E-11	-	-	-	-	8.0E-15	-	3.7E-10	9.2E-11	5.2E-11	6.3E-11	2.2E-10	2.4E-09	1.0E-13	-	3.3E-12	3.2E-09
S26	1.7E-11	-	-	-	-	6.0E-15	-	2.7E-10	6.9E-11	3.9E-11	4.7E-11	1.5E-10	1.3E-09	7.8E-14	-	2.0E-12	1.9E-09
SUBTOTAL	3.1E-09	1.8E-12	3.7E-12	2.8E-11	2.3E-11	4.6E-13	-	2.0E-08	5.1E-09	2.9E-09	3.5E-09	1.4E-08	2.2E-07	5.7E-12	7.5E-14	2.6E-10	2.7E-07
TOTAL	3.2E-09	4.2E-11	6.5E-12	4.9E-10	9.3E-11	7.4E-12	-	2.1E-08	5.3E-09	3.2E-09	3.6E-09	1.4E-08	2.2E-07	4.8E-11	3.1E-12	5.2E-10	2.7E-07



Table 11 Source Contribution to Non-Cancer Hazard Index at Offsite MEI (315400E, 6249200N)

Source	Hexachloro- benzene	Chloroform	Carbon tetrachloride	Tetrachloro- ethylene	Chloro- benzene	Toluene	Ethylbenzene	Xylenes	1,4-Dichloro- benzene	1,2,3-trichloro- propane	g-BHC (lindane)	Dieldrin	DDX	Endosulfan II	Mercury (total organic)	Naphthalene	1,1-Dichloro- ethane	1,1-Dichloro- ethylene	1,2-Dichloro- ethylene	1,1,1-Trichloro- ethane	Vinyl Chloride	Total HI
Inhalation																						
Excavations / Vapour																						
S1	9.0E-07	-	-	2.1E-06	2.5E-06	1.1E-06	-	-	3.7E-08	8.0E-06	1.8E-06	-	-	1.8E-06	3.1E-06	9.0E-08	-	-	-	-	6.3E-06	2.6E-05
S8	8.6E-06	6.3E-06	4.5E-04	1.3E-05	2.0E-05	8.5E-06	-	-	3.1E-07	7.0E-05	1.7E-05	-	-	1.7E-05	2.6E-05	8.4E-07	-	9.6E-07	6.9E-06	6.6E-07	3.7E-05	6.7E-04
S9	1.1E-05	8.2E-06	5.9E-04	1.7E-05	2.7E-05	1.1E-05	-	-	4.1E-07	9.2E-05	2.2E-05	-	-	2.2E-05	3.4E-05	1.1E-06	-	1.3E-06	9.1E-06	8.6E-07	4.9E-05	8.7E-04
S12	1.2E-05	-	-	2.5E-05	3.3E-05	1.4E-05	-	-	4.9E-07	1.1E-04	2.4E-05	-	-	2.4E-05	4.1E-05	1.2E-06	-	-	-	-	7.5E-05	3.3E-04
S16	1.4E-06	-	-	3.4E-06	3.9E-06	1.7E-06	-	-	5.8E-08	1.2E-05	2.6E-06	-	-	2.6E-06	4.8E-06	1.4E-07	-	-	-	-	1.0E-05	4.1E-05
S25	4.7E-07	-	-	1.1E-06	1.3E-06	5.8E-07	-	-	2.0E-08	4.2E-06	9.2E-07	-	-	9.2E-07	1.6E-06	4.7E-08	-	-	-	-	3.3E-06	1.4E-05
S26	1.4E-07	-	-	3.8E-07	4.2E-07	1.9E-07	-	-	6.2E-09	1.3E-06	2.7E-07	-	-	2.7E-07	5.2E-07	1.4E-08	-	-	-	-	1.2E-06	4.4E-06
SUBTOTAL	3.5E-05	1.4E-05	1.0E-03	6.1E-05	8.8E-05	3.8E-05	-	-	1.3E-06	2.9E-04	-	-	-	6.9E-05	1.1E-04	3.5E-06	-	2.2E-06	1.6E-05	1.5E-06	1.8E-04	2.0E-03
Inhalation																						
Excavations / Dust																						
S1	3.2E-09	-	-	1.2E-11	6.0E-11	1.6E-11	-	-	1.5E-12	5.4E-10	2.6E-07	-	-	2.6E-07	2.0E-10	1.7E-11	-	-	-	-	1.6E-11	2.7E-07
S8	6.2E-10	8.2E-12	3.5E-10	2.4E-12	1.2E-11	3.2E-12	-	-	2.9E-13	1.0E-10	5.1E-08	-	-	5.1E-08	4.0E-11	3.4E-12	-	4.6E-13	8.6E-12	4.4E-13	3.1E-12	5.2E-08
S9	4.3E-09	5.7E-11	2.5E-09	1.6E-11	8.0E-11	2.2E-11	-	-	2.0E-12	7.2E-10	3.5E-07	-	-	3.5E-07	2.7E-10	2.3E-11	-	3.2E-12	5.9E-11	3.0E-12	2.2E-11	3.6E-07
S12	1.9E-09	-	-	7.2E-12	3.6E-11	9.6E-12	-	-	8.7E-13	3.2E-10	1.6E-07	-	-	1.6E-07	1.2E-10	1.0E-11	-	-	-	-	9.6E-12	1.6E-07
S16	3.9E-10	-	-	1.5E-12	7.3E-12	2.0E-12	-	-	1.8E-13	6.6E-11	3.2E-08	-	-	3.2E-08	2.5E-11	2.1E-12	-	-	-	-	2.0E-12	3.2E-08
S25	1.1E-10	-	-	4.3E-13	2.1E-12	5.8E-13	-	-	5.2E-14	1.9E-11	9.3E-09	-	-	9.3E-09	7.3E-12	6.2E-13	-	-	-	-	5.7E-13	9.4E-09
S26	4.5E-11	-	-	1.7E-13	8.4E-13	2.3E-13	-	-	2.1E-14	7.5E-12	3.6E-09	-	-	3.6E-09	2.8E-12	2.4E-13	-	-	-	-	2.3E-13	3.7E-09
SUBTOTAL	1.1E-08	6.5E-11	2.8E-09	4.0E-11	2.0E-10	5.4E-11	-	-	4.9E-12	1.8E-09	-	-	-	8.6E-07	6.7E-10	5.8E-11	-	3.7E-12	6.8E-11	3.5E-12	5.3E-11	8.8E-07
Inhalation																						
DTD	5.8E-07	7.7E-09	3.3E-07	2.2E-09	2.5E-08	2.9E-09	-	9.9E-10	7.2E-09	9.8E-08	-	-	-	4.7E-05	3.7E-03	3.2E-09	-	4.4E-10	8.0E-09	4.1E-10	2.9E-09	3.8E-03
Inhalation																						
FSB/ECS	1.3E-06	8.0E-06	6.1E-04	3.7E-06	9.5E-06	1.9E-06	-	4.2E-07	1.7E-06	1.2E-05	-	-	-	2.5E-06	5.1E-06	1.3E-07	-	1.3E-06	8.7E-06	9.2E-07	1.0E-05	6.8E-04
Direct Contact																						
Excavations / Dust Deposition																						
S1	1.4E-06	-	-	3.0E-08	1.1E-08	8.1E-10	-	-	7.8E-09	1.8E-09	2.7E-07	6.0E-06	1.1E-05	2.3E-06	3.5E-08	8.3E-11	-	-	-	-	4.1E-08	2.1E-05
S8	2.9E-07	7.4E-10	2.3E-07	6.1E-09	1.5E-09	9.8E-11	-	-	1.2E-09	2.3E-10	2.6E-08	7.8E-07	1.9E-06	1.8E-07	6.4E-09	7.0E-12	4.8E-11	1.4E-10	1.3E-09	9.0E-11	7.3E-09	3.4E-06
S9	1.9E-06	4.9E-09	1.5E-06	4.1E-08	9.9E-09	6.5E-10	-	-	8.0E-09	1.5E-09	1.7E-07	5.2E-06	1.2E-05	1.2E-06	4.3E-08	4.7E-11	3.2E-10	9.1E-10	8.3E-09	5.9E-10	4.8E-08	2.3E-05
S12	7.4E-07	-	-	1.6E-08	3.7E-09	2.4E-10	-	-	3.0E-09	5.7E-10	6.1E-08	1.9E-06	4.8E-06	4.1E-07	1.6E-08	1.7E-11	-	-	-	-	1.8E-08	8.0E-06
S16	1.8E-07	-	-	3.8E-09	1.4E-09	1.0E-10	-	-	9.9E-10	2.3E-10	3.5E-08	7.7E-07	1.4E-06	2.9E-07	4.5E-09	1.1E-11	-	-	-	-	5.2E-09	2.7E-06
S25	4.5E-08	-	-	9.4E-10	3.6E-10	2.6E-11	-	-	2.5E-10	5.7E-11	8.8E-09	1.9E-07	3.5E-07	7.2E-08	1.1E-09	2.6E-12	-	-	-	-	1.3E-09	6.7E-07
S26	2.1E-08	-	-	4.3E-10	2.2E-10	1.6E-11	-	-	1.4E-10	3.4E-11	6.0E-09	1.2E-07	1.8E-07	5.2E-08	5.6E-10	1.8E-12	-	-	-	-	6.7E-10	3.8E-07
SUBTOTAL	4.6E-06	5.6E-09	1.8E-06	9.7E-08	2.8E-08	1.9E-09	-	-	2.1E-08	4.4E-09	5.8E-07	1.5E-05	3.2E-05	4.4E-06	1.1E-07	1.7E-10	3.6E-10	1.1E-09	9.6E-09	6.8E-10	1.2E-07	5.9E-05
TOTAL	4.2E-05	2.2E-05	1.7E-03	6.5E-05	9.7E-05	3.9E-05	-	4.2E-07	3.0E-06	3.1E-04	5.8E-07	1.5E-05	3.2E-05	1.2E-04	3.8E-03	3.6E-06	3.6E-10	3.5E-06	2.5E-05	2.4E-06	1.9E-04	6.4E-03



7.4.1 Estimated Carcinogenic Health Risks

The incremental cancer risks were estimated for the receptor grid and are presented in Figure 3. Health risks have been estimated based on a resident exposed through inhalation for the duration of the remediation process, but continued exposure through secondary exposure (i.e. soil ingestion, dermal contact and produce ingestion) for the remaining period of 70 years total exposure.

The model estimates the incremental lifetime cancer risk for the maximum exposed off-site individual (MEI) (determined to be the residential receptor on the corner of Miller Road and Abott Park (AMG 314 500E, 6 249 200N)), to be approximately 3×10^{-7} (0.3 in 1 000 000), which is below the acceptable cancer risk of 1×10^{-6} .

MEI Analysis

Table 10 presents the breakdown of cancer risk at the MEI by chemical, source and pathway. The cancer risk through inhalation (vapour and dust) is 4×10^{-9} , which makes up 1.3% of the total cancer risk. The balance of the cancer risk is contributed by deposition of dust and secondary exposure over 70 year duration.

Of the direct contact exposure through dust deposition, DDX contributes the greatest to cancer risk of 2.2×10^{-7} (81%), with the majority for sources S1 (Zone 9) S9 (Zones 1a, 1b, 2, CHS) totalling 1.7×10^{-7} .

Upon close inspection of the calculations for risk for DDX through direct contact at the MEI the following was identified:

- ▶ S1 and S9 were responsible for the majority of the cancer risk to the MEI;
- ▶ From dust deposition, the estimated increase in soil concentration of DDX in the residential property was around 0.09 mg/kg;
- ▶ The incremental cancer risk associated with soil ingestion was 5.2×10^{-11} ;
- ▶ The incremental cancer risk associated with dermal (skin) absorption was 3.3×10^{-11} ; and
- ▶ The incremental cancer risk associated with uptake and consumption of home-grown produce was 1.7×10^{-7} .

The uptake of organic chemicals by fruit and vegetables is highly uncertain. DDX is known to be bioaccumulative, which is responsible for the high uptake rate, and consequent risk. It should be noted that the National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) Health Investigation Level for Standard residential (HIL-A) for DDX is 200 mg/kg, which is well above estimated soil concentration of 0.09 mg/kg.

The above analysis indicates that if plant uptake and consumption was excluded from the risk estimate, the revised incremental cancer risk would be 4×10^{-9} .

7.4.2 Estimated Non-Carcinogenic Health Risks

The noncancer HIs were estimated for the receptor grid and are presented in Figure 4. HIs have been estimated based on residents exposed through inhalation for the duration of the remediation process, and exposure through secondary exposure (i.e. soil ingestion, dermal contact and produce ingestion)



concurrently during the remediation works. Note that as all the excavation works will be conducted in sequence, the HIs for inhalation are not additive, instead the HIs for each excavation source has been weighted based on the number of days operation compared with the total number of days involving excavation of contaminated soil. This is discussed in Section 7.3.

The model estimates the noncancer HI for the maximum exposed off-site individual (determined to be the residential receptor on the corner of Miller Road and Abott Park (AMG 314 500E, 6 249 200N)), to be approximately 0.0064, which is below the acceptable HI of 0.2.

MEI Analysis

Table 11 presents the breakdown of noncancer HI at the MEI by chemical, source and pathway. HIs through inhalation of vapours emitted from the DTD contributes 58% (the major contributor is mercury) of the total HI, and vapour from excavations contributes 30% of the total HI, with sources S8 and S9 (Zones 1a, 1b, 2 and CHS) contributing the largest proportion.

The chemicals contributing the greatest portion to the noncancer HI were:

- ▶ Mercury – 59%; and
- ▶ Carbon tetrachloride – 25%.

It should be noted that the largest contribution of mercury risk is from the DTD which assumes zero removal efficiency for this chemical.

7.5 Assessment of Childhood Exposure

The CAPCOA risk model estimates health risk for 70 years exposure duration, and is based on typical exposure parameters for adults. When considering exposure to children there are some specific considerations which are described in the following sections.

7.5.1 Early-Life Exposure

In March 2005, US EPA issued new *Guidelines for Carcinogenic Risk Assessment* (EPA/630/P-03/001B), updating the 1986 guidelines and 1999 interim final guidelines. Also included was *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA/630/R-03/003F). The guideline requires that risk developmental issues be account for in carcinogenic risks for early-life exposure (i.e. first two years of life).

US EPA's guideline indicates that where chemicals which show mutagenic mode of action, a factor of 10 should be applied to the cancer unit risk / slope factor for the first two years of exposure.

DDX accounts for 81% of the total carcinogenic risks. The DDX toxicology summary by ATSDR (2002) states:

“Possible genotoxic effects in humans have been reported in a few studies, but simultaneous exposure to other chemicals and lack of control for relevant confounders make the results inconclusive. For the most part, DDT and related compounds are not mutagenic in prokaryotic organisms.”

DDX is also not listed by US EPA as a chemical with known early-life developmental effects. For this reason, this additional factor has not been applied to DDX.



Of the COPC, the only chemicals with known developmental toxicity are benzo(a)pyrene (and carcinogenic PAHs) and vinyl chloride. The total cancer risk due to carcinogenic PAHs was estimated as 4.8×10^{-11} (0.018%). Conservatively multiplying the total cancer risk by 10 would increase the risk from carcinogenic PAHs to 4.8×10^{-10} , which would not change the total cancer risk with two significant figures (9.8×10^{-7}).

For vinyl chloride, the carcinogenic inhalation Unit Risk and oral Slope Factor used are those presented by USEPA Integrated Risk Information System (IRIS) which are based on cancer risks during exposure from child through to adulthood, and protective of the developmental early childhood stage. These toxicity values are twice those for continuous adult exposure.

7.5.2 Inhalation Exposure

The methodology for estimating health risk through inhalation pathway in CAPCOA is consistent with the recent release of the USEPA document *Risk Assessment Guidelines for Superfund, Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA, 2009). The inhalation dosimetry method indicates that cancer risk and HI are not adjusted for inhalation rate or body weight, as risk is not based on dosage (i.e. intake per body weight) as previously advised by US EPA (1989).

Risk and HI are based on air exposure concentrations and adjusted for exposure time only. Therefore, the only difference in inhalation risk between adults and children (excluding the early-life exposure discussed above) is behavioural differences. For the purpose of this assessment residential exposure has been assumed to occur 24 hours per day, everyday during the remediation works, for both adults and children. Therefore no adjustment of estimated risks is required for the assessment of children.

7.5.3 Direct Contact Exposure

For direct contact, an adjustment of risk is required to take account of children. This is because children display different behaviour (hand in mouth activities), and children have lower body weight than adults.

Exposure through direct contact has been assessed for 70 year duration, from the deposited dust in top soil. Typically the first six years of childhood is considered the most sensitive due to the differences in soil ingestion rate and body weight. The following parameters are recommendations of EnHealth (2004).

Table 12 Recommended Soil Ingestion Parameters

Parameter	2-3 yr old	Adult
Soil Ingestion rate (mg/d)	100	25
Body weight (kg)	13.2	64

Notes: EnHealth (2004)

It should be noted that the soil ingestion rate used in the CAPCOA model was 110 mg/d for adults, and therefore is over estimated by a factor of 4 is using Australian based parameter of 25 mg/d. The ratio of adult to child body weight is 4.8. Therefore, the reduction of risk associated with soil ingestion rate, would be balanced by the change in body weight, so there would be no significant change in the risk estimate. It should be noted that the cancer risk associated with soil ingestion, as discussed in Section 7.4.1 was 5.2×10^{-11} , which is insignificant compared to the total cancer risk of 2.7×10^{-7} .



The majority of cancer risk, as discussed in Section 7.4.1 was from the uptake and consumption of home-grown produce. While the body weight of an adult is a factor of 4.8 times a child, the ingestion rate of home-grown food is also likely to be much smaller than an adults' diet. Consequently, it is unlikely that there would be any increase in the level of cancer risk for home-grown produce.



8. Uncertainty Analysis

8.1 Introduction

The assumptions underlying the calculations of health risk have been discussed in the previous sections. It is the purpose of this section to draw together some of the issues regarding the uncertainties which underlie the calculations.

8.2 Chemicals for Evaluation

The selection of the COPC has been based on the remediation action plan (RAP) by AECOM (2010).

8.3 Distribution of Contaminants

Concentrations of contaminants for each zone have been based on the highest weighted mean concentrations by volume of soil for any zone, and therefore conservative when applied site wide. The concentrations have been provided by Thiess, which are based on the historical measurements by URS and AECOM.

8.4 Nature of Effect

It is possible that some chemicals will act as promoters of adverse effects by other chemicals. Examples of this are the carcinogenic promoters, which enhance the carcinogenicity of other chemicals. Potential co-carcinogens are recognised as promoter agents. All promoters have a tendency to display at least a tumorigenic activity in the absence of a known initiator. These properties can give rise to a risk level which is higher than estimated. In general, strategies for emission controls will provide for an additional level of protection where these can be practically implemented.

8.5 Toxicity

The estimation of risk is directly dependent on the toxicity of the chemicals. Toxicity criteria used for this risk assessment have been drawn from well recognised sources (NHMRC, WHO and USEPA) and these are accepted as being appropriate for this type of work.

Notwithstanding that well accepted sources have been used for sourcing the toxicity criteria, the toxicity criteria have in most cases been derived from animal studies, and there is considerable uncertainty in applying these findings to humans because of the physiological and biochemical differences between the animal species and humans, and mode of effect. Because of this, a series of uncertainty factors (also known as safety factors) are applied to the data to provide estimates of the toxicity criteria that are relevant to humans. It is generally considered that these safety factors are conservative, and it is possible that the toxicity of certain chemicals will be significantly overestimated.



In addition, there is considerable uncertainty for some chemicals as to whether there is a threshold dose below which there will be no effect, or whether the likelihood of effect varies with the dose and there is no threshold below which no effect will occur. Most carcinogenic chemicals are assumed to not have a threshold, whereas chemicals which exhibit non-cancer effects are assumed to have a threshold.

8.6 Exposure Modelling

The mathematical models used to estimate exposure introduce uncertainty in that the models involve a number of assumptions and often rely on semi-empirical relationships which in turn rely on the various physical and chemical properties of the chemicals and soils. The assumptions underlying the models have been discussed in the preceding sections of this report and can be regarded as conservative.



9. Conclusions

The risk assessment for the Orica Villawood remediation project considered potential human exposure to airborne chemicals from multiple emissions source. The key findings of this assessment are:

- ▶ The maximum off-site exposed individual (MEI) has been predicted to be located in the residential premises to the east of the site on Miller Road, next to Abott Park;
- ▶ The lifetime risk of cancer for the MEI was estimated to be 3×10^{-7} (0.3 in 1 000 000). This estimate is below the nominated risk level of 1×10^{-6} , and therefore carcinogenic health risk is considered acceptable;
- ▶ The primary chemical contributing to cancer health risk was DDX (81%), with nearly all of this through the home-grown produce pathway, which is dependent on dust deposition rates. Excluding plant uptake and consumption from the risk estimate resulted in an incremental cancer risk of 4×10^{-9} ;
- ▶ The sources that contribute the greatest to offsite risk were S1 and S9 (Zone 1a, 1b, 2, 9 and CHS), due to the proximity of the sources to the eastern site boundary; and
- ▶ The total non-carcinogenic hazard index (HI) for the MEI was estimated to be 0.0064. This value is below the DECCW's acceptable limit of 0.2, and therefore is considered acceptable.

Limitations pertaining to this assessment and the conclusions are presented in Section 10, and should be referred to.



10. Limitations

This report presents the results of an assessment of the health risks associated with discharge of contaminants from soil into air, and was produced specifically for Thiess Services Pty Ltd and for the purposes of this commission. GHD accepts no responsibility for other use of the data. No warranties, expressed or implied, are offered to any third parties and no liability will be accepted for use of this report by any third party.

The information provided in this report is based in part on data supplied by third parties on soil contamination and soil properties at the site, and relate to tests of samples of soil taken from certain investigation locations. Soil contamination is often highly variable, and it is possible that the contamination data used for the assessment may not reflect the conditions that may be encountered elsewhere on the site. GHD has not undertaken field test work to obtain data or to verify the data provided.

Likewise, air dispersion modelling has been conducted by PAE Holmes Pty Ltd. GHD has not undertaken verification of the modelling results supplied.

The work conducted by GHD under this commission has been to the standard that would normally be expected of professional environmental consulting firm practising in this field in the State of NSW. Effort has been made to identify and assess the significant risks to human health associated with the contamination; however, there is a high level of uncertainty in such estimates as indicated in Section 8 of this report. It is possible that variations in the contaminant concentrations and their nature, soil conditions, exposure scenarios and toxicity of chemicals may vary from those assumed, and this could give rise to variations in the estimated level of risk.

This report should not be altered, amended or abbreviated, issued in part and issued incomplete in any way without prior checking and approval by GHD. GHD accepts no responsibility for any circumstances that arise from the issue of the report that has been modified other than by GHD.



11. References

- ABS 1992, *Home Produce of Selected Foodstuffs, Australia, Year Ending April 1992*, Australian Bureau of Statistics.
- AECOM 2010, *Remedial Action Plan, 2 Christina Road, Villawood, NSW, Prepared for: Orica Australia Pty Ltd*, AECOM Australia Pty Limited, Ref: S4149701_Final_RAP_2June10.
- ASTM 1995, *Standard Guide for Risk-Based Corrective Action at Petroleum Release Sites*, Designation: E 1739-95.
- ATSDR 2002, *Toxicological Profile for DDT, DDE and DDD*, September 2002.
- ATSDR 2007a, *Toxicological Profile for Ethylbenzene*, Draft for Public Comment, September 2007.
- ATSDR 2007b, *Toxicological Profile for Chloroform*, September 2007.
- CAPCOA 1993, *Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines*, Toxics Committee of the California Air Pollution Control Officers Association, October 1993.
- CAPCOA 1996, *Health Risk Assessment Program, version 2.0e*, California Air Pollution Control Officers Association.
- EnHealth 2004, *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*, Department of Health and Aging and enHealth Council, June 2004.
- Fitzgerald J 1998, 'The benchmark dose approach and health-based investigation level for polycyclic aromatic hydrocarbons (PAHs)', in A Langley, P Imray, W Lock & H Hill (eds), *The Health Risk Assessment and Management of Contaminated Sites*, Contaminated Sites Monograph Series No.7, South Australian Health Commission, Adelaide.
- HLA 2007, *Remedial Action Plan, 2 Christina Road, Villawood, NSW, Prepared for: Orica Australia Pty Ltd*, HLA-Envirosciences Pty Limited (HLA ENSR), HLA ENSR Ref: S4066001_Final_RAP_3Oct07, 3 October 2007.
- Johnson P.C. and Ettinger R.A. 1991, *Heuristic Model for Predicting the Intrusive Rate of Contaminant vapours into Buildings*, Environ. Sci. Technol. 1991, v25, 1445-1452.
- NEPC 1999, *National Environment Protection (Assessment of Site Contamination) Measure*, National Environment Protection Council, December 1999.
- NHMRC 2004, *Australian Drinking Water Guidelines*, National Health and Medical Research Council.
- NSW DEC 2005, *Approved Methods and Guidance: For the Modelling and Assessment of Air Pollutants in New South Wales*, NSW Department of Environment and Conservation.
- PAEH 2010, *Air Quality Impact Assessment for Orica Villawood Remediation Project*, Consultancy Report prepared for Thiess Services Pty Ltd, PAE Holmes, Document No. 3672, April 2010.
- Powell 1976, *A Formulation of Time-varying Depths of Daytime Mixed Layer and Night-time Stable Layer for Use in Air Pollution Assessment Models*, Annual Report for 1976, Part 3, Battelle PNL Atmospheric Sciences, 185-189.



RAIS 2010, *Risk Assessment Information Systems*, on-line database, [http://risk.lsd.ornl.gov/rap_hp.shtml].

URS 2007, *Human Health and Environmental Risk Assessment*.

URS 2010, *Human Health and Environmental Risk Assessment, 2 Christina Road, Villawood NSW*.

US EPA 1989, *Risk Assessment Guidance for Superfund, Volume 1 Human Health Evaluation Manual, Part A*. Interim Final, EPA/540/1-89/002. US EPA Office of Emergency and Remedial Response. Washington, D.C.

US EPA 2005a, *Guidelines for Carcinogenic Risk Assessment* (EPA/630/P-03/001B), March 2005.

US EPA 2005b, *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA/630/R-03/003F).

US EPA 2009, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)*. EPA-540-R-070-002, January 2009.

USEPA 2010, *Regional Screening Levels, May 2010*, [<http://www.epa.gov/region9/superfund/prg/index.html>].

USEPA 2010, *Integrated Risk Information System (IRIS)*, on-line database [<http://www.epa.gov/iris/>].

Venkatram 1980, *Dispersion from an elevated source in a convective boundary layer*, *Atmospheric Environment*, Volume 10, 1-10.

WHO 2008, *Guidelines for Drinking-Water Quality, Health criteria and other supporting information*, Third Edition Including the First and Second Addenda, World Health Organisation.

WHO 2000, *Guidelines for Air Quality*, World Health Organisation, Geneva, [<http://www.who.int/peh/air/Airqualitygd.htm>].



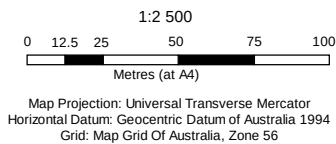
Figures

Figure 1 Site Location

Figure 2 Zones of Contamination Emission

Figure 3 Contours of Total Cancer Risk

Figure 4 Contours of Total Non-Cancer Hazard Index



LEGEND

SSF/FSB - SECURE STORAGE FACILITY / FEED SOIL BUILDING
(INCL. EXTENSION)

ECS - EMISSION CONTROL SYSTEM STACK

DTD - DIRECT THERMAL DESORBER PLANT

S1 - EXCAVATION SOURCE ZONE



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Revision B
Date 6 July 2010

Zones of
Contamination Emissions

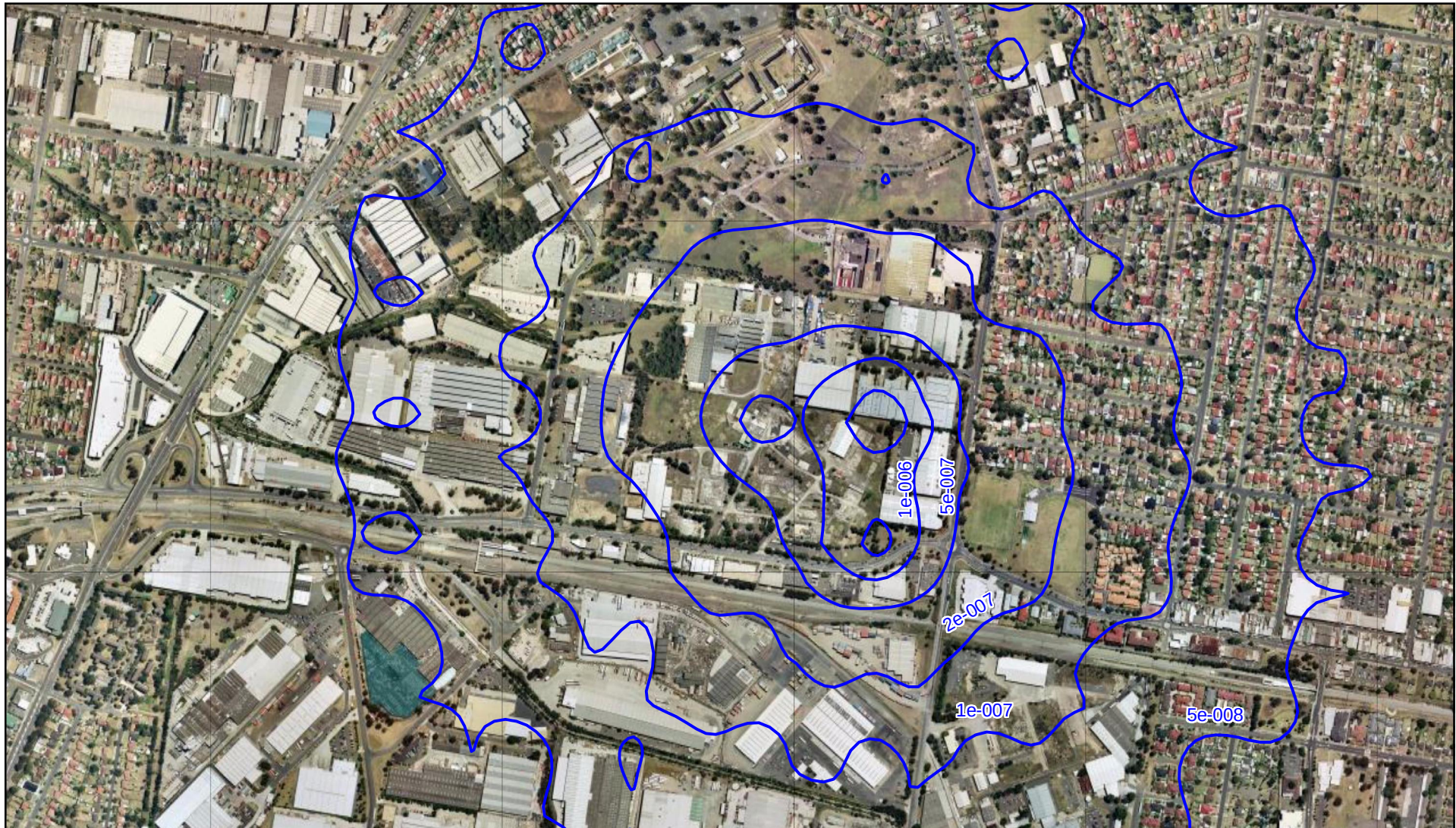
Figure 2

G:\31\25359\GIS\MapInfo\Fig 2 Sources.WOR

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1:10 000
0 0.05 0.1 0.2 0.3 0.4
Kilometres (at A4)
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid Of Australia, Zone 56



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Contours of Total
Cancer Risk

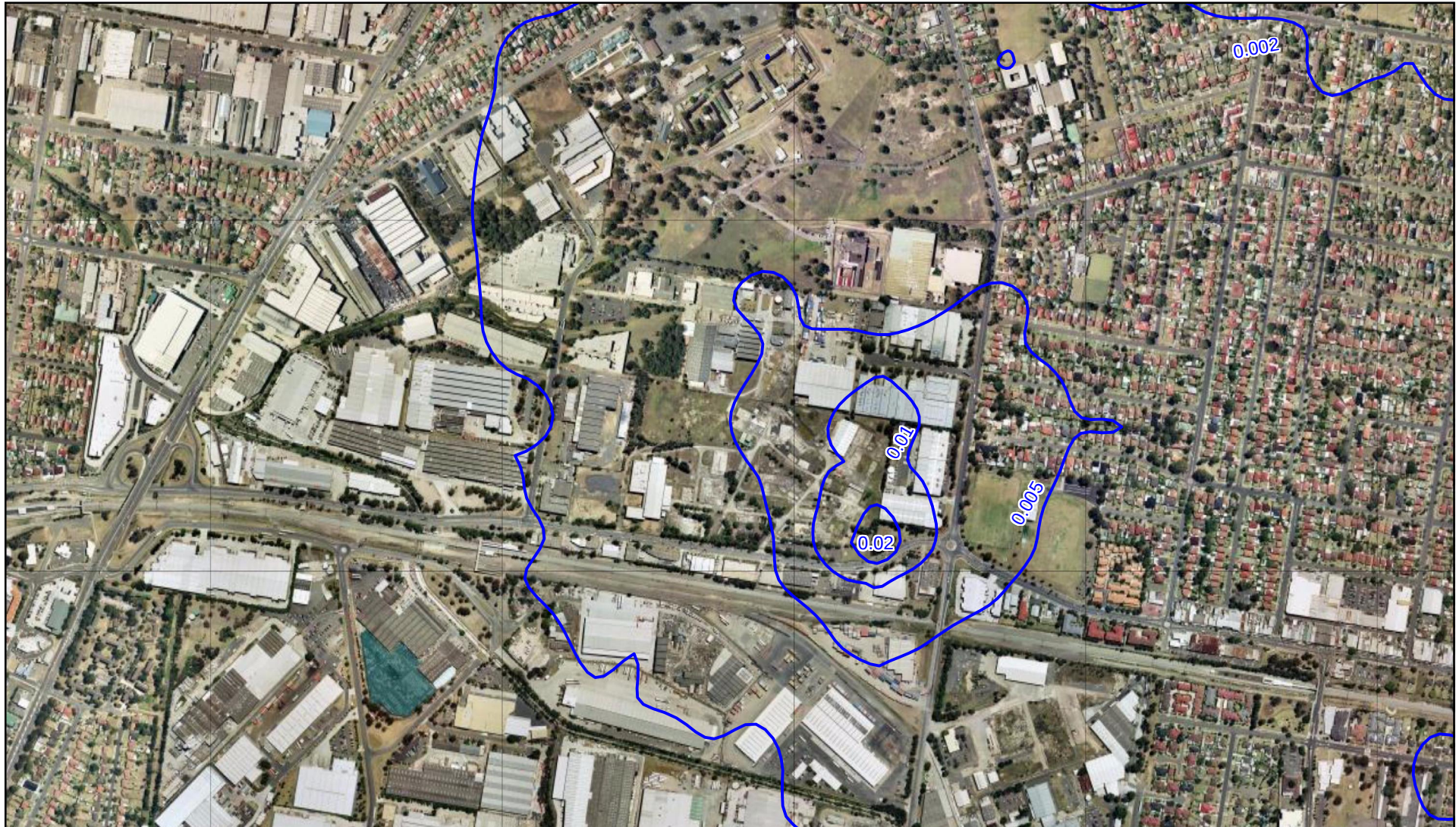
Figure 3

G:\31\25359\GIS\Mapinfo\Fig 3 Cancer Risk.WOR

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1:10 000
0 0.05 0.1 0.2 0.3 0.4
Kilometres (at A4)
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid Of Australia, Zone 56



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Contours of Total
Non-Cancer Hazard Index

Figure 4

G:\31\25359\GIS\MapInfo\Fig 4 Noncancer HI.WOR

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Appendix A

Excavation Dimensions



Excavation Dimensions

To calculate residence time for fresh face exposure, it is assumed that walls will be excavated/sliced in 2 m increments. For example: if excavation occurs at 500 m³ per 10 hours; an excavation zone of 1 000 m² with depth of 0.5 m, of dimension 20 m x 50 m. If the excavation face is the 20 m side (i.e. area of 20 x 0.5 = 10 m²), each face is freshly exposed for 20 m³ (10 m² x 2 m), which takes 0.04 x 10 hours = 0.4 h = 24 minutes.

Hence residence time is 24 minutes.

Stage 1A: Zone 9 (S1)

Volume 1 000 m³, Area 930 m², Average depth = 1.075 m

Approx: dimensions: 25 m x 40 m

Assume excavation occurs with 40 m wide wall, 1.075 m high (exposed face = 43 m²).

Excavation occurs over 2 days

Stage 2: Zone 1a, 1b, 2 (S8, S9)

Volume 3 840 m³, Area 7 685 m², Average depth = 0.5 m

Approx: dimensions: 72 m x 106 m

Assume excavation occurs with 72 m wide wall, 0.5 m high (exposed face = 36 m²).

Excavation occurs over 8 days

Stage 2: Zone 1b (bottom)

Volume 2 200 m³, Area 625 m², Average depth = 3.5 m (0.5 m to 4 m)

Approx: dimensions: 25 m x 25 m

Assume excavation occurs in 1m depth slices; with 25 m wide wall, 1 m high (exposed face = 25 m²) + floor

Excavation occurs over 5 days

Stage 2: Zone 8 (S12)

Volume 5 000 m³, Area 3 241 m², Average depth = 1.54 m

Approx: dimensions: 60 m x 54 m

Assume excavation occurs with 54 m wide wall, 1.54 m high (exposed face = 83 m²).

Excavation occurs over 10 days

Stage 3: Zone 7 (S16)

Volume 1 000 m³, Area 780 m², Average depth = 1.28 m



Approx: dimensions: 30 m x 26 m

Assume excavation occurs with 26 m wide wall, 1.28 m high (exposed face = 33 m²).

Excavation occurs over 2 days

Stage 3: Zone 5(1) (S26)

Volume 500 m³, Area 410 m², Average depth = 1.22 m

Approx: dimensions: 20 m x 20 m

Assume excavation occurs with 20 m wide wall, 1.22 m high (exposed face = 24 m²).

Excavation occurs over 1 day

Stage 3: Zone 5(2) (S25)

Volume 1 000 m³, Area 930 m², Average depth = 1.075 m

Approx: dimensions: 25 m x 40 m

Assume excavation occurs with 40 m wide wall, 1.075 m high (exposed face = 43 m²).

Excavation occurs over 2 days

Pre-treatment Emission Control System

Incorporates the Secure Storage Facility and Excavated Stockpiles – mix is proportion to total volume to be treated. ECS assumes 99.75% removal efficiency.

Secure Storage Facility

Assume covered.

Volume 10 000 m³

Exposed face during excavation = 40 m². Excavation occurs in 1m slices.

Excavation occurs over 26 weeks (156 days, over 24 hours)



Pre-treatment building stockpile

Assume covered.

Total volume over project 15 760 (includes Chester Hill)

Exposed face during excavation = 20 m². Excavation occurs in 1 m slices.

Excavation occurs over 26 weeks (156 days, over 24 hours)



Appendix B

Soil Properties



Soil Properties

Insitu soil;	Clay / Shale
Total Porosity	0.41
Moisture Content	12%
Solid porosity	0.59
particle density	2.65 t/m3
bulk density (dry)	1.5635 t/m3
water mass	0.18762 t/m3
bulk density (wet)	1.75112
water porosity	0.18762
air porosity	0.22238
Organic carbon content	0.3%



Soil Properties

Stockpiled soil

Clay / Shale

Total Porosity	0.495
Moisture Content	12%
Solid porosity	0.505
particle density	2.65 t/m3
bulk density (dry)	1.33825 t/m3
water mass	0.16059 t/m3
bulk density (wet)	1.49884
water porosity	0.16059
air porosity	0.33441
Organic carbon content	0.3%



Soil Properties

Stockpiled soil

Clay / Shale

Total Porosity	0.43
Moisture Content	12%
Solid porosity	0.57
particle density	2.65 t/m3
bulk density (dry)	1.5105 t/m3
water mass	0.18126 t/m3
bulk density (wet)	1.69176
water porosity	0.18126
air porosity	0.24874
Organic carbon content	0.3%



Soil Properties

Stockpiled soil

Chester Hill

Total Porosity	0.46
Moisture Content	12%
Solid porosity	0.54
particle density	2.65 t/m3
bulk density (dry)	1.431 t/m3
water mass	0.17172 t/m3
bulk density (wet)	1.60272
water porosity	0.17172
air porosity	0.28828
Organic carbon content	0.3%



Appendix C

Vapour Emission Calculations

Villawood Remediation
Summary of Emission Rates
Total Emission Rate



Chemical	S1 Z9 g/s *	S8 *** Z1a, 1b, 2, CHS g/s *	S9 *** Z1a, 1b, 2, CHS g/s *	S12 Z8 g/s *	S16 Z7 g/s *	S26 Z5(1) g/s *	S25 Z5(2) g/s *	ECS g/s **	DTD g/s **
Hexachlorobenzene	2.56E-05	3.41E-05	3.41E-05	3.55E-05	2.25E-05	1.93E-05	2.56E-05	1.02E-06	1.85E-06
1,2-dichloroethane (EDC)	0.00E+00	6.89E-04	6.89E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-04	4.86E-06
Chloroform	0.00E+00	8.64E-04	8.64E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.19E-04	8.47E-07
Carbon tetrachloride	0.00E+00	3.87E-03	3.87E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E-03	2.28E-06
TCE	0.00E+00	2.03E-02	2.03E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.42E-03	1.44E-05
PCE	5.37E-03	4.45E-03	4.45E-03	6.39E-03	5.06E-03	4.74E-03	5.37E-03	2.61E-04	6.22E-07
Chlorobenzene	1.28E-02	1.43E-02	1.43E-02	1.67E-02	1.16E-02	1.04E-02	1.28E-02	1.33E-03	1.39E-05
Benzene	2.14E-04	2.25E-04	2.25E-04	2.73E-04	1.96E-04	1.77E-04	2.14E-04	1.00E-05	5.25E-08
Toluene	2.96E-03	3.11E-03	3.11E-03	3.78E-03	2.70E-03	2.44E-03	2.96E-03	1.38E-04	8.65E-07
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E-04	9.72E-07
1,4-Dichlorobenzene	3.81E-04	4.37E-04	4.37E-04	5.01E-04	3.44E-04	3.05E-04	3.81E-04	4.63E-04	8.17E-06
1,2,3-trichloropropane	2.44E-05	2.96E-05	2.96E-05	3.27E-05	2.18E-05	1.91E-05	2.44E-05	1.05E-06	3.31E-08
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	7.94E-05	1.06E-04	1.06E-04	1.10E-04	6.98E-05	5.98E-05	7.94E-05	2.43E-06	1.36E-05
b-BHC	7.44E-05	9.93E-05	9.93E-05	1.03E-04	6.55E-05	5.61E-05	7.44E-05	2.28E-06	1.20E-05
d-BHC	2.84E-05	3.78E-05	3.78E-05	3.94E-05	2.50E-05	2.14E-05	2.84E-05	8.74E-07	1.94E-06
g-BHC (lindane)	7.88E-05	1.05E-04	1.05E-04	1.10E-04	6.93E-05	5.94E-05	7.88E-05	2.42E-06	1.34E-05
dieldrin	8.95E-06	1.19E-05	1.19E-05	1.24E-05	7.87E-06	6.75E-06	8.95E-06	3.10E-07	2.82E-06
DDX	2.12E-04	2.83E-04	2.83E-04	2.94E-04	1.86E-04	1.59E-04	2.12E-04	7.39E-06	6.55E-04
endosulfan II	3.07E-05	4.10E-05	4.10E-05	4.26E-05	2.70E-05	2.31E-05	3.07E-05	1.20E-06	9.17E-05
mercury (total organic)	3.17E-05	3.61E-05	3.61E-05	4.16E-05	2.87E-05	2.55E-05	3.17E-05	1.44E-06	4.18E-03
Naphthalene	2.76E-06	3.55E-06	3.55E-06	3.78E-06	2.44E-06	2.11E-06	2.76E-06	1.13E-07	1.07E-08
Benzo(a)pyrene - TEQ	3.87E-08	5.18E-08	5.18E-08	5.39E-08	3.41E-08	2.92E-08	3.87E-08	1.09E-09	4.86E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.42E-04	2.42E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.26E-05	1.82E-07
1,1-Dichloroethylene (11DCE)	0.00E+00	2.70E-04	2.70E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.41E-05	9.82E-08
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	5.85E-04	5.85E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.46E-04	5.44E-07
1,1,1-Trichloroethane (111TCA)	0.00E+00	4.62E-03	4.62E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28E-03	2.30E-06
Vinyl Chloride	6.45E-03	5.28E-03	5.28E-03	7.64E-03	6.08E-03	5.70E-03	6.45E-03	2.81E-04	3.31E-07

* Emission Rate based on working hours

** Emission Rate based on 24 hours per day

*** Vapour emissions divided evenly between adjacent source locations

Villawood Remediation
Stage of Works: 1A - Zone 9 excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003
Fresh Slice Residence Time	6192 s

Excavation Parameters

Total Time for excavation	20 hrs
Excavation Depth	1.075 m
Slice Depth	2 m
Wall Width	40 m
Volume Slice	86 m3
Total Excavation Volume	1000 m3

Surface Parameters

Length of Pit	40 m	4000 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	200 cm	
Exposure Area	43 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	5.24E-02	3.28E-03	3.28E-03	5.92E-04	2.55E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	3.34E-01	1.42E+00	3.34E-01	6.03E-02	2.59E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	1.28E+00	3.54E+00	1.28E+00	2.31E-01	9.92E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	1.95E-02	8.53E-01	1.95E-02	3.51E-03	1.51E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	2.71E-01	1.92E+00	2.71E-01	4.89E-02	2.10E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	3.95E-02	2.98E-01	3.95E-02	7.14E-03	3.07E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	2.74E-03	1.47E-01	2.74E-03	4.95E-04	2.13E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	2.55E-02	1.02E-02	1.02E-02	1.84E-03	7.92E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	2.24E-02	9.56E-03	9.56E-03	1.73E-03	7.42E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	3.64E-03	3.86E-03	3.64E-03	6.57E-04	2.83E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	2.51E-02	1.01E-02	1.01E-02	1.83E-03	7.86E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	2.05E-03	1.15E-03	1.15E-03	2.08E-04	8.93E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	2.05E-01	2.73E-02	2.73E-02	4.92E-03	2.12E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	3.82E-01	3.95E-03	3.95E-03	7.13E-04	3.07E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.72E-02	3.25E-03	3.25E-03	5.87E-04	2.53E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	3.37E-04	1.20E-02	3.37E-04	6.09E-05	2.62E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	4.99E-06	1.50E-05	4.99E-06	9.01E-07	3.87E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	3.92E-01	1.17E+01	3.92E-01	7.07E-02	3.04E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 1A - Zone 9 excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	20 hrs
Total Excavation Volume	1000 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	3.06E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.43E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.78E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.33E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.55E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.40E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.08E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.68E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.68E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.50E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.68E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.88E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.49E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	4.02E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.48E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.41E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.51E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.41E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 1A - Zone 9 excavation
Total Emission Rate (S1)



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	2.55E-05	8.43E-08	2.56E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	2.59E-03	2.78E-03	5.37E-03
Chlorobenzene	9.92E-03	2.90E-03	1.28E-02
Benzene	1.51E-04	6.33E-05	2.14E-04
Toluene	2.10E-03	8.55E-04	2.96E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.07E-04	7.40E-05	3.81E-04
1,2,3-trichloropropane	2.13E-05	3.08E-06	2.44E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	7.92E-05	1.68E-07	7.94E-05
b-BHC	7.42E-05	1.68E-07	7.44E-05
d-BHC	2.83E-05	1.50E-07	2.84E-05
g-BHC (lindane)	7.86E-05	1.68E-07	7.88E-05
dieldrin	8.93E-06	1.88E-08	8.95E-06
DDX	2.12E-04	3.49E-08	2.12E-04
endosulfan II	3.07E-05	4.02E-09	3.07E-05
mercury (total organic)	2.53E-05	6.48E-06	3.17E-05
Naphthalene	2.62E-06	1.41E-07	2.76E-06
Benzo(a)pyrene - TEQ	3.87E-08	2.51E-12	3.87E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.04E-03	3.41E-03	6.45E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 2 - Zone 1a, 1b, 2 excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003
Fresh Slice Residence Time	5400 s

Excavation Parameters

Total Time for excavation	80 hrs
Excavation Depth	0.5 m
Slice Depth	2 m
Wall Width	72 m
Volume Slice	72 m3
Total Excavation Volume	3840 m3

Surface Parameters

Length of Pit	72 m	7200 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	200 cm	
Exposure Area	36 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	1.01E-01	6.32E-03	6.32E-03	6.34E-04	2.28E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	6.43E-01	2.74E+00	6.43E-01	6.45E-02	2.32E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	2.46E+00	6.83E+00	2.46E+00	2.47E-01	8.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	3.75E-02	1.65E+00	3.75E-02	3.76E-03	1.35E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	5.22E-01	3.70E+00	5.22E-01	5.23E-02	1.88E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	7.62E-02	5.74E-01	7.62E-02	7.64E-03	2.75E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	5.28E-03	2.84E-01	5.28E-03	5.30E-04	1.91E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	4.91E-02	1.97E-02	1.97E-02	1.97E-03	7.10E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	4.31E-02	1.84E-02	1.84E-02	1.85E-03	6.65E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	7.01E-03	7.43E-03	7.01E-03	7.04E-04	2.53E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	4.84E-02	1.95E-02	1.95E-02	1.96E-03	7.05E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	3.96E-03	2.22E-03	2.22E-03	2.22E-04	8.01E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	3.95E-01	5.25E-02	5.25E-02	5.27E-03	1.90E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	7.36E-01	7.61E-03	7.61E-03	7.63E-04	2.75E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	3.31E-02	6.27E-03	6.27E-03	6.29E-04	2.26E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	6.50E-04	2.31E-02	6.50E-04	6.52E-05	2.35E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	9.62E-06	2.90E-05	9.62E-06	9.65E-07	3.47E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	7.55E-01	2.26E+01	7.55E-01	7.57E-02	2.73E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 1a, 1b, 2 excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	80 hrs
Total Excavation Volume	3840 m3
Fraction of air released	0.1
Excavation Rate:	48 m3/hr
	1.33E-02 m3/s
Volume Air emitted	2.93E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.10E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.67E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.79E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.08E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.21E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.10E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.96E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.62E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.62E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.44E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.62E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.80E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.35E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	3.85E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.22E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.35E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.41E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.27E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 1a, 1b, 2 excavation
Total Emission Rate



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	2.28E-05	8.10E-08	2.29E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	2.32E-03	2.67E-03	5.00E-03
Chlorobenzene	8.90E-03	2.79E-03	1.17E-02
Benzene	1.35E-04	6.08E-05	1.96E-04
Toluene	1.88E-03	8.21E-04	2.70E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	2.75E-04	7.10E-05	3.46E-04
1,2,3-trichloropropane	1.91E-05	2.96E-06	2.20E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	7.10E-05	1.62E-07	7.12E-05
b-BHC	6.65E-05	1.62E-07	6.67E-05
d-BHC	2.53E-05	1.44E-07	2.55E-05
g-BHC (lindane)	7.05E-05	1.62E-07	7.06E-05
dieldrin	8.01E-06	1.80E-08	8.02E-06
DDX	1.90E-04	3.35E-08	1.90E-04
endosulfan II	2.75E-05	3.85E-09	2.75E-05
mercury (total organic)	2.26E-05	6.22E-06	2.89E-05
Naphthalene	2.35E-06	1.35E-07	2.48E-06
Benzo(a)pyrene - TEQ	3.47E-08	2.41E-12	3.47E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	2.73E-03	3.27E-03	6.00E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 2 - Zone 1b (bottom) excavation
Vapourisation from Exposed Surface (Wall)



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003
Fresh Slice Residence Time	2045.455 s

Excavation Parameters

Total Time for excavation	50 hrs
Excavation Depth	0.5 m
Slice Depth	2 m
Wall Width	25 m
Volume Slice	25 m3
Total Excavation Volume	2200 m3

Surface Parameters

Length of Pit	25 m	2500 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	200 cm	
Exposure Area	12.5 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	5.70E-02	3.57E-03	3.57E-03	1.03E-03	1.29E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	3.63E-01	1.55E+00	3.63E-01	1.05E-01	1.31E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	1.39E+00	3.85E+00	1.39E+00	4.02E-01	5.02E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	2.12E-02	9.28E-01	2.12E-02	6.11E-03	7.64E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	2.94E-01	2.09E+00	2.94E-01	8.50E-02	1.06E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	4.30E-02	3.24E-01	4.30E-02	1.24E-02	1.55E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	2.98E-03	1.60E-01	2.98E-03	8.61E-04	1.08E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	2.77E-02	1.11E-02	1.11E-02	3.20E-03	4.01E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	2.43E-02	1.04E-02	1.04E-02	3.00E-03	3.75E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	3.96E-03	4.19E-03	3.96E-03	1.14E-03	1.43E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	2.73E-02	1.10E-02	1.10E-02	3.18E-03	3.98E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	2.23E-03	1.25E-03	1.25E-03	3.61E-04	4.52E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	2.23E-01	2.96E-02	2.96E-02	8.56E-03	1.07E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	4.15E-01	4.29E-03	4.29E-03	1.24E-03	1.55E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.87E-02	3.54E-03	3.54E-03	1.02E-03	1.28E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	3.67E-04	1.31E-02	3.67E-04	1.06E-04	1.32E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	5.43E-06	1.63E-05	5.43E-06	1.57E-06	1.96E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	4.26E-01	1.28E+01	4.26E-01	1.23E-01	1.54E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 1b (bottom) excavation
Vapourisation from Exposed Surface (Floor)



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003
Fresh Slice Residence Time	25568.18 s

Excavation Parameters

Total Time for excavation	50 hrs
Excavation Depth	3.5 m
Slice Depth	0.5 m
Floor Area	625 m2
Volume Slice	312.5 m3
Total Excavation Volume	2200 m3

Surface Parameters

Length of Pit	25 m	2500 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	200 cm	
Exposure Area	625 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	1.61E-02	1.01E-03	1.01E-03	2.91E-04	1.82E-04
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	1.03E-01	4.37E-01	1.03E-01	2.97E-02	1.85E-02
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	3.93E-01	1.09E+00	3.93E-01	1.14E-01	7.10E-02
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	5.99E-03	2.62E-01	5.99E-03	1.73E-03	1.08E-03
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	8.33E-02	5.91E-01	8.33E-02	2.41E-02	1.50E-02
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	1.22E-02	9.17E-02	1.22E-02	3.51E-03	2.20E-03
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	8.43E-04	4.53E-02	8.43E-04	2.44E-04	1.52E-04
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	7.83E-03	3.14E-03	3.14E-03	9.06E-04	5.66E-04
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	6.88E-03	2.94E-03	2.94E-03	8.49E-04	5.31E-04
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	1.12E-03	1.19E-03	1.12E-03	3.23E-04	2.02E-04
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	7.72E-03	3.11E-03	3.11E-03	9.00E-04	5.62E-04
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	6.32E-04	3.54E-04	3.54E-04	1.02E-04	6.39E-05
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	6.31E-02	8.38E-03	8.38E-03	2.42E-03	1.51E-03
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	1.17E-01	1.21E-03	1.21E-03	3.51E-04	2.19E-04
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	5.29E-03	1.00E-03	1.00E-03	2.89E-04	1.81E-04
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	1.04E-04	3.69E-03	1.04E-04	2.99E-05	1.87E-05
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	1.53E-06	4.62E-06	1.53E-06	4.43E-07	2.77E-07
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	1.20E-01	3.61E+00	1.20E-01	3.48E-02	2.17E-02

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 1b (bottom) excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	50 hrs
Total Excavation Volume	2200 m3
Fraction of air released	0.1
Excavation Rate:	44 m3/hr
	1.22E-02 m3/s
Volume Air emitted	2.69E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	7.42E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.45E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.56E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	5.57E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	7.52E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	6.51E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.71E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.48E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.48E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.32E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.48E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.65E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.07E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	3.53E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	5.70E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.24E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.21E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.00E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 1b (bottom) excavation
Total Emission Rate



Chemical	E from Wall Surface g/s	E from Floor Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	1.29E-05	1.82E-04	7.42E-08	1.95E-04
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	1.31E-03	1.85E-02	2.45E-03	2.23E-02
Chlorobenzene	5.02E-03	7.10E-02	2.56E-03	7.86E-02
Benzene	7.64E-05	1.08E-03	5.57E-05	1.21E-03
Toluene	1.06E-03	1.50E-02	7.52E-04	1.68E-02
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	1.55E-04	2.20E-03	6.51E-05	2.42E-03
1,2,3-trichloropropane	1.08E-05	1.52E-04	2.71E-06	1.66E-04
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	4.01E-05	5.66E-04	1.48E-07	6.07E-04
b-BHC	3.75E-05	5.31E-04	1.48E-07	5.69E-04
d-BHC	1.43E-05	2.02E-04	1.32E-07	2.17E-04
g-BHC (lindane)	3.98E-05	5.62E-04	1.48E-07	6.02E-04
dieldrin	4.52E-06	6.39E-05	1.65E-08	6.84E-05
DDX	1.07E-04	1.51E-03	3.07E-08	1.62E-03
endosulfan II	1.55E-05	2.19E-04	3.53E-09	2.35E-04
mercury (total organic)	1.28E-05	1.81E-04	5.70E-06	1.99E-04
Naphthalene	1.32E-06	1.87E-05	1.24E-07	2.02E-05
Benzo(a)pyrene - TEQ	1.96E-08	2.77E-07	2.21E-12	2.97E-07
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	1.54E-03	2.17E-02	3.00E-03	2.63E-02

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 2 - Chester Hill Stockpile
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry)	1.431 t/m3
Air filled porosity	0.288
Water filled porosity	0.171
Total porosity	0.459
Fraction organic carbon	0.003
Fresh Slice Residence Time	2880 s

Excavation Parameters

Total Time for excavation	40 hrs
Exposure Area	40 m2
Slice Depth	1 m
Stockpile Width	20 m
Volume Slice	40 m3
Total Excavation Volume	2000 m3

Surface Parameters

Length of Pit	20 m	2000 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	400 cm	
Exposure Area	40 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	0.00E+00	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	0.00E+00	2.76E-04	0.00E+00	4.08E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,2-dichloroethane (EDC)	1.35E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	2.62E+00	4.20E+02	2.62E+00	6.45E-03	1.66E-01	2.11E+00	1.66E-01	1.20E-01	4.81E-03
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.33E+00	1.26E+03	5.33E+00	5.78E-03	1.80E-01	2.78E+00	1.80E-01	1.30E-01	5.21E-03
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	3.06E+01	9.53E+02	3.06E+01	5.86E-03	7.15E-01	3.99E+00	7.15E-01	5.17E-01	2.07E-02
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.56E+02	4.86E+02	1.56E+02	5.17E-03	3.80E+00	6.72E+00	3.80E+00	2.75E+00	1.10E-01
PCE	0.00E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	0.00E+00	1.65E+02	0.00E+00	3.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chlorobenzene	0.00E+00	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	0.00E+00	7.30E+01	0.00E+00	5.42E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	0.00E+00	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	0.00E+00	3.98E+02	0.00E+00	6.73E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toluene	0.00E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	0.00E+00	1.41E+02	0.00E+00	5.85E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	5.15E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	6.37E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	0.00E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	0.00E+00	1.38E+01	0.00E+00	4.14E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,2,3-trichloropropane	0.00E+00	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	0.00E+00	2.92E+01	0.00E+00	4.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	4.43E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
b-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
d-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
g-BHC (lindane)	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	1.53E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dieldrin	0.00E+00	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	0.00E+00	6.15E-05	0.00E+00	1.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DDX	0.00E+00	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	0.00E+00	1.14E-04	0.00E+00	1.46E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
endosulfan II	0.00E+00	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	0.00E+00	1.31E-05	0.00E+00	2.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
mercury (total organic)	0.00E+00	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	0.00E+00	2.12E-02	0.00E+00	2.31E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Naphthalene	0.00E+00	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	0.00E+00	5.85E-01	0.00E+00	4.44E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene - TEQ	0.00E+00	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	0.00E+00	7.44E-08	0.00E+00	5.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.65E+00	1.21E+03	1.65E+00	6.29E-03	4.85E-02	1.31E+00	4.85E-02	3.50E-02	1.40E-03
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.51E+00	3.31E+03	2.51E+00	6.49E-03	4.47E-02	1.62E+00	4.47E-02	3.23E-02	1.29E-03
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.44E+00	1.05E+03	3.44E+00	6.65E-03	1.25E-01	2.18E+00	1.25E-01	9.00E-02	3.60E-03
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	4.24E+01	8.87E+02	4.24E+01	4.87E-03	7.71E-01	3.53E+00	7.71E-01	5.57E-01	2.23E-02
Vinyl Chloride	0.00E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	0.00E+00	1.00E+04	0.00E+00	8.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Chester Hill Stockpile
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.431 t/m3
Air filled porosity	0.288
Water filled porosity	0.171
Total porosity	0.459
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	40 hrs
Total Excavation Volume	2000 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	4.00E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	0.00E+00	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	0.00E+00	2.76E-04	0.00E+00	0.00E+00
1,2-dichloroethane (EDC)	1.35E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	2.62E+00	4.20E+02	2.62E+00	1.05E-03
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.33E+00	1.26E+03	5.33E+00	2.13E-03
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	3.06E+01	9.53E+02	3.06E+01	1.22E-02
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.56E+02	4.86E+02	1.56E+02	6.23E-02
PCE	0.00E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	0.00E+00	1.65E+02	0.00E+00	0.00E+00
Chlorobenzene	0.00E+00	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	0.00E+00	7.30E+01	0.00E+00	0.00E+00
Benzene	0.00E+00	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	0.00E+00	3.98E+02	0.00E+00	0.00E+00
Toluene	0.00E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	0.00E+00	1.41E+02	0.00E+00	0.00E+00
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	0.00E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	0.00E+00	1.38E+01	0.00E+00	0.00E+00
1,2,3-trichloropropane	0.00E+00	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	0.00E+00	2.92E+01	0.00E+00	0.00E+00
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	0.00E+00
b-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	0.00E+00
d-BHC	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	0.00E+00
g-BHC (lindane)	0.00E+00	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	0.00E+00	5.51E-04	0.00E+00	0.00E+00
dieldrin	0.00E+00	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	0.00E+00	6.15E-05	0.00E+00	0.00E+00
DDX	0.00E+00	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	0.00E+00	1.14E-04	0.00E+00	0.00E+00
endosulfan II	0.00E+00	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	0.00E+00	1.31E-05	0.00E+00	0.00E+00
mercury (total organic)	0.00E+00	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	0.00E+00	2.12E-02	0.00E+00	0.00E+00
Naphthalene	0.00E+00	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	0.00E+00	5.85E-01	0.00E+00	0.00E+00
Benzo(a)pyrene - TEQ	0.00E+00	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	0.00E+00	7.44E-08	0.00E+00	0.00E+00
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.65E+00	1.21E+03	1.65E+00	6.59E-04
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.51E+00	3.31E+03	2.51E+00	1.00E-03
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.44E+00	1.05E+03	3.44E+00	1.38E-03
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	4.24E+01	8.87E+02	4.24E+01	1.70E-02
Vinyl Chloride	0.00E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	0.00E+00	1.00E+04	0.00E+00	0.00E+00

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Chester Hill Stockpile
Total Emission Rate



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	0.00E+00	0.00E+00	0.00E+00
1,2-dichloroethane (EDC)	4.81E-03	1.05E-03	5.86E-03
Chloroform	5.21E-03	2.13E-03	7.35E-03
Carbon tetrachloride	2.07E-02	1.22E-02	3.29E-02
TCE	1.10E-01	6.23E-02	1.72E-01
PCE	0.00E+00	0.00E+00	0.00E+00
Chlorobenzene	0.00E+00	0.00E+00	0.00E+00
Benzene	0.00E+00	0.00E+00	0.00E+00
Toluene	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	0.00E+00	0.00E+00	0.00E+00
1,2,3-trichloropropane	0.00E+00	0.00E+00	0.00E+00
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	0.00E+00	0.00E+00	0.00E+00
b-BHC	0.00E+00	0.00E+00	0.00E+00
d-BHC	0.00E+00	0.00E+00	0.00E+00
g-BHC (lindane)	0.00E+00	0.00E+00	0.00E+00
dieldrin	0.00E+00	0.00E+00	0.00E+00
DDX	0.00E+00	0.00E+00	0.00E+00
endosulfan II	0.00E+00	0.00E+00	0.00E+00
mercury (total organic)	0.00E+00	0.00E+00	0.00E+00
Naphthalene	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene - TEQ	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethane (11DCA)	1.40E-03	6.59E-04	2.06E-03
1,1-Dichloroethylene (11DCE)	1.29E-03	1.00E-03	2.30E-03
cis-1,2-Dichloroethylene (12DCE)	3.60E-03	1.38E-03	4.98E-03
1,1,1-Trichloroethane (111TCA)	2.23E-02	1.70E-02	3.92E-02
Vinyl Chloride	0.00E+00	0.00E+00	0.00E+00

* Emission Rate based on working hours



Villawood Remediation
Stage of Works: 2 - Summary of S8 & S9
Total Emission Rate

Chemical	Z1a, 1b(top), 2 g/s	Z1b(bot) g/s	Chester Stockpile g/s	Weighted Mean g/s	S8	S9
Hexachlorobenzene	2.29E-05	1.95E-04	0.00E+00	6.82E-05	3.41E-05	3.41E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	5.86E-03	1.38E-03	6.89E-04	6.89E-04
Chloroform	0.00E+00	0.00E+00	7.35E-03	1.73E-03	8.64E-04	8.64E-04
Carbon tetrachloride	0.00E+00	0.00E+00	3.29E-02	7.74E-03	3.87E-03	3.87E-03
TCE	0.00E+00	0.00E+00	1.72E-01	4.05E-02	2.03E-02	2.03E-02
PCE	5.00E-03	2.23E-02	0.00E+00	8.91E-03	4.45E-03	4.45E-03
Chlorobenzene	1.17E-02	7.86E-02	0.00E+00	2.86E-02	1.43E-02	1.43E-02
Benzene	1.96E-04	1.21E-03	0.00E+00	4.49E-04	2.25E-04	2.25E-04
Toluene	2.70E-03	1.68E-02	0.00E+00	6.23E-03	3.11E-03	3.11E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.46E-04	2.42E-03	0.00E+00	8.74E-04	4.37E-04	4.37E-04
1,2,3-trichloropropane	2.20E-05	1.66E-04	0.00E+00	5.91E-05	2.96E-05	2.96E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	7.12E-05	6.07E-04	0.00E+00	2.12E-04	1.06E-04	1.06E-04
b-BHC	6.67E-05	5.69E-04	0.00E+00	1.99E-04	9.93E-05	9.93E-05
d-BHC	2.55E-05	2.17E-04	0.00E+00	7.57E-05	3.78E-05	3.78E-05
g-BHC (lindane)	7.06E-05	6.02E-04	0.00E+00	2.10E-04	1.05E-04	1.05E-04
dieldrin	8.02E-06	6.84E-05	0.00E+00	2.39E-05	1.19E-05	1.19E-05
DDX	1.90E-04	1.62E-03	0.00E+00	5.66E-04	2.83E-04	2.83E-04
endosulfan II	2.75E-05	2.35E-04	0.00E+00	8.20E-05	4.10E-05	4.10E-05
mercury (total organic)	2.89E-05	1.99E-04	0.00E+00	7.22E-05	3.61E-05	3.61E-05
Naphthalene	2.48E-06	2.02E-05	0.00E+00	7.10E-06	3.55E-06	3.55E-06
Benzo(a)pyrene - TEQ	3.47E-08	2.97E-07	0.00E+00	1.04E-07	5.18E-08	5.18E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	2.06E-03	4.84E-04	2.42E-04	2.42E-04
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	2.30E-03	5.40E-04	2.70E-04	2.70E-04
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	4.98E-03	1.17E-03	5.85E-04	5.85E-04
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	3.92E-02	9.23E-03	4.62E-03	4.62E-03
Vinyl Chloride	6.00E-03	2.63E-02	0.00E+00	1.06E-02	5.28E-03	5.28E-03
DAYS OF OPERATION	8	5	4	17		

* Emission Rate based on working hours

** Assume operations evenly divided between S8 and S9

Villawood Remediation
Stage of Works: 2 - Zone 8 excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry) 1.56 t/m3
Air filled porosity 0.22
Water filled porosity 0.19
Total porosity 0.41
Fraction organic carbon 0.003
Fresh Slice Residence Time 11975.04 s

Excavation Parameters

Total Time for excavation 100 hrs
Excavation Depth 1.54 m
Slice Depth 2 m
Wall Width 54 m
Volume Slice 166.32 m3
Total Excavation Volume 5000 m3

Surface Parameters

Length of Pit 54 m 5400 cm
Average wind speed 13000 m/h 361.1111 cm/s
air box height 200 cm
Exposure Area 83.16 m2

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	5.09E-02	3.18E-03	3.18E-03	4.26E-04	3.54E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	3.24E-01	1.38E+00	3.24E-01	4.33E-02	3.60E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	1.24E+00	3.44E+00	1.24E+00	1.66E-01	1.38E-02
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	1.89E-02	8.28E-01	1.89E-02	2.53E-03	2.10E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	2.63E-01	1.86E+00	2.63E-01	3.51E-02	2.92E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	3.84E-02	2.89E-01	3.84E-02	5.13E-03	4.27E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	2.66E-03	1.43E-01	2.66E-03	3.56E-04	2.96E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	2.47E-02	9.90E-03	9.90E-03	1.32E-03	1.10E-04
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	2.17E-02	9.28E-03	9.28E-03	1.24E-03	1.03E-04
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	3.53E-03	3.74E-03	3.53E-03	4.72E-04	3.93E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	2.44E-02	9.83E-03	9.83E-03	1.31E-03	1.09E-04
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	1.99E-03	1.12E-03	1.12E-03	1.49E-04	1.24E-05
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	1.99E-01	2.65E-02	2.65E-02	3.54E-03	2.94E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	3.71E-01	3.83E-03	3.83E-03	5.13E-04	4.26E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.67E-02	3.16E-03	3.16E-03	4.22E-04	3.51E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	3.27E-04	1.17E-02	3.27E-04	4.38E-05	3.64E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	4.84E-06	1.46E-05	4.84E-06	6.48E-07	5.39E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	3.80E-01	1.14E+01	3.80E-01	5.08E-02	4.23E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 8 excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	100 hrs
Total Excavation Volume	5000 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	3.06E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.43E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.78E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.33E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.55E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.40E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.08E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.68E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.68E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.50E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.68E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.88E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.49E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	4.02E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.48E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.41E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.51E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.41E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 8 excavation
Total Emission Rate (S12)



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	3.54E-05	8.43E-08	3.55E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	3.60E-03	2.78E-03	6.39E-03
Chlorobenzene	1.38E-02	2.90E-03	1.67E-02
Benzene	2.10E-04	6.33E-05	2.73E-04
Toluene	2.92E-03	8.55E-04	3.78E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	4.27E-04	7.40E-05	5.01E-04
1,2,3-trichloropropane	2.96E-05	3.08E-06	3.27E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.10E-04	1.68E-07	1.10E-04
b-BHC	1.03E-04	1.68E-07	1.03E-04
d-BHC	3.93E-05	1.50E-07	3.94E-05
g-BHC (lindane)	1.09E-04	1.68E-07	1.10E-04
dieldrin	1.24E-05	1.88E-08	1.24E-05
DDX	2.94E-04	3.49E-08	2.94E-04
endosulfan II	4.26E-05	4.02E-09	4.26E-05
mercury (total organic)	3.51E-05	6.48E-06	4.16E-05
Naphthalene	3.64E-06	1.41E-07	3.78E-06
Benzo(a)pyrene - TEQ	5.39E-08	2.51E-12	5.39E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	4.23E-03	3.41E-03	7.64E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 2 - Zone 7 excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry) 1.56 t/m3
Air filled porosity 0.22
Water filled porosity 0.19
Total porosity 0.41
Fraction organic carbon 0.003
Fresh Slice Residence Time 4792.32 s

Excavation Parameters

Total Time for excavation 20 hrs
Excavation Depth 1.28 m
Slice Depth 2 m
Wall Width 26 m
Volume Slice 66.56 m3
Total Excavation Volume 1000 m3

Surface Parameters

Length of Pit 26 m 2600 cm
Average wind speed 13000 m/h 361.1111 cm/s
air box height 200 cm
Exposure Area 33.28 m2

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	3.87E-02	2.42E-03	2.42E-03	6.73E-04	2.24E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	2.47E-01	1.05E+00	2.47E-01	6.85E-02	2.28E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	9.44E-01	2.62E+00	9.44E-01	2.62E-01	8.73E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	1.44E-02	6.31E-01	1.44E-02	3.99E-03	1.33E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	2.00E-01	1.42E+00	2.00E-01	5.56E-02	1.85E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	2.92E-02	2.20E-01	2.92E-02	8.11E-03	2.70E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	2.03E-03	1.09E-01	2.03E-03	5.63E-04	1.87E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	1.88E-02	7.54E-03	7.54E-03	2.09E-03	6.97E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	1.65E-02	7.06E-03	7.06E-03	1.96E-03	6.53E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	2.69E-03	2.85E-03	2.69E-03	7.47E-04	2.49E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	1.86E-02	7.48E-03	7.48E-03	2.08E-03	6.92E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	1.52E-03	8.50E-04	8.50E-04	2.36E-04	7.86E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	1.52E-01	2.01E-02	2.01E-02	5.59E-03	1.86E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	2.82E-01	2.92E-03	2.92E-03	8.10E-04	2.70E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.27E-02	2.40E-03	2.40E-03	6.68E-04	2.22E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	2.49E-04	8.87E-03	2.49E-04	6.92E-05	2.30E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	3.69E-06	1.11E-05	3.69E-06	1.02E-06	3.41E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	2.89E-01	8.68E+00	2.89E-01	8.04E-02	2.68E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 7 excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	20 hrs
Total Excavation Volume	1000 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	3.06E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.43E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.78E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.33E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.55E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.40E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.08E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.68E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.68E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.50E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.68E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.88E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.49E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	4.02E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.48E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.41E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.51E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.41E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2 - Zone 7 excavation
Total Emission Rate (S16)



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	2.24E-05	8.43E-08	2.25E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	2.28E-03	2.78E-03	5.06E-03
Chlorobenzene	8.73E-03	2.90E-03	1.16E-02
Benzene	1.33E-04	6.33E-05	1.96E-04
Toluene	1.85E-03	8.55E-04	2.70E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	2.70E-04	7.40E-05	3.44E-04
1,2,3-trichloropropane	1.87E-05	3.08E-06	2.18E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	6.97E-05	1.68E-07	6.98E-05
b-BHC	6.53E-05	1.68E-07	6.55E-05
d-BHC	2.49E-05	1.50E-07	2.50E-05
g-BHC (lindane)	6.92E-05	1.68E-07	6.93E-05
dieldrin	7.86E-06	1.88E-08	7.87E-06
DDX	1.86E-04	3.49E-08	1.86E-04
endosulfan II	2.70E-05	4.02E-09	2.70E-05
mercury (total organic)	2.22E-05	6.48E-06	2.87E-05
Naphthalene	2.30E-06	1.41E-07	2.44E-06
Benzo(a)pyrene - TEQ	3.41E-08	2.51E-12	3.41E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	2.68E-03	3.41E-03	6.08E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 3 - Zone 5(1) excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry) 1.56 t/m3
Air filled porosity 0.22
Water filled porosity 0.19
Total porosity 0.41
Fraction organic carbon 0.003
Fresh Slice Residence Time 3513.6 s

Excavation Parameters

Total Time for excavation 10 hrs
Excavation Depth 1.22 m
Slice Depth 2 m
Wall Width 20 m
Volume Slice 48.8 m3
Total Excavation Volume 500 m3

Surface Parameters

Length of Pit 20 m 2000 cm
Average wind speed 13000 m/h 361.1111 cm/s
air box height 200 cm
Exposure Area 24.4 m2

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	3.48E-02	2.18E-03	2.18E-03	7.86E-04	1.92E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	2.22E-01	9.43E-01	2.22E-01	8.00E-02	1.95E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	8.48E-01	2.35E+00	8.48E-01	3.06E-01	7.48E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	1.29E-02	5.66E-01	1.29E-02	4.66E-03	1.14E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	1.80E-01	1.27E+00	1.80E-01	6.49E-02	1.58E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	2.62E-02	1.98E-01	2.62E-02	9.48E-03	2.31E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	1.82E-03	9.78E-02	1.82E-03	6.57E-04	1.60E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	1.69E-02	6.77E-03	6.77E-03	2.44E-03	5.97E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	1.49E-02	6.35E-03	6.35E-03	2.29E-03	5.59E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	2.42E-03	2.56E-03	2.42E-03	8.72E-04	2.13E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	1.67E-02	6.72E-03	6.72E-03	2.43E-03	5.92E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	1.36E-03	7.63E-04	7.63E-04	2.76E-04	6.73E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	1.36E-01	1.81E-02	1.81E-02	6.53E-03	1.59E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	2.54E-01	2.62E-03	2.62E-03	9.47E-04	2.31E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.14E-02	2.16E-03	2.16E-03	7.80E-04	1.90E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	2.24E-04	7.97E-03	2.24E-04	8.08E-05	1.97E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	3.31E-06	9.98E-06	3.31E-06	1.20E-06	2.92E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	2.60E-01	7.79E+00	2.60E-01	9.39E-02	2.29E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 3 - Zone 5(1) excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	10 hrs
Total Excavation Volume	500 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	3.06E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.43E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.78E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.33E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.55E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.40E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.08E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.68E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.68E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.50E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.68E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.88E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.49E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	4.02E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.48E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.41E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.51E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.41E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 3 - Zone 5(1) excavation
Total Emission Rate (S26)



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	1.92E-05	8.43E-08	1.93E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	1.95E-03	2.78E-03	4.74E-03
Chlorobenzene	7.48E-03	2.90E-03	1.04E-02
Benzene	1.14E-04	6.33E-05	1.77E-04
Toluene	1.58E-03	8.55E-04	2.44E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	2.31E-04	7.40E-05	3.05E-04
1,2,3-trichloropropane	1.60E-05	3.08E-06	1.91E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	5.97E-05	1.68E-07	5.98E-05
b-BHC	5.59E-05	1.68E-07	5.61E-05
d-BHC	2.13E-05	1.50E-07	2.14E-05
g-BHC (lindane)	5.92E-05	1.68E-07	5.94E-05
dieldrin	6.73E-06	1.88E-08	6.75E-06
DDX	1.59E-04	3.49E-08	1.59E-04
endosulfan II	2.31E-05	4.02E-09	2.31E-05
mercury (total organic)	1.90E-05	6.48E-06	2.55E-05
Naphthalene	1.97E-06	1.41E-07	2.11E-06
Benzo(a)pyrene - TEQ	2.92E-08	2.51E-12	2.92E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	2.29E-03	3.41E-03	5.70E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 3 - Zone 5(2) excavation
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry) 1.56 t/m3
Air filled porosity 0.22
Water filled porosity 0.19
Total porosity 0.41
Fraction organic carbon 0.003
Fresh Slice Residence Time 6192 s

Excavation Parameters

Total Time for excavation 20 hrs
Excavation Depth 1.075 m
Slice Depth 2 m
Wall Width 40 m
Volume Slice 86 m3
Total Excavation Volume 1000 m3

Surface Parameters

Length of Pit 40 m 4000 cm
Average wind speed 13000 m/h 361.1111 cm/s
air box height 200 cm
Exposure Area 43 m2

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.09E-03	5.24E-02	3.28E-03	3.28E-03	5.92E-04	2.55E-05
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	3.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	2.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	2.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	1.94E-03	3.34E-01	1.42E+00	3.34E-01	6.03E-02	2.59E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.77E-03	1.28E+00	3.54E+00	1.28E+00	2.31E-01	9.92E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	3.44E-03	1.95E-02	8.53E-01	1.95E-02	3.51E-03	1.51E-04
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	2.99E-03	2.71E-01	1.92E+00	2.71E-01	4.89E-02	2.10E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	2.63E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	3.26E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	2.12E-03	3.95E-02	2.98E-01	3.95E-02	7.14E-03	3.07E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	2.23E-03	2.74E-03	1.47E-01	2.74E-03	4.95E-04	2.13E-05
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.37E-03	2.55E-02	1.02E-02	1.02E-02	1.84E-03	7.92E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.37E-03	2.24E-02	9.56E-03	9.56E-03	1.73E-03	7.42E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.37E-03	3.64E-03	3.86E-03	3.64E-03	6.57E-04	2.83E-05
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.37E-03	2.51E-02	1.01E-02	1.01E-02	1.83E-03	7.86E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	7.54E-04	2.05E-03	1.15E-03	1.15E-03	2.08E-04	8.93E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	9.80E-04	2.05E-01	2.73E-02	2.73E-02	4.92E-03	2.12E-04
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.28E-03	3.82E-01	3.95E-03	3.95E-03	7.13E-04	3.07E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	1.18E-03	1.72E-02	3.25E-03	3.25E-03	5.87E-04	2.53E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	2.28E-03	3.37E-04	1.20E-02	3.37E-04	6.09E-05	2.62E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.17E-03	4.99E-06	1.50E-05	4.99E-06	9.01E-07	3.87E-08
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	3.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	3.32E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	2.49E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	4.11E-03	3.92E-01	1.17E+01	3.92E-01	7.07E-02	3.04E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 3 - Zone 5(2) excavation
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.56 t/m3
Air filled porosity	0.22
Water filled porosity	0.19
Total porosity	0.41
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	20 hrs
Total Excavation Volume	1000 m3
Fraction of air released	0.1
Excavation Rate:	50 m3/hr
	1.39E-02 m3/s
Volume Air emitted	3.06E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	8.43E-08
1,2-dichloroethane (EDC)	0.00E+00	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	0.00E+00	4.20E+02	0.00E+00	0.00E+00
Chloroform	0.00E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	0.00E+00	1.26E+03	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	0.00E+00	9.53E+02	0.00E+00	0.00E+00
TCE	0.00E+00	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	0.00E+00	4.86E+02	0.00E+00	0.00E+00
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	9.11E+00	1.65E+02	9.11E+00	2.78E-03
Chlorobenzene	6.30E+01	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	9.51E+00	7.30E+01	9.51E+00	2.90E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.07E-01	3.98E+02	2.07E-01	6.33E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.80E+00	1.41E+02	2.80E+00	8.55E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	0.00E+00	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	0.00E+00	4.56E+01	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.10E+00	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	2.42E-01	1.38E+01	2.42E-01	7.40E-05
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.08E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.68E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.68E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.50E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.68E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.88E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	3.49E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	4.02E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.91E-01	2.12E-02	2.12E-02	6.48E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.41E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	2.51E-12
1,1-Dichloroethane (11DCA)	0.00E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	0.00E+00	1.21E+03	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	0.00E+00	3.31E+03	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	0.00E+00	1.05E+03	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	0.00E+00	8.87E+02	0.00E+00	0.00E+00
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.11E+01	1.00E+04	1.11E+01	3.41E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 3 - Zone 5(2) excavation
Total Emission Rate (S25)



Chemical	E from Surface g/s	E from Vap Release g/s	Total E g/s
Hexachlorobenzene	2.55E-05	8.43E-08	2.56E-05
1,2-dichloroethane (EDC)	0.00E+00	0.00E+00	0.00E+00
Chloroform	0.00E+00	0.00E+00	0.00E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00
TCE	0.00E+00	0.00E+00	0.00E+00
PCE	2.59E-03	2.78E-03	5.37E-03
Chlorobenzene	9.92E-03	2.90E-03	1.28E-02
Benzene	1.51E-04	6.33E-05	2.14E-04
Toluene	2.10E-03	8.55E-04	2.96E-03
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00
Xylenes	0.00E+00	0.00E+00	0.00E+00
1,4-Dichlorobenzene	3.07E-04	7.40E-05	3.81E-04
1,2,3-trichloropropane	2.13E-05	3.08E-06	2.44E-05
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00
a-BHC	7.92E-05	1.68E-07	7.94E-05
b-BHC	7.42E-05	1.68E-07	7.44E-05
d-BHC	2.83E-05	1.50E-07	2.84E-05
g-BHC (lindane)	7.86E-05	1.68E-07	7.88E-05
dieldrin	8.93E-06	1.88E-08	8.95E-06
DDX	2.12E-04	3.49E-08	2.12E-04
endosulfan II	3.07E-05	4.02E-09	3.07E-05
mercury (total organic)	2.53E-05	6.48E-06	3.17E-05
Naphthalene	2.62E-06	1.41E-07	2.76E-06
Benzo(a)pyrene - TEQ	3.87E-08	2.51E-12	3.87E-08
1,1-Dichloroethane (11DCA)	0.00E+00	0.00E+00	0.00E+00
1,1-Dichloroethylene (11DCE)	0.00E+00	0.00E+00	0.00E+00
cis-1,2-Dichloroethylene (12DCE)	0.00E+00	0.00E+00	0.00E+00
1,1,1-Trichloroethane (111TCA)	0.00E+00	0.00E+00	0.00E+00
Vinyl Chloride	3.04E-03	3.41E-03	6.45E-03

* Emission Rate based on working hours

Villawood Remediation
Stage of Works: 2, 3 - Secure Storage Facility
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry) 1.51 t/m3
Air filled porosity 0.249
Water filled porosity 0.181
Total porosity 0.43
Fraction organic carbon 0.003
Fresh Slice Residence Time 53913.6 s

Excavation Parameters

Total Time for excavation 3744 hrs
Exposure Area 40 m2
Slice Depth 1 m
Stockpile Width 20 m
Volume Slice 40 m3
Total Excavation Volume 10000 m3

Surface Parameters

Length of Pit 20 m 2000 cm
Average wind speed 13000 m/h 361.1111 cm/s
air box height 400 cm
Exposure Area 40 m2

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	2.86E-03	5.12E-03	3.20E-04	3.20E-04	2.31E-04	9.25E-06
1,2-dichloroethane (EDC)	5.00E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	9.77E+00	4.20E+02	9.77E+00	4.53E-03	1.23E-01	8.06E-01	1.23E-01	8.88E-02	3.55E-03
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.44E+00	1.26E+03	5.44E+00	4.06E-03	3.63E-02	5.52E-01	3.63E-02	2.62E-02	1.05E-03
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	3.21E+01	9.53E+02	3.21E+01	4.12E-03	1.46E-01	7.94E-01	1.46E-01	1.05E-01	4.21E-03
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.62E+02	4.86E+02	1.62E+02	3.63E-03	7.71E-01	1.34E+00	7.71E-01	5.57E-01	2.23E-02
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	8.84E+00	1.65E+02	8.84E+00	2.67E-03	3.21E-02	1.39E-01	3.21E-02	2.32E-02	9.28E-04
Chlorobenzene	1.43E+02	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	2.15E+01	7.30E+01	2.15E+01	3.81E-03	2.83E-01	5.21E-01	2.83E-01	2.05E-01	8.18E-03
Benzene	5.40E+01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.06E-01	3.98E+02	2.06E-01	4.72E-03	1.90E-03	8.34E-02	1.90E-03	1.37E-03	5.47E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.78E+00	1.41E+02	2.78E+00	4.11E-03	2.64E-02	1.88E-01	2.64E-02	1.90E-02	7.62E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	3.62E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	1.00E+01	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	1.63E+00	4.56E+01	1.63E+00	4.47E-03	2.23E-02	1.18E-01	2.23E-02	1.61E-02	6.44E-04
1,4-Dichlorobenzene	8.40E+01	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	6.56E+00	1.38E+01	6.56E+00	2.90E-03	1.05E-01	1.52E-01	1.05E-01	7.55E-02	3.02E-03
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.05E-03	2.68E-04	1.44E-02	2.68E-04	1.93E-04	7.74E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	3.22E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.39E-03	2.14E-03	8.55E-04	8.55E-04	6.18E-04	2.47E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.39E-03	1.88E-03	8.02E-04	8.02E-04	5.79E-04	2.32E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.39E-03	3.05E-04	3.23E-04	3.05E-04	2.20E-04	8.82E-06
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.39E-03	2.11E-03	8.49E-04	8.49E-04	6.13E-04	2.45E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	8.71E-04	1.84E-04	1.03E-04	1.03E-04	7.44E-05	2.98E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	1.15E-03	1.85E-02	2.46E-03	2.46E-03	1.78E-03	7.10E-05
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	1.73E-03	3.70E-02	3.83E-04	3.83E-04	2.77E-04	1.11E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.76E-01	2.12E-02	2.12E-02	1.62E-03	1.66E-03	3.18E-04	3.18E-04	2.30E-04	9.18E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	3.12E-03	3.29E-05	1.17E-03	3.29E-05	2.38E-05	9.50E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	5.76E-03	4.02E-07	1.21E-06	4.02E-07	2.90E-07	1.16E-08
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.70E+00	1.21E+03	1.70E+00	4.41E-03	9.79E-03	2.61E-01	9.79E-03	7.07E-03	2.83E-04
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.76E+00	3.31E+03	2.76E+00	4.55E-03	9.31E-03	3.22E-01	9.31E-03	6.73E-03	2.69E-04
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.51E+00	1.05E+03	3.51E+00	4.67E-03	2.51E-02	4.33E-01	2.51E-02	1.81E-02	7.24E-04
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	4.53E+01	8.87E+02	4.53E+01	3.42E-03	1.59E-01	7.01E-01	1.59E-01	1.14E-01	4.58E-03
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.04E+01	1.00E+04	1.04E+01	5.65E-03	3.69E-02	1.15E+00	3.69E-02	2.67E-02	1.07E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2, 3 - Secure Storage Facility
Emission from Vapour Release



Soil Parameters

Specific gravity (dry) 1.51 t/m3
 Air filled porosity 0.249
 Water filled porosity 0.181
 Total porosity 0.43
 Fraction organic carbon 0.003

Excavation Parameters

Total Time for excavation 3744 hrs
 Total Excavation Volume 10000 m3
 Fraction of air released 0.1
 Excavation Rate: 2.670940171 m3/hr
 7.42E-04 m3/s
 Volume Air emitted 1.85E-05 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	5.10E-09
1,2-dichloroethane (EDC)	5.00E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	9.77E+00	4.20E+02	9.77E+00	1.81E-04
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.44E+00	1.26E+03	5.44E+00	1.01E-04
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	3.21E+01	9.53E+02	3.21E+01	5.93E-04
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.62E+02	4.86E+02	1.62E+02	2.99E-03
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	8.84E+00	1.65E+02	8.84E+00	1.63E-04
Chlorobenzene	1.43E+02	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	2.15E+01	7.30E+01	2.15E+01	3.98E-04
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	2.06E-01	3.98E+02	2.06E-01	3.80E-06
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.78E+00	1.41E+02	2.78E+00	5.14E-05
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	1.00E+01	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	1.63E+00	4.56E+01	1.63E+00	3.00E-05
1,4-Dichlorobenzene	8.40E+01	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	6.56E+00	1.38E+01	6.56E+00	1.21E-04
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	1.87E-07
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.02E-08
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.02E-08
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	9.08E-09
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.02E-08
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.14E-09
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	2.11E-09
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	2.43E-10
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.76E-01	2.12E-02	2.12E-02	3.92E-07
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	8.52E-09
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	1.52E-13
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.70E+00	1.21E+03	1.70E+00	3.14E-05
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.76E+00	3.31E+03	2.76E+00	5.10E-05
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.51E+00	1.05E+03	3.51E+00	6.49E-05
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	4.53E+01	8.87E+02	4.53E+01	8.38E-04
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	1.04E+01	1.00E+04	1.04E+01	1.92E-04

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2, 3 - Feed Soil Storage Stockpiles
Vapourisation from Exposed Surface



Soil Parameters

Specific gravity (dry)	1.34 t/m3
Air filled porosity	0.334
Water filled porosity	0.161
Total porosity	0.495
Fraction organic carbon	0.003
Fresh Slice Residence Time	17104.57 s

Excavation Parameters

Total Time for excavation	3744 hrs
Exposure Area	20 m2
Slice Depth	1 m
Stockpile Width	20 m
Volume Slice	20 m3
Total Excavation Volume	15760 m3

Surface Parameters

Length of Pit	20 m	2000 cm
Average wind speed	13000 m/h	361.1111 cm/s
air box height	400 cm	
Exposure Area	20 m2	

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	Dseff cm2/s	Ci (3ph) mg/m3	Ci (sep) mg/m3	Ci (min) mg/m3	F mg/m2/s	E (g/s)
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	5.74E-03	1.21E-02	7.59E-04	7.59E-04	5.48E-04	1.10E-05
1,2-dichloroethane (EDC)	5.00E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	9.60E+00	4.20E+02	9.60E+00	9.08E-03	2.89E-01	1.91E+00	2.89E-01	2.09E-01	4.17E-03
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.17E+00	1.26E+03	5.17E+00	8.14E-03	8.37E-02	1.31E+00	8.37E-02	6.05E-02	1.21E-03
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	2.88E+01	9.53E+02	2.88E+01	8.26E-03	3.27E-01	1.88E+00	3.27E-01	2.36E-01	4.72E-03
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.48E+02	4.86E+02	1.48E+02	7.28E-03	1.75E+00	3.16E+00	1.75E+00	1.26E+00	2.52E-02
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	7.92E+00	1.65E+02	7.92E+00	5.35E-03	7.20E-02	3.29E-01	7.20E-02	5.20E-02	1.04E-03
Chlorobenzene	1.43E+02	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	2.13E+01	7.30E+01	2.13E+01	7.64E-03	6.66E-01	1.23E+00	6.66E-01	4.81E-01	9.63E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	1.99E-01	3.98E+02	1.99E-01	9.48E-03	4.42E-03	1.97E-01	4.42E-03	3.19E-03	6.38E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.71E+00	1.41E+02	2.71E+00	8.24E-03	6.17E-02	4.44E-01	6.17E-02	4.45E-02	8.91E-04
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	7.25E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xylenes	1.00E+01	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	1.60E+00	4.56E+01	1.60E+00	8.97E-03	5.24E-02	2.80E-01	5.24E-02	3.79E-02	7.58E-04
1,4-Dichlorobenzene	8.40E+01	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	6.52E+00	1.38E+01	6.52E+00	5.82E-03	2.47E-01	3.59E-01	2.47E-01	1.78E-01	3.57E-03
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	6.09E-03	6.32E-04	3.40E-02	6.32E-04	4.57E-04	9.13E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	6.12E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	1.83E-03	4.10E-03	1.64E-03	1.64E-03	1.19E-03	2.37E-05
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	1.83E-03	3.61E-03	1.54E-03	1.54E-03	1.11E-03	2.22E-05
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.83E-03	5.86E-04	6.21E-04	5.86E-04	4.23E-04	8.47E-06
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	1.83E-03	4.05E-03	1.63E-03	1.63E-03	1.18E-03	2.36E-05
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	1.43E-03	3.95E-04	2.21E-04	2.21E-04	1.60E-04	3.19E-06
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	1.92E-03	4.00E-02	5.32E-03	5.32E-03	3.84E-03	7.68E-05
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	3.43E-03	8.72E-02	9.01E-04	9.01E-04	6.51E-04	1.30E-05
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.17E-01	2.12E-02	2.12E-02	3.25E-03	3.72E-03	7.53E-04	7.53E-04	5.44E-04	1.09E-05
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	6.25E-03	7.79E-05	2.77E-03	7.79E-05	5.62E-05	1.12E-06
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	6.34E-03	7.05E-07	2.12E-06	7.05E-07	5.09E-07	1.02E-08
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.58E+00	1.21E+03	1.58E+00	8.85E-03	2.23E-02	6.19E-01	2.23E-02	1.61E-02	3.23E-04
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.24E+00	3.31E+03	2.24E+00	9.14E-03	1.99E-02	7.64E-01	1.99E-02	1.44E-02	2.87E-04
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.33E+00	1.05E+03	3.33E+00	9.36E-03	5.78E-02	1.03E+00	5.78E-02	4.17E-02	8.35E-04
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	3.90E+01	8.87E+02	3.90E+01	6.86E-03	3.48E-01	1.66E+00	3.48E-01	2.52E-01	5.03E-03
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	8.26E+00	1.00E+04	8.26E+00	1.13E-02	7.80E-02	2.72E+00	7.80E-02	5.63E-02	1.13E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2, 3 - Feed Soil Storage Stockpiles
Emission from Vapour Release



Soil Parameters

Specific gravity (dry)	1.34 t/m3
Air filled porosity	0.334
Water filled porosity	0.161
Total porosity	0.495
Fraction organic carbon	0.003

Excavation Parameters

Total Time for excavation	3744 hrs
Total Excavation Volume	15760 m3
Fraction of air released	1
Excavation Rate:	4.209401709 m3/hr
	1.17E-03 m3/s
Volume Air emitted	3.91E-04 m3/s

Chemicals

Chemical	Cs mg/kg	H' -	log Koc -	Dair cm2/s	Dwat cm2/s	MW g/mol	VP mmHg	Csa (3ph) g/m3	Csa (sep) g/m3	Csa (min) g/m3	E g/s
Hexachlorobenzene	1.90E+01	6.95E-02	3.79E+00	5.42E-02	5.91E-06	285	1.80E-05	7.05E-02	2.76E-04	2.76E-04	1.08E-07
1,2-dichloroethane (EDC)	5.00E+01	4.82E-02	1.60E+00	8.57E-02	1.10E-05	99	78.9	9.60E+00	4.20E+02	9.60E+00	3.75E-03
Chloroform	8.71E+00	1.50E-01	1.50E+00	7.69E-02	1.09E-05	119	197	5.17E+00	1.26E+03	5.17E+00	2.02E-03
Carbon tetrachloride	2.35E+01	1.20E+00	2.27E+00	7.80E-02	8.80E-06	154	115	2.88E+01	9.53E+02	2.88E+01	1.12E-02
TCE	1.48E+02	4.03E-01	1.78E+00	6.87E-02	1.02E-05	131	69	1.48E+02	4.86E+02	1.48E+02	5.78E-02
PCE	6.40E+00	7.24E-01	1.98E+00	5.05E-02	9.46E-06	166	18.5	7.92E+00	1.65E+02	7.92E+00	3.09E-03
Chlorobenzene	1.43E+02	1.27E-01	2.37E+00	7.21E-02	9.48E-06	113	12	2.13E+01	7.30E+01	2.13E+01	8.31E-03
Benzene	5.40E-01	2.27E-01	2.16E+00	8.95E-02	1.03E-05	78.1	94.8	1.99E-01	3.98E+02	1.99E-01	7.79E-05
Toluene	8.90E+00	2.71E-01	2.37E+00	7.78E-02	9.20E-06	92.1	28.4	2.71E+00	1.41E+02	2.71E+00	1.06E-03
Ethylbenzene	0.00E+00	3.22E-01	2.65E+00	6.85E-02	8.46E-06	106	9.6	0.00E+00	5.48E+01	0.00E+00	0.00E+00
Xylenes	1.00E+01	2.12E-01	2.58E+00	8.47E-02	9.90E-06	106	7.99	1.60E+00	4.56E+01	1.60E+00	6.26E-04
1,4-Dichlorobenzene	8.40E+01	9.85E-02	2.57E+00	5.50E-02	8.68E-06	147	1.74	6.52E+00	1.38E+01	6.52E+00	2.54E-03
1,2,3-trichloropropane	3.40E-01	1.40E-02	2.06E+00	5.75E-02	9.24E-06	147	3.69	1.01E-02	2.92E+01	1.01E-02	3.94E-06
Bis(2-chloroethyl)ether	0.00E+00	6.95E-04	1.51E+00	5.67E-02	8.71E-06	143	1.55	0.00E+00	1.19E+01	0.00E+00	0.00E+00
a-BHC	1.40E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.44E-03	5.51E-04	5.51E-04	2.15E-07
b-BHC	1.23E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.02E-03	5.51E-04	5.51E-04	2.15E-07
d-BHC	2.00E+01	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	4.91E-04	5.51E-04	4.91E-04	1.92E-07
g-BHC (lindane)	1.38E+02	2.10E-04	3.45E+00	1.42E-02	7.34E-06	291	3.52E-05	3.39E-03	5.51E-04	5.51E-04	2.15E-07
dieldrin	2.90E+01	4.09E-04	4.30E+00	1.25E-02	4.74E-06	381	3.00E-06	1.96E-04	6.15E-05	6.15E-05	2.40E-08
DDX	6.74E+03	3.40E-04	5.07E+00	1.69E-02	4.76E-06	354	6.00E-06	6.47E-03	1.14E-04	1.14E-04	4.46E-08
endosulfan II	9.43E+02	2.66E-03	3.83E+00	3.22E-02	4.67E-06	407	6.00E-07	1.23E-01	1.31E-05	1.31E-05	5.13E-09
mercury (total organic)	4.30E-01	4.74E-01	1.72E+00	3.07E-02	6.30E-06	201	1.96E-03	5.17E-01	2.12E-02	2.12E-02	8.28E-06
Naphthalene	1.10E-01	2.00E-02	3.19E+00	5.90E-02	7.50E-06	128	0.085	4.61E-04	5.85E-01	4.61E-04	1.80E-07
Benzo(a)pyrene - TEQ	5.00E-01	4.70E-05	5.98E+00	4.30E-02	9.00E-06	252	5.49E-09	8.20E-09	7.44E-08	8.20E-09	3.20E-12
1,1-Dichloroethane (11DCA)	1.87E+00	2.30E-01	1.50E+00	8.36E-02	1.06E-05	99	227	1.58E+00	1.21E+03	1.58E+00	6.16E-04
1,1-Dichloroethylene (11DCE)	1.01E+00	1.07E+00	1.50E+00	8.63E-02	1.10E-05	96.9	634	2.24E+00	3.31E+03	2.24E+00	8.75E-04
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	1.67E-01	1.60E+00	8.84E-02	1.13E-05	96.9	201	3.33E+00	1.05E+03	3.33E+00	1.30E-03
1,1,1-Trichloroethane (111TCA)	2.37E+01	7.03E-01	1.64E+00	6.48E-02	9.60E-06	133	124	3.90E+01	8.87E+02	3.90E+01	1.52E-02
Vinyl Chloride	3.40E+00	1.14E+00	1.34E+00	1.07E-01	1.20E-05	62.5	2980	8.26E+00	1.00E+04	8.26E+00	3.22E-03

Notes: Physical properties from RAIS (2010)

Villawood Remediation
Stage of Works: 2, 3 - Emission Control System
Total Emission Rate



Chemical	E from Surface SSF g/s	E from Vap Release SSF g/s	E from Surface Feed Soil SP g/s	E from Vap Release Feed Soil SP g/s	Total E g/s	Removal Efficiency	Discharge Emission rate g/s
Hexachlorobenzene	9.25E-06	5.10E-09	1.10E-05	1.08E-07	2.03E-05	0.95	1.02E-06
1,2-dichloroethane (EDC)	3.55E-03	1.81E-04	4.17E-03	3.75E-03	1.17E-02	0.95	5.83E-04
Chloroform	1.05E-03	1.01E-04	1.21E-03	2.02E-03	4.37E-03	0.95	2.19E-04
Carbon tetrachloride	4.21E-03	5.93E-04	4.72E-03	1.12E-02	2.08E-02	0.95	1.04E-03
TCE	2.23E-02	2.99E-03	2.52E-02	5.78E-02	1.08E-01	0.95	5.42E-03
PCE	9.28E-04	1.63E-04	1.04E-03	3.09E-03	5.22E-03	0.95	2.61E-04
Chlorobenzene	8.18E-03	3.98E-04	9.63E-03	8.31E-03	2.65E-02	0.95	1.33E-03
Benzene	5.47E-05	3.80E-06	6.38E-05	7.79E-05	2.00E-04	0.95	1.00E-05
Toluene	7.62E-04	5.14E-05	8.91E-04	1.06E-03	2.76E-03	0.95	1.38E-04
Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.95	0.00E+00
Xylenes	6.44E-04	3.00E-05	7.58E-04	6.26E-04	2.06E-03	0.95	1.03E-04
1,4-Dichlorobenzene	3.02E-03	1.21E-04	3.57E-03	2.54E-03	9.25E-03	0.95	4.63E-04
1,2,3-trichloropropane	7.74E-06	1.87E-07	9.13E-06	3.94E-06	2.10E-05	0.95	1.05E-06
Bis(2-chloroethyl)ether	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.95	0.00E+00
a-BHC	2.47E-05	1.02E-08	2.37E-05	2.15E-07	4.87E-05	0.95	2.43E-06
b-BHC	2.32E-05	1.02E-08	2.22E-05	2.15E-07	4.56E-05	0.95	2.28E-06
d-BHC	8.82E-06	9.08E-09	8.47E-06	1.92E-07	1.75E-05	0.95	8.74E-07
g-BHC (lindane)	2.45E-05	1.02E-08	2.36E-05	2.15E-07	4.83E-05	0.95	2.42E-06
dieldrin	2.98E-06	1.14E-09	3.19E-06	2.40E-08	6.19E-06	0.95	3.10E-07
DDX	7.10E-05	2.11E-09	7.68E-05	4.46E-08	1.48E-04	0.95	7.39E-06
endosulfan II	1.11E-05	2.43E-10	1.30E-05	5.13E-09	2.41E-05	0.95	1.20E-06
mercury (total organic)	9.18E-06	3.92E-07	1.09E-05	8.28E-06	2.87E-05	0.95	1.44E-06
Naphthalene	9.50E-07	8.52E-09	1.12E-06	1.80E-07	2.26E-06	0.95	1.13E-07
Benzo(a)pyrene - TEQ	1.16E-08	1.52E-13	1.02E-08	3.20E-12	2.18E-08	0.95	1.09E-09
1,1-Dichloroethane (11DCA)	2.83E-04	3.14E-05	3.23E-04	6.16E-04	1.25E-03	0.95	6.26E-05
1,1-Dichloroethylene (11DCE)	2.69E-04	5.10E-05	2.87E-04	8.75E-04	1.48E-03	0.95	7.41E-05
cis-1,2-Dichloroethylene (12DCE)	7.24E-04	6.49E-05	8.35E-04	1.30E-03	2.93E-03	0.95	1.46E-04
1,1,1-Trichloroethane (111TCA)	4.58E-03	8.38E-04	5.03E-03	1.52E-02	2.57E-02	0.95	1.28E-03
Vinyl Chloride	1.07E-03	1.92E-04	1.13E-03	3.22E-03	5.61E-03	0.95	2.81E-04

**Villawood Remediation
Direct Thermal Desorption Plant
Vapourisation from Exposed Surface**



Chemical	Cs mg/kg	Feed Soil t/h	E pre treat mg/hr	Destruction Efficiency	E mg/hr	E g/s
Hexachlorobenzene	1.90E+01	3.50E+01	6.65E+05	99.999%	6.65E+00	1.85E-06
1,2-dichloroethane (EDC)	5.00E+01	3.50E+01	1.75E+06	99.999%	1.75E+01	4.86E-06
Chloroform	8.71E+00	3.50E+01	3.05E+05	99.999%	3.05E+00	8.47E-07
Carbon tetrachloride	2.35E+01	3.50E+01	8.23E+05	99.999%	8.22E+00	2.28E-06
TCE	1.48E+02	3.50E+01	5.18E+06	99.999%	5.18E+01	1.44E-05
PCE	6.40E+00	3.50E+01	2.24E+05	99.999%	2.24E+00	6.22E-07
Chlorobenzene	1.43E+02	3.50E+01	5.01E+06	99.999%	5.00E+01	1.39E-05
Benzene	5.40E-01	3.50E+01	1.89E+04	99.999%	1.89E-01	5.25E-08
Toluene	8.90E+00	3.50E+01	3.12E+05	99.999%	3.11E+00	8.65E-07
Ethylbenzene	0.00E+00	3.50E+01	0.00E+00	99.999%	0.00E+00	0.00E+00
Xylenes	1.00E+01	3.50E+01	3.50E+05	99.999%	3.50E+00	9.72E-07
1,4-Dichlorobenzene	8.40E+01	3.50E+01	2.94E+06	99.999%	2.94E+01	8.17E-06
1,2,3-trichloropropane	3.40E-01	3.50E+01	1.19E+04	99.999%	1.19E-01	3.31E-08
Bis(2-chloroethyl)ether	0.00E+00	3.50E+01	0.00E+00	99.999%	0.00E+00	0.00E+00
a-BHC	1.40E+02	3.50E+01	4.90E+06	99.999%	4.90E+01	1.36E-05
b-BHC	1.23E+02	3.50E+01	4.31E+06	99.999%	4.30E+01	1.20E-05
d-BHC	2.00E+01	3.50E+01	7.00E+05	99.999%	7.00E+00	1.94E-06
g-BHC (lindane)	1.38E+02	3.50E+01	4.83E+06	99.999%	4.83E+01	1.34E-05
dieldrin	2.90E+01	3.50E+01	1.02E+06	99.999%	1.01E+01	2.82E-06
DDX	6.74E+03	3.50E+01	2.36E+08	99.999%	2.36E+03	6.55E-04
endosulfan II	9.43E+02	3.50E+01	3.30E+07	99.999%	3.30E+02	9.17E-05
mercury (total organic)	4.30E-01	3.50E+01	1.51E+04	0.000%	1.51E+04	4.18E-03
Naphthalene	1.10E-01	3.50E+01	3.85E+03	99.999%	3.85E-02	1.07E-08
Benzo(a)pyrene - TEQ	5.00E-01	3.50E+01	1.75E+04	99.999%	1.75E-01	4.86E-08
1,1-Dichloroethane (11DCA)	1.87E+00	3.50E+01	6.55E+04	99.999%	6.54E-01	1.82E-07
1,1-Dichloroethylene (11DCE)	1.01E+00	3.50E+01	3.54E+04	99.999%	3.53E-01	9.82E-08
cis-1,2-Dichloroethylene (12DCE)	5.60E+00	3.50E+01	1.96E+05	99.999%	1.96E+00	5.44E-07
1,1,1-Trichloroethane (111TCA)	2.37E+01	3.50E+01	8.30E+05	99.999%	8.29E+00	2.30E-06
Vinyl Chloride	3.40E+00	3.50E+01	1.19E+05	99.999%	1.19E+00	3.31E-07



Appendix D

Summary of Risk Estimates



Risk Calculations for lifetime exposure

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Total Risk
312700	6248200	3.38E-11	4.67E-11	1.62E-10	3.00E-14	2.43E-10	3.51E-09	3.75E-09
312700	6248400	3.95E-11	4.06E-11	1.37E-10	3.35E-14	2.17E-10	4.44E-09	4.66E-09
312700	6248600	4.47E-11	3.58E-11	1.21E-10	3.81E-14	2.01E-10	5.34E-09	5.54E-09
312700	6248800	4.59E-11	3.15E-11	1.08E-10	4.11E-14	1.85E-10	5.97E-09	6.16E-09
312700	6249000	4.32E-11	2.75E-11	9.09E-11	3.93E-14	1.62E-10	6.18E-09	6.34E-09
312700	6249200	4.05E-11	2.55E-11	7.98E-11	3.62E-14	1.46E-10	6.03E-09	6.18E-09
312700	6249400	4.10E-11	2.12E-11	6.81E-11	3.61E-14	1.30E-10	6.00E-09	6.13E-09
312700	6249600	4.30E-11	2.33E-11	7.02E-11	3.78E-14	1.37E-10	6.33E-09	6.46E-09
312700	6249800	4.51E-11	2.57E-11	7.39E-11	3.74E-14	1.45E-10	6.87E-09	7.02E-09
312700	6250000	4.75E-11	2.87E-11	8.66E-11	3.86E-14	1.63E-10	7.25E-09	7.42E-09
312700	6250200	4.75E-11	2.97E-11	9.58E-11	3.94E-14	1.73E-10	7.28E-09	7.45E-09
312700	6250400	4.41E-11	2.87E-11	9.34E-11	3.56E-14	1.66E-10	6.92E-09	7.08E-09
312700	6250600	3.96E-11	2.71E-11	9.02E-11	3.03E-14	1.57E-10	6.29E-09	6.44E-09
312700	6250800	3.54E-11	2.73E-11	9.23E-11	2.64E-14	1.55E-10	5.54E-09	5.70E-09
312700	6251000	3.20E-11	2.70E-11	9.31E-11	2.37E-14	1.52E-10	4.80E-09	4.95E-09
312900	6248200	3.72E-11	3.99E-11	1.37E-10	3.47E-14	2.14E-10	3.78E-09	4.00E-09
312900	6248400	4.48E-11	4.20E-11	1.43E-10	3.94E-14	2.30E-10	5.06E-09	5.29E-09
312900	6248600	5.29E-11	3.41E-11	1.17E-10	4.55E-14	2.04E-10	6.52E-09	6.73E-09
312900	6248800	5.76E-11	3.23E-11	1.12E-10	5.15E-14	2.02E-10	7.72E-09	7.92E-09
312900	6249000	5.53E-11	2.87E-11	9.79E-11	5.16E-14	1.82E-10	8.31E-09	8.49E-09
312900	6249200	5.17E-11	2.59E-11	8.38E-11	4.74E-14	1.61E-10	8.23E-09	8.39E-09
312900	6249400	5.24E-11	2.24E-11	7.33E-11	4.72E-14	1.48E-10	8.18E-09	8.33E-09
312900	6249600	5.52E-11	2.66E-11	7.79E-11	4.89E-14	1.60E-10	8.74E-09	8.90E-09
312900	6249800	5.82E-11	3.09E-11	8.86E-11	4.85E-14	1.78E-10	9.50E-09	9.68E-09
312900	6250000	6.03E-11	3.53E-11	1.07E-10	5.06E-14	2.03E-10	9.85E-09	1.00E-08
312900	6250200	5.69E-11	3.62E-11	1.14E-10	4.77E-14	2.08E-10	9.49E-09	9.70E-09
312900	6250400	5.07E-11	3.32E-11	1.11E-10	4.02E-14	1.95E-10	8.61E-09	8.80E-09
312900	6250600	4.46E-11	3.10E-11	1.01E-10	3.43E-14	1.77E-10	7.54E-09	7.72E-09
312900	6250800	3.97E-11	3.15E-11	1.06E-10	3.02E-14	1.77E-10	6.38E-09	6.55E-09
312900	6251000	3.59E-11	3.20E-11	1.05E-10	2.80E-14	1.73E-10	5.35E-09	5.53E-09
313100	6248200	4.00E-11	4.28E-11	1.37E-10	3.99E-14	2.20E-10	3.90E-09	4.12E-09
313100	6248400	5.08E-11	4.34E-11	1.49E-10	4.72E-14	2.43E-10	5.59E-09	5.84E-09
313100	6248600	6.29E-11	4.18E-11	1.45E-10	5.53E-14	2.50E-10	7.78E-09	8.03E-09
313100	6248800	7.33E-11	3.63E-11	1.29E-10	6.54E-14	2.38E-10	1.01E-08	1.03E-08
313100	6249000	7.38E-11	3.17E-11	1.13E-10	7.02E-14	2.19E-10	1.16E-08	1.18E-08
313100	6249200	6.91E-11	2.83E-11	9.61E-11	6.55E-14	1.94E-10	1.18E-08	1.20E-08
313100	6249400	7.02E-11	2.44E-11	8.28E-11	6.47E-14	1.77E-10	1.18E-08	1.20E-08
313100	6249600	7.40E-11	3.46E-11	9.85E-11	6.59E-14	2.07E-10	1.27E-08	1.29E-08
313100	6249800	7.84E-11	4.08E-11	1.17E-10	6.65E-14	2.36E-10	1.37E-08	1.39E-08
313100	6250000	7.66E-11	4.49E-11	1.37E-10	6.66E-14	2.58E-10	1.37E-08	1.40E-08
313100	6250200	6.78E-11	4.29E-11	1.38E-10	5.64E-14	2.49E-10	1.25E-08	1.27E-08
313100	6250400	5.84E-11	4.09E-11	1.33E-10	4.64E-14	2.32E-10	1.06E-08	1.09E-08
313100	6250600	5.10E-11	3.92E-11	1.26E-10	4.01E-14	2.16E-10	8.82E-09	9.04E-09
313100	6250800	4.54E-11	3.91E-11	1.26E-10	3.69E-14	2.10E-10	7.18E-09	7.39E-09
313100	6251000	4.07E-11	3.54E-11	1.14E-10	3.46E-14	1.90E-10	5.86E-09	6.05E-09
313300	6248200	4.18E-11	4.80E-11	1.40E-10	4.37E-14	2.29E-10	3.86E-09	4.09E-09
313300	6248400	5.66E-11	5.55E-11	1.74E-10	5.58E-14	2.86E-10	5.84E-09	6.13E-09
313300	6248600	7.48E-11	5.69E-11	1.96E-10	6.91E-14	3.28E-10	8.96E-09	9.29E-09
313300	6248800	9.52E-11	4.56E-11	1.64E-10	8.54E-14	3.05E-10	1.31E-08	1.34E-08
313300	6249000	1.03E-10	3.76E-11	1.40E-10	9.97E-14	2.81E-10	1.68E-08	1.71E-08
313300	6249200	9.89E-11	3.39E-11	1.21E-10	9.79E-14	2.54E-10	1.82E-08	1.84E-08
313300	6249400	1.00E-10	3.11E-11	1.08E-10	9.52E-14	2.39E-10	1.83E-08	1.85E-08
313300	6249600	1.06E-10	4.70E-11	1.33E-10	9.61E-14	2.86E-10	1.98E-08	2.01E-08
313300	6249800	1.09E-10	5.58E-11	1.64E-10	9.69E-14	3.29E-10	2.10E-08	2.13E-08
313300	6250000	9.69E-11	5.78E-11	1.80E-10	8.56E-14	3.34E-10	1.94E-08	1.97E-08
313300	6250200	8.09E-11	5.34E-11	1.71E-10	6.75E-14	3.06E-10	1.62E-08	1.65E-08
313300	6250400	6.87E-11	5.16E-11	1.57E-10	5.66E-14	2.78E-10	1.29E-08	1.32E-08
313300	6250600	5.96E-11	4.69E-11	1.43E-10	5.13E-14	2.50E-10	1.01E-08	1.04E-08
313300	6250800	5.17E-11	4.62E-11	1.45E-10	4.65E-14	2.43E-10	7.87E-09	8.12E-09



Risk Calculations for lifetime exposure

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Total Risk
313300	6251000	4.38E-11	4.41E-11	1.35E-10	4.03E-14	2.23E-10	6.22E-09	6.44E-09
313500	6248200	4.07E-11	3.77E-11	9.47E-11	4.45E-14	1.73E-10	3.81E-09	3.99E-09
313500	6248400	6.06E-11	4.52E-11	1.30E-10	6.30E-14	2.36E-10	5.89E-09	6.13E-09
313500	6248600	8.86E-11	5.32E-11	1.77E-10	8.68E-14	3.18E-10	9.80E-09	1.01E-08
313500	6248800	1.26E-10	5.36E-11	2.03E-10	1.16E-13	3.82E-10	1.66E-08	1.70E-08
313500	6249000	1.56E-10	4.72E-11	1.84E-10	1.51E-13	3.87E-10	2.57E-08	2.61E-08
313500	6249200	1.57E-10	4.50E-11	1.68E-10	1.63E-13	3.70E-10	3.12E-08	3.15E-08
313500	6249400	1.59E-10	4.20E-11	1.50E-10	1.57E-13	3.51E-10	3.21E-08	3.25E-08
313500	6249600	1.67E-10	6.72E-11	1.92E-10	1.57E-13	4.26E-10	3.54E-08	3.59E-08
313500	6249800	1.54E-10	8.47E-11	2.55E-10	1.46E-13	4.93E-10	3.42E-08	3.47E-08
313500	6250000	1.23E-10	7.88E-11	2.51E-10	1.10E-13	4.52E-10	2.75E-08	2.80E-08
313500	6250200	9.94E-11	7.70E-11	2.36E-10	8.74E-14	4.12E-10	2.05E-08	2.09E-08
313500	6250400	8.23E-11	6.41E-11	1.92E-10	7.63E-14	3.38E-10	1.51E-08	1.54E-08
313500	6250600	6.70E-11	5.80E-11	1.62E-10	6.45E-14	2.87E-10	1.11E-08	1.14E-08
313500	6250800	5.35E-11	5.48E-11	1.51E-10	5.15E-14	2.59E-10	8.36E-09	8.61E-09
313500	6251000	4.28E-11	5.34E-11	1.51E-10	4.05E-14	2.47E-10	6.44E-09	6.68E-09
313700	6248200	3.91E-11	3.37E-11	6.73E-11	4.63E-14	1.40E-10	4.13E-09	4.27E-09
313700	6248400	5.98E-11	3.38E-11	7.78E-11	6.63E-14	1.71E-10	6.10E-09	6.28E-09
313700	6248600	1.01E-10	4.15E-11	1.21E-10	1.04E-13	2.64E-10	1.03E-08	1.06E-08
313700	6248800	1.68E-10	4.66E-11	1.76E-10	1.64E-13	3.91E-10	2.05E-08	2.09E-08
313700	6249000	2.52E-10	6.02E-11	2.49E-10	2.46E-13	5.62E-10	3.94E-08	4.00E-08
313700	6249200	2.83E-10	6.17E-11	2.44E-10	3.12E-13	5.88E-10	6.11E-08	6.17E-08
313700	6249400	2.98E-10	5.76E-11	2.12E-10	3.11E-13	5.68E-10	6.96E-08	7.01E-08
313700	6249600	2.92E-10	1.13E-10	3.23E-10	2.98E-13	7.29E-10	7.49E-08	7.56E-08
313700	6249800	2.20E-10	1.17E-10	3.65E-10	2.22E-13	7.03E-10	5.87E-08	5.94E-08
313700	6250000	1.61E-10	1.15E-10	3.46E-10	1.58E-13	6.22E-10	3.81E-08	3.87E-08
313700	6250200	1.21E-10	9.98E-11	2.77E-10	1.24E-13	4.98E-10	2.45E-08	2.50E-08
313700	6250400	8.90E-11	7.93E-11	2.02E-10	9.20E-14	3.70E-10	1.65E-08	1.69E-08
313700	6250600	6.64E-11	7.12E-11	1.66E-10	6.65E-14	3.03E-10	1.17E-08	1.20E-08
313700	6250800	5.15E-11	6.23E-11	1.46E-10	5.05E-14	2.59E-10	8.57E-09	8.83E-09
313700	6251000	4.16E-11	5.84E-11	1.41E-10	4.07E-14	2.41E-10	6.53E-09	6.77E-09
313900	6248200	4.72E-11	4.08E-11	7.33E-11	5.91E-14	1.61E-10	5.26E-09	5.42E-09
313900	6248400	6.53E-11	4.15E-11	7.62E-11	7.93E-14	1.83E-10	7.46E-09	7.64E-09
313900	6248600	1.06E-10	4.49E-11	8.88E-11	1.20E-13	2.40E-10	1.18E-08	1.20E-08
313900	6248800	2.17E-10	4.44E-11	1.19E-10	2.21E-13	3.80E-10	2.37E-08	2.41E-08
313900	6249000	4.43E-10	5.72E-11	2.29E-10	4.28E-13	7.30E-10	6.02E-08	6.09E-08
313900	6249200	6.25E-10	9.13E-11	4.02E-10	7.03E-13	1.12E-09	1.33E-07	1.34E-07
313900	6249400	8.18E-10	8.72E-11	3.16E-10	9.37E-13	1.22E-09	2.56E-07	2.58E-07
313900	6249600	5.54E-10	2.13E-10	6.14E-10	6.68E-13	1.38E-09	1.91E-07	1.93E-07
313900	6249800	3.17E-10	1.94E-10	5.61E-10	3.77E-13	1.07E-09	9.31E-08	9.42E-08
313900	6250000	1.95E-10	1.61E-10	3.91E-10	2.31E-13	7.47E-10	4.71E-08	4.78E-08
313900	6250200	1.24E-10	1.37E-10	2.93E-10	1.38E-13	5.54E-10	2.67E-08	2.73E-08
313900	6250400	8.68E-11	9.45E-11	1.83E-10	9.33E-14	3.64E-10	1.71E-08	1.75E-08
313900	6250600	6.56E-11	8.29E-11	1.64E-10	6.95E-14	3.12E-10	1.18E-08	1.21E-08
313900	6250800	5.20E-11	7.76E-11	1.55E-10	5.49E-14	2.85E-10	8.55E-09	8.83E-09
313900	6251000	4.27E-11	7.14E-11	1.53E-10	4.49E-14	2.67E-10	6.47E-09	6.74E-09
314100	6248200	7.01E-11	6.52E-11	1.09E-10	8.72E-14	2.45E-10	7.39E-09	7.64E-09
314100	6248400	9.89E-11	6.50E-11	1.08E-10	1.21E-13	2.72E-10	1.09E-08	1.12E-08
314100	6248600	1.55E-10	6.99E-11	1.21E-10	1.87E-13	3.46E-10	1.78E-08	1.81E-08
314100	6248800	2.83E-10	7.27E-11	1.43E-10	3.25E-13	4.99E-10	3.31E-08	3.36E-08
314100	6249000	7.93E-10	7.80E-11	1.69E-10	7.86E-13	1.04E-09	9.09E-08	9.20E-08
314100	6249200	2.31E-09	7.81E-11	2.36E-10	2.20E-12	2.63E-09	3.67E-07	3.69E-07
314100	6249400	3.29E-09	2.01E-10	5.72E-10	5.07E-12	4.07E-09	1.38E-06	1.38E-06
314100	6249600	8.76E-10	4.88E-10	9.03E-10	1.55E-12	2.27E-09	4.04E-07	4.07E-07
314100	6249800	3.65E-10	2.87E-10	4.14E-10	5.28E-13	1.07E-09	1.13E-07	1.14E-07
314100	6250000	1.99E-10	1.92E-10	2.73E-10	2.59E-13	6.64E-10	4.90E-08	4.97E-08
314100	6250200	1.27E-10	1.61E-10	2.55E-10	1.56E-13	5.43E-10	2.66E-08	2.71E-08
314100	6250400	8.94E-11	1.21E-10	2.03E-10	1.05E-13	4.14E-10	1.66E-08	1.70E-08
314100	6250600	6.75E-11	9.91E-11	1.77E-10	7.72E-14	3.44E-10	1.14E-08	1.17E-08



Risk Calculations for lifetime exposure

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Total Risk
314100	6250800	5.30E-11	9.58E-11	1.91E-10	5.96E-14	3.40E-10	8.24E-09	8.58E-09
314100	6251000	4.32E-11	8.28E-11	1.73E-10	4.80E-14	2.99E-10	6.25E-09	6.55E-09
314300	6248200	1.10E-10	9.78E-11	1.37E-10	1.33E-13	3.45E-10	9.61E-09	9.96E-09
314300	6248400	1.65E-10	1.22E-10	1.61E-10	1.96E-13	4.47E-10	1.48E-08	1.53E-08
314300	6248600	2.80E-10	1.58E-10	1.92E-10	3.28E-13	6.30E-10	2.61E-08	2.67E-08
314300	6248800	5.86E-10	2.15E-10	2.70E-10	6.58E-13	1.07E-09	5.56E-08	5.67E-08
314300	6249000	1.89E-09	3.85E-10	5.16E-10	1.88E-12	2.79E-09	1.77E-07	1.80E-07
314300	6249200	2.22E-08	9.98E-10	1.29E-09	2.35E-11	2.45E-08	2.87E-06	2.89E-06
314300	6249400	6.92E-09	3.66E-09	2.01E-09	1.66E-11	1.26E-08	3.71E-06	3.72E-06
314300	6249600	8.89E-10	5.33E-10	3.20E-10	1.79E-12	1.74E-09	2.98E-07	3.00E-07
314300	6249800	3.59E-10	2.61E-10	2.85E-10	5.88E-13	9.05E-10	9.01E-08	9.10E-08
314300	6250000	1.94E-10	2.29E-10	2.96E-10	2.81E-13	7.19E-10	4.11E-08	4.18E-08
314300	6250200	1.23E-10	1.94E-10	2.82E-10	1.64E-13	6.00E-10	2.31E-08	2.37E-08
314300	6250400	8.70E-11	1.51E-10	2.44E-10	1.10E-13	4.82E-10	1.48E-08	1.52E-08
314300	6250600	6.57E-11	1.28E-10	2.22E-10	7.98E-14	4.16E-10	1.03E-08	1.07E-08
314300	6250800	5.20E-11	1.25E-10	2.44E-10	6.15E-14	4.21E-10	7.55E-09	7.98E-09
314300	6251000	4.25E-11	1.05E-10	2.13E-10	4.93E-14	3.60E-10	5.80E-09	6.16E-09
314500	6248200	1.18E-10	1.25E-10	2.03E-10	1.44E-13	4.46E-10	1.05E-08	1.09E-08
314500	6248400	1.64E-10	1.56E-10	2.50E-10	1.99E-13	5.71E-10	1.58E-08	1.64E-08
314500	6248600	2.52E-10	2.10E-10	3.59E-10	2.97E-13	8.22E-10	2.62E-08	2.70E-08
314500	6248800	4.80E-10	2.77E-10	4.11E-10	5.45E-13	1.17E-09	5.01E-08	5.12E-08
314500	6249000	1.10E-09	4.49E-10	5.36E-10	1.29E-12	2.09E-09	1.14E-07	1.16E-07
314500	6249200	2.09E-09	7.16E-10	6.50E-10	2.58E-12	3.46E-09	2.68E-07	2.71E-07
314500	6249400	1.54E-09	1.26E-09	1.23E-09	2.34E-12	4.03E-09	2.97E-07	3.01E-07
314500	6249600	5.65E-10	1.01E-09	7.85E-10	1.07E-12	2.36E-09	1.30E-07	1.32E-07
314500	6249800	2.70E-10	3.93E-10	3.65E-10	4.39E-13	1.03E-09	5.33E-08	5.43E-08
314500	6250000	1.60E-10	2.03E-10	2.55E-10	2.33E-13	6.18E-10	2.83E-08	2.89E-08
314500	6250200	1.08E-10	1.71E-10	2.57E-10	1.47E-13	5.36E-10	1.74E-08	1.80E-08
314500	6250400	7.92E-11	1.39E-10	2.30E-10	1.03E-13	4.48E-10	1.19E-08	1.23E-08
314500	6250600	6.12E-11	1.31E-10	2.46E-10	7.76E-14	4.38E-10	8.60E-09	9.04E-09
314500	6250800	4.93E-11	1.10E-10	2.13E-10	6.11E-14	3.73E-10	6.53E-09	6.90E-09
314500	6251000	4.08E-11	9.97E-11	2.02E-10	4.97E-14	3.43E-10	5.11E-09	5.45E-09
314700	6248200	9.27E-11	1.29E-10	2.37E-10	1.14E-13	4.59E-10	9.59E-09	1.01E-08
314700	6248400	1.31E-10	1.51E-10	2.48E-10	1.60E-13	5.31E-10	1.36E-08	1.42E-08
314700	6248600	2.13E-10	2.06E-10	3.05E-10	2.59E-13	7.25E-10	2.07E-08	2.14E-08
314700	6248800	3.41E-10	2.71E-10	3.27E-10	4.34E-13	9.40E-10	3.41E-08	3.50E-08
314700	6249000	5.35E-10	3.61E-10	3.77E-10	6.66E-13	1.27E-09	5.81E-08	5.93E-08
314700	6249200	6.78E-10	3.85E-10	4.99E-10	9.02E-13	1.56E-09	8.85E-08	9.01E-08
314700	6249400	6.01E-10	5.28E-10	7.58E-10	8.25E-13	1.89E-09	9.62E-08	9.81E-08
314700	6249600	3.83E-10	6.55E-10	7.19E-10	5.77E-13	1.76E-09	6.57E-08	6.75E-08
314700	6249800	2.03E-10	4.72E-10	4.95E-10	3.30E-13	1.17E-09	3.50E-08	3.62E-08
314700	6250000	1.24E-10	2.84E-10	3.17E-10	1.85E-13	7.25E-10	2.01E-08	2.08E-08
314700	6250200	8.55E-11	1.62E-10	2.22E-10	1.20E-13	4.69E-10	1.29E-08	1.34E-08
314700	6250400	6.48E-11	1.24E-10	1.88E-10	8.62E-14	3.77E-10	9.17E-09	9.54E-09
314700	6250600	5.20E-11	1.05E-10	1.79E-10	6.69E-14	3.35E-10	6.90E-09	7.23E-09
314700	6250800	4.31E-11	9.21E-11	1.71E-10	5.43E-14	3.06E-10	5.40E-09	5.70E-09
314700	6251000	3.67E-11	8.85E-11	1.82E-10	4.56E-14	3.07E-10	4.34E-09	4.64E-09
314900	6248200	8.67E-11	1.36E-10	2.50E-10	1.08E-13	4.73E-10	8.17E-09	8.64E-09
314900	6248400	1.24E-10	1.63E-10	2.62E-10	1.57E-13	5.49E-10	1.11E-08	1.16E-08
314900	6248600	1.65E-10	2.05E-10	2.78E-10	2.16E-13	6.48E-10	1.57E-08	1.63E-08
314900	6248800	2.19E-10	2.51E-10	3.02E-10	2.77E-13	7.72E-10	2.28E-08	2.36E-08
314900	6249000	2.98E-10	2.61E-10	3.47E-10	3.85E-13	9.06E-10	3.21E-08	3.30E-08
314900	6249200	3.21E-10	2.97E-10	4.52E-10	4.22E-13	1.07E-09	4.10E-08	4.21E-08
314900	6249400	3.06E-10	3.40E-10	5.92E-10	4.04E-13	1.24E-09	4.46E-08	4.58E-08
314900	6249600	2.46E-10	4.00E-10	5.03E-10	3.35E-13	1.15E-09	3.71E-08	3.82E-08
314900	6249800	1.65E-10	3.54E-10	4.04E-10	2.46E-13	9.23E-10	2.45E-08	2.54E-08
314900	6250000	1.05E-10	2.51E-10	2.79E-10	1.57E-13	6.35E-10	1.55E-08	1.61E-08
314900	6250200	7.33E-11	1.93E-10	2.44E-10	1.04E-13	5.10E-10	1.04E-08	1.09E-08
314900	6250400	5.51E-11	1.38E-10	2.01E-10	7.55E-14	3.94E-10	7.42E-09	7.81E-09



Risk Calculations for lifetime exposure

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Total Risk
314900	6250600	4.42E-11	1.04E-10	1.69E-10	5.83E-14	3.17E-10	5.64E-09	5.96E-09
314900	6250800	3.70E-11	8.29E-11	1.43E-10	4.77E-14	2.63E-10	4.49E-09	4.75E-09
314900	6251000	3.18E-11	7.78E-11	1.50E-10	4.02E-14	2.60E-10	3.65E-09	3.91E-09
315100	6248200	8.31E-11	1.47E-10	3.00E-10	1.07E-13	5.30E-10	6.93E-09	7.46E-09
315100	6248400	9.99E-11	1.76E-10	3.21E-10	1.33E-13	5.97E-10	9.01E-09	9.61E-09
315100	6248600	1.19E-10	2.01E-10	3.20E-10	1.55E-13	6.40E-10	1.19E-08	1.25E-08
315100	6248800	1.58E-10	1.99E-10	2.92E-10	1.99E-13	6.50E-10	1.57E-08	1.63E-08
315100	6249000	1.80E-10	1.93E-10	3.26E-10	2.42E-13	6.99E-10	1.97E-08	2.04E-08
315100	6249200	1.86E-10	2.27E-10	3.92E-10	2.41E-13	8.06E-10	2.32E-08	2.40E-08
315100	6249400	1.85E-10	2.35E-10	4.25E-10	2.36E-13	8.45E-10	2.49E-08	2.58E-08
315100	6249600	1.58E-10	2.79E-10	3.95E-10	2.07E-13	8.33E-10	2.27E-08	2.35E-08
315100	6249800	1.33E-10	2.72E-10	3.41E-10	1.76E-13	7.45E-10	1.73E-08	1.81E-08
315100	6250000	9.34E-11	2.19E-10	2.62E-10	1.37E-13	5.74E-10	1.23E-08	1.29E-08
315100	6250200	6.58E-11	1.81E-10	2.39E-10	9.41E-14	4.86E-10	8.62E-09	9.11E-09
315100	6250400	4.98E-11	1.58E-10	2.53E-10	6.91E-14	4.61E-10	6.30E-09	6.76E-09
315100	6250600	3.96E-11	1.11E-10	1.78E-10	5.36E-14	3.29E-10	4.83E-09	5.16E-09
315100	6250800	3.29E-11	9.85E-11	1.90E-10	4.34E-14	3.21E-10	3.83E-09	4.15E-09
315100	6251000	2.82E-11	8.15E-11	1.62E-10	3.64E-14	2.72E-10	3.14E-09	3.41E-09
315300	6248200	6.86E-11	1.48E-10	3.37E-10	9.21E-14	5.54E-10	5.89E-09	6.45E-09
315300	6248400	7.71E-11	1.67E-10	3.62E-10	1.02E-13	6.06E-10	7.36E-09	7.96E-09
315300	6248600	9.52E-11	1.65E-10	2.98E-10	1.21E-13	5.59E-10	9.21E-09	9.77E-09
315300	6248800	1.18E-10	1.50E-10	2.64E-10	1.53E-13	5.32E-10	1.12E-08	1.18E-08
315300	6249000	1.20E-10	1.57E-10	2.98E-10	1.61E-13	5.74E-10	1.32E-08	1.37E-08
315300	6249200	1.23E-10	1.70E-10	3.12E-10	1.58E-13	6.05E-10	1.48E-08	1.54E-08
315300	6249400	1.25E-10	1.72E-10	3.19E-10	1.58E-13	6.16E-10	1.59E-08	1.65E-08
315300	6249600	1.12E-10	2.15E-10	3.77E-10	1.44E-13	7.04E-10	1.51E-08	1.58E-08
315300	6249800	9.94E-11	2.23E-10	3.48E-10	1.26E-13	6.70E-10	1.26E-08	1.33E-08
315300	6250000	8.40E-11	1.92E-10	2.84E-10	1.12E-13	5.61E-10	9.77E-09	1.03E-08
315300	6250200	6.15E-11	1.50E-10	2.13E-10	8.75E-14	4.24E-10	7.32E-09	7.74E-09
315300	6250400	4.62E-11	1.41E-10	2.19E-10	6.41E-14	4.06E-10	5.49E-09	5.90E-09
315300	6250600	3.69E-11	1.16E-10	1.97E-10	5.02E-14	3.50E-10	4.26E-09	4.61E-09
315300	6250800	3.04E-11	1.13E-10	2.36E-10	4.09E-14	3.80E-10	3.38E-09	3.76E-09
315300	6251000	2.60E-11	8.81E-11	1.91E-10	3.42E-14	3.05E-10	2.78E-09	3.08E-09
315500	6248200	5.54E-11	1.34E-10	3.25E-10	7.43E-14	5.15E-10	5.01E-09	5.53E-09
315500	6248400	6.43E-11	1.41E-10	3.16E-10	8.37E-14	5.21E-10	6.05E-09	6.57E-09
315500	6248600	8.02E-11	1.25E-10	2.43E-10	1.02E-13	4.48E-10	7.23E-09	7.68E-09
315500	6248800	8.81E-11	1.10E-10	2.03E-10	1.18E-13	4.01E-10	8.40E-09	8.80E-09
315500	6249000	8.60E-11	1.18E-10	2.15E-10	1.15E-13	4.19E-10	9.42E-09	9.84E-09
315500	6249200	8.93E-11	1.26E-10	2.35E-10	1.13E-13	4.51E-10	1.03E-08	1.08E-08
315500	6249400	9.20E-11	1.33E-10	2.57E-10	1.15E-13	4.82E-10	1.10E-08	1.15E-08
315500	6249600	8.49E-11	1.72E-10	3.45E-10	1.08E-13	6.02E-10	1.08E-08	1.14E-08
315500	6249800	7.57E-11	1.84E-10	3.48E-10	9.53E-14	6.07E-10	9.50E-09	1.01E-08
315500	6250000	7.02E-11	1.75E-10	2.91E-10	8.78E-14	5.37E-10	7.80E-09	8.33E-09
315500	6250200	5.85E-11	1.51E-10	2.62E-10	7.80E-14	4.72E-10	6.17E-09	6.64E-09
315500	6250400	4.43E-11	1.24E-10	2.13E-10	6.12E-14	3.81E-10	4.83E-09	5.21E-09
315500	6250600	3.49E-11	1.10E-10	1.87E-10	4.73E-14	3.31E-10	3.81E-09	4.14E-09
315500	6250800	2.89E-11	1.08E-10	2.35E-10	3.87E-14	3.72E-10	3.05E-09	3.43E-09
315500	6251000	2.45E-11	9.70E-11	2.21E-10	3.27E-14	3.42E-10	2.51E-09	2.85E-09



Risk Calculations for Noncancer

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Hazard Index
312700	6248200	3.13E-05	4.41E-05	9.36E-04	1.02E-08	1.01E-03	7.58E-07	1.01E-03
312700	6248400	3.64E-05	3.82E-05	7.91E-04	1.14E-08	8.66E-04	9.58E-07	8.67E-04
312700	6248600	4.09E-05	3.38E-05	6.98E-04	1.30E-08	7.73E-04	1.15E-06	7.74E-04
312700	6248800	4.13E-05	2.97E-05	6.21E-04	1.40E-08	6.92E-04	1.28E-06	6.93E-04
312700	6249000	3.85E-05	2.59E-05	5.25E-04	1.34E-08	5.89E-04	1.33E-06	5.91E-04
312700	6249200	3.63E-05	2.40E-05	4.61E-04	1.23E-08	5.21E-04	1.29E-06	5.22E-04
312700	6249400	3.72E-05	2.00E-05	3.93E-04	1.23E-08	4.50E-04	1.29E-06	4.52E-04
312700	6249600	3.90E-05	2.19E-05	4.05E-04	1.29E-08	4.66E-04	1.36E-06	4.67E-04
312700	6249800	4.09E-05	2.42E-05	4.27E-04	1.27E-08	4.92E-04	1.48E-06	4.93E-04
312700	6250000	4.30E-05	2.71E-05	5.00E-04	1.31E-08	5.70E-04	1.56E-06	5.71E-04
312700	6250200	4.27E-05	2.80E-05	5.53E-04	1.34E-08	6.23E-04	1.56E-06	6.25E-04
312700	6250400	3.93E-05	2.70E-05	5.39E-04	1.21E-08	6.05E-04	1.48E-06	6.07E-04
312700	6250600	3.53E-05	2.56E-05	5.21E-04	1.03E-08	5.82E-04	1.35E-06	5.83E-04
312700	6250800	3.16E-05	2.57E-05	5.33E-04	9.00E-09	5.90E-04	1.19E-06	5.91E-04
312700	6251000	2.86E-05	2.54E-05	5.37E-04	8.06E-09	5.91E-04	1.03E-06	5.92E-04
312900	6248200	3.45E-05	3.76E-05	7.88E-04	1.18E-08	8.60E-04	8.18E-07	8.61E-04
312900	6248400	4.15E-05	3.96E-05	8.28E-04	1.34E-08	9.09E-04	1.09E-06	9.10E-04
312900	6248600	4.88E-05	3.22E-05	6.77E-04	1.55E-08	7.58E-04	1.41E-06	7.59E-04
312900	6248800	5.22E-05	3.05E-05	6.48E-04	1.75E-08	7.30E-04	1.66E-06	7.32E-04
312900	6249000	4.93E-05	2.70E-05	5.65E-04	1.76E-08	6.42E-04	1.78E-06	6.43E-04
312900	6249200	4.63E-05	2.44E-05	4.84E-04	1.61E-08	5.54E-04	1.76E-06	5.56E-04
312900	6249400	4.75E-05	2.11E-05	4.23E-04	1.61E-08	4.92E-04	1.76E-06	4.94E-04
312900	6249600	5.00E-05	2.50E-05	4.50E-04	1.67E-08	5.25E-04	1.88E-06	5.27E-04
312900	6249800	5.28E-05	2.91E-05	5.11E-04	1.65E-08	5.93E-04	2.04E-06	5.95E-04
312900	6250000	5.43E-05	3.32E-05	6.19E-04	1.72E-08	7.06E-04	2.11E-06	7.08E-04
312900	6250200	5.07E-05	3.41E-05	6.61E-04	1.62E-08	7.46E-04	2.04E-06	7.48E-04
312900	6250400	4.50E-05	3.13E-05	6.42E-04	1.37E-08	7.18E-04	1.85E-06	7.20E-04
312900	6250600	3.97E-05	2.93E-05	5.85E-04	1.17E-08	6.54E-04	1.62E-06	6.55E-04
312900	6250800	3.54E-05	2.96E-05	6.09E-04	1.03E-08	6.75E-04	1.37E-06	6.76E-04
312900	6251000	3.21E-05	3.02E-05	6.08E-04	9.54E-09	6.71E-04	1.15E-06	6.72E-04
313100	6248200	3.75E-05	4.04E-05	7.91E-04	1.36E-08	8.69E-04	8.44E-07	8.69E-04
313100	6248400	4.73E-05	4.09E-05	8.59E-04	1.61E-08	9.48E-04	1.21E-06	9.49E-04
313100	6248600	5.84E-05	3.94E-05	8.36E-04	1.88E-08	9.34E-04	1.68E-06	9.36E-04
313100	6248800	6.70E-05	3.42E-05	7.43E-04	2.23E-08	8.44E-04	2.17E-06	8.46E-04
313100	6249000	6.59E-05	2.99E-05	6.53E-04	2.39E-08	7.49E-04	2.49E-06	7.51E-04
313100	6249200	6.17E-05	2.67E-05	5.55E-04	2.23E-08	6.43E-04	2.53E-06	6.46E-04
313100	6249400	6.36E-05	2.30E-05	4.78E-04	2.20E-08	5.65E-04	2.54E-06	5.67E-04
313100	6249600	6.68E-05	3.26E-05	5.69E-04	2.25E-08	6.68E-04	2.72E-06	6.71E-04
313100	6249800	7.09E-05	3.84E-05	6.75E-04	2.26E-08	7.85E-04	2.94E-06	7.88E-04
313100	6250000	6.81E-05	4.23E-05	7.89E-04	2.27E-08	8.99E-04	2.94E-06	9.02E-04
313100	6250200	6.01E-05	4.05E-05	7.96E-04	1.92E-08	8.97E-04	2.67E-06	9.00E-04
313100	6250400	5.18E-05	3.86E-05	7.68E-04	1.58E-08	8.59E-04	2.28E-06	8.61E-04
313100	6250600	4.53E-05	3.69E-05	7.28E-04	1.37E-08	8.10E-04	1.89E-06	8.12E-04
313100	6250800	4.04E-05	3.69E-05	7.26E-04	1.26E-08	8.03E-04	1.54E-06	8.05E-04
313100	6251000	3.63E-05	3.34E-05	6.58E-04	1.18E-08	7.27E-04	1.26E-06	7.29E-04
313300	6248200	3.95E-05	4.52E-05	8.06E-04	1.49E-08	8.90E-04	8.37E-07	8.91E-04
313300	6248400	5.33E-05	5.23E-05	1.00E-03	1.90E-08	1.11E-03	1.27E-06	1.11E-03
313300	6248600	7.00E-05	5.37E-05	1.13E-03	2.36E-08	1.25E-03	1.94E-06	1.26E-03
313300	6248800	8.82E-05	4.30E-05	9.49E-04	2.91E-08	1.08E-03	2.82E-06	1.08E-03
313300	6249000	9.28E-05	3.54E-05	8.09E-04	3.40E-08	9.37E-04	3.62E-06	9.41E-04
313300	6249200	8.78E-05	3.19E-05	6.98E-04	3.33E-08	8.18E-04	3.89E-06	8.22E-04
313300	6249400	9.02E-05	2.93E-05	6.24E-04	3.24E-08	7.43E-04	3.92E-06	7.47E-04
313300	6249600	9.56E-05	4.43E-05	7.66E-04	3.27E-08	9.06E-04	4.26E-06	9.10E-04
313300	6249800	9.69E-05	5.26E-05	9.46E-04	3.30E-08	1.10E-03	4.50E-06	1.10E-03
313300	6250000	8.54E-05	5.44E-05	1.04E-03	2.91E-08	1.18E-03	4.16E-06	1.18E-03
313300	6250200	7.13E-05	5.03E-05	9.88E-04	2.30E-08	1.11E-03	3.48E-06	1.11E-03
313300	6250400	6.08E-05	4.86E-05	9.08E-04	1.93E-08	1.02E-03	2.77E-06	1.02E-03
313300	6250600	5.29E-05	4.42E-05	8.27E-04	1.75E-08	9.25E-04	2.17E-06	9.27E-04
313300	6250800	4.59E-05	4.36E-05	8.38E-04	1.58E-08	9.27E-04	1.69E-06	9.29E-04



Risk Calculations for Noncancer

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Hazard Index
313300	6251000	3.89E-05	4.16E-05	7.81E-04	1.37E-08	8.61E-04	1.33E-06	8.63E-04
313500	6248200	3.87E-05	3.56E-05	5.47E-04	1.51E-08	6.21E-04	8.26E-07	6.22E-04
313500	6248400	5.77E-05	4.26E-05	7.50E-04	2.15E-08	8.50E-04	1.28E-06	8.52E-04
313500	6248600	8.42E-05	5.02E-05	1.02E-03	2.96E-08	1.15E-03	2.13E-06	1.16E-03
313500	6248800	1.18E-04	5.06E-05	1.17E-03	3.95E-08	1.34E-03	3.60E-06	1.34E-03
313500	6249000	1.42E-04	4.45E-05	1.06E-03	5.13E-08	1.25E-03	5.53E-06	1.26E-03
313500	6249200	1.38E-04	4.24E-05	9.73E-04	5.56E-08	1.15E-03	6.68E-06	1.16E-03
313500	6249400	1.43E-04	3.96E-05	8.65E-04	5.36E-08	1.05E-03	6.89E-06	1.05E-03
313500	6249600	1.49E-04	6.34E-05	1.11E-03	5.35E-08	1.32E-03	7.59E-06	1.33E-03
313500	6249800	1.34E-04	7.99E-05	1.47E-03	4.96E-08	1.69E-03	7.31E-06	1.69E-03
313500	6250000	1.07E-04	7.43E-05	1.45E-03	3.73E-08	1.63E-03	5.89E-06	1.63E-03
313500	6250200	8.74E-05	7.26E-05	1.36E-03	2.98E-08	1.52E-03	4.38E-06	1.53E-03
313500	6250400	7.26E-05	6.04E-05	1.11E-03	2.60E-08	1.24E-03	3.22E-06	1.24E-03
313500	6250600	5.91E-05	5.47E-05	9.34E-04	2.20E-08	1.05E-03	2.38E-06	1.05E-03
313500	6250800	4.72E-05	5.17E-05	8.72E-04	1.75E-08	9.71E-04	1.79E-06	9.73E-04
313500	6251000	3.78E-05	5.03E-05	8.69E-04	1.38E-08	9.58E-04	1.38E-06	9.59E-04
313700	6248200	3.67E-05	3.18E-05	3.88E-04	1.58E-08	4.57E-04	8.93E-07	4.58E-04
313700	6248400	5.71E-05	3.19E-05	4.49E-04	2.26E-08	5.38E-04	1.32E-06	5.39E-04
313700	6248600	9.77E-05	3.91E-05	6.98E-04	3.55E-08	8.35E-04	2.25E-06	8.37E-04
313700	6248800	1.62E-04	4.39E-05	1.01E-03	5.58E-08	1.22E-03	4.46E-06	1.22E-03
313700	6249000	2.37E-04	5.67E-05	1.44E-03	8.38E-08	1.73E-03	8.54E-06	1.74E-03
313700	6249200	2.50E-04	5.81E-05	1.41E-03	1.06E-07	1.71E-03	1.31E-05	1.73E-03
313700	6249400	2.63E-04	5.43E-05	1.22E-03	1.06E-07	1.54E-03	1.49E-05	1.56E-03
313700	6249600	2.51E-04	1.07E-04	1.87E-03	1.01E-07	2.23E-03	1.60E-05	2.24E-03
313700	6249800	1.88E-04	1.11E-04	2.11E-03	7.55E-08	2.41E-03	1.25E-05	2.42E-03
313700	6250000	1.40E-04	1.08E-04	2.00E-03	5.38E-08	2.24E-03	8.13E-06	2.25E-03
313700	6250200	1.05E-04	9.40E-05	1.60E-03	4.23E-08	1.80E-03	5.24E-06	1.80E-03
313700	6250400	7.76E-05	7.48E-05	1.16E-03	3.13E-08	1.32E-03	3.54E-06	1.32E-03
313700	6250600	5.81E-05	6.71E-05	9.56E-04	2.27E-08	1.08E-03	2.50E-06	1.08E-03
313700	6250800	4.53E-05	5.87E-05	8.40E-04	1.72E-08	9.44E-04	1.84E-06	9.46E-04
313700	6251000	3.68E-05	5.51E-05	8.15E-04	1.39E-08	9.07E-04	1.40E-06	9.08E-04
313900	6248200	4.38E-05	3.85E-05	4.23E-04	2.01E-08	5.05E-04	1.14E-06	5.06E-04
313900	6248400	6.13E-05	3.91E-05	4.40E-04	2.70E-08	5.40E-04	1.61E-06	5.42E-04
313900	6248600	1.02E-04	4.23E-05	5.13E-04	4.09E-08	6.57E-04	2.55E-06	6.60E-04
313900	6248800	2.13E-04	4.18E-05	6.87E-04	7.54E-08	9.42E-04	5.18E-06	9.47E-04
313900	6249000	4.34E-04	5.39E-05	1.32E-03	1.46E-07	1.81E-03	1.32E-05	1.82E-03
313900	6249200	5.62E-04	8.61E-05	2.32E-03	2.39E-07	2.97E-03	2.86E-05	3.00E-03
313900	6249400	6.63E-04	8.22E-05	1.83E-03	3.19E-07	2.57E-03	5.43E-05	2.63E-03
313900	6249600	4.49E-04	2.01E-04	3.54E-03	2.27E-07	4.19E-03	4.06E-05	4.24E-03
313900	6249800	2.68E-04	1.83E-04	3.24E-03	1.28E-07	3.69E-03	1.98E-05	3.71E-03
313900	6250000	1.65E-04	1.52E-04	2.26E-03	7.86E-08	2.57E-03	1.00E-05	2.58E-03
313900	6250200	1.07E-04	1.29E-04	1.69E-03	4.70E-08	1.93E-03	5.71E-06	1.93E-03
313900	6250400	7.56E-05	8.91E-05	1.06E-03	3.18E-08	1.22E-03	3.66E-06	1.23E-03
313900	6250600	5.75E-05	7.81E-05	9.44E-04	2.37E-08	1.08E-03	2.52E-06	1.08E-03
313900	6250800	4.59E-05	7.31E-05	8.96E-04	1.87E-08	1.02E-03	1.83E-06	1.02E-03
313900	6251000	3.78E-05	6.73E-05	8.82E-04	1.53E-08	9.87E-04	1.39E-06	9.88E-04
314100	6248200	6.53E-05	6.14E-05	6.32E-04	2.97E-08	7.59E-04	1.60E-06	7.60E-04
314100	6248400	9.31E-05	6.13E-05	6.22E-04	4.13E-08	7.77E-04	2.35E-06	7.79E-04
314100	6248600	1.47E-04	6.59E-05	6.99E-04	6.38E-08	9.13E-04	3.85E-06	9.16E-04
314100	6248800	2.75E-04	6.85E-05	8.28E-04	1.11E-07	1.17E-03	7.19E-06	1.18E-03
314100	6249000	8.14E-04	7.36E-05	9.73E-04	2.68E-07	1.86E-03	2.00E-05	1.88E-03
314100	6249200	2.27E-03	7.37E-05	1.36E-03	7.49E-07	3.71E-03	8.06E-05	3.79E-03
314100	6249400	2.31E-03	1.90E-04	3.30E-03	1.72E-06	5.81E-03	2.91E-04	6.10E-03
314100	6249600	6.92E-04	4.60E-04	5.21E-03	5.26E-07	6.36E-03	8.55E-05	6.45E-03
314100	6249800	3.01E-04	2.70E-04	2.39E-03	1.80E-07	2.96E-03	2.40E-05	2.99E-03
314100	6250000	1.68E-04	1.81E-04	1.57E-03	8.82E-08	1.92E-03	1.05E-05	1.93E-03
314100	6250200	1.09E-04	1.52E-04	1.47E-03	5.30E-08	1.73E-03	5.67E-06	1.74E-03
314100	6250400	7.80E-05	1.14E-04	1.17E-03	3.58E-08	1.37E-03	3.55E-06	1.37E-03
314100	6250600	5.92E-05	9.34E-05	1.02E-03	2.63E-08	1.18E-03	2.43E-06	1.18E-03



Risk Calculations for Noncancer

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Hazard Index
314100	6250800	4.67E-05	9.03E-05	1.10E-03	2.03E-08	1.24E-03	1.77E-06	1.24E-03
314100	6251000	3.82E-05	7.80E-05	9.98E-04	1.63E-08	1.11E-03	1.34E-06	1.12E-03
314300	6248200	1.04E-04	9.22E-05	7.93E-04	4.52E-08	9.89E-04	2.08E-06	9.92E-04
314300	6248400	1.58E-04	1.15E-04	9.27E-04	6.68E-08	1.20E-03	3.22E-06	1.20E-03
314300	6248600	2.74E-04	1.49E-04	1.11E-03	1.12E-07	1.53E-03	5.67E-06	1.54E-03
314300	6248800	5.90E-04	2.03E-04	1.56E-03	2.24E-07	2.35E-03	1.22E-05	2.36E-03
314300	6249000	2.00E-03	3.63E-04	2.98E-03	6.42E-07	5.34E-03	3.91E-05	5.38E-03
314300	6249200	2.53E-02	9.41E-04	7.45E-03	8.04E-06	3.37E-02	6.55E-04	3.44E-02
314300	6249400	4.47E-03	3.45E-03	1.16E-02	5.66E-06	1.95E-02	7.81E-04	2.03E-02
314300	6249600	7.06E-04	5.03E-04	1.84E-03	6.09E-07	3.05E-03	6.33E-05	3.12E-03
314300	6249800	2.99E-04	2.46E-04	1.64E-03	2.00E-07	2.19E-03	1.92E-05	2.21E-03
314300	6250000	1.66E-04	2.16E-04	1.71E-03	9.57E-08	2.09E-03	8.78E-06	2.10E-03
314300	6250200	1.07E-04	1.83E-04	1.63E-03	5.60E-08	1.92E-03	4.95E-06	1.93E-03
314300	6250400	7.60E-05	1.42E-04	1.41E-03	3.73E-08	1.63E-03	3.16E-06	1.63E-03
314300	6250600	5.78E-05	1.21E-04	1.28E-03	2.72E-08	1.46E-03	2.21E-06	1.46E-03
314300	6250800	4.59E-05	1.18E-04	1.41E-03	2.09E-08	1.57E-03	1.62E-06	1.57E-03
314300	6251000	3.77E-05	9.85E-05	1.23E-03	1.68E-08	1.36E-03	1.24E-06	1.37E-03
314500	6248200	1.11E-04	1.17E-04	1.17E-03	4.90E-08	1.40E-03	2.27E-06	1.40E-03
314500	6248400	1.56E-04	1.47E-04	1.45E-03	6.78E-08	1.75E-03	3.44E-06	1.75E-03
314500	6248600	2.42E-04	1.98E-04	2.07E-03	1.01E-07	2.51E-03	5.69E-06	2.52E-03
314500	6248800	4.75E-04	2.61E-04	2.37E-03	1.86E-07	3.11E-03	1.09E-05	3.12E-03
314500	6249000	1.09E-03	4.23E-04	3.09E-03	4.41E-07	4.61E-03	2.50E-05	4.63E-03
314500	6249200	1.96E-03	6.75E-04	3.75E-03	8.79E-07	6.39E-03	5.88E-05	6.45E-03
314500	6249400	1.27E-03	1.18E-03	7.12E-03	7.95E-07	9.57E-03	6.37E-05	9.63E-03
314500	6249600	4.61E-04	9.52E-04	4.53E-03	3.65E-07	5.95E-03	2.77E-05	5.97E-03
314500	6249800	2.27E-04	3.71E-04	2.11E-03	1.50E-07	2.70E-03	1.14E-05	2.72E-03
314500	6250000	1.37E-04	1.91E-04	1.47E-03	7.93E-08	1.80E-03	6.06E-06	1.80E-03
314500	6250200	9.40E-05	1.61E-04	1.49E-03	4.99E-08	1.74E-03	3.73E-06	1.74E-03
314500	6250400	6.96E-05	1.31E-04	1.33E-03	3.51E-08	1.53E-03	2.55E-06	1.53E-03
314500	6250600	5.41E-05	1.23E-04	1.42E-03	2.64E-08	1.60E-03	1.84E-06	1.60E-03
314500	6250800	4.37E-05	1.04E-04	1.23E-03	2.08E-08	1.38E-03	1.40E-06	1.38E-03
314500	6251000	3.63E-05	9.39E-05	1.17E-03	1.69E-08	1.30E-03	1.10E-06	1.30E-03
314700	6248200	8.69E-05	1.22E-04	1.37E-03	3.89E-08	1.58E-03	2.08E-06	1.58E-03
314700	6248400	1.25E-04	1.42E-04	1.43E-03	5.45E-08	1.70E-03	2.96E-06	1.70E-03
314700	6248600	2.05E-04	1.94E-04	1.76E-03	8.82E-08	2.16E-03	4.50E-06	2.17E-03
314700	6248800	3.25E-04	2.56E-04	1.89E-03	1.48E-07	2.47E-03	7.42E-06	2.48E-03
314700	6249000	5.13E-04	3.40E-04	2.18E-03	2.27E-07	3.03E-03	1.27E-05	3.04E-03
314700	6249200	6.22E-04	3.63E-04	2.88E-03	3.07E-07	3.87E-03	1.93E-05	3.89E-03
314700	6249400	5.28E-04	4.98E-04	4.37E-03	2.81E-07	5.40E-03	2.07E-05	5.42E-03
314700	6249600	3.23E-04	6.17E-04	4.15E-03	1.97E-07	5.09E-03	1.41E-05	5.10E-03
314700	6249800	1.72E-04	4.45E-04	2.86E-03	1.12E-07	3.47E-03	7.48E-06	3.48E-03
314700	6250000	1.07E-04	2.68E-04	1.83E-03	6.29E-08	2.20E-03	4.30E-06	2.21E-03
314700	6250200	7.46E-05	1.53E-04	1.28E-03	4.08E-08	1.51E-03	2.77E-06	1.51E-03
314700	6250400	5.71E-05	1.16E-04	1.09E-03	2.94E-08	1.26E-03	1.97E-06	1.26E-03
314700	6250600	4.60E-05	9.86E-05	1.03E-03	2.28E-08	1.18E-03	1.48E-06	1.18E-03
314700	6250800	3.84E-05	8.68E-05	9.86E-04	1.85E-08	1.11E-03	1.16E-06	1.11E-03
314700	6251000	3.27E-05	8.34E-05	1.05E-03	1.55E-08	1.16E-03	9.32E-07	1.17E-03
314900	6248200	8.20E-05	1.28E-04	1.44E-03	3.68E-08	1.65E-03	1.77E-06	1.66E-03
314900	6248400	1.17E-04	1.54E-04	1.51E-03	5.34E-08	1.78E-03	2.40E-06	1.79E-03
314900	6248600	1.54E-04	1.93E-04	1.61E-03	7.36E-08	1.95E-03	3.40E-06	1.96E-03
314900	6248800	2.08E-04	2.36E-04	1.74E-03	9.45E-08	2.19E-03	4.95E-06	2.19E-03
314900	6249000	2.76E-04	2.46E-04	2.00E-03	1.31E-07	2.53E-03	6.97E-06	2.53E-03
314900	6249200	2.94E-04	2.80E-04	2.61E-03	1.44E-07	3.18E-03	8.90E-06	3.19E-03
314900	6249400	2.73E-04	3.20E-04	3.42E-03	1.38E-07	4.01E-03	9.62E-06	4.02E-03
314900	6249600	2.18E-04	3.77E-04	2.91E-03	1.14E-07	3.50E-03	7.95E-06	3.51E-03
314900	6249800	1.42E-04	3.34E-04	2.33E-03	8.38E-08	2.81E-03	5.24E-06	2.81E-03
314900	6250000	9.04E-05	2.37E-04	1.61E-03	5.35E-08	1.94E-03	3.31E-06	1.94E-03
314900	6250200	6.39E-05	1.82E-04	1.41E-03	3.55E-08	1.66E-03	2.22E-06	1.66E-03
314900	6250400	4.85E-05	1.30E-04	1.16E-03	2.57E-08	1.34E-03	1.59E-06	1.34E-03



Risk Calculations for Noncancer

Easting X	Northing Y	Vapour Excav	Vapour ECS	Vapour DTD	Dust-Exc Inh	Total Inh Risk	Dust-Exc DC	Hazard Index
314900	6250600	3.91E-05	9.78E-05	9.77E-04	1.99E-08	1.11E-03	1.21E-06	1.11E-03
314900	6250800	3.29E-05	7.81E-05	8.27E-04	1.62E-08	9.38E-04	9.63E-07	9.39E-04
314900	6251000	2.84E-05	7.33E-05	8.65E-04	1.37E-08	9.67E-04	7.85E-07	9.68E-04
315100	6248200	7.77E-05	1.39E-04	1.73E-03	3.66E-08	1.95E-03	1.50E-06	1.95E-03
315100	6248400	9.24E-05	1.66E-04	1.85E-03	4.52E-08	2.11E-03	1.95E-06	2.11E-03
315100	6248600	1.11E-04	1.90E-04	1.85E-03	5.28E-08	2.15E-03	2.58E-06	2.15E-03
315100	6248800	1.48E-04	1.88E-04	1.69E-03	6.79E-08	2.02E-03	3.39E-06	2.03E-03
315100	6249000	1.64E-04	1.81E-04	1.88E-03	8.25E-08	2.22E-03	4.27E-06	2.23E-03
315100	6249200	1.71E-04	2.14E-04	2.27E-03	8.20E-08	2.65E-03	5.01E-06	2.66E-03
315100	6249400	1.67E-04	2.22E-04	2.45E-03	8.05E-08	2.84E-03	5.38E-06	2.84E-03
315100	6249600	1.41E-04	2.63E-04	2.28E-03	7.06E-08	2.69E-03	4.88E-06	2.69E-03
315100	6249800	1.18E-04	2.56E-04	1.97E-03	5.99E-08	2.34E-03	3.71E-06	2.34E-03
315100	6250000	8.09E-05	2.06E-04	1.51E-03	4.65E-08	1.80E-03	2.64E-06	1.80E-03
315100	6250200	5.74E-05	1.71E-04	1.38E-03	3.21E-08	1.61E-03	1.85E-06	1.61E-03
315100	6250400	4.38E-05	1.48E-04	1.46E-03	2.35E-08	1.65E-03	1.35E-06	1.66E-03
315100	6250600	3.51E-05	1.05E-04	1.03E-03	1.83E-08	1.17E-03	1.04E-06	1.17E-03
315100	6250800	2.92E-05	9.28E-05	1.09E-03	1.48E-08	1.22E-03	8.22E-07	1.22E-03
315100	6251000	2.52E-05	7.68E-05	9.35E-04	1.24E-08	1.04E-03	6.75E-07	1.04E-03
315300	6248200	6.31E-05	1.39E-04	1.95E-03	3.14E-08	2.15E-03	1.27E-06	2.15E-03
315300	6248400	7.13E-05	1.57E-04	2.09E-03	3.48E-08	2.32E-03	1.59E-06	2.32E-03
315300	6248600	8.93E-05	1.56E-04	1.72E-03	4.14E-08	1.97E-03	1.99E-06	1.97E-03
315300	6248800	1.09E-04	1.42E-04	1.52E-03	5.20E-08	1.77E-03	2.43E-06	1.77E-03
315300	6249000	1.08E-04	1.48E-04	1.72E-03	5.49E-08	1.97E-03	2.84E-06	1.98E-03
315300	6249200	1.13E-04	1.60E-04	1.80E-03	5.38E-08	2.08E-03	3.20E-06	2.08E-03
315300	6249400	1.14E-04	1.62E-04	1.84E-03	5.38E-08	2.12E-03	3.42E-06	2.12E-03
315300	6249600	9.96E-05	2.03E-04	2.18E-03	4.89E-08	2.48E-03	3.25E-06	2.48E-03
315300	6249800	8.95E-05	2.10E-04	2.01E-03	4.28E-08	2.31E-03	2.71E-06	2.31E-03
315300	6250000	7.42E-05	1.81E-04	1.64E-03	3.81E-08	1.90E-03	2.09E-06	1.90E-03
315300	6250200	5.36E-05	1.41E-04	1.23E-03	2.98E-08	1.42E-03	1.57E-06	1.43E-03
315300	6250400	4.06E-05	1.33E-04	1.26E-03	2.18E-08	1.44E-03	1.18E-06	1.44E-03
315300	6250600	3.26E-05	1.09E-04	1.14E-03	1.71E-08	1.28E-03	9.14E-07	1.28E-03
315300	6250800	2.70E-05	1.07E-04	1.36E-03	1.39E-08	1.50E-03	7.26E-07	1.50E-03
315300	6251000	2.31E-05	8.31E-05	1.10E-03	1.16E-08	1.21E-03	5.96E-07	1.21E-03
315500	6248200	5.09E-05	1.26E-04	1.88E-03	2.53E-08	2.05E-03	1.08E-06	2.06E-03
315500	6248400	5.99E-05	1.33E-04	1.82E-03	2.85E-08	2.01E-03	1.31E-06	2.02E-03
315500	6248600	7.46E-05	1.18E-04	1.40E-03	3.48E-08	1.59E-03	1.56E-06	1.60E-03
315500	6248800	8.01E-05	1.04E-04	1.17E-03	4.01E-08	1.35E-03	1.82E-06	1.36E-03
315500	6249000	7.82E-05	1.11E-04	1.24E-03	3.91E-08	1.43E-03	2.03E-06	1.43E-03
315500	6249200	8.18E-05	1.19E-04	1.36E-03	3.86E-08	1.56E-03	2.23E-06	1.56E-03
315500	6249400	8.36E-05	1.25E-04	1.48E-03	3.90E-08	1.69E-03	2.37E-06	1.70E-03
315500	6249600	7.61E-05	1.62E-04	1.99E-03	3.68E-08	2.23E-03	2.32E-06	2.23E-03
315500	6249800	6.80E-05	1.73E-04	2.01E-03	3.24E-08	2.25E-03	2.04E-06	2.25E-03
315500	6250000	6.32E-05	1.65E-04	1.68E-03	2.99E-08	1.91E-03	1.67E-06	1.91E-03
315500	6250200	5.16E-05	1.43E-04	1.51E-03	2.65E-08	1.71E-03	1.32E-06	1.71E-03
315500	6250400	3.88E-05	1.17E-04	1.23E-03	2.08E-08	1.38E-03	1.04E-06	1.38E-03
315500	6250600	3.08E-05	1.03E-04	1.08E-03	1.61E-08	1.21E-03	8.17E-07	1.21E-03
315500	6250800	2.56E-05	1.02E-04	1.36E-03	1.32E-08	1.48E-03	6.56E-07	1.48E-03
315500	6251000	2.18E-05	9.14E-05	1.28E-03	1.11E-08	1.39E-03	5.39E-07	1.39E-03



Appendix E

Toxicological Information



DDT and Its Derivatives

(Extract from WHO Drinking Water Guidelines Rev 2, 1996)

General Description

Identity

CAS no.: 107917-42-0

Molecular formula: $C_{14}H_9Cl_5$

The term DDT refers to p,p'-DDT, or p,p'-dichlorodiphenyl trichloroethane. The compounds structure permits several different isomeric forms, such as o,p'-DDT. The term DDT is also applied to commercial products consisting predominantly of p,p'-DDT, but also containing smaller amounts of other compounds, including p,p'- and o,p'-DDD (dichlorodiphenyl dichloroethane) and p,p'- and o,p'-DDE (dichlorodiphenyl dichloroethene) (1).

Environmental Fate

DDT and its metabolites are persistent in the environment and resistant to complete degradation by microorganisms, although photochemical degradation does occur. The persistence of DDT is substantially lower in tropical climates than in temperate ones (a few months as compared with years) (1).

DDT and its metabolites are readily adsorbed on to sediments and soils, which can act both as sinks and as long-term sources of exposure. Because of its strong tendency to be adsorbed on to surfaces, most DDT that enters water is and remains firmly attached to soil particles. If it does find its way into water, it is gradually lost by adsorption on to surfaces (1).

The physical and chemical properties of DDT and its metabolites enable these compounds to be taken up readily by organisms from the surrounding medium and from food. In aquatic organisms, uptake from water is generally more important, whereas food is the major source for terrestrial fauna. High lipid solubility and low water solubility lead to the retention of DDT and its stable metabolites in fatty tissue. In general, organisms at higher trophic levels tend to contain more DDT-type compounds than those at lower ones. These compounds can be transported around the world in the bodies of animals, as well as in ocean and air currents (1).

Analytical Methods

DDT and its metabolites may be determined in water by gas chromatography with electron-capture detection. The limits of detection are 60 ng/litre for p,p'-DDT, 10 ng/litre for p,p'-DDE, and 2.5 ng/litre for p,p'-DDD (3).

Environmental Levels and Human Exposure

Air

When DDT is sprayed, any that fails to adhere to its target drifts away; vaporization from treated fields can be detected for more than six months after application. Although most of it settles in the same area, some drifts over long distances. Traces of DDT have been found in dust known to have drifted over 1 000 km and in water produced by melting Antarctic snow.



With rare exceptions, concentrations of DDT in air in nonagricultural areas have been in the range $<1\text{--}2.36\text{ ng/m}^3$. In agricultural communities, concentrations have ranged from 1 to 22 ng/m^3 . In communities with antimosquito fogging programmes, concentrations may be much higher, $8.5\text{ }\mu\text{g/m}^3$ being the highest level recorded (4).

Water

In a study of surface waters in the USA during 1964-1968, the highest level recorded for a DDT-related compound was $0.84\text{ }\mu\text{g/litre}$. Concentrations in Germany were even lower, averaging 10 ng/litre and never going as high as $1\text{ }\mu\text{g/litre}$. The average concentrations of total DDT in drinking-water in Czechoslovakia were 11 and 15 ng/litre in 1972 and 1973, respectively. DDT was not detected (limit 0.01 ng/litre) in tapwater in a 1977 survey carried out in Ottawa (Canada) (4).

Within the Global Environment Monitoring System (GEMS) water network, DDT and its metabolites were found in some rivers during 1979-84. The following average concentrations were measured (5): India, 560 ng/litre ; Italy, 3 ng/litre ; Netherlands, $<2\text{ ng/litre}$; USA, 0.2 ng/litre ; Canada and France, not detected.

Food

Daily intake of DDT from food has been measured in several countries. During 1985-88, in Australia, Finland, Guatemala, Japan, Thailand, the United Kingdom, and the USA, the reported mean daily dietary intake by the average adult was less than $2\text{ }\mu\text{g}$ (6). In Egypt, in 1988, a mean daily intake of $960\text{ }\mu\text{g}$ was reported for the average adult (7).

Human milk may contain a higher concentration of DDT than cows' milk in the same country. So far, there is no evidence that this difference is of any significance for breast-fed babies, even where the concentration of DDT in human milk is comparatively high (4). The average concentration of total DDT in whole human milk in 15 countries between 1976 and 1986 ranged from 2 to $380\text{ }\mu\text{g/litre}$ (8). On the assumption that a 5-kg infant consumes 0.6 litres of milk per day, the intake at the highest concentration found would amount to about $200\text{ }\mu\text{g/day}$, or $40\text{ }\mu\text{g/kg}$ of body weight per day. It should be remembered that such intake is limited to a few months in a lifetime. Furthermore, neonates are not at increased risk, as they are not particularly susceptible to DDT's adverse effects (9).

Estimated Total Exposure and Relative Contribution of Drinking-Water

It has been estimated that over 90% of the DDT stored in the general population is derived from food (4). In 1965, intake in the USA was approximately $40\text{ }\mu\text{g/day}$ per person from food, less than 46 ng/day from water, less than 60 ng/day from urban air, and less than $0.5\text{ }\mu\text{g/day}$ from air in small agricultural communities. Other investigators have also concluded that food is the major source of intake of DDT and related compounds for the general population (4).

Kinetics and Metabolism in Laboratory Animals and Humans

DDT is absorbed after inhalation and ingestion, the latter being the more important route of absorption. Absorption of small doses, such as those found in food residues, is virtually complete and is facilitated by the presence of fat in food. Even in solution, DDT is poorly absorbed through the skin.

Most of the known facts concerning the distribution, storage, and excretion of DDT have been demonstrated in humans as well as in laboratory animals. The compound is stored preferentially in fat, and its storage in organs and other tissues following repeated intake is proportional to their neutral fat content. However, uptake of DDT by fat is slow; therefore, much more is distributed to other tissues



following a single, large dose, and much more to adipose tissue following many small doses. In spite of the affinity of DDT for adipose tissues, most of the DDT-related compounds in blood are carried by proteins, less than 1% being carried in the tiny droplets of fat normally present in the blood.

Following repeated doses, storage in adipose tissue increases rapidly at first and then more gradually until a steady state is reached. Storage is relatively less at higher dosages because excretion is relatively greater. In humans, the time necessary to reach storage equilibrium is at least one year. There is a gradual reduction in the amount of DDT stored in the tissues if exposure to the compound is discontinued.

Like most species, humans convert some DDT to DDE, which is stored even more avidly than the parent compound. A small amount of DDD, an intermediate in the formation of the main excretory product 2,2-bis(4-chlorophenyl)-ethanoic acid (DDA), may also be found in tissues. A number of other metabolites have been detected in laboratory animals but not in humans. Technical DDT is more readily excreted and less readily stored than p,p'-DDT because it contains 15-20% of o,p'-DDT (4).

Effects on Laboratory Animals and In Vitro Test Systems

Acute Exposure

The acute toxicity of DDT is high in insects (LD₅₀ is 14 mg/kg of body weight) and lower in mammals (oral LD₅₀: 150-400 mg/kg of body weight). Acute intoxication with DDT elicits symptoms mainly from the central nervous system, and death is usually caused by respiratory arrest. Large doses cause focal necrosis of liver cells in several species (3).

Long-term Exposure

Long-term studies of oral administration have been performed in rats, mice, hamsters, dogs, and monkeys. The liver is one of the main target organs, and hepatic effects range from increased liver weights to cellular necrosis. The NOAEL for hepatic effects was 32 mg/kg of body weight per day for 78 weeks in rats and about 10 mg/kg of body weight per day when given to rhesus monkeys for 3.5-7.5 years (3).

Effects on the central nervous system, such as tremors and hyperactivity, are also associated with longterm exposure to DDT. Nervous symptoms were apparent at doses of 20 mg/kg of body weight per day in rats, whereas hamsters showed no clinical signs of neurotoxicity at doses of up to 40 mg/kg of body weight per day for life (3,9).

Reproductive Toxicity, Embryotoxicity and Teratogenicity

Levels of DDT as high as 200 mg/kg of food that do not produce any sign of poisoning have not produced any adverse effects in rats and mice on fertility, gestation, viability, lactation, and the health of the progeny. Reproduction was normal in dogs receiving a dosage of 10 mg/kg of body weight per day, which is approximately equivalent to a dietary level of 500 mg/kg for this species (4).

Because of its estrogenic properties, DDT was considered as a possible cause of abortion in dairy cattle, but no evidence of a relationship was found. Except for the weak estrogenic properties of o,p'-DDT, the endocrine-related effects of DDT and its analogues are confined to the adrenal glands, and even these effects are now considered to be mainly secondary to microsomal enzyme induction in the liver (4).

No teratogenic effects of DDT have been observed in multigeneration studies of reproduction in several animal species (4).



Mutagenicity and Related End-Points

In most studies, DDT did not induce genotoxic effects in rodent or human cell systems, nor was it mutagenic to fungi or bacteria (3).

Carcinogenicity

DDT produces an increase in liver tumours in mice. However, the susceptibility of the mouse to the formation of liver tumours when exposed to it may be the consequence of major species differences in the metabolism of DDT and in the activation of chemical carcinogens by this species. Mice form more DDE than humans and other species; humans form more of the polar metabolite DDA. Indeed, DDE has been considered to be the metabolite responsible for carcinogenicity in mice (9).

Male and female Porton Wistar rats were fed 125, 250, or 500 mg of DDT per kg in the diet for life. No adverse effects were observed on body weight gain or growth or on the survival rate. The study showed slight increases in the incidence of hepatomas in females only at 250 and 500 mg/kg in the diet; the 125 mg/kg dose level was without effect, and no increase in the incidence of cancer was seen in males at any of these doses. No metastases of any kind were observed. JMPR concluded that the 125 mg/kg dose, equivalent to 6.25 mg/kg of body weight per day, was the NOAEL for tumorigenesis in the rat (9).

Effects on Humans

Signs and symptoms reported following acute intoxication by DDT include nausea, vomiting, paraesthesia, dizziness, ataxia, confusion, tremor, and, in severe cases, convulsions (3).

Repeated exposure of workers for 25 years at an average dosage of 0.25 mg/kg of body weight per day was without any adverse effect, and this may be taken as a no-effect level for humans (9).

Epidemiological observations of humans have not provided firm evidence that DDT has any reproductive or teratogenic effects. All epidemiological studies in humans have indicated that DDT is not carcinogenic (9).

Guideline Value

IARC has concluded that there is insufficient evidence in humans and sufficient evidence in experimental animals for the carcinogenicity of DDT (Group 2B) (3).

The USEPA publish an oral cancer slope factor in IRIS of $0.34 \text{ (mg/kg/d)}^{-1}$ based on liver tumours in rats (10). Twenty-five animal carcinogenicity assays have been reviewed for DDT, only one of these studies, conducted for 78 weeks, showed no indication of DDT tumorigenicity. Both hepatocellular adenomas and carcinomas were observed in six mouse liver tumour studies. Both benign and malignant lung tumours were observed in two studies wherein mice were exposed both in utero and throughout their lifetime. The derived slope factor is a geometric mean of all the derived slope factors.

An inhalation unit risk of $9.7 \times 10^{-5} \text{ (ug/m}^3\text{)}^{-1}$ was extrapolated from the oral data.

Based on NOAELs of 6.25 mg/kg of body weight per day in rats, 10 mg/kg of body weight per day in monkeys, and 0.25 mg/kg of body weight per day in humans, JMPR recommended an ADI for humans of 0.02 mg/kg of body weight (9). For adults, this ADI would provide a 500-fold margin of safety for the NOAEL of 10 mg/kg of body weight per day found in the study in monkeys.



References

1. *DDT and its derivatives-environmental aspects*. Geneva, World Health Organization, 1989 (Environmental Health Criteria, No. 83).
2. Zoeteman BCJ. *Sensory assessment of water quality*. Oxford, Pergamon Press, 1980.
3. International Agency for Research on Cancer. *Occupational exposures in insecticide application, and some pesticides*. Lyon, 1991:179-249 (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 53).
4. *DDT and its derivatives*. Geneva, World Health Organization, 1979 (Environment Health Criteria, No. 9).
5. Meybeck M, Chapman D, Helmer R, eds. *Global freshwater quality: WHO/UNEP Global Environment Monitoring System*. Oxford, Alden Press, 1989.
6. Galal-Gorchev H. *Dietary intake of pesticide residues, cadmium, mercury, and lead*. Food additives and contaminants, 1991, 8:793-806.
7. Abdel-Gawaad AA, Shams El Dine A. *Insecticide residues in total diet samples*. Journal of the Egyptian Society of Toxicology, 1989, 4:79-89.
8. United Nations Environment Programme. *Assessment of chemical contaminants in food: Global Environment Monitoring System*. Nairobi, 1988.
9. Food and Agriculture Organization of the United Nations. *Pesticide residues in food-1984 evaluations*. Rome, 1985 (Joint FAO/WHO Meeting on Pesticide Residues: FAO Plant Production and Protection Paper 67).
10. US EPA Integrated Risk Information System

Aldrin and Dieldrin

(Extract from WHO Drinking Water Guidelines Rev 2, 1996)

General Description

Identity

Compound	CAS no.	Molecular formula
Aldrin	309-00-2	C ₁₂ H ₈ Cl ₆
Dieldrin	60-57-1	C ₁₂ H ₈ Cl ₆ O

The IUPAC name for aldrin is (1R,4S,4aS,5S,8R,8aR)-1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene (HHDN). Aldrin is most commonly used to mean HHDN with a purity greater than 95%, except in Denmark and the countries of the former Soviet Union, where it is the name given to pure HHDN. Impurities include octachlorocyclopentene, hexachlorobutadiene, toluene, and polymerization products (1).

The IUPAC name for dieldrin is (1R,4S,4aS,5R,6R,7S,8S,8aR)-1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphthalene (HEOD). Dieldrin is most commonly used to mean HEOD with a purity greater than 85%, except in Denmark and the countries of



the former Soviet Union, where it is the name given to pure HEOD. Impurities include other polychloroepoxyoctahydrodimethanonaphthalenes and endrin (1).

Environmental Fate

In soil, aldrin is removed by oxidation to dieldrin and evaporation. In temperate climates, only 75% is oxidized within a year after application. The further disappearance of dieldrin is very slow under these conditions; the half-life is approximately 5 years. Under tropical conditions, both oxidation and further disappearance of dieldrin are rapid, 90% disappearing within 1 month, primarily by volatilization (1).

Analytical Methods

Aldrin and dieldrin are determined by extraction with pentane followed by gas chromatography with electron-capture detection. The detection limits in tap-water and river water are about 0.001 µg/litre for aldrin and 0.002 µg/litre for dieldrin.

Environmental Levels and Human Exposure

Air

Dieldrin has been detected at very low concentrations in ambient air, on dust particles, and in rainwater. In nonagricultural areas, concentrations of 0.06-1.6 ng/m³ have been reported; in agricultural areas, mean levels are in the range 1-2 ng/m³, with a maximum of about 40 ng/m³ (1).

Concentrations found in the air of houses treated for termites are much higher (40-7 000 ng/m³). The presence of aldrin/dieldrin-treated wood in houses results in indoor air concentrations of 10-500 ng/m³ (1).

Water

The concentrations of aldrin and dieldrin in aquatic environments and drinking-water are normally less than 10 ng/litre. Higher levels are attributed to contamination from industrial effluents and soil erosion during agricultural use. River sediments may contain higher amounts (up to 1 mg/kg). These pesticides are rarely present in groundwater, as little leaching from soils occurs (1).

Food

Dieldrin is stored in the adipose tissue, liver, brain, and muscle of mammals, fish, birds, and other parts of the food-chain. The reduction in use since the 1970s has decreased the residues in food in many countries to well below the levels that may result in an intake of 0.1 µg/kg of body weight per day (the ADI established by the Joint FAO/WHO Meeting on Pesticide Residues) (6). The intake in 1980-82 was estimated to be 0-0.2 µg/kg of body weight per day in several countries (1).

Dieldrin has been detected in breast milk at a mean concentration of 0.5-11 µg/kg of milk in Europe and the USA. Breast-fed babies receive doses of approximately 1 µg/kg of body weight per day when mothers' milk contains 6 µg of dieldrin per litre (1). Although concentrations in breast milk decreased from an average of 1.33 µg/kg of milk in 1982 to 0.85 µg/kg of milk in 1986 (7), higher concentrations (mean 13 µg/litre) have been found in breast milk from women whose houses were treated annually with aldrin (8).

Kinetics and Metabolism in Laboratory Animals and Humans

Aldrin and dieldrin are absorbed by the oral, inhalation, and dermal routes. They tend to accumulate in adipose tissue. A steady state between intake, storage, and excretion is reached following repeated



dosing. Aldrin and dieldrin can be mobilized from the adipose tissue compartment, causing an increase in blood level that results in toxic manifestations. Dieldrin is metabolized in the liver and is excreted, with its metabolites, primarily in the faeces via the bile in humans and in most animals tested (mouse, rat, monkey). The major metabolite is 9-hydroxy dieldrin. Small amounts of trans-6,7-hydroxy dieldrin, dicarboxylic acids, and bridged pentachloroketone are excreted, but only in laboratory animals. The ratios between the amounts of the various metabolites produced differ for different animals (1).

Effects on Laboratory Animals and *In Vitro* Test Systems

Acute Exposure

Acute oral LD₅₀s of 33-65 mg/kg of body weight have been reported for aldrin and dieldrin for mice, rats, dogs, pigs, and rabbits. The reported value for dieldrin in monkeys is 3 mg/kg of body weight (1).

Short-term Exposure

Short-term studies on rodents have shown that the liver is the major target organ of aldrin and dieldrin exposure. The liver-to-body-weight ratio increases, and histopathological changes are observed, which have become known as “chlorinated hydrocarbon insecticide rodent liver.” In rats, the changes were minimal at a dose of 0.025 mg/kg of body weight per day, and this value was selected as the LOAEL (1).

Long-term Exposure

Dogs seem more sensitive to aldrin and dieldrin than rats. In a 2-year study with beagle dogs receiving dieldrin in olive oil at doses of 0.005 or 0.05 mg/kg of body weight per day, female dogs given 0.05 mg/kg of body weight per day had an increased liver-to-body-weight ratio. The NOAEL was estimated to be 0.005 mg/kg of body weight per day (1).

Reproductive Toxicity, Embryotoxicity and Teratogenicity

The results of a number of reproductive studies suggest that dieldrin at levels of 2 mg/kg in the rat diet and 3 mg/kg in the mouse diet has no effects on reproduction. At these levels, however, there may be biochemical and histopathological effects.

In a limited study with dogs fed aldrin or dieldrin, pup survival was generally lower. No effects were observed in dogs receiving 0.2 mg of dieldrin per kg in the diet (1).

Mutagenicity and Related End-Points

The majority of studies on aldrin and dieldrin have not shown them to be mutagenic. In one study in which dieldrin was mutagenic in two out of three strains of *Salmonella typhimurium*, a dose-response relationship was not demonstrated (1).

Carcinogenicity

A number of long-term studies have shown aldrin and dieldrin to produce benign and malignant tumours of the liver in various strains of mice but not in other species. This indicates that the effect of aldrin/dieldrin on the mouse liver is species-specific. Aldrin and dieldrin have also been tested for carcinogenicity by the oral route in hamsters, dogs, and monkeys (1). After assessing much of the available data, IARC concluded that the evidence for the carcinogenicity to animals for both aldrin and dieldrin is limited, and classified both chemicals in Group 3 (9).



Effects on Humans

Both aldrin and dieldrin are highly toxic to humans, the target organs being the central nervous system and the liver. Severe cases of both accidental and occupational poisoning and a number of fatalities have been reported. The lethal dose of dieldrin is estimated to be approximately 10 mg/kg of body weight per day. The majority of those poisoned by aldrin or dieldrin recover, and irreversible effects have not been reported.

Male volunteers exposed to dieldrin doses of 0-3 µg/kg of body weight per day for 18 months showed no effects on health. The concentration of dieldrin in blood and adipose tissue was found to be proportional to the daily intake (1).

Effects on occupationally exposed workers have been studied in two epidemiological mortality studies. In one study (232 subjects), no indication of specific carcinogenic activity was found. In another study (1040 subjects), the mortality due to malignant neoplasms was lower than expected. There was a slight excess of cancers of the oesophagus, rectum, and liver, based on very small numbers. The only disease showing higher mortality rates than expected was non-malignant respiratory system disease, specifically pneumonia (1).

Chromosome studies have been carried out on human peripheral lymphocytes from agricultural workers and workers engaged in the control of Chagas disease with at least 10 years of exposure to dieldrin. There were no differences between the control and exposure groups in structural chromosomal aberrations and sister chromatid exchange (1).

Guideline Value

In 1977 JMPR recommended an ADI of 0.1 µg/kg of body weight (combined total for aldrin and dieldrin). This was based on NOAELs of 1 mg/kg of diet in the dog and 0.5 mg/kg of diet in the rat, which are equivalent to 0.025 mg/kg of body weight per day in both species. JMPR applied an uncertainty factor of 250 based on concern about carcinogenicity observed in mice (6).

The USEPA publish an oral cancer slope factor of $16 \text{ (mg/kg/d)}^{-1}$ based on the geometric mean of 13 slope factors calculated from liver carcinoma data in both sexes of several strains of mice (10). At different dose levels the effects range from benign liver tumours, to hepatocarcinomas with transplantation confirmation, to pulmonary metastases.

An inhalation unit risk of $4.6 \times 10^{-3} \text{ (ug/m}^3\text{)}^{-1}$ was extrapolated from the oral data.

References

1. *Aldrin and dieldrin*. Geneva, World Health Organization, 1989 (Environmental Health Criteria, No. 91).
2. Worthing CR, ed. *The pesticide manual*, 9th ed. Farnham, British Crop Protection Council, 1991.
3. Office of Health and Environmental Assessment. *Carcinogenicity assessment of aldrin and dieldrin*. Washington, DC, US Environmental Protection Agency, 1987 (EPA/600/6-87-006).
4. Waggot A, Bell SM. *An inventory of organic compounds potentially causing taste and odour problems in water*. Medmenham, Water Research Centre, 1988.
5. Meister R, ed. *Farm chemicals handbook*. Willoughby, OH, Meister Publishing, 1989.



6. Food and Agriculture Organization of the United Nations. *Pesticide residues in food: 1977 evaluation*. Rome, 1978 (Joint FAO/WHO Meeting on Pesticide Residues: FAO Plant Production and Protection Paper 10, Suppl.).
7. National Board of Health (Denmark). *Dioxins in mothers milk*. Copenhagen, 1987 (Hygeijnemeddelelser 7).
8. Stacey CI, Tatum T. House treatment with organochlorine pesticides and their levels in human milk - Perth, Western Australia. *Bulletin of environmental contamination and toxicology*, 1985, 35:202-208.
9. International Agency for Research on Cancer. *Overall evaluations of carcinogenicity: an updating of IARC Monographs volumes 1-42*. Lyon, 1987:88-89 (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Suppl. 7).
10. US EPA Integrated Risk Information System

Trichloroethylene (also known as trichloroethene)

(Extract from WHO Drinking Water Guidelines Rev 2, 1996)

Kinetics and Metabolism in Laboratory Animals and Humans

Analysis of human blood and breath following inhalation of 546 mg/m³ trichloroethene showed that peak levels were reached within 1 h of exposure. In rats, 72-85% of an orally administered dose was detected in expired air and 10-20% in urine, indicating that at least 80% of ingested trichloroethene is systemically absorbed. Transplacental diffusion has been demonstrated in humans following inhalation; the ratio of the concentrations in fetal and maternal blood ranged between 0.52 and 1.90. Trichloroethene was widely distributed in rats given it by gavage, the highest concentration being in body fat.

Inhalation studies in humans show that 40-75% of the retained dose is metabolized. The principal urinary metabolites are trichloroacetaldehyde, trichloroethanol, trichloroacetic acid, and trichloroethanol glucuronide. An important metabolic intermediate is the reactive epoxide, trichloroethene oxide, which can alkylate nucleic acids and proteins. Trichloroethene is eliminated with a half-time of about 1.5 h. Metabolites are excreted more slowly; the biological half-life measured in human urine is about 50 h for trichloroethanol and 36-73 h for trichloroethanoic acid.

Effects on Laboratory Animals and In-Vitro Test Systems

Acute Exposure

The acute oral LD50s for trichloroethene in rats and mice are 4 920 mg/kg of body weight and 2 400 mg/kg of body weight, respectively.

Short-term Exposure

In a study in which groups of 12B24 male Swiss-Cox mice received trichloroethene by gavage in corn oil, five days per week for six weeks, at doses of 0, 100, 200, 400, 800, 1 600, 2 400, or 3 200 mg/kg of body weight per day, dose-related increases in hepatic DNA, relative liver weight, and hypertrophy of the liver were apparent at 100 mg/kg of body weight per day and above, and glucose-6-phosphate levels were decreased by 30-40% at 800 mg/kg of body weight per day and above. The LOAEL was 100 mg/kg of body weight per day.



Fischer 344/N rats and B6C3F1 mice (10 per sex per dose) were given trichloroethene at doses of up to 2 000 (male rats), 1 000 (female rats), or 6 000 (mice) mg/kg of body weight per day in corn oil by gavage, five days per week for 13 weeks. Survival in mice was greatly decreased at 3 000 and 6 000 mg/kg of body weight per day. Body weight was decreased in male rats at 2 000 mg/kg of body weight per day and in male mice at 750 mg/kg of body weight per day and above. Mild to moderate cytomegaly and enlarged cell nuclei of the renal tubular epithelial cells in the inner cortex were observed in both sexes of both species at 1 000 and 2 000 mg/kg of body weight per day (rats) and 3 000 and 6 000 mg/kg of body weight per day (mice).

In rats exposed to air containing 300 mg/m³ trichloroethene five days per week for 14 weeks, liver weights were elevated, possibly as the result of fatty accumulation. Haematological parameters, liver and renal function tests, blood glucose, and organ-to-body-weight ratios were the same as in controls.

Long-term Exposure

The toxicity of trichloroethene (epichlorohydrin-free) was investigated in F344 rats and B6C3F1 mice (50 per sex per dose) given 0, 500, or 1 000 mg/kg of body weight per day (rats) and 0 or 1 000 mg/kg of body weight per day (mice) in corn oil, five days per week for 103 weeks. Survival was reduced in male rats and mice but not in females. Toxic nephrosis, characterized as cytomegaly, occurred in rats at 500 and 1 000 mg/kg of body weight per day and in mice at 1 000 mg/kg of body weight per day. LOAELs of 500 mg/kg of body weight per day for rats and 1 000 mg/kg of body weight per day for mice were identified.

Reproductive Toxicity, Embryotoxicity and Teratogenicity

No statistically significant effects on sperm count, motility, or morphology were detected in male Long-Evans rats (10 per dose) intubated with 1, 10, 100, or 1 000 mg of trichloroethene per kg of body weight per day, five days per week for six weeks. Copulatory behaviour was impaired at 100 mg/kg of body weight per day during the initial four weeks of exposure but returned to normal by week five.

A continuous-breeding fertility study was conducted in which male and female Fischer 344 rats were fed diets containing microencapsulated trichloroethene at dose levels of approximately 0, 75, 150, or 300 mg/kg of body weight per day from seven days before mating to the birth of the F2 generation. Although testicular and epididymal weights decreased in the F1 generation, no histopathological changes were observed. In a similar study in CD-1 mice given up to 750 mg trichloroethene per kg of body weight per day, sperm motility was reduced by 45% in F0 males and 18% in F1 males. There were no treatment related effects on mating, fertility, or reproductive performance in the F0 or F1 mice.

Mice and rats exposed to trichloroethene vapour at a concentration of 1 600 mg/m³ on days 6-15 of gestation for 7 h per day did not experience any teratogenic effects, although there was some evidence of haemorrhages in the cerebral ventricles and a few cases of undescended testicles.

Mutagenicity and Related End-Points

There are numerous studies of the genotoxicity of trichloroethene, but the evidence is conflicting, in part because of impurities in the test material and the presence of stabilizers that are themselves mutagenic. In a range of in vitro assays, the data indicate that it is either negative or only weakly positive. A dose dependent increase in DNA single-strand breaks was observed in liver and kidney, but not lung, of male NMRI mice 1 h, but not 24 h, after intraperitoneal injection of 4-10 mmol of trichloroethene per kg of body weight.



Carcinogenicity

There was a significant increase in hepatocellular tumours in both sexes of B6C3F1 mice given trichloroethene by gavage in corn oil. However, in a similar study in a strain of mice with a low background incidence of liver tumours, there was no evidence of increased tumour incidence. There was some indication of a small increase in renal tumours in male rats given 250 mg of trichloroethene per kg of body weight by gavage in corn oil, but these tumours are of doubtful significance for humans.

In an inhalation study, a dose-related increase in malignant lymphomas was reported in female HAN:NMRI mice exposed to 546 or 819 mg/m³ trichloroethene vapour 6 h per day, five days per week for 18 months; this strain of mice has a high incidence of spontaneous lymphomas. An increased incidence of pulmonary adenocarcinomas was found in female ICR mice exposed to 820 or 2 460 mg/m³ trichloroethene vapour as compared with controls, but no such increase was found in female Sprague-Dawley rats.

Effects on Humans

Acute exposure to high concentrations of trichloroethene causes central nervous system depression. Exposure to 147 mg/m³ in air for 4 h caused drowsiness and mucous membrane irritation; at 442 mg/m³, it caused headaches. Drowsiness, lethargy, and nausea were observed within 5 min at 10.9 g/m³. Coma and respiratory depression may occur following prolonged exposure to levels above 10.9 g/m³. Hepatic failure and subsequent death were reported following the use of trichloroethene as an anaesthetic, generally in patients with complicating transfusions. Oral exposure of humans to 15-25 ml (21-35 g) resulted in vomiting and abdominal pain, followed by transient unconsciousness.

Humans exposed occupationally to trichloroethene had an increase in serum aminotransferases, indicating damage to the liver parenchyma. Neurological abnormalities were associated with occupational exposure to 76-464 mg/m³ trichloroethene for between one month and 15 years, including decreased appetite, sleep disturbances, ataxia, vertigo, headache, and short-term memory loss.

Guideline Value

IARC has classified trichloroethylene as a Group 2A carcinogen (probably carcinogenic to humans). This classification was based on sufficient evidence in animals and limited evidence in humans.

Using the data on the incidence of pulmonary adenomas in B3C6F1 mice and on pulmonary adenomas/carcinomas in Swiss mice, unit risks of 9.3×10^{-8} and 1.6×10^{-7} , respectively, can be calculated by applying the linearized multistage model. Applying the same model on the incidence of Leydig cell tumours in the testes of rats, a unit risk of 4.3×10^{-7} can be derived.

Tetrachloroethylene (also known as tetrachloroethene and perchloroethylene)

(Extract from WHO Drinking Water Guidelines Rev 2, 1996)

Kinetics and Metabolism in Laboratory Animals and Humans

The results from animal studies indicate that tetrachloroethene is rapidly and completely absorbed from the gastrointestinal tract. It reached near-steady-state levels in the blood of human volunteers after 2 h of continuous inhalation. Rats given a gavage dose of radio labelled tetrachloroethene contained radioactivity in the liver, kidney, and fat. Occupationally exposed subjects had whole-blood levels as high as 2 500 µg/litre, as compared with 0.4 µg/litre in controls.



Metabolic products appear to be similar in humans and experimental animals. Tetrachloroethene is metabolized by a cytochrome P-450-mediated oxidation to tetrachloroethene oxide and trichloroacetyl chloride to form trichloroethanoic acid and trichloroethanol. In mice, trichloroethanoic acid is the major metabolite formed, whereas it is formed in relatively small amounts in rats. In humans, only 1.8% of the retained dose was converted into trichloroethanoic acid; 1.0% was converted into an unknown metabolite in 67 h.

Saturation of metabolism has been observed both in inhalation studies in rats and in gavage studies in mice. After saturation of metabolism via the oxidative pathway, a second metabolic pathway through conjugation with glutathione to form a highly reactive trichlorovinylthiol compound has been shown to occur in rat kidney, activated by renal β -lyase enzyme. This metabolic pathway appears to be absent in humans and to be significant only in male rats.

Tetrachloroethene is eliminated from the body primarily via the lungs; the half-life is about 65 h. Trichloroethanoic acid is eliminated via the urine with a half-life of 144 h.

Effects on Laboratory Animals and In-Vitro Test Systems

Acute Exposure

LD50s of 3 835 and 3 005 mg/kg of body weight were found for male and female rats to which single doses of tetrachloroethene were administered by gavage. Acute effects are dominated by central nervous system depression.

Short-term Exposure

Groups of male Swiss-Cox mice were given oral doses of tetrachloroethene in corn oil at 0, 20, 100, 1 000, or 2 000 mg/kg of body weight, five days per week for six weeks (equivalent to 0, 14, 70, 700, or 1 400 mg/kg of body weight per day). Mice treated with doses as low as 70 mg/kg of body weight per day exhibited significantly increased liver triglyceride levels and liver-to-body-weight ratios. At higher doses, hepatotoxic effects included decreased DNA content, increased serum alanine aminotransferase, decreased glucose- 6-phosphatase serum levels, and hepatocellular necrosis, degeneration, and polyploidy. The NOAEL was 14 mg/kg of body weight per day.

Sprague-Dawley rats (20 per sex per dose) were given tetrachloroethene in drinking-water at doses of 14, 400, or 1 400 mg/kg of body weight per day for 90 days. Males in the high-dose group and females in the mid- and high-dose groups exhibited depressed body weights. Increased liver- and kidney-to-body-weight ratios (equivocal evidence of hepatotoxicity) were also observed at the two highest doses.

There was moderate fatty degeneration of the liver in mice following a 4-h exposure to air containing 1 340 mg of tetrachloroethene per m³. Exposure to this same level for 4 h per day, six days per week for up to eight weeks increased the severity of the lesions.

Long-term Exposure

Male and female Osborne-Mendel rats and B6C3F1 mice were exposed to tetrachloroethene by corn oil gavage for 78 weeks at doses ranging from 471 to 1 072 mg/kg of body weight per day. Increased mortality and nephropathy, as shown by degenerative tubule changes, fatty changes, and cloudy swelling, were observed in all treated animals.

Exposure of F344 rats to tetrachloroethene administered by inhalation at doses of 0, 1.36, or 2.72 g/m³ for 103 weeks, five days per week, resulted in a significant reduction in survival, increased renal



karyomegaly in both sexes, and renal tubular cell hyperplasia in males at both doses. Similar exposure of B6C3F1 mice to 0, 1.36, or 2.72 g/m³ resulted in reduced survival and increased renal nephrosis, tubular cell karyomegaly, and renal casts, as well as hepatic degeneration and necrosis.

Reproductive Toxicity, Embryotoxicity and Teratogenicity

Inhalation exposures to tetrachloroethene have resulted in maternal and fetal toxicity in mice, rats, and rabbits.

Mutagenicity and Related End-Points

Short-term studies indicate that tetrachloroethene induces single-strand DNA breaks in the mouse but does not cause chromosomal aberrations in rat bone marrow or human lymphocytes. In vitro assays in *Salmonella typhimurium*, *Escherichia coli*, and *Saccharomyces cerevisiae* were negative both with and without microsomal activation.

Carcinogenicity

The exposure by inhalation (6 h per day, five days per week for 103 weeks) of F344/N rats to 0, 1.36, or 2.72 g/m³ tetrachloroethene produced a small (but not statistically significant) increase in the combined incidence of renal tubular-cell adenomas and adenocarcinomas in males but not in females. In both sexes, there was an increase in the incidence of mononuclear cell leukaemias at both doses, but the incidence was also unusually high in concurrent as compared with historical controls.

It has been suggested that the induction of kidney tumours in male rats is the combined result of the formation of a highly reactive metabolite and cell damage produced by renal accumulation of hyaline droplets.

The exposure by inhalation (6 h per day, five days per week for 103 weeks) of B6C3F1 mice at 0, 1.36, or 2.72 g/m³ resulted in an increase in hepatocellular carcinomas in both males and females. In an earlier bioassay, in which tetrachloroethene was administered by gavage in corn oil, there was an increase in the incidence of hepatocellular carcinomas in both male and female mice but not in Osborne-Mendel rats. In this experiment, survival was reduced in both species as a result of pneumonia, and impurities later shown to be carcinogenic were present in the tetrachloroethene.

Hepatotoxic and related carcinogenic effects of tetrachloroethene in mice appear to be due to trichloroethanoic acid, which is formed in greater amounts by mice than by rats or humans. In addition, mice are more sensitive than rats to trichloroethanoic acid, a peroxisome proliferator in mice.

Effects on Humans

Oral doses of 4.2-6 g of tetrachloroethene administered to patients to control parasitic worm infections caused central nervous system effects, such as inebriation, perceptual distortion, and exhilaration. Several developmental effects, such as eye, ear, central nervous system, chromosomal, and oral cleft anomalies, were associated with exposure to tetrachloroethene and other solvents in contaminated drinking-water supplies. Inhalation exposures have been associated in female dry-cleaning workers with reproductive effects, including menstrual disorders and spontaneous abortions.

A few case reports and small-scale epidemiological and clinical studies involving a group of men occupationally exposed to tetrachloroethene at levels of 1 890-2 600 mg/m³ suggest an association between such exposure and serious central nervous system problems. However, workers were often simultaneously exposed to several solvents. Evidence for the carcinogenicity of tetrachloroethene was



obtained by observing laundry and dry-cleaning workers, but was rated as inadequate by IARC. Although an increased incidence of cancer was reported in several cohort and proportionate mortality studies and increased risks of cancer in workers exposed to tetrachloroethene were found in case-control studies, study limitations, such as concomitant exposures to other chemicals and small sample size, make it difficult to reach a definite conclusion.

Guideline Value

IARC has concluded that there is sufficient evidence of carcinogenicity in animals to classify tetrachloroethene in Group 2B: possible human carcinogen. It reportedly produces liver tumours in mice, with some evidence of mononuclear cell leukaemia in rats and kidney tumours in male rats. However, overall evidence indicates that this compound is not genotoxic.

In view of the overall evidence for nongenotoxicity and evidence for a saturable metabolic pathway leading to kidney tumours in rats, it is appropriate to use a NOAEL with a suitable uncertainty factor for calculation of the TDI. A 6-week gavage study in male mice and a 90-day drinking-water study in male and female rats both indicated a NOAEL for hepatotoxic effects of 14 mg/kg of body weight per day. A TDI of 14 µg/kg of body weight was calculated by applying an uncertainty factor of 1 000 (100 for intra- and interspecies variation and 10 for carcinogenic potential).

(extract from WHO Air Quality Guidelines, 2000)

Given the limitations of the weight of the epidemiological evidence, and the uncertainty of the relevance to humans of the induction of tumours in animals exposed to tetrachloroethylene, the derivation of a guideline value is at present based on non-neoplastic effects rather than on carcinogenicity as the critical endpoint.

On the basis of a long-term LOAEL for kidney effects of 102 mg/m³ in dry-cleaning workers, a guideline value of 0.25 mg/m³ is calculated. In deriving this guideline value, the LOAEL is converted to continuous exposure (dividing by a factor of 4.2, 168/40) and divided by an uncertainty factor of 100 (10 for use of an LOAEL and 10 for intraspecies variation).

Carbon Tetrachloride

Health Risk Evaluation

(extract from NHMRC Australian Drinking Water Guidelines, 2004)

Carbon tetrachloride is absorbed readily from the gastrointestinal tract, the respiratory tract and the skin. It is distributed to all major organs, with highest concentrations in fatty tissues. It is metabolised in the liver to chloroform and other products, and excreted in breath, urine and faeces.

In humans, acute inhalation can result in central nervous system depression, and kidney and liver toxicity. Occupational exposure to carbon tetrachloride by inhalation has been associated with cancer of several organs but the evidence is inconclusive. No data are available on the effects of long-term ingestion of carbon tetrachloride. In animals, the effects of long-term exposure include toxicity to the liver and kidney. Liver tumours have been reported in studies with mice, rats and hamsters, but at doses higher than those that cause liver toxicity.

Carbon tetrachloride does not exhibit any evidence of mutagenic activity in tests with bacteria or cultured liver cells.



The International Agency for Research on Cancer has concluded that carbon tetrachloride is possibly carcinogenic to humans (Group 2B, inadequate evidence in humans but sufficient evidence in animals) (IARC 1987).

Guidelines

The USEPA publish an oral cancer slope factor in IRIS of $0.13 \text{ (mg/kg/d)}^{-1}$ based on evidence of hepatocellular carcinomas in rodents by oral, inhalation, and parenteral exposure. Researchers at the NCI conducted a series of oral gavage studies in mice of various strains and found large increases in the incidence of liver tumours in treated mice and a similar result was obtained in hamsters.

An inhalation unit risk of $1.5 \times 10^{-5} \text{ (ug/m}^3\text{)}^{-1}$ was developed based on pheochromocytoma in mice.

An oral TDI was published by NHMRC (2004) of 0.0012 mg/kg/day based on a no effect level based on a 90-day gavage study using mice and a 1 000 fold safety factor in using the results of an animal study as a basis for human exposure.

The WHO (2000) presents a guideline value of 6.1 ug/m^3 for air.

1,2-Dichloroethane

Health Risk Evaluation

(extract from WHO Air Quality Guidelines, 2000)

Human studies point to effects on the central nervous system and the liver, but the limited data do not allow a definitive conclusion regarding a LOAEL or NOAEL. In animals, long-term inhalation exposure (>6 months) to 1,2-dichloroethane levels of approximately 700 mg/m^3 and above has been shown to result in histological changes in the liver. The same animal studies reported no adverse histological changes in the liver and kidneys of guinea pigs and rats at levels of about 400 mg/m^3 . Findings concerning effects on reproduction are contradictory.

Animal data suggest a NOAEL in laboratory animals of 400 mg/m^3 and a LOAEL of 700 mg/m^3 .

With regard to mutagenicity as an endpoint and to the causal connections between DNA damage and the initiation of carcinogenicity, 1,2-dichloroethane has been shown to be weakly mutagenic in *Salmonella typhimurium*, both in the absence and in the presence of microsomal activation systems. It has also been demonstrated to be mutagenic in other test species and in in-vitro tests using mammalian cells.

In a lifetime study in rats and mice in which 1,2-dichloroethane was administered by gavage, it caused tumours at multiple sites in both species. In the only inhalation study performed, exposure to 1,2-dichloroethane did not result in an increased tumour incidence. The negative results obtained in this study, however, do not detract from the positive findings of the oral study when differences in total dose, exposure time and pharmacokinetics are considered.

Guidelines

Inhalation

1,2-Dichloroethane was evaluated in 1979 by IARC as a chemical for which there is sufficient evidence of carcinogenicity in experimental animals and inadequate evidence in humans. To date there are two publications giving quantitative carcinogenic risk estimates based on animal data. One, developed by the



National Institute of Public Health in the Netherlands on the basis of oral exposure of rats by gavage, indicates a lifetime risk of one in a million from exposure to $0.48 \mu\text{g}/\text{m}^3$, which corresponds to a unit risk of about $2.8 \times 10^{-6} (\mu\text{g}/\text{m}^3)^{-1}$.

Oral

Australian Drinking Water Guidelines (2004) establish a guideline value for 1,2-dichloroethane in drinking water at 0.003 mg/L. The WHO has conservatively calculated, using an extrapolation model based on a 78 week study in rats, that consumption of water containing 0.003 mg/L of 1,2-dichloroethane would pose a lifetime risk of one additional cancer per million people. This equates to a slope factor of $0.02 (\text{mg}/\text{kg}/\text{d})^{-1}$.

Mercury

Health Risk Evaluation

The toxic effects of inorganic mercury compounds are seen mainly in the kidney in both humans and laboratory animals following short- and long-term exposure. In rats, effects include increased absolute and relative kidney weights, tubular necrosis, proteinuria and hypoalbuminaemia. In humans, acute oral poisoning results primarily in haemorrhagic gastritis and colitis; the ultimate damage is to the kidney. The overall weight of evidence is that mercury(II) chloride has the potential to increase the incidence of some benign tumours at sites where tissue damage is apparent and that it possesses weak genotoxic activity but does not cause point mutations.

Less than 15% of inorganic mercury intake is absorbed by the gastrointestinal tract. Inorganic mercury compounds accumulate in the kidney and have a long biological half-life, probably many years. Many studies have looked at groups of workers occupationally exposed to mercury, and have reported health effects including tremors, mental disturbances and gingivitis (inflammation of the mucous membrane surrounding the teeth). The main toxic effects are to the kidney, leading to kidney failure.

In animal studies, the principal target organs of mercury toxicity are the kidney and the central nervous system. Some disruption to ovulation in female rats has also been reported. Various reports indicate that inorganic mercury binds to, and damages, mammalian DNA. Some evidence of carcinogenicity in rats has been reported.

Guidelines

Inhalation

The LOAELs for mercury vapour are around $15\text{--}30 \mu\text{g}/\text{m}^3$. Applying an uncertainty factor of 20 (10 for uncertainty due to variable sensitivities in higher risk populations and, on the basis of dose–response information, a factor of 2 to extrapolate from a LOAEL to a likely NOAEL), a guideline for inorganic mercury vapour of $1 \mu\text{g}/\text{m}^3$ as an annual average has been established by WHO. Since cationic inorganic mercury is retained only half as much as the vapour, the guideline also protects against mild renal effects caused by cationic inorganic mercury. Present knowledge suggests, however, that effects on the immune system at lower exposures cannot be excluded.

Oral

The Australian Drinking Water Guidelines (2004) establish a guideline value of 0.001 mg/L based on a tolerable daily intake of 0.00047 mg/kg/d.



1,4-Dichlorobenzene (para-Dichlorobenzene)

IARC evaluation

IARC last evaluated 1,4-dichlorobenzene (1,4-DCB) in 1999 and placed it in Group 2B – possibly carcinogenic to humans due to liver tumours in male and female mice. In particular:

- ▶ There is weak evidence for the genotoxicity of *para*-dichlorobenzene in mammalian cells *in vitro*;
- ▶ There is *inadequate evidence* in humans for the carcinogenicity of dichlorobenzenes; and
- ▶ There is *sufficient evidence* in experimental animals for the carcinogenicity of *para*-dichlorobenzene.

IPCS Evaluation – Environmental Health Criteria 128

IPCS evaluated 1,4-DCB in 1991, as part of *Environmental Health Criteria 128: Chlorobenzenes other than hexachlorobenzene, WHO, 1991*. 1,4-DCB and other chlorobenzenes do not appear to be mutagenic. However, increased DNA replication in the mouse liver and the increased incidence of hepatocellular adenomas and carcinomas in mice suggest that it may act as a non-genotoxic carcinogen. It is therefore appropriate to develop a guideline in the form of a TDI, with uncertainty factors included for neoplastic effects.

- ▶ Estimated *inhalation* TDI – 1 µg/kg bw/day; and
- ▶ Estimated *ingestion* TDI – 0.1 µg/kg bw/day.

WHO Guidelines for Air Quality

The WHO guideline for air quality uses the same end point as the EHC 128 to derive a tolerable concentration of 1000 µg/m³.

WHO Guidelines for Drinking-Water Quality

WHO does not consider 1,4-DCB to be genotoxic and calculates a guideline value using the TDI approach. A TDI of 107 µg/kg of bw was used to derive a guideline value of 300 µg/L. Uncertainty factors were included for intraspecies variation and the use of a Low Observable Adverse Effects Limit instead of a No Observable Adverse Effects Limit for a carcinogenic endpoint.

NHMRC Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines sets a limit of 0.04 mg/L for 1,4-DCB. This is lower than the WHO guideline of 0.3 mg/L because the Australian value includes an extra safety factor of 10 to account for possible carcinogenic effects. Note that the following factors were used to convert the toxicity value of 150 mg/kg bw/day to the 0.0107 mg/kg bw/day used in this risk assessment:

- ▶ 10 000 for the use of an animal study as a basis for human exposure; and
- ▶ 5/7 to convert data based on a five day per week gavage study to a 7-day week equivalent.

Other non-carcinogenic effects that were considered include liver damage, blood disorders, and disturbances to the immune system, the central nervous system or the respiratory tract. Skin contact may result in skin pigmentation and allergic dermatitis.



Worksafe Australia standard

The Worksafe Australia standard for 1,4-DCB is a Time Weighted Average of 75 ppm (451 mg/m³). This value is set out in the National Exposure Standards [NOHSC:1003(1995)].

1,4-Dichlorobenzene references

IARC (1999), "Dichlorobenzenes", IARC Summary and Evaluation, Volume 73, available: <http://www.inchem.org/documents/iarc/vol73/73-08.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (2000), "Guidelines for Air Quality", available: http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available: http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1998), "Chlorobenzenes other than hexachlorobenzene", Environmental Health Criteria 128, available: <http://www.inchem.org/documents/ehc/ehc/ehc128.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Hexachlorobenzene

IARC Evaluation

IARC, in 1987, classified hexachlorobenzene as a Group 2B carcinogen, ie, *possibly carcinogenic to humans*. IARC re-evaluated hexachlorobenzene in 2001 (IARC Volume 79), and again it was classified as Group 2B. IARC determined that:

- ▶ There is *inadequate evidence* in humans for the carcinogenicity of hexachlorobenzene; and
- ▶ There is *sufficient evidence* in experimental animals for the carcinogenicity of hexachlorobenzene.

IPCS Evaluation

IPCS evaluated hexachlorobenzene in 1997, see *Environmental Health Criteria 195 Hexachlorobenzene, WHO, 1997*. The principle non-cancer effect of interest is the interruption of haem biosynthesis in the liver. IPCS also concluded that animal studies have shown that hexachlorobenzene causes cancer and affects a wide range of organ systems, including the liver, lungs, kidneys, thyroid, reproductive tissues, nervous and immune systems.

An important IPCS finding is that hexachlorobenzene, while exhibiting some genotoxic activity, does so much more weakly than known genotoxic carcinogens. IPCS concluded that hexachlorobenzene "has little capability to induce directly gene mutation, chromosomal damage and DNA repair. It exhibited weak mutagenic activity in a small number of the available studies on bacteria and yeast, although it should be noted that each of these studies has limitations. There is also some evidence of low-level binding to DNA *in vitro* and *in vivo*, but at levels well below those expected for genotoxic carcinogens". Therefore, since hexachlorobenzene has been found by IPCS not to be a genotoxic carcinogen, a TDI is



the appropriate toxicological criterion to apply to human health risk assessments, rather than a cancer risk slope factor, which is appropriate for genotoxic carcinogens.

The IPCS concluded that “the available data are sufficient to develop guidance values for non-neoplastic and neoplastic effects of” hexachlorobenzene and proposed TDIs of 0.17µg/kg bodyweight/day for non-cancer effects and 0.16µg/kg bodyweight/day for neoplastic effects. The lower of the two TDIs should be used in human health risk assessment.

IPCS recommended that in order to reduce uncertainty in the risk assessment (i.e. toxicological evaluation) of hexachlorobenzene, research into primary mechanism(s) of action for tumorigenic, thyroid, reproductive, porphyrogenic, neurotoxic and immunologic effects of hexachlorobenzene should be undertaken. The role of the Ah receptor-linked mechanisms should also be evaluated more fully. To a certain extent the severity of effect factor used by IPCS accounts for the lack of No Observed Effect Level data for a number of end-points for which there are Lowest Observed Effect data.

WHO Air Quality Guidelines

WHO does not endorse an air quality guideline value for hexachlorobenzene.

WHO Guidelines for Drinking-Water Quality

The guidelines published in 2004 do not establish a guideline value for hexachlorobenzene because it “Occurs in drinking-water at concentrations well below those at which toxic effects may occur”.

However, the second edition guidelines (1993) set a drinking water guideline for hexachlorobenzene of 1µg/L for a 10⁻⁵ lifetime excess cancer risk based on rat liver tumour data. Applying Australian public health carcinogen policy (NHMRC/ARMCANZ 2004) lowers the drinking water guideline concentration to 0.1µg/L. This is because NHMRC/ARMCANZ 2004 applies a 10⁻⁶ lifetime cancer risk for genotoxic carcinogens in drinking water. Applying endorsed exposure factors (ie, a 2L/day drinking water ingestion rate and 70kg bodyweight) leads to an estimate of effective intake from drinking water of 0.003µg/kg bodyweight/day at a 10⁻⁶ lifetime cancer risk. In the meantime, the IPCS has reviewed hexachlorobenzene and derived new TDIs that supersede the previous WHO evaluation, see below.

NHMRC Australian Drinking Water Guidelines

The NHMRC has not endorsed a hexachlorobenzene HBSIL. NHMRC/ARMCANZ 2004 does not address hexachlorobenzene.

USEPA Evaluation

The USEPA set a carcinogenic oral slope factor of 1.6 (mg/kg/d)⁻¹ for sufficient evidence of cancer. Liver appears to be the primary target organ for hexachlorobenzene-induced cancer, although neoplasms of the thyroid and kidney have been observed as well. This is based on a 130-week study of liver effects in rats. The USEPA also set an oral reference dose (RfD) of 0.0008mg/kg/day. USEPA also present an air cancer unit risk of 4.6 x 10⁻⁴ (ug/m³)⁻¹ extrapolated from the oral exposure data.

Worksafe Australia standard

Worksafe Australia has not endorsed a standard for hexachlorobenzene

Hexachlorobenzene references

IARC (1987), “Hexachlorobenzene”, IARC Summary and Evaluation, Supplement7, available: <http://www.inchem.org/documents/iarc/suppl7/hexachlorobenzene.html>



NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (1993), "Guidelines for Drinking-water Quality", 2nd Edition, available: http://www.who.int/water_sanitation_health/dwq/guidelines4/en/

WHO (2000), "Guidelines for Air Quality", available: http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available: http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1997), "Hexachlorobenzene", Environmental Health Criteria 195, available: <http://www.inchem.org/documents/ehc/ehc/ehc195.htm>

USEPA IRIS <http://www.epa.gov/ncea/iris/subst/0374.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Naphthalene

IARC Evaluation

IARC evaluated naphthalene in 2002 and classified it as a Group 2B carcinogen, ie, *possibly carcinogenic to humans*. The IARC concluded that no relevant data were available to the Working Group on the carcinogenicity of naphthalene to humans. In inhalation studies in rodents, naphthalene caused an increase in the incidence of bronchio-alveolar adenomas in female mice, and of neuroblastomas of the olfactory epithelium and adenomas of the nasal respiratory epithelium in male and female rats.

IPCS Evaluation

The IPCS reviewed PAHs in *Selected Non-Heterocyclic Polycyclic Aromatic Hydrocarbons, Environmental Health Criteria 202, IPCS, 1998*. IPCS did not recommend guideline values. However, IPCS did find that the available evidence for naphthalene genotoxicity was negative.

WHO Guidelines for Drinking-Water Quality

WHO does not endorse a guideline value for naphthalene in drinking water.

WHO Air Quality Guidelines

WHO does not endorse a guideline value for naphthalene in air.

ATSDR Evaluation

A toxicological profile for naphthalene was prepared by ATSDR, see *Toxicological Profile for Naphthalene, 1-Methylnaphthalene and 2-Methylnaphthalene, ATSDR, 1995*. ATSDR calculated a minimal risk level of 0.02 mg/kg/day for intermediate duration oral exposure, and a minimal risk level of 0.002 ppm or 0.01 mg/m³ for chronic inhalation exposure.



NHMRC Australian Drinking Water Guidelines

The NHMRC has not endorsed a naphthalene HBSIL, stating that data are inadequate to set guideline values for PAHs other than benzo(a)pyrene. This position reflects that of the WHO 1993. It could be considered that the HBSIL for Total PAHs might apply to naphthalene, however, that appears not to have been the intention of regulators. The NEPM does not discuss the derivation of the Total PAH HBSIL, which appears to apply to PAH mixtures in soils, and presumably is related to the concentration of benzo(a)pyrene. Its purpose appears to be to trigger more detailed investigations.

National Contaminated Sites Workshops

Fitzgerald applied the benchmark dose methodology to PAHs in *The Benchmark Dose Approach and Health-Based Investigation Level for Polycyclic Aromatic Hydrocarbons (PAHs)*, *The Health Risk Assessment and Management of Contaminated Sites, Proceedings of the Fourth National Workshop on the Health Risk Assessment and Management of Contaminated Sites, Langley, Imray, Lock and Hill, Contaminated Sites Monograph series, No. 7, 1998*. The Fitzgerald PAH methodology has not received regulatory endorsement.

USEPA Evaluation

The USEPA set an oral reference dose (RfD) of 0.02 mg/kg/day based on decreased mean terminal bodyweights in male rats. Although there is high confidence in the study used to set the RfD there is low confidence in the database because the number of adequate studies is insufficient. Hence, there is low confidence in the RfD. The USEPA also set an inhalation reference concentration (RfC) of 0.003 mg/m³ (or an equivalent RfD of 0.00086 mg/kg/d) based on hyperplasia and metaplasia in mice respiratory and olfactory epithelium, respectively. There is medium confidence in the study, and low to medium confidence in the database because of insufficient adequate studies. Hence, there is low to medium confidence in the RfC.

Non-Cancer Health Effects of Concern

The important non-cancer human health effect of concern is hemolytic anemia, particularly of the unborn or breast-fed child. Cataract formation is also possible. The health effects database for naphthalene has significant omissions, for example, it does not include studies of reproductive, developmental and immunological toxicity, and has limited information on genotoxicity.

Naphthalene references

ATSDR (1995), "Toxicological Profile for Naphthalene, 1-Methylnaphthalene and 2-Methylnaphthalene"

Fitzgerald, J. (1997), "The Benchmark Dose Approach and Health-Based Investigation Level for Polycyclic Aromatic Hydrocarbons (PAHs)", *The Health Risk Assessment and Management of Contaminated Sites, Proceedings of the Fourth National Workshop on the Health Risk Assessment and Management of Contaminated Sites, Langley, Imray, Lock and Hill, Contaminated Sites Monograph series, No. 7, 1998*.

IARC (2002), "Naphthalene", IARC Summary and Evaluation, Volume 82, available: <http://www.inchem.org/documents/iarc/vol82/82-06.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>



USEPA (2004), "Preliminary Remediation Goals", Region 9: Superfund, available:
<http://www.epa.gov/region09/waste/sfund/prg/index.htm>

WHO (2000), "Guidelines for Air Quality", available:
http://www.rshm.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1997), "Hexachlorobenzene", Environmental Health Criteria 195, available:
<http://www.inchem.org/documents/ehc/ehc/ehc195.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Carcinogenic PAHs

IARC Evaluation

The IARC evaluation of PAHs is summarised in the table below.

IPCS Evaluation – EHC 202

The IPCS reviewed PAHs in 1998, see *Selected Non-Heterocyclic Polycyclic Aromatic Hydrocarbons, Environmental Health Criteria 202, IPCS, 1998*. IPCS did not recommend guideline values.

The WHO Air Quality Guidelines has taken the TEFs from IPCS EHC 202 to derive health-based guideline values for PAHs. The TEFs are shown in the accompanying table. It would appear that these TEFs should be considered for use in calculating benzo(a)pyrene equivalents.

NHMRC evaluations – NEPM & Drinking Water Guidelines

The NHMRC has endorsed HBSILs for benzo(a)pyrene and total PAHs for several land uses (NEPM). The benzo(a)pyrene HBSIL has a basis in a toxicological evaluation, however, the total PAH HBSIL appears to be related to typical soil concentrations of PAHs, which should ensure that benzo(a)pyrene meets its HBSIL.

NHMRC/ARMCANZ 2004 has toxicologically evaluated benzo(a)pyrene, however, data are insufficient for all other PAHs. This position reflects that in WHO 2004. Benzo(a)pyrene is genotoxic and, therefore, is represented toxicologically by a slope factor, which in NHMRC/ARMCANZ 2004 is 0.46 (mg/kg bw/day)⁻¹ (recalling that the WHO source uses a bodyweight of 60kg).

The 1993 WHO Drinking Water Guidelines derived a TDI of 0.0125 mg/kg bodyweight/day for fluoranthene. This was done to address the need for a public health appraisal of fluoranthene arising from coal-tar-based linings of water supply systems. No drinking water guideline was set.

National Contaminated Sites Workshops

Fitzgerald applied the benchmark dose methodology to PAHs, on a trial basis, in *The Benchmark Dose Approach and Health-Based Investigation Level for Polycyclic Aromatic Hydrocarbons (PAHs), The Health Risk Assessment and Management of Contaminated Sites, Proceedings of the Fourth National Workshop on the Health Risk Assessment and Management of Contaminated Sites, Langley, Imray, Lock and Hill, Contaminated Sites Monograph series, No. 7, 1998*. The PAH methodology in the



Fitzgerald paper has not received regulatory endorsement. The TEFs used by Fitzgerald are listed in the table below for comparison purposes only.

NSW EPA

The NSW EPA in the *Protection of the Environment Operations (General) Regulation 1998* requires certain benzo(a)pyrene equivalents to be used in Load Based Licensing calculations. The equivalents are based on the California Air Resources Board (CARB) Potency Equivalency Factors for PAHs. These factors are not endorsed for use in contaminated sites human health risk assessments (NEPM). Both the NSW EPA and the CARB potency equivalency factors are listed in the accompanying table for information only.

Table E1 – IARC Classification of PAHs and Relative Carcinogenic Potencies

Polycyclic Aromatic Hydrocarbons	IARC Classification [1]	PAH Relative Potency IPCS [2]	NSW EPA LBL PAH PEFs [3]	California Air Resources Board PAH PEFs [4]	Fitzgerald 1998 PAH TEFs [5]
Benz[a]anthracene	2A	0.014 - 0.145	0.1	0.1	0.1
Benzo[a]pyrene (B(a)P)	2A	1	1	1	1
Dibenz[a,h]anthracene	2A	0.89 – 5	0.4	0.4	4
Benzo[b]fluoranthene	2B	0.1 – 0.141	0.1	0.1	0.1
Benzo[j]fluoranthene	2B	0.045 – 0.1	-	0.1	-
Benzo[k]fluoranthene	2B	0.01 – 0.1	0.1	0.1	0.1
Dibenzo[a,e]pyrene	2B	1	-	1	-
Dibenzo[a,h]pyrene	2B	1 – 1.2	-	10	-
Dibenzo[a,i]pyrene	2B	0.1	-	10	-
Dibenzo[a,l]pyrene	2B	100	-	10	-
Indeno[1,2,3-cd]pyrene	2B	0.067 – 0.232	0.1	0.1	0.1
5-Methylchrysene	2B	-	-	1	-
Naphthalene	2B	-	-	-	0.001
Anthanthrene	3	0.28 – 0.32	-	-	-
Anthracene	3	-	-	-	-



Polycyclic Aromatic Hydrocarbons	IARC Classification [1]	PAH Relative Potency IPCS [2]	NSW EPA LBL PAH PEFs [3]	California Air Resources Board PAH PEFs [4]	Fitzgerald 1998 PAH TEFs [5]
Benzo[ghi]fluoranthene	3	-	-	-	-
Benzo[a]fluorene	3	-	-	-	-
Benzo[b]fluorene	3	-	-	-	-
Benzo[c]fluorene	3	-	-	-	-
Benzo[ghi]perylene	3	-	-	-	0.1
Benzo[c]phenanthrene	3	-	-	-	-
Benzo[e]pyrene	3	-	-	-	-
Chrysene	3	0.001 - 0.1	-	0.01	0.1
Coronene	3	-	-	-	-
Cyclopenta[cd]pyrene	3	0.012 – 0.1	-	-	-
Dibenz[a,c]anthracene	3	0.1	-	-	-
Dibenz[a,j]anthracene	3	-	-	-	-
Dibenzo[a,e]fluoranthene	3	1	-	-	-
1,4-Dimethylphenanthrene	3	-	-	-	-
Fluoranthene	3	0.001 – 0.01	-	-	0.01
Fluorene	3	-	-	-	0.001
1-Methylchrysene	3	-	-	-	-
2-Methylchrysene	3	-	-	-	-
3-Methylchrysene	3	-	-	-	-
4-Methylchrysene	3	-	-	-	-
6-Methylchrysene	3	-	-	-	-
2-Methylfluoranthene	3	-	-	-	-



Polycyclic Aromatic Hydrocarbons	IARC Classification [1]	PAH Relative Potency IPCS [2]	NSW EPA LBL PAH PEFs [3]	California Air Resources Board PAH PEFs [4]	Fitzgerald 1998 PAH TEFs [5]
3-Methylfluoranthene	3	-	-	-	-
1-Methylphenanthrene	3	-	-	-	-
Perylene	3	-	-	-	-
Phenanthrene	3	-	-	-	0.001
Pyrene	3	-	-	-	0.001
Triphenylene	3	-	-	-	-
Acenaphthene	-	-	-	-	0.001
Acenaphthylene	-	-	-	-	0.001
7,12-Dimethylbenzanthracene	-	-	-	-	-

PAH References

Fitzgerald, J. (1997), "The Benchmark Dose Approach and Health-Based Investigation Level for Polycyclic Aromatic Hydrocarbons (PAHs)", The Health Risk Assessment and Management of Contaminated Sites, Proceedings of the Fourth National Workshop on the Health Risk Assessment and Management of Contaminated Sites, Langley, Imray, Lock and Hill, Contaminated Sites Monograph series, No. 7, 1998.

IARC website, www.iarc.fr

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

NSW EPA (1997), "Protection of the Environment Operations (General) Regulation"

WHO (1993), "Guidelines for Drinking-water Quality", 2nd Edition

WHO – IPCS (1998), "Selected Non-Heterocyclic Polycyclic Aromatic Hydrocarbons", Environmental Health Criteria 202, available: <http://www.inchem.org/documents/ehc/ehc/ehc202.htm>



Benzo(a)pyrene

IARC Evaluation

IARC last evaluated benzo(a)pyrene (B(a)P) in 1983, with a supplement in 1987. B(a)P is in Group 2A – probably carcinogenic to humans. There is limited evidence of carcinogenicity in humans and sufficient evidence that benzo[a]pyrene is carcinogenic to experimental animals. The exposure circumstance entails exposures that are probably carcinogenic to humans.

IPCS Evaluation – Environmental Health Criteria 202

IPCS evaluated B(a)P in 1998, as part of *Environmental Health Criteria 202: Selected non-heterocyclic Polycyclic Aromatic Hydrocarbons*, WHO 1998. B(a)P is one of the most potent Polycyclic Aromatic Hydrocarbons (PAHs) carcinogens. Humans are generally exposed to B(a)P as part of a complex mixture of PAHs. Exposure occurs through air pollution, tobacco smoke, contaminated food and drinking water and other products. About one person in 10 000 or 100 000 would be expected to develop lung cancer in his or her lifetime as a result of exposure to B(a)P in air.

There are numerous animal studies that show B(a)P triggers tumour growth. Evidence that mixtures of PAHs are carcinogenic to humans comes mainly from occupational studies of workers following inhalation and dermal exposure.

At high concentrations, B(a)P is toxic to genes, foetuses, the immune system and bone marrow.

WHO Guidelines for Air Quality

Because B(a)P is a carcinogen, the WHO guideline value for air quality is expressed as a unit risk. The guideline value is $8.7 \times 10^{-2} \text{ } [\mu\text{g}/\text{m}^3]^{-1}$, based on lung cancer in humans.

WHO Guidelines for Drinking-Water Quality

The WHO drinking water quality guideline value for B(a)P is 0.7 $\mu\text{g}/\text{L}$, which corresponds to an excess lifetime cancer risk of 10^{-5} . The value was derived from an oral carcinogenicity study in mice.

NHMRC Australian Drinking Water Guidelines

The guideline value for B(a)P is 0.00001 mg/L (10 ng/L), which is the analytical limit of determination. Because B(a)P is probably a potent genotoxic carcinogen, the NHMRC accepts no safe level for B(a)P. The guideline value is slightly less than the value associated with a cancer risk of 10^{-6} , according to a feeding study using mice. This is the same study used in WHO's drinking water guidelines.

Worksafe Australia standard

Worksafe Australia considers B(a)P a potent probable and established human carcinogen. It is not currently possible to assign an appropriate exposure standard. Exposure should be controlled to the lowest practicable level.

Benzo(a)pyrene references

IARC (1983), "Benzo[a]pyrene", IARC Summary and Evaluation, Volume 32, available: <http://www.inchem.org/documents/iarc/suppl7/benzene.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>



WHO (2000), "Guidelines for Air Quality", available:

http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2005), "Guidelines for Drinking-water Quality", 3rd Edition, available:

http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1998), "Selected Non-Heterocyclic Polycyclic Aromatic Hydrocarbons", Environmental Health Criteria 202, available: <http://www.inchem.org/documents/ehc/ehc/ehc202.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Benzene

IARC Evaluation

IARC last evaluated benzene in 1987 and determined that it is carcinogenic to humans (Group 1).

IPCS Evaluation – Environmental Health Criteria 150

IPCS evaluated benzene in the *Environmental Health Criteria 150*, WHO, 1999. Benzene is a well-established human carcinogen. There are numerous epidemiological studies that demonstrate a causal link between occupational exposure to benzene and the occurrence of various types of leukaemia. These include independent cohort studies of occupational exposure to benzene. The first stage of benzene toxicity is bone marrow depression.

Dermal exposure may cause skin irritation.

As benzene is a human carcinogen, not TDI has been established.

WHO Guidelines for Air Quality

As benzene is a human carcinogen, the WHO guideline for air quality is expressed as a unit risk. The guideline value is $(4.4 - 7.5) \times 10^{-6} [\mu\text{g}/\text{m}^3]^{-1}$, based the incidence of leukaemia in workers.

WHO Guidelines for Drinking-Water Quality

WHO limits the concentration of benzene in drinking water to 10 $\mu\text{g}/\text{L}$. The derivation of this guideline is described in the second edition of the Guidelines, published in 1993. The guideline corresponds to an excess lifetime cancer risk of 10^{-5} , based on the development of cancer in mice and rats.

NHMRC Australian Drinking Water Guidelines

The Australian Drinking Water Guideline for benzene is 0.001 mg/L. The Guidelines state, "No safe concentration for benzene in drinking water can be confidently set. However, for practical purposes the concentration should be less than 0.001 mg/L, which is the limit of determination."

Human health data are mainly from studies where benzene had been inhaled. Benzene can induce toxic effects, especially on white blood cells. Occupational exposure to low benzene concentrations for periods as short as 12 months may result in leukemia, which is why benzene is considered a genotoxic human carcinogen.



Worksafe Australia standard

The Worksafe Australia standard for benzene is a Time Weighted Average of 1 ppm (3.2 mg/m³). This value is set out in the April 2003 amendment of the National Exposure Standards [NOHSC:1003(1995)].

Benzene references

IARC (1987), "Benzene", IARC Summary and Evaluation, Supplement 7, available: <http://www.inchem.org/documents/iarc/suppl7/benzene.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (2000), "Guidelines for Air Quality", available: http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available: http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1993), "Benzene", Environmental Health Criteria 150, available: <http://www.inchem.org/documents/ehc/ehc/ehc150.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Toluene

IARC Evaluation

IARC last evaluated toluene in 1999 and placed it in Group 3 – not classifiable as to its carcinogenicity to humans. In particular:

- ▶ There is *inadequate evidence* in humans for the carcinogenicity of toluene; and
- ▶ There is *evidence suggesting lack of carcinogenicity* of toluene in experimental animals.

IPCS Evaluation – Environmental Health Criteria 52

IPCS evaluated toluene in the *Environmental Health Criteria 52, WHO, 1986*.

Animal tests show that this substance possibly causes toxicity to human reproduction or development, however the data is inconclusive. In the short term, the substance may irritate eyes and the respiratory tract. Long-term occupational exposure may be associated with permanent pathological changes. The critical target organs for toluene are the central nervous system. Effects on the central nervous system begin to appear with an inhalation exposure of 375 mg/m³, for 6 h/day, over 4 days. Effects may be depressant or excitatory, with euphoria preceding disorientation, tremulousness, hallucinations, ataxia, and coma. These effects are readily reversible, as toluene is rapidly metabolised and excreted from the body.

EHC 52 does not recommend a particular TDI.



WHO Guidelines for Air Quality

The WHO guideline value for toluene in air is 260 $\mu\text{g}/\text{m}^3$ over an averaging time of one week. This is based on a health endpoint of CNS effects on workers and odour annoyance.

WHO Guidelines for Drinking-Water Quality

The WHO guideline value for toluene in drinking water is 700 $\mu\text{g}/\text{L}$. The derivation of this guideline is described in the second edition of the guidelines. The value is based on a TDI of 223 $\mu\text{g}/\text{kg bw}/\text{day}$ using a Lowest Observable Adverse Effects Level for marginal hepatotoxic effects in a 13 week gavage study in mice. The following safety factors were used:

- ▶ 1 000 (uncertainty due to use of animal study for human effects, the short duration of the study and use of Lowest rather than No Observable Adverse Effects Level; and
- ▶ 5/7 to convert data based on a 5 day per week gavage study to a 7-day week equivalent.

NHMRC Australian Drinking Water Guidelines

The Australian drinking water guideline value for toluene is 0.8 mg/L . The guideline is based on the same data used for the WHO Drinking Water Guidelines, however an adult body weight of 70 kg was used instead of 60 kg, as in the WHO derivation. The difference is not significant.

Worksafe Australia standard

The Worksafe Australia stand for toluene is a Time Weighted Average of 100 ppm (377 mg/m^3). This value is set out in the National Exposure Standards [NOHSC:1003(1995)].

Toluene references

IARC (1999), "Toluene", IARC Summary and Evaluation, Volume 71, available:
<http://www.inchem.org/documents/iarc/vol71/030-toluene.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (2000), "Guidelines for Air Quality", available:
http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1986), "Toluene", Environmental Health Criteria 52, available:
<http://www.inchem.org/documents/ehc/ehc/ehc52.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995



Ethylbenzene

IARC Evaluation

IARC has classified ethylbenzene in Group 2B (possible carcinogenic to humans) based on inadequate evidence but sufficient evidence in animals. To date only California EPA present cancer slope factors for ethylbenzene, and therefore toxicity have been based on threshold endpoints.

IPCS Evaluation – Environmental Health Criteria 186

IPCS evaluated ethylbenzene in the *Environmental Health Criteria 186*, WHO, 1996.

Ethylbenzene is readily absorbed from the human gastrointestinal tract. It can be stored in fat and is metabolised to mandelic and phenylglyoxalic acids and excreted in the urine. It can cross the placenta. No data are available on the health effects in humans after oral exposure, and inhalation data are limited to short-term studies.

A six-month gavage study using rats reported enlargement of the liver and kidney at high doses (400 mg/kg body weight per day). Liver effects were also observed in a number of inhalation studies. No longer-term studies are available.

Studies on the mutagenic activity of ethylbenzene to bacteria, insects and mammalian cells have reported negative results.

WHO Guidelines for Air Quality

WHO (2000) provide a review of inhalation exposures to ethylbenzene utilising a NOAEL associated with increased organ weight, establishing a guideline value (based on one year) of 22 mg/m³.

ATSDR Toxicological Profile

ATSDR has derived a chronic-duration inhalation MRL of 0.3 ppm (1.3 mg/m³) for ethylbenzene based on a LOAEL of 75 ppm for a significant increase in the severity of nephropathy in female rats exposed to ethylbenzene by inhalation for 5 days/week, 6 hours/day, for 104 weeks. The MRL was derived by dividing the LOAEL-HEC of 75 ppm by an uncertainty factor of 300 (10 for use of a LOAEL, 3 for animal to human extrapolation with dosimetric adjustment, and 10 for human variability).

NHMRC Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines (NHMRC 2004) establish a guideline value of 0.3 mg/L based on a six-month gavage study using rats where NOAEL was determined to be 136 mg/kg and applying a safety factor of 1 000 (10 for interspecies variations, 10 for intraspecies variations and 10 because a less than lifetime study was used). Applying a study duration factor of 5/7 results in an ADI of 0.097 mg/kg/d.

Worksafe Australia standard

The Worksafe Australia stand for toluene is a Time Weighted Average of 100 ppm (434 mg/m³). This value is set out in the National Exposure Standards [NOHSC:1003(1995)].

Ethylbenzene references

ATSDR 2007, *Toxicological Profile for Ethylbenzene Draft for Public Comment, September 2007*, available: <http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=383&tid=66>



IARC (2000), "Ethylbenzene", IARC Summary and Evaluation, Volume 77, available:
<http://www.inchem.org/documents/iarc/vol77/77-05.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (2000), "Guidelines for Air Quality", available:
http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1996), "Ethylbenzene", Environmental Health Criteria 186, available:
<http://www.inchem.org/documents/ehc/ehc/ehc186.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008 (1995) and National Exposure Standards: NOHSC1003(1995), May 1995

Xylenes

IARC Evaluation

IARC last evaluated xylenes in 1999 and placed it them Group 3 – not classifiable as to their carcinogenicity to humans. In particular:

- There is *inadequate evidence* in humans for the carcinogenicity of xylenes; and
- There is *inadequate evidence* in experimental animals for the carcinogenicity of xylenes.

IPCS Evaluation – Environmental Health Criteria 190

IPCS evaluated xylenes in *Environmental Health Criteria 190: Xylenes, WHO 1997*. Humans are exposed to xylene mainly by inhalation. Xylene appears not to be a mutagen or a carcinogen. Xylene is efficiently metabolised and does not accumulate significantly in the human body. The most significant risk is developmental toxicity, which was detected in rats that inhaled xylenes at 870 mg/m³. Based on this study, WHO recommends an exposure limit of 0.87 mg/m³.

IPCS – Poisons Information Monograph 565

Workers are usually exposed to xylenes as part of a mixture of solvents. Mild exposures may show eye, nose and throat irritation, nausea, headache, irritability, lassitude, possibly impaired reaction time and impaired short-term memory. With moderate exposures, there may be dizziness, weakness, tremor, increasing confusion and effects on the eye, kidneys and blood.

WHO Guidelines for Air Quality

WHO recommends the concentration of xylenes in air be limited to 870 µg/m³ over an averaging time of one year. The end point is developmental neurotoxicity in rats.



WHO Guidelines for Drinking-Water Quality

The WHO drinking-water guideline for xylenes is 500 µg/L. This guideline value is based a TDI of 179 µg/kg bw/day. The TDI comes from the No Observable Adverse Effects Level of a 103-week study in rats. A safety factor of 1 000 was applied to account for inter- and intra-species variation and limited data.

The acute oral toxicity of xylenes is low. No convincing evidence for carcinogenicity, teratogenicity and mutagenicity has been found.

NHMRC Australian Drinking Water Guidelines

The Australian drinking water guideline value for xylenes is 0.02 mg/L. This is based on aesthetic considerations. Xylenes are not a health concern unless concentrations are above 0.6 mg/L.

There was no evidence of carcinogenicity in animal studies. The health-based guideline value is based on a no effect level of 250 mg/kg bw/day from a 2-year gavage study using rats. This is converted to a TDI of 179 µg/kg bw/day using the following factors:

- ▶ 1 000 for using the results of an animal study as a basis for human exposure
- ▶ 5/7 to convert data based on a 5 day per week feeding study to a 7-day week equivalent.

Worksafe Australia standard

The Worksafe Australia standard for xylenes (o-, m-, p- isomers) is a Time Weighted Average of 80 ppm (350 mg/m³). This value is set out in the National Exposure Standards [NOHSC:1003(1995)].

Xylenes references

IARC (1999), "Xylenes", IARC Summary and Evaluation, Volume 71, available:
<http://www.inchem.org/documents/iarc/vol71/052-xylenes.html>

NHMRC/ARMCANZ (2004), "Australian Drinking Water Guidelines 2004", endorsed by NHMRC 10 – 11 April 2003, available: <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

WHO (1992), "Xylene", Poisons Information Monograph 565, available:
<http://www.inchem.org/documents/pims/chemical/xylene.htm>

WHO (2000), "Guidelines for Air Quality", available:
http://www.rsh.m.saglik.gov.tr/hki/pdf/Guidelines_for_Air_Quality.pdf

WHO (2004), "Guidelines for Drinking-water Quality", 3rd Edition, available:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/

WHO – IPCS (1997), "Xylenes", Environmental Health Criteria 190, available:
<http://www.inchem.org/documents/ehc/ehc/ehc190.htm>

Worksafe Australia (1995), "Exposure standards for atmospheric contaminants in the occupational environment", Guidance Note NOHSC:3008(1995) and National Exposure Standards: NOHSC1003(1995), May 1995



Appendix F

Schedule of Remediation Works

				Material	Surface	Distance	Plant									
Stage of Works	Area	Zone	Scope of Works	Volume	Area			No.	Duration							
				m3	m2	m			Hrs/Day	Days/Wk	Total Wks	Total Days	Week Number			Sources
1A	G	9	Excavate Zone 9	1000	930		25t excavator	1	10	6		2	1			1
			Transport to PTB			100	25t Moxi	2	10	6		2				2
			Demolish tank farm				25t excavator	1	10	6		2				7
			Transport concrete	100	500	300	25t Moxi	1	10	6		2				2,3,4,5,24
			Level area		8000		padfoot roller	1	10	6		4				1,2,6,7
							bulldozer	1	10	6		4				1,2,6,7
1B	G		Construct ECS				Cranes	2	10	6	2		2 to 11			1
			Construct DTD				Franna	1	10	6	10					6
							EWP	2	10	6	10					
							Small tools		10	6	10					
2	I	1a, 1b and 2	Excavate Zones 1a, 1b and 2	5000	3241		25t excavator	1	10	6	2		11, 12, 13			8,9
			Load Chester Hill material	2000			25t excavator	1	10	6	1					9
			Transport to PTB			200	25t Moxi	2	10	6	3					3,8,9
			Excavate borrow pit	9000	4000		25t excavator	1	10	6	3		14, 15, 16			8,9
			Transport to stockpile			200	25t Moxi	2	10	6	3					19,8,9,10
			Demolish concrete slabs and load	600	4350		25t excavator	1	10	6		1				11
			Transport to stockpile			200	25t Moxi	1	10	6		1				4,5,24
			Scrape surface fill and load	650	6532		25t excavator	1	10	6		1				8,9,10,11
			Transport to stockpile			100	25t Moxi	1	10	6		1				11
			Chase out trade waste lines	300		150	25t excavator	1	10	6		1				11
			Transport to stockpile			200	25t excavator	1	10	6		1				11
	H	8	Excavate Zone 8	5000	3241		25t excavator	1	10	6	2		17, 18			12
			Transport to PTB			50	25t Moxi	2	10	6	2					13
			Demolish concrete slabs and load	600	6000		25t excavator	1	10	6		1				12,13,17
			Transport to stockpile			300	25t Moxi	1	10	6		1				3,4,5,24
			Scrape surface fill and load	2500	10000		25t excavator	1	10	6	1		19			12,13,17
			Transport to stockpile			100	25t Moxi	1	10	6	1					13
			Chase out trade waste lines	300		150	25t excavator	1	10	6		1				13
			Transport to stockpile			100	25t excavator	1	10	6		1				13
			Load and transport surface fill to cell	1875			Loader	1	10	6		4	20			13
						75	25t Moxi	1	10	6		4				3,4,8
			Compact in cell				padfoot roller	1	10	6		4				8
							Bulldozer	1	10	6		4				8
			Load and transport surface fill to final level	1875			Loader	1	10	6		4				13
						100	25t Moxi	1	10	6		4				12,13,17,16
							padfoot roller	1	10	6		4				12,13,17,16
							Bulldozer	1	10	6		4				12,13,17,16
	B		Excavate and transport to screen	19500	13000	75	25t excavator	1	10	6	7		11 to 17			14
							25t Moxi	2	10	6	7					14
			Screen material				screen	1	10	6	7					15
							loader	1	10	6	7					15
			Replace and compact				padfoot roller	1	10	6	7					14
3	H	7	Excavate Zone 7	1000	780		25t excavator	1	10	6		2	20			16
			Transport to PTB			50	25t Moxi	2	10	6		2				17,13
	B	5	Excavate Zone 5	500	410		25t excavator	1	10	6		1				26
			Transport to PTB			200	25t Moxi	2	10	6		1				26,27,3
	G	9	Excavate Zone 5	1000	930		25t excavator	1	10	6		2				25
			Transport to PTB			150	25t Moxi	2	10	6		2				25,27,3
	D		Demolish concrete slabs and load	1250	8300		25t excavator	1	10	6		9	21, 22			18
			Transport to stockpile			300	25t Moxi	1	10	6		9				5,24
			Scrape surface fill and load	2320	11600		25t excavator	1	10	6	1					18
			Transport to stockpile			100	25t Moxi	1	10	6	1					18
	F		Demolish concrete slabs and load	690	4600		25t excavator	1	10	6	1		23			19
			Transport to stockpile			75	25t Moxi	1	10	6	1					5,24
			Scrape surface fill and load	2675	10700		25t excavator	1	10	6	1					19
			Transport to stockpile			100	25t Moxi	1	10	6	1					19
			Chase out trade waste lines	900		450	25t excavator	1	10	6		3				19
			Transport to stockpile			100	25t Moxi	1	10	6		3				19
	E		Demolish concrete slabs and load	690	4600		25t excavator	1	10	6	1		24			20
			Transport to stockpile			75	25t Moxi	1	10	6	1					24
			Scrape surface fill and load	2675	10700		25t excavator	1	10	6	1					20
			Transport to stockpile			100	25t Moxi	1	10	6	1					20
			Chase out trade waste lines	900		450	25t excavator	1	10	6		3				20
			Transport to stockpile			100	25t excavator	1	10	6		3				20
	G		Demolish concrete slabs and load	1350	9000		25t excavator	1	10	6	2		25, 26			21
			Transport to stockpile			100	25t Moxi	1	10	6	2					28,24
			Scrape surface fill and load	720	2400		25t excavator	1	10	6		5	27			21
			Transport to stockpile			50	25t Moxi	1	10	6		5				21
			Chase out trade waste lines	800		400	25t excavator	1	10	6		3				21
			Transport to stockpile			50	25t excavator	1	10	6		3				21
4	G,H		Decon and demolish PTB				EWP	2	10	6	3		36, 37, 38			22
							Small tools		10	6	3					
			Demolish concrete slabs and load	180	1200	200	25t excavator	1	10	6		2				22,6
							25t Moxi	1	10	6		2				22,6,3,4,5,24

			Decon, dismantle and remove DTD				EWP	2	10	6	8		37 to 44	6
							Small tools		10	6	8			
							Cranes	2	10	6	1			
							Franna	1	10	6	4			
			Decon, dismantle and remove ECS				EWP	2	10	6	2		45, 46	1
							Small tools		10	6	2			
							Crane	1	10	6		2		
							Franna	1	10	6		2		
			Decon, dismantle and remove WTP				EWP	2	10	6	2		47, 48	23
							Small tools		10	6	2			
							Crane	1	10	6		2		
							Franna	1	10	6	2			
			Crush concrete	6000			crusher	1	10	6	2		48, 49	24
			Load and transport to final area				Loader	1	10	6	2			24
							25t Moxi	1	10	6	2			18
			Remove site sheds				Crane	1	10	6		2	50	11
							Small tools		10	6		2		11
			Remove bitumen		1200		25t excavator	1	10	6		1		11
							25t Moxi	1	10	6		1		11
			Scrape surface fill and load	300	1200		25t excavator	1	10	6		1		11
			Transport to stockpile			25	25t Moxi	1	10	6		1		11
			Load and transport surface fill to cell	150			Loader	1	10	6		1		11
						100	25t Moxi	1	10	6		1		11,8
			Compact in cell				padfoot roller	1	10	6		1		8
							Bulldozer	1	10	6		1		8
			Load and transport surface fill to final level	150			Loader	1	10	6		1		11
						25	25t Moxi	1	10	6		1		11
							padfoot roller	1	10	6		1		11
							Bulldozer	1	10	6		1		11
Thermal Treatment			Treat contaminated material, inc. PoP	24500			DTD plant	1	24	7	26		11 to 36	6
			Load and transport treated material to final level	24500			Loader	1	10	2			13 to 38	6
						100	25t Moxi	1	10	2				14,21,13,11,1 9,20,18,10
							padfoot roller	1	10	2				14,21,13,11,1 9,20,18,10
							Bulldozer	1	10	2				14,21,13,11,1 9,20,18,10
			Emission control system				ECS	1	24	7	26		11 to 36	1



Appendix G

CAPCOA Algorithm Modifications



CAPCOA ALGORITHM MODIFICATIONS

Introduction

The health risk assessment model used in this project is based on the model developed by the California Air Pollution Control Officers Association (CAPCOA). HRA96 (CAPCOA, 1996) is a program intended to be specifically used for the assessment of health risk associated with air emissions from industrial and manufacturing facilities. The model combines site-specific emission data and air dispersion factors, and is designed to be run in conjunction with a compatible air dispersion model.

The HRA96 program incorporates chemical-specific toxicity criteria and generic exposure assumptions and default parameters recommended by the California Office of Environmental Health Hazard Assessment (OEHHA) for risk assessment purposes. These parameters are built into the HRA program and cannot be modified. It is for this reason that the HRA96 program cannot be used directly to assess health risk at the former Lednez site, as carcinogenic health risks are calculated on a 70 year exposure basis, whereas, remediation operations at the site are expected to be complete within 5 years. Using the HRA96 would produce an unrealistic result.

The HRA program, therefore has been simulated in spreadsheet format, using the algorithms used in the program (CAPCOA, 1993). Two alterations have been made to the algorithms to account for the fact that operations at the site are not continuous for 70 years. These are described below.

Health Risk Calculation

The CAPCOA health risk model is generally conservative as it assumes exposure for a 70 year period, where a resident lives in the same location for 70 years of their life. For carcinogenic chemicals, exposure duration is important as risk is defined as the accumulative risk over a lifetime (70 years).

In the case of inhalation exposure, risk is adjusted to account for the duration of operations at the site being less than 70 years. The adjustment is made as follows:

$$\text{Risk} = \text{Cair} \times \text{UR} \times \frac{\text{ED}}{70}$$

Where: Risk = Incremental lifetime risk of cancer

Cair = Ambient air concentration ($\mu\text{g}/\text{m}^3$)

UR = Unit Risk ($\mu\text{g}/\text{m}^3$)⁻¹

ED = Exposure duration of operations (yrs)

Risk has not been adjusted for oral ingestion, dermal, or homegrown produce ingestion. Contaminated deposition in soils will remain longer than the duration of the remediation process at the site. Chemicals which do not degrade could remain in top soil indefinitely. The CAPCOA methodology assumes that someone may be exposed for 70 years and therefore these pathways have not been adjusted directly, as was done for inhalation.

Non-carcinogenic chemicals are assessed independently of exposure duration, and therefore have not been altered.



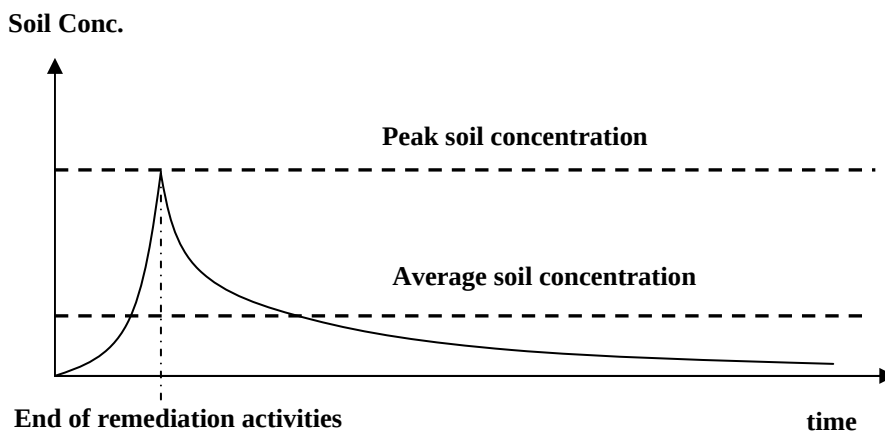
Soil Concentration Calculation

While residents may be exposed to contaminated soil for 70 years duration (and hence the risk calculations have not been changed), the concentrations in the soil will change due to the change in operation duration.

The original CAPCOA model calculates soil concentration using a mass balance approach. The model assumes a constant deposition rate over a 70 year period, which accumulates in a specified thickness of top soil. The chemical also disappears assuming a first order decay rate (chemical specific). The concentration used in the model is the average soil concentration over the 70 year period, which is calculated by integrating the mass balance equation and solving for soil concentration.

At the former Lednez site, remediation operations will be conducted for a short period of time (say 5 years). The original CAPCOA model represents this mode of operation. However, once the remediation is completed, no further deposition will occur. Therefore, the contaminants in the soil will slowly deplete away for the remaining 65 years. The average concentration used in the model should represent across both time periods. Figure G1 depicts the soil concentration at a receptor over the 70 year period.

Figure G1 – Varying Soil Concentration at a Receptor





As presented in the CAPCOA guidance (CAPCOA, 1993) the average soil concentration for the first stage (during operations) is calculated as follows:

$$C_{S1} = \frac{Dep}{k \cdot SD \cdot \rho \cdot (t_f - t_0)} \left[t_f - t_0 + \frac{e^{-kt_f}}{k} - \frac{e^{-kt_0}}{k} \right]$$

Where:

- C_{S1} = Average soil concentration during remediation (ug/kg)
- Dep = Deposition on the affected soil area per day (ug/m²/d)
- t_0 = Start day of operation (d) (assumed zero)
- t_f = Final day of remediation (d)
- SD = Soil mixing depth (m)
- ρ = Soil bulk density (kg/m³)
- k = Soil elimination constant (d⁻¹)
- = 0.693 / $t_{1/2}$

The peak soil concentration is estimated as follows:

$$C_f = \frac{Dep}{k \cdot SD \cdot \rho} [1 - e^{-kt_f}]$$

Where C_f is the peak soil concentration, and occurs at time t_f .

The second calculation is a first order decay calculation, where the starting time is t_f and the end time is t_e (which is set to 70 years or 25 550 days). By integrating the mass balance equation and setting the soil concentration to C_f at time t_f , the average soil concentration is calculated as follows:

$$C_{S2} = \frac{-Z}{k \cdot (t_e - t_f)} [e^{-kt_e} - e^{-kt_f}] \quad \text{and} \quad Z = e^{kt_f + \ln(C_f)}$$

Where: C_{S2} = Average soil concentration for period after remediation (ug/kg)



Finally, in order to calculate the average concentration across both time periods, the following averaging of concentrations is made based on exposure duration:

$$C_{ave} = \frac{C_{S1}(t_f - t_0) + C_{S2}(t_e - t_f)}{t_e - t_0}$$

This concentration is used to estimate exposure to carcinogenic chemicals for oral, dermal and homegrown produce ingestion pathways. The peak concentration (C_f) is used as the soil concentration for non-carcinogenic chemicals.



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