

Prepared for:

Thiess Services PTY LTD

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Blacktown NSW 2148

Screening Human Health Risk Assessment: Volatile Organic Compounds in Air at the Lednez Remediation Site, Rhodes, Sydney

Final

HLA-Envirosciences Pty Limited (HLA ENSR)

30 October 2007

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Glossary

COPC	Chemicals of Potential Concern
CRC	Community Reference Committee
DECC	NSW Department of Environment and Climate Change
DOH	NSW Department of Health
HI	Hazard Index
HQ	Non-cancer Hazard Quotient
MILs	Monitoring Investigation Levels
NEPC	Australian National Environment Protection Council
NEPM	National Environment Protection Measure
OEHHA	Office of Environmental Health Hazard Assessment, California Environmental Protection Agency
PID	Photoionisation detector tubes
RA	Risk Assessment
REL	Reference Exposure Level
RLs	Site Specific Response Levels
TDI	Tolerable Daily Intake
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WHO	World Health Organisation

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Executive Summary

A screening risk assessment has been undertaken to estimate potential human health impacts of volatile organic compound emissions from the Lednez remediation site, Rhodes, from 2006 to mid 2007.

Estimation of risks using modelled annual average concentrations of the chemicals of potential concern indicate that:

- Non-cancer chronic health risk estimates are low for individual chemicals but the combined chemical risk estimate falls into the zone where the NSW DECC risk acceptability criteria require reduction by best practice measures.
- With respect to short term non-cancer exposures, the modelled average exposures for 2006 and early 2007 are generally below regulatory guidance exposure levels adopted for short-term exposures. Benzene and chloroform concentration estimates at the southern boundary and residential receptors are above guidance values. Because the guidance values used are for longer-term exposure the actual risks are expected to be lower than the estimates in the screening risk assessment.
- Cancer health risk estimates are low, but for the southern residential receptor area immediately adjacent the Lednez site fall into the zone where the NSW DECC risk acceptability criteria require reduction by best practice measures.

While the regulatory guidance levels provide a certain margin of safety, continued exceedance is not recommended. Furthermore, some of the volatile chemicals detected may cause significant physical irritation and discomfort for some people even at the levels estimated.

Further information on work practices and on periods of non-emission in 2006-2007 may be expected to refine and probably reduce the estimated concentrations of chemicals in air, thereby reducing the estimated risks.

Utilisation of rapid air testing data may offer a practical approach to exposure minimisation through rapid daily assessment of VOC concentrations at the site boundary and immediate comparison with meteorological data.

The screening risk assessment may provide the basis for the development and adoption of air Response Levels (RLs) in consultation with the DECC, NSW Department of Health (DOH) and Community Reference Committee subject to definition of appropriate site work programme responses.

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1.0 Introduction

Thiess Services Pty Ltd (Thiess Services) has requested from HLA ENSR a report on the potential health implications for persons beyond the boundary of the Lednez site at Rhodes. The advice was requested following higher than usual emissions of volatile organic compounds (VOCs) in air, particularly during May 2007 soil remediation activities.

HLA ENSR has based its advice on a screening risk assessment conducted using modelled air quality data supplied by Thiess Services. The modelling estimates of ambient air concentrations of VOCs has been undertaken by Holmes Air Sciences using source term and site boundary air quality monitoring “grab” sample data measured by Parsons Brinkerhoff and continuous sampling data from the June to August 2007 period.

This Screening Risk Assessment is the initial report in a series which will be prepared over the remainder of the remediation project, including a screening risk assessment report based on current and ongoing emissions, a report on recommended RLs, and follow-up reports on emissions and risks at regular intervals.

The report provides a basis for the ultimate development of environmental Response Levels (RLs). The present report is a screening risk assessment for the period 2006 to mid 2007. Development of RLs as the subject of a further report will include reference to the present report. The RLs would specify air quality characteristics with respect to VOC concentrations at the boundary of the site and provide confidence that public health risk beyond the site boundary is appropriately protected.

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2.0 Background

2.1 Lednez Remediation Project

The Lednez site at Rhodes, Sydney, is being remediated following earlier industrial and chemical activities undertaken on the site. The remediation of the site involves excavation of contaminated soil and sediment and treatment to remove contaminants. Soil excavation has been undertaken for approximately 18 months to date. Contaminated soil has been excavated and stored in a covered on-site storage cell prior to treatment. Elevated levels of volatile organic compounds and odours were experienced and measured around the period of May and June of 2007 when adverse meteorological conditions and increased site soil emissions were encountered.

2.2 Risk Assessment Guidance

The document titled 'Approved Methods for the Modelling and Assessment Of Air Pollutants in New South Wales 2005' (DECC 2005) published by NSW Department of Environment and Climate Change in 2005 describes the use of risk assessment (RA) to assess potential risk from exposure to emissions of toxic pollutants. The DECC approach recommends that guidance be based on documentation from the Australian enHealth Council¹, which uses toxicity criteria published in 'Guidelines for Air Quality, World Health Organization, Geneva, 2000', and from the Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (CalEPA), USA² and associated toxicity criteria. Table 7.3 of DECC (2005) includes the Acceptance Criteria for Risk and Hazard Index which states that carcinogenic risk less than one in one million (1×10^{-6}) is acceptable, risks between one in one million and one in ten thousand (1×10^{-6} to 1×10^{-4}) require best practice reduction for air toxics, and risks greater than one in ten thousand (1×10^{-4}) are not acceptable. Non-cancer risk with Hazard Index (HI)³ less than 0.2 is considered acceptable, risks with HI between 0.2 and 10 require best practice reduction for air toxics and risks with HI greater than 10 are not acceptable.

Risk assessment in the current context aims to estimate upper-bound health risks (i.e. risks in the actual case are no higher and almost certainly lower than the estimates) as a basis for avoiding potential health effects. The screening risk assessment undertaken in the current report is consistent with the conservative approaches, the assumptions and the uncertainties described in established regulatory guidance sources^{1,2}.

¹ enHealth Council 'Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2002, Dept of Health and Ageing and enHealth Council, Canberra

² Air Toxics Hot Spots Program 'Guidance Manual for Preparation of Health Risk Assessments 2003', Office of Environmental Health Hazard Assessment, California Environmental Protection Agency

³ HI is the sum of individual chemical non-cancer hazard quotients. The hazard quotient is a comparison of the experienced air concentration of a chemical to an exposure level published as acceptable by certain regulatory agencies.

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3.0 Approach

3.1 Approach to the Screening Risk Assessment

The screening risk assessment considers the potential human ('receptor') exposures and relevant chemical toxicities which might occur in the present remediation situation. An estimate of possible upper-bound health risks, using realistic but worst case assumptions of contact with the chemicals, is made. The assessment aims to estimate upper-bound health risks (risk estimates that in the actual case are no higher and almost certainly lower) as a basis for in this case managing and avoiding potential health effects.

Individual person-specific risks resulting from exposures may be estimated by taking into account actual individual exposure duration factors. Such individual estimation requires more detailed risk assessment using information for the individual and the duration concerned.

The screening risk assessment undertaken in the current report is consistent with the conservative approaches, assumptions and uncertainties described in the established guidance sources described within the report.

3.2 Chemicals of Potential Concern

VOC levels in air have been monitored at the Lednez site routinely using photoionisation detector in 2006 and 2007. Since June 2007 continuous boundary monitoring of volatile organic compounds has been undertaken. Only pre-June 2007 data are the subject of the present report. Post June and current data will be the subject of a further report.

Speciated VOCs present in air at the Lednez site eastern boundary were sampled intermittently using charcoal tube sampling at the eastern and southern site boundaries in 2006 and early 2007 including May and June 2007^{4,5}.

Volatile and semi-volatile Chemicals of Potential Concern (COPC) that were detected at the site boundary and which are being assessed further based on their detection at the site^{4,5} and on published inhalational toxicology databases include:

- Benzene
- Chlorobenzene
- Chloroform
- 1,4-dichlorobenzene
- Ethylbenzene
- Hexachlorobenzene
- Styrene
- Toluene

⁴ See Thiess Lednez Air Quality Monitoring Report 2006

⁵ See Thiess Lednez Air Quality Monitoring Report May and June 2007

- Trichloroethene
- Xylenes

Data for all reported VOCs in the period 2006 to mid 2007 are included in the risk considerations and tables below.

3.3 Risk Considerations

The potential impact of the chemicals on human health beyond the site boundary depends upon factors including: 1) the concentrations of the chemicals present in the air when contacted by a person; 2) the duration of contact at that concentration; and 3) the toxicity of the COPC and potential additive effects of the chemicals. The following summarises each of these factors with respect to the site in more detail:

3.3.1 Concentration

Chemical concentrations in air have been modelled at the Lednez site by Holmes Air Sciences using meteorological data for 2006 to provide annual averages, and incorporating continuous VOC monitoring data supplied by Thiess Services for June and July 2007. Modelling using Ausplume was conducted utilising two on-site sources of VOCs, the work pit and the storage cell^{6,7,8}. The monitoring results from the site were used to scale the dispersion model to reflect measured VOC levels in previous periods and to generate annual average concentrations of VOCs from mid 2006 to mid 2007⁷. The modelling produced estimates of VOC concentrations at four points, the eastern site boundary (E1), the southern site boundary (S1), and at eastern and southern receptors in the nearest residential areas (E2 and S2)⁶.

3.3.2 Duration

An exposure period of 18 months has been used in this screening risk assessment, relevant to the period 2006 to mid 2007 involving site remediation works.

The days on which VOC concentrations were reported as elevated were interspersed with a significant number of days in which the VOCs were below levels of detection. Initial examination of VOC and air quality estimates during 2006 and early 2007 indicate intermittently increased detectable chemicals in air over the period. The variations between estimated concentrations of chemicals using different sampling techniques also suggest some variation in concentrations during the day.

The modelling reported by Holmes Air Sciences^{6,7} is considered to provide a reasonable representation of actual VOC levels at these receptor points and to be an adequate basis for assessment of likely annual average and associated levels of exposure to total VOCs in the location of off-site receptors modelled.

Specific inhalation and body weight parameters have been included for adults and for children⁹, for adult men 70kg body weight and 0.96m³/hr inhalation rate, and for children 13.2kg and 34.5kg, respectively,

⁶ Summary of VOC modelling results at East and South boundaries, Holmes Air Sciences letter report to Thiess Services, 18th October 2007

⁷ Summary of analysis of SVOC and Dioxin monitoring results for the Lednez site for 2007, Holmes Air Sciences letter report to Thiess Services, 18th October 2007

⁸ Additional analysis of SVOC monitoring results for the Lednez site for 2007, Holmes Air Sciences letter report to Thiess Services, 18th October 2007

⁹ Enhealth Exposure Assessment Handbook- Consultation Draft, 2003

for children 0-5 yrs and 5-15 yrs, and inhalation rates 3.8m³/d (0.16m³/hr) and 15m³ (0.63m³/hr), respectively.

Receptors at the boundaries E1 and S1 are expected to principally comprise workers who will be present for less hours per day than the screening assessment modelled, resulting in a lower occupational-based risk estimate.

3.3.3 Toxicity

The toxicity of the COPCs has been assessed based on information provided by the following sources: National Environment Protection Council, World Health Organization, US Integrated Risk Information System, and the US EPA Region Nine PRG toxicity data.

Risks from exposure to an individual COPC have been estimated by calculating the individual chemical species concentrations in air (**Table 1 Appendix A**). The calculation is based on: a) averaging the speciated VOCs detected in air at the Lednez site eastern and southern boundaries using charcoal tube sampling in May and June 2007 and b) applying the annual average and 24 hour maximum VOC concentrations modelled and reported by Holmes Air Sciences^{6,7,8}.

Potential combined or interactive effects of COPC are addressed, based on regulatory guidance^{1,2}, by using conservative assumptions for the toxicity of individual chemicals, adding together individual risk estimates for combined COPC exposures, and setting acceptable risk targets at reduced levels for chemical combinations.

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4.0 Screening Risk Assessment

4.1 Background

Cancer and non-cancer outcomes are considered to arise by different toxicological mechanisms. Hence, cancer and non-cancer risks are estimated separately in the current screening risk assessment.

The relevant exposure pathway for off-site public exposure to site-generated VOCs is via inhalation (breathing air adjacent the site) with no site-specific dermal or oral (skin contact or food/soil intake) public exposures expected.

Estimates of cancer and non-cancer risks have been calculated for those detected VOCs which show listed toxicity factors in WHO¹⁰ and California Office of Environmental Health hazard Assessment¹¹ databases. Risks have been estimated at four receptor points: the site eastern boundary (E1); a point over the railway line adjacent residential areas (E2); and the site southern boundary (S1) and nearest residential area (S2).

Cancer risk is estimated by applying toxicity potency factors¹² to the modelled predicted annual average air concentrations¹³.

Non-cancer risk is estimated by comparing the modelled, annual average, hourly and 24-hour maximum air concentrations of a chemical to WHO Tolerance Values or Guidance Values¹⁰ or to a Reference Exposure Level (REL)¹⁴. A chronic REL is an airborne level that would pose no significant health risk to individuals indefinitely exposed to that level. A 'hazard quotient' for each chemical compares its concentration with the REL and for acceptable concentrations the quotient¹⁵ should be less than unity (i.e. less than 1).

4.2 Results

Non-cancer risks estimated for potential continued chronic exposure to the COPC are described in **Table 2 (Appendix B)**. The results indicate that the Hazard Index¹⁶ (HI) estimated for combined COPCs is less than unity (i.e. less than 1) at the eastern site boundary (E1) and eastern residential receptor

¹⁰ WHO Air Quality Guidelines 2000 <http://www.who.int/phe/en> (accessed 20.8.07)

¹¹ http://www.oehha.ca.gov/air/hot_spots/index.html (accessed 20.8.07)

¹² http://www.oehha.ca.gov/air/hot_spots/pdf/TSDlookup2002.pdf (accessed 20.8.07)

¹³ Confirmation of the approach to risk estimation is provided for worked examples with calculations in **Appendix F**.

¹⁴ http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html (accessed 20.8.07)

¹⁵ See Appendix F (b) for an example.

¹⁶ HI is the sum of individual chemical non-cancer hazard quotients. The hazard quotient is a comparison of the experienced air concentration of a chemical to an exposure level published as acceptable by certain regulatory agencies.

(E2), but exceeds unity at the southern boundary (S1) and southern residential receptor (S2). The HIs exceed the risk acceptability criterion of $HI < 0.2$ published in DECC 2005 for non-cancer risk, thereby requiring best practice reduction of ongoing VOC concentrations in air to a level below the recent annual average levels.

Exposure for 1.5 years in some regulatory jurisdictions such as the USA is considered sub-chronic exposure. Therefore the guidance values applied in **Table 2** can be considered conservative.

Cancer risks estimated for potential long-term chronic exposure to the COPCs are described in **Table 3 (Appendix C)**. The Table and confirmatory example calculations in **Appendix F(a)** indicate that exposure to the annual average concentration of benzene for the past year and a half of the project would result in a predicted upperbound lifetime cancer risk of approximately one chance in one million (1.0×10^{-6}) at the E2 receptor for adults and four chances in one million (4.2×10^{-6}) at the S2 receptor for adults, with slightly elevated risks (1.5×10^{-6} and 6.5×10^{-6} respectively) for older children (5-15 years).

The results indicate that at the eastern boundary and both the southern boundary and southern residential receptor (E1, S1 and S2) the cancer risk estimates for 1.5 year of exposure to carcinogenic benzene have moved into the one chance in 1,000,000 to one chance in 10,000 zone for lifetime cancer risk at which point the (DECC 2005) risk acceptability criteria require reduction by best practice measures.

Hexachlorobenzene measurements presented in **Table 2** consider the vapour component and not particle-bound hexachlorobenzene. The original Lednez EIS data showed over 96 percent of the hexachlorobenzene to be present as vapour rather than particle-bound. Other SVOCs listed in the EIS showed a similar vapour to particle ratio.

With respect to short term exposure risks, the WHO and OEHHA publish Tolerability and Guidance concentrations and RELs, respectively, for acute (short term) exposure¹⁷ for several of the COPCs. These are listed in **Table 4 (Appendix D)**. Modelled average exposures to COPCs estimated at E1, E2, S1 and S2 receptors including for 2006-mid 2007⁶ are below these values except for benzene and chloroform at the southern boundary and southern residential receptor (S1 and S2). Because the guidance values used are for longer-term exposure the actual risks are expected to be lower.

NOTE: The toxicity potency factors and exposure assumptions used in the screening risk assessment are designed to estimate upper-bound health risks as a basis for avoiding potential health effects. Individual-specific risks resulting from recent exposures may be estimated by taking into account exposure duration factors which may reduce chemical exposure estimates. Such estimation requires more detailed risk assessment and has not been performed as part of the current screening risk assessment.

4.3 Physical Irritation and Discomfort

While most COPC modelled levels for 2006-2007 did not exceed the acute tolerance and guideline concentrations and RELs, exposure at lower levels to some COPCs such as dichlorobenzene, ethylbenzene and styrene may lead to significant physical irritation and discomfort for some people. Reduction of these effects is a goal of site management and is a key consideration in development of site RLs (see Sections 4.4 and 4.5 below) including proactive management responses to meteorological and emission conditions.

¹⁷ <http://www.who.int/phe/en> and http://www.oehha.ca.gov/air/acute_rels/allAcRELS.html (accessed 20.8.07)

4.4 Australian Monitoring Investigation Levels

The Australian National Environment Protection (Air Toxics) Measure defines Monitoring Investigation levels (MILs) for several of the COPC. Exceedence of MILs requires any Australian jurisdiction to undertake evaluation to determine the circumstances which led to the exceedence, including the likely sources and the influence of natural factors¹⁸. A list of the COPCs for which MILs are published and the relevant MIL are provided in **Table 5 (Appendix E)**. The recent estimated annual average concentration for benzene exceeded the MIL (**Appendix E**) at the southern receptor area adjacent the site.

4.5 Development of Boundary Air Response Levels (RLs)

The screening risk assessment may provide the basis for the development and adoption of air Response Levels (RLs) in consultation with the DECC, NSW Department of Health (DOH) and Community Reference Committee. These would define air quality characteristics at the boundary of the site which predict adverse air quality under particular work programme and meteorological conditions, potentially allowing preventive responses at the worksite management level to avoid public impacts beyond the site boundary.

It is considered important from a public health protection perspective that the proposed Lednez site remediation RLs are developed through consultation with DECC, DOH and between local stakeholder groups. An important consideration is the ability of the RLs to both prevent adverse air quality events while ensuring that the work on the project site may continue to improve the soil and Homebush Bay sediment quality at the earliest possible time, thereby minimising exposures to airborne residues and contributing to protection of health and the local environment.

It is also important that the RLs established for the site at Rhodes reflect the fact that the sites will be remediated only over a period of several years. Adjustments for the reduced exposure duration have been made in the current screening risk assessment.

Consideration of the roles of MILs may be relevant to development of interim RLs for the Lednez sites consistent with discussion of work programme responses required based on RLs.

Practical approaches to minimising exposures to VOC emissions through work programme management during adverse weather conditions are worthy of consideration. These may, for example, include daily rapid assessment of VOC concentrations in air at regular times (by PID tubes) and immediate comparison with meteorological data to indicate whether the conditions may be expected to lead to increased VOC exposures during work or at night. This approach may complement the development of RLs, particularly should measurement of air quality samples for comparison with an RL require an unavoidable delay due to laboratory testing requirements.

4.6 Uncertainties

The estimates of dispersion of chemicals in air and the potential human health impacts is affected by the "grab" sample nature of the initial data, by the intermittent nature of the sampling, and by site-specific factors which may affect source term emissions, including covering of the material storage cell.

¹⁸ https://www.nepc.gov.au/ephc/pdf/Air_Toxics/FinalAirToxicsNEPM.pdf (accessed 20.8.07)

Air dispersion modelling assumptions and uncertainties are addressed in the reports by Holmes Air Sciences^{6,7,8}. A considerable proportion of reporting days in 2006 and 2007 registered no detection of VOC in air¹⁹.

It is possible that the constant source emission assumptions required for air dispersion modelling and the speciation calculations in the present report may overestimate individual VOC concentrations in air. The assumptions have been included in the risk assessment in order to provide a conservative (safer) assessment.

A further factor which would be expected to reduce the assumed concentrations of individual VOCs in air is the inclusion of non-work periods of 2006-2007 when VOC emissions were not being generated. These data have not at this time been collected or incorporated into the air dispersion modelling or risk assessment assumptions.

Air quality data uncertainties are being addressed for future estimations by continuous air quality sampling devised in consultation with the DECC and DOH and currently being implemented.

The screening risk assessment aims to estimate upper-bound health risks (risks in the actual case are no higher and almost certainly lower). Site-specific risks to individuals encountering VOCs in air are expected to be reduced compared with the estimated risks due to factors including, for example, reduced absorption of chemical, and reduced duration of exposure through time spent away from the Rhodes area. The boundary risk estimates would be expected to be reduced for receptors present only during working hours, where an industrial exposure scenario would be used to estimate risks.

The USEPA is continuing consideration of a more specific assessment and dose response approach to genotoxic and mutagenic chemical carcinogens in order to provide more detailed guidance for childhood cancer risk. The agency has indicated that use of the linear low-dose extrapolation on which the present screening risk assessment has been based provides adequate public health conservatism in the absence of chemical-specific data indicating differential early life sensitivity²⁰.

The screening risk assessment has been undertaken consistent with established regulatory guidance^{1,2} on potential combined or interactive effects of COPC by using conservative assumptions for the toxicity of individual chemicals, adding together individual risk estimates for combined COPC exposures, and recognising acceptable risk targets at reduced levels for chemical combinations.

¹⁹ See Thiess Lednez Air Quality Monitoring Reports 2006-2007

²⁰ USEPA 'Guidelines for Carcinogen Risk Assessment', 2005, Report EPA/630/P-03/001F

5.0 Conclusions

The screening risk assessment for estimated annual average air concentration levels of VOCs at receptors on or near the Lednez site for mid 2006 to 2007 indicates that:

- 1 The estimated non-cancer Hazard Indexes for continued chronic exposure to the COPC are less than unity at the eastern boundary (E1) and eastern residential receptor (E2), but exceed unity at the southern boundary (S1) and at the southern residential receptor area adjacent the site (S2). Overall the HIs exceed the DECC risk goal criterion of HI < 0.2 published in 'Approved Methods for the Modelling and Assessment Of Air Pollutants in New South Wales 2005' for non-cancer risk, and therefore require best practice reduction of ongoing VOC concentrations in air below the recent annual average levels.
- 2 The cancer risk estimates for one and one half years of continuous exposure to benzene at the southern boundary and residential receptors (S1 and S2) exceed approximately one chance in one million of a lifetime cancer event whereby the DECC risk acceptability goal requires reduction by best practice measures. Both the non-cancer and cancer risk estimates are calculated as upper-bound estimates such that risks in the actual case are no higher and almost certainly lower than the estimates.
- 3 Further information on work practices and on periods of non-emissions during 2006-2007 may be expected to refine and probably reduce the estimated concentrations of chemicals in air, thereby reducing the estimated risks.
- 4 With respect to acute exposures, the modelled exposures to COPCs at E1, E2, S1 and S2 receptors for 2006 and early 2007 are for most chemicals below the accepted OEHHA RELs and WHO Tolerance or Guidance values. However benzene and chloroform levels exceed the values at the southern boundary and residential receptor. Because the guidance values used are for longer-term exposure the actual risks are expected to be lower than the estimates in the screening risk assessment.
- 5 With respect to potential physical discomfort effects COPCs such as dichlorobenzene, ethylbenzene and styrene may cause significant physical irritation and discomfort for some people at relatively low levels.
- 6 The MILs used in Australia may be relevant during development of RLs for the Lednez site subject to definition of appropriate site work programme responses.
- 7 Utilisation of rapid VOC monitoring and air modelling data may represent a practical approach to exposure minimisation through rapid daily assessment of VOC concentrations at the site boundary and immediate comparison with meteorological data.

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Site, Rhodes, Sydney

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Appendix A: VOC COPC Species as % of Total VOCs Detected

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Table 1: VOC COPC Species as % of Total VOCs Detected

Chemical	Charcoal Tube Average % of VOCs	Annual Av Conc at Receptor (mg/m ³) E1	Annual Av Conc at Receptor (mg/m ³) E2	Annual Av Conc at Receptor (mg/m ³) S1	Annual Av Conc at Receptor (mg/m ³) S2
Acetone	1.17%	0.0017	0.0008	0.0050	0.0033
1,1,- dichloroethane	1.17%	0.0029	0.0014	0.0087	0.0058
2-butanone	1.17%	0.0002	0.0001	0.0007	0.0005
Chloroform	1.17%	0.0035	0.0017	0.0104	0.0069
benzene	6.66%	0.0128	0.0064	0.0384	0.0256
1-heptene	1.17%	0.0028	0.0014	0.0085	0.0057
n-heptene	1.17%	0.0028	0.0014	0.0085	0.0057
Trichloroethene	1.17%	0.0038	0.0019	0.0114	0.0076
MIBK	1.17%	0.0029	0.0014	0.0087	0.0058
Toluene	9.08%	0.0204	0.0102	0.0613	0.0408
2-hexanone	1.17%	0.0029	0.0014	0.0087	0.0058
Chlorobenzene	16.14%	0.0441	0.0220	0.1322	0.0881
Ethyl Benzene	4.27%	0.0110	0.0055	0.0331	0.0220
m-& p-xylene	12.16%	0.0317	0.0159	0.0952	0.0635
o-xylene	5.13%	0.0134	0.0067	0.0401	0.0268
Styrene	1.17%	0.0030	0.0015	0.0089	0.0059
Cyclohexanone	1.17%	0.0028	0.0014	0.0085	0.0056
Isopropylbenzene	1.17%	0.0037	0.0018	0.0110	0.0073
2-chlorotoluene	1.17%	0.0036	0.0018	0.0109	0.0073
4-chlorotoluene	1.17%	0.0036	0.0018	0.0109	0.0073
1,3,5-trimethylbenzene	2.16%	0.0065	0.0032	0.0194	0.0129
n-decane	1.22%	0.0042	0.0021	0.0127	0.0085
1,2,4-trimethylbenzene	2.66%	0.0080	0.0040	0.0240	0.0160

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Chemical	Charcoal Tube Average % of VOCs	Annual Av Conc'n at Receptor (mg/m ³) E1	Annual Av Conc'n at Receptor (mg/m ³) E2	Annual Av Conc'n at Receptor (mg/m ³) S1	Annual Av Conc'n at Receptor (mg/m ³) S2
1,3-dichlorobenzene	1.25%	0.0045	0.0022	0.0135	0.0090
1,4-dichlorobenzene	10.77%	0.0388	0.0194	0.1165	0.0777
1,2-dichlorobenzene	9.72%	0.0356	0.0178	0.1067	0.0711
n-butylbenzene	1.17%	0.0039	0.0019	0.0116	0.0077
hexachlorobutadiene	1.17%	0.0075	0.0038	0.0225	0.0150

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Appendix B: COPC VOC Annual Average Concentrations and Estimated Receptor Non-cancer Risks

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Table 2: COPC VOC Annual Average Concentrations and Estimated Receptor Non-cancer Risks

Chemical	Receptor	Annual Average Conc²¹ (ug/m3)	Published Chronic Air Conc²² (ug/m3)	Non-cancer Hazard Quotient (Chronic)
Benzene	Receptor E1	13	60 ²²	0.22
	Receptor E2	6		0.10
	Receptor S1	38		0.66
	Receptor S2	26		0.43
Chlorobenzene	Receptor E1	44	1000 ²²	0.04
	Receptor E2	22		0.02
	Receptor S1	132		0.13
	Receptor S2	88		0.09
Chloroform	Receptor E1	4	Adult 50 ²³	0.08
	Receptor E2	2		0.04
	Receptor S1	10		0.20
	Receptor S2	7		0.14
Chloroform	Receptor E2	2	Child 35 ²³	0.06
	Receptor S2	7		0.20
1,4-dichlorobenzene	Receptor E1	39	1000 ²⁴	0.04
	Receptor E2	19		0.02
	Receptor S1	116		0.11

²¹ Rounded to significant figures for comparison with published concentrations

²² OEHHA Chronic REL http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html (accessed 20.8.07)

²³ Calculated from the WHO (2000)TDI using body weight and inhalation rate.

²⁴ WHO (2000) One Year Tolerance Concentration.

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Chemical	Receptor	Annual Average Conc ²¹ (ug/m3)	Published Chronic Air Conc (ug/m3)	Non-cancer Hazard Quotient (Chronic)
	Receptor S2	78		0.08
Ethylbenzene	Receptor E1	11	22000 ²⁵	0.001
	Receptor E2	6		0.001
	Receptor S1	33		0.002
	Receptor S2	22		0.001
Hexachlorobenzene	Receptor E1 ²⁶	0.25	Adult 0.6 ²³	0.40
	Receptor E2 ²⁶	0.14		0.23
	Receptor S1	0.01		0.02
	Receptor S2	0.01		0.02
Hexachlorobenzene	Receptor E2 ²⁶	0.14	Child 0.4 ²³	0.35
	Receptor S2	0.01		0.03
Styrene	Receptor E1	3	900 ²⁷	0.01
	Receptor E2	2		0.01
	Receptor S1	9		0.01
	Receptor S2	6		0.01
Toluene	Receptor E1	20	300 ²⁸	0.08

²⁵ WHO (2000) One Year Guidance Value.

²⁶ This concentration is a single monitoring measurement and not an annual average. Comparison with long-term exposure criteria is likely to be very conservative

²⁷ Based on OEHHA Chronic REL. The WHO (2000) One Week Guidance Value Concentration is 260 ug/m3.

²⁸ Based on OEHHA Chronic REL. The WHO (2000) One Week Guidance Value Concentration is 260 ug/m3.

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Chemical	Receptor	Annual Average Conc ⁿ (ug/m3) ²¹	Published Chronic Air Conc (ug/m3)	Non-cancer Hazard Quotient (Chronic)
	Receptor E2	10		0.04
	Receptor S1	61		0.23
	Receptor S2	41		0.16
Trichloroethene	Receptor E1	4	600 ²²	0.01
	Receptor E2	2		0.01
	Receptor S1	11		0.02
	Receptor S2	8		0.01
Xylenes	Receptor E1	45	870 ²⁵	0.05
	Receptor E2	23		0.03
	Receptor S1	135		0.16
	Receptor S2	90		0.10
Hazard Indexes:	Receptor E1		Adult	HI = 0.93
	Receptor E2			HI = 0.49
	Receptor S1			HI = 1.55
	Receptor S2			HI = 1.03
Hazard Indexes:	Receptor E2		Child	HI = 0.64
	Receptor S2			HI = 1.10

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Appendix C: Estimated Receptor Cancer Risks for 1.5 Years of Exposure to COPC VOC Annual Average Concentrations

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Table 3: Estimated Receptor Cancer Risks for 1.5 Years of Exposure to COPC VOC

Chemical	Receptor	Annual Average Concn²⁰ (ug/m3)	Unit Risk²⁹ ([ug/m3]-1)	Cancer Risk (1.5 years)
Benzene-Adult	Receptor E1	13	7.5×10^{-6}	2.1×10^{-6}
	Receptor E2	6	"	1.0×10^{-6}
	Receptor S1	38	"	6.1×10^{-6}
	Receptor S2	26	"	4.2×10^{-6}
Benzene-Child (0-5 yrs old)	Receptor E2	6	See Appx F	1.0×10^{-6}
	Receptor S2	26		4.3×10^{-6}
Benzene-Child (5-15 yrs old)	Receptor E2	6	See Appx F	1.5×10^{-6}
	Receptor S2	26		6.5×10^{-6}

²⁹ Guidelines for Air Quality, World Health Organization, Geneva, 2000 (accessed 20.10.07)

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Appendix D: COPC VOC Acute Air RELs

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Table 4: COPC VOC Acute Air Values and RELs

Chemical	Receptor	Max Hourly Conc'n 2006-2007 (ug/m3)	Acute Air REL³⁰ (ug/m3)
Benzene³¹	Receptor E1	0.3 x10 ³	1.3x10³
	Receptor E2	0.2 x10 ³	
	Receptor S1	1.7 x10³	
	Receptor S2	1.4 x10³	
Chloroform³²	Receptor E1	0.7x10 ²	1.5x10²
	Receptor E2	0.5x10 ²	
	Receptor S1	4.5x10²	
	Receptor S2	3.9x10²	
Styrene	Receptor E1	0.06 x10 ³	2.1x10⁴
	Receptor E2	0.04 x10 ³	
	Receptor S1	0.4 x10 ³	
	Receptor S2	0.3 x10 ³	
Toluene	Receptor E1	0.4 x10 ³	3.7x10⁴
	Receptor E2	0.3 x10 ³	
	Receptor S1	2.7 x10 ³	
	Receptor S2	2.3 x10 ³	
Xylenes³³	Receptor E1	0.9 x10 ³	2.2x10⁴

³⁰ OEHHA Acute REL http://www.oehha.ca.gov/air/acute_rels/allAcRELS.htm (accessed 20.8.07)

³¹ The OEHHA REL used here is based on 6 hour averaging time and so, together with likely peak-to-mean considerations results in a conservative comparison in this Table.

³² The OEHHA REL used here is based on 7 hour averaging time and so, together with likely peak-to-mean considerations results in a conservative comparison in this Table.

³³ WHO (2000) One Day Guidance Value Concentration is 4.8 x10³

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Chemical	Receptor	Max Hourly Concn 2006- 2007 (ug/m3)	Acute Air REL ³⁰ (ug/m3)
	Receptor E2	0.6 x10 ³	
	Receptor S1	5.9 x10 ³	
	Receptor S2	5.1 x10 ³	

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Appendix E: COPC VOC Annual Average Concentrations and Australian NEPM MILs

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Table 5: COPC VOC Concentrations and Australian NEPM MILs

Pollutant	Receptor	Annual Average Conc (ppm) [mg/m ³]	Conv Factor (ppm to mg/m ³)	Monitoring Investigation Level- Annual Average (ppm)	24 Hour Maximum (ppm) [mg/m ³]	Monitoring Investigation Level- 24 Hour Period (ppm)
Benzene	Receptor E2	(0.002) [0.006]	3.2	0.003	(0.012) [0.038]	-
	Receptor S2	(0.008) [0.026]		"	(0.055) [0.177]	"
Toluene	Receptor E2	(0.003) [0.010]	3.75	0.1	(0.016) [0.061]	1
	Receptor S2	(0.011) [0.041]		"	(0.075) [0.283]	"
Xylenes	Receptor E2	(0.005) [0.023]	4.35	0.2	(0.031) [0.135]	0.25
	Receptor S2	(0.021) [0.090]		"	(0.144) [0.624]	"

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Appendix F: Sample Risk Calculation Confirmation

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Sample Risk Calculation Confirmation

(a) Inhalation Cancer Risk- 1.5 years of continuous exposure

(i) Adult Inhalation Cancer Risk

Benzene Modelled Annual Average Concentration in Air

≈ 0.006 mg/m³ (East 2 Receptor) for 1.5 year of Continuous Exposure

$$I = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

I = (Chemical Intake) = mg/kg-d

CA (Chemical concentration in air) = 0.006mg/m³

IR (Inhalation rate) = 0.96 m³/h

ET (Exposure time) = 24 h/d

EF (Exposure frequency) = 365 d/y

ED (Exposure duration) = 1.5 years

BW (Body weight) = 70kg

AT (Averaging time) = 25550d

$$I = \frac{0.006 \times 0.96 \times 24 \times 365 \times 1.5}{70 \times 25550}$$

$$= 4.2 \times 10^{-5} \text{ mg/kg-d}$$

$$\text{RISK} = \text{SF}^{34} (\text{mg/kg-d})^{-1} \times I (\text{mg/kg -d})$$

$$= 2.6 \times 10^{-2} \times 4.2 \times 10^{-5}$$

$$\approx 1.1 \times 10^{-6}$$

Where:

SF = (Cancer potency slope factor) = [mg/kg-d]⁻¹

³⁴ Derived from *Guidelines for Air Quality, World Health Organization, Geneva, 2000*

(ii) Child 0-5 years old Inhalation Cancer Risk

Benzene Modelled Annual Average Concentration in Air

≈ 0.006 mg/m³ (East 2 Receptor) for 1.5 year of Continuous Exposure

$$I = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

I = (Chemical Intake) = mg/kg-d

CA (Chemical concentration in air) = 0.006mg/m³

IR (Inhalation rate) = 0.16 m³/h

ET (Exposure time) = 24 h/d

EF (Exposure frequency) = 365 d/y

ED (Exposure duration) = 1.5 years

BW (Body weight) = 13.2kg

AT (Averaging time) = 25550d

$$I = \frac{0.006 \times 0.16 \times 24 \times 365 \times 1.5}{13.2 \times 25550}$$

$$= 3.7 \times 10^{-5} \text{ mg/kg-d}$$

$$\text{RISK} = \text{SF}^{30} (\text{mg/kg-d})^{-1} \times I (\text{mg/kg -d})$$

$$= 2.6 \times 10^{-2} \times 4.2 \times 10^{-5}$$

$$\approx 1.0 \times 10^{-6}$$

Where:

SF = (Cancer potency slope factor) = [mg/kg-d]⁻¹

(iii) Child 5-15 years old Inhalation Cancer Risk

Benzene Modelled Annual Average Concentration in Air

≈ 0.006 mg/m³ (East 2 Receptor) for 1.5 year of Continuous Exposure

$$I = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

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I = (Chemical Intake) = mg/kg-d

CA (Chemical concentration in air) = 0.006mg/m³

IR (Inhalation rate) = 0.63 m³/h

ET (Exposure time) = 24 h/d

EF (Exposure frequency) = 365 d/y

ED (Exposure duration) = 1.5 years

BW (Body weight) = 34.5kg

AT (Averaging time) = 25550d

$$I = \frac{0.006 \times 0.63 \times 24 \times 365 \times 1.5}{34.5 \times 25550}$$

$$= 5.6 \times 10^{-5} \text{ mg/kg-d}$$

$$\text{RISK} = \text{SF}^{30} (\text{mg/kg-d})^{-1} \times I (\text{mg/kg -d})$$

$$= 2.6 \times 10^{-2} \times 5.6 \times 10^{-5}$$

$$\approx 1.5 \times 10^{-6}$$

Where:

SF = (Cancer potency slope factor) = [mg/kg-d]⁻¹

(b) Inhalation Non-Cancer Risk

Benzene Modelled Annual Average Concentration in Air

≈ 0.006 mg/m³ (East 2 Receptor)

HQ = Chemical Concentration in Air

Chronic Air REL

Where:

HQ = (Hazard Quotient)

REL = (Chronic Air Reference Exposure level) in mg/m³

$$\text{HQ} = \frac{0.006}{0.06}$$

$$= 0.1$$

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