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Empowering Through Knowledge

Your Reference:
Our Reference: BTS 04/0009

Mr Lance Whitewood
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Kwinana Refinery
PO Box 161
Kwinana 6167

Dear Lance

Enclosed please find the final report by BenchMark Toxicology Services of the Peer Review of the Environ Document entitled *Atmospheric Emissions Screening Assessment. Upgraded Kwinana Liquor Burner.*

As previously advised, the draft report which I sent you on 5 July 2004 for comment by Environ and the stakeholder Reference Group has been amended taking into account the comments received. As predicted the conclusions of the review have not altered.

Thank you for the opportunity to work with you and the Stakeholder Reference Group on this project.

Yours sincerely

Peter N Di Marco PhD, Fellow ATS
Managing Director & Principal Consultant
BENCHMARK TOXICOLOGY SERVICES

23 July 2004

BenchMark Toxicology Services

As Trustee for the P & K Family Trust (ABN 72 217 434 679)

Empowering Through Knowledge

Peer Review of
Atmospheric Emissions Screening Assessment. Upgraded Kwinana Liquor Burner
by Environ Australia Pty Ltd
25 June 2004

Prepared for:

Alcoa World Alumina Australia
on Behalf of
The Stakeholder Reference Group (SRG)

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ATMOSPHERIC EMISSIONS SCREENING ASSESSMENT. UPGRADED KWINANA LIQUOR BURNER
BY ENVIRON AUSTRALIA PTY LTD
25 JUNE 2004

1. Executive Summary

1. The screening assessment of the emissions from the Liquor Burner by Environ is based on well-established and acceptable health risk assessment methods used by regulatory agencies both in Australia and overseas.
2. The approach is relatively conservative, which leads in all likelihood to an overestimation, rather than an underestimation, of the potential risks. BenchMark Toxicology Services considers that the outcomes provide sufficient and adequate protection of public health.
3. Two scenarios are considered for exposure assessment: historical stack monitoring data at the Liquor Burner at the Alcoa Kwinana refinery before operations were stopped in 2002, and updated emission estimates for the proposed upgraded Liquor Burner.
4. Ground level concentrations for the quantifiable components of the emissions are estimated using air dispersion modelling for the two exposure scenarios. Ground level concentrations are estimated for each of the 13 identified receptor locations within the industrial area and the buffer zone. Receptors 1 and 6 within the industrial area are identified as the most likely exposed receptors and receptor 12 as the least exposed.
5. Acute (1-h and 24-h averages, maximum and 99.5th percentile) and chronic (annual average) ground level concentrations are estimated. BenchMark Toxicology Services considers that these averaging times are adequate.
6. Environ compares the estimated ground level concentrations with appropriate air quality guidelines and toxicity values where available to assess the potential impacts on health. BenchMark Toxicology Services considers that the sources of the air quality guidelines and toxicity values are appropriate and consistent with Australian health risk assessment guidelines.
7. Importantly the potential impact of all the components of the emissions is assessed, as well as assessing each component individually, by using an additive model. This is consistent with the default US EPA approach – one of the few jurisdictions that have developed guidelines for assessing risks of complex mixtures.
8. The assessment suggests that the historical emissions have not impacted adversely on the health of the identified residents and public places subject to exposure from the emissions.
9. As future emissions from the upgraded emission controls on the Liquor Burner are predicted to be much lower than historical emission, the use of the Liquor Burner in future is highly unlikely to pose any risk of adverse health effects.
10. In future, Alcoa should undertake emission monitoring and use appropriate analytical techniques to identify and quantify emissions from the Liquor Burner to confirm the predicted emission and further define and quantify the emission profile and composition.

PEER REVIEW OF
ATMOSPHERIC EMISSIONS SCREENING ASSESSMENT. UPGRADED KWINANA LIQUOR BURNER
BY ENVIRON AUSTRALIA PTY LTD
25 JUNE 2004

2. Background and Scope

Alcoa World Alumina Australia (Alcoa) has retained BenchMark Toxicology Services Pty Ltd to provide an independent review of the toxicological and health risk assessment aspects of the report *Atmospheric Emissions Screening Assessment. Upgraded Kwinana Liquor Burner* by Environ Australia Pty Ltd dated 25 June 2004. The ensuing report is to be presented to the Stakeholder Reference Group (SRG).

The document prepared by Environ Australia comprises a screening health risk assessment of emissions from the Liquor Burner at Alcoa's Kwinana Refinery based on predicted ground-level concentrations of emission components (derived by modelling) of:

1. Historical emissions before the Liquor Burner at Alcoa's Kwinana Refinery ceased operating in 2002.
2. Updated emission estimates for the proposed upgraded Liquor Burner at the same facility.

BenchMark Toxicology Services has not evaluated either the air dispersion modelling or the predicted stack emissions from the upgraded Liquor Burner as they fall outside its area of expertise. Consequently, the estimated ground level concentrations have been taken at face value in reviewing the screening assessment.

The covering letter attached to the Environ report (from Brian Bell of Environ to Alcoa) refers to *the findings of the review undertaken by Dr Roger Drew of Toxikos Pty Ltd (24 May 2004)* having been taken into account in the revision of the document. Benchmark Toxicology Services has not reviewed the Toxikos document as it is outside the scope of its contract with Alcoa.

In assessing the proposal and establishing a contract for the project with Alcoa, Peter Di Marco, Managing Director of BenchMark Toxicology Services, has had a number of telephone conversations with Lance Whitewood and Stephen Mills of Alcoa. In addition, in the process of the review, Peter Di Marco contacted Karla Hinkley of Environ by telephone on 2 July 2004 to clarify the value of the phenanthrene concentration reported in Table 10 of the Environ report.

Subsequently, Environ was given a copy of the draft report and has provided satisfactory explanations for a number of the issues raised and the draft report amended accordingly. BenchMark Toxicology Services attended a meeting of the SRG held in Kwinana on Thursday 15 July 2004 and has amended the draft report to take into account the issues raised/tabled by members at the meeting.

3. Overview / General Comments

The health risk assessment of emissions from the Liquor Burner is based on well-established and acceptable methods used by regulatory agencies both in Australia and overseas. The approach is relatively conservative, which leads in all likelihood to an overestimation of the potential risks rather than an

underestimation. Consequently, BenchMark Toxicology Services considers that the outcomes provide sufficient and adequate protection of public health.

Two scenarios are considered for exposure assessment: historical stack monitoring data at the Liquor Burner at the Alcoa Kwinana refinery before operations were stopped in 2002 and updated emission estimates for the proposed upgraded Liquor Burner.

Sixty components were quantified from historical emission data and used in the risk assessment. Twenty four other components were either present in the emissions at too low a concentration to be quantified by the analytical methods used or their identity was uncertain. The updated emission estimates were based on definitions for mass emissions for 8 components and industrial experience or manufacturer's advice for the remainder.

Air dispersion modelling, based on historical stack emissions and predicted stack emissions from upgraded emission controls in the future, is used to estimate ground level concentrations for each of the identified and quantified emission components at 13 identified receptor locations within the industrial area and the buffer zone. Receptors 1 and 6 within the industrial area are identified as the most likely exposed receptors and receptor 12 within the buffer zone as the least exposed.

The estimates included 1-h and 24-h averages (maximum and 99.5th percentile values) for assessing potential acute effects, and annual averages for assessing chronic effects. This is considered appropriate.

The risk assessment is based on a comparison of the estimated ground level concentrations with ambient air quality guidelines for non-carcinogenic effects (acute and chronic) and calculation of risks for carcinogenic effects. Only inhalational exposure is considered – this is justifiable.

An additive model is used to assess the potential adverse health effects of the emissions as a whole. In the case of non-carcinogenic endpoints, the Hazard Quotient (ratio of air concentration to guideline value, HQ) for each component of the emissions is calculated and the result for each component added to give a Hazard Index (HI) for the emissions. The HQ and HI are measures of the margin of safety, which is reflected in the size of the HI or the HQ - the smaller the HI or HQ, the larger the margin of safety.

In the case of carcinogenic effects, the incremental lifetime cancer risks for each substance are summed to give the total incremental lifetime cancer risk for all carcinogenic substances in the emissions.

These approaches are overall consistent with national and international practices and relatively conservative. Use of the additive model is consistent with the default US EPA approach for complex mixtures – one of the few jurisdictions that have developed guidelines for assessing risks of complex mixtures.

Environ has identified ambient air quality guidelines (acute and chronic) or unit cancer risks that have been developed and published by national or international jurisdictions for 38 of the emission components and air guidelines for another 10 components that have been developed and published by the state of Texas in the USA. BenchMark Toxicology Services has identified toxicity values and guidelines for another four components that could be used in the risk assessment.

Environ does not clearly distinguish between toxicity values (estimates of a *safe* or acceptable dose) and air quality guidelines or criteria (to which Environ refers as *health protective guidelines*). In some, but not all case, these may be

the same. The distinction is important for understanding the outcomes and interpreting exceedances.

BenchMark Toxicology Services supports the use of unit risk factors in the assessment of benzene and arsenic. They are classified as *known human carcinogens* by the International Agency for Research on Cancer (IARC). Formaldehyde is classified as a *probable human carcinogen* by IRAC and normally would also be assessed using unit risk factors. However, irritation and cell death in the nasopharyngeal tissues precede the carcinogenic effects. Cancer does not develop in the absence of tissue damage, which occurs at higher concentration of formaldehyde than required to cause irritation. Therefore, a health guideline that is protective against irritation will also be protective against cancer. Consequently the assessment of formaldehyde (and the closely related acetaldehyde) is based on a non-cancer adverse effect, ie, irritation.

Environ assesses fluoranthene (a polycyclic aromatic hydrocarbon, PAH) using the unit risk factors of 8.7-87 x 10^{-5} $(\mu g/m^3)^{-1}$ derived by WHO from the unit risk for benzo(a)pyrene (8.7 x 10^{-2} $(\mu g/m^3)^{-1}$) and a potency factor of 0.001-0.01 relative to benzo(a)pyrene (ie, fluoranthene is 100-1000 times less potent than benzo(a)pyrene). Benzo(a)pyrene is he most studied of the PAH congeners and is also a very potent animal carcinogen. Hence, it is used as a reference compound for other PAH compounds in assessing their relative potencies.

The carcinogenic potential of fluoranthene cannot be classified because of insufficient scientific data (unclassifiable by IARC and US EPA). Usually such substances are assessed using toxicity values based on non-carcinogenic effects. Non-cancer toxicity values for fluoranthene have been developed and published by the US EPA and it would have been appropriate to use these in the screening assessment. The approach taken by Environ, although inconsistent with Australian practices, is a more conservative approach, hence more health protective.

The calculated HI or the incremental lifetime risks for arsenic and benzene are within acceptable levels based on historical emissions for all the quantified emission components for which ambient air guidelines were identified. The predicted emissions when the upgraded emission controls are installed are around one to two orders of magnitude lower than historical emissions. Consequently, the likelihood of adverse health effects from the emissions is very low.

The screening assessment by Environ is consistent with national and international practices. The approach is conservative so that the potential risks are likely to be overestimated rather than underestimated. Importantly, the potential adverse health effects of the emissions as a whole are assessed as well as those of the individual components of the mixture. The outcomes indicate that the historical emissions are unlikely to have affected adversely the health of the identified receptors in the past, and the likelihood is even less if the Liquor Burner emissions comply with predicted emissions in future.

Adequate monitoring of emissions and analytical techniques to identify and quantify the individual components of the emissions should ensure compliance with the set limits and verify the predicted emissions.

Specific comments are provided in the sections that follow.

Limitations

Environ has clearly identified a number of uncertainties associated with the risk assessment, emissions monitoring and air dispersion modelling. The

outcomes of the risk assessment are valid for the information used and the way it is used, thus reflect the weight (amount) and strength (quality) of the scientific data and processes.

Generally, a conservative approach is taken in risk assessment to compensate for its limitations - toxicity values tend to be underestimated (lower values) and exposure tends to be overestimated (higher values). This is to ensure, as far as possible, that overall risks to health are overestimated rather than underestimated. Thus providing a reasonable degree of confidence that human health is protected if exposure is less than the acceptable levels.

However, it is important to stress that risk assessment is only one of the tools that inform decision-making in environmental issues. It is not a solution or an end in itself.

The type of screening risk assessment undertaken by Environ examines the likely impacts of the emissions on health as measured by toxicological effects, pathological changes and generally measurable adverse health effects in experimental or epidemiological studies. It does not assess health in the broader context of wellbeing. This is not unique to the work carried out by Environ for the Alcoa emissions. It is a limitation that applies generally to current risk assessment practices and the available information on which they are based.

Assessment of health in the broader context requires different methodologies, which have not been fully developed nor used to any great extent in Australia. The development of the proposed Health Impact Assessment in Australia will go some way towards addressing this issue, in particular engendering pro-activity and fostering cooperation between stakeholders and interested parties.

4. Detailed review of document and specific comments

The following are specific comments on each of the section of the Environ report. Specifically they address the different components of risk assessment, hazard identification, exposure assessment, toxicity assessment and risk characterisation, as well as the results of the screening assessment and discussion of the uncertainties.

4.1. Section 2. - Overview of the screening assessment approach

The health risk assessment of the emissions from the Liquor Burner is based on well-established and acceptable methods used by regulatory agencies both in Australia and overseas. The approach is relatively conservative, which leads in all likelihood to an overestimation of the potential risks rather than an underestimation. Consequently, the outcomes provide sufficient and adequate protection of public health.

Further, an additive model is used to assess the potential health impacts of the components in the emissions as a whole. The calculated quantitative health risk indicators for each individual compound emitted from the Liquor Burner are added to give an overall health indicator for the emissions.

This is an additional degree of conservatism that is introduced, since additivity is normally considered for substances that cause toxic effects through common or comparable mechanisms of action. However, it is consistent with the default approach taken when the mechanisms of action of the individual substances in a mixture or the interactions between the chemicals are not sufficiently understood or are unknown. Specifically, it is consistent with the default US EPA approach – one of the few jurisdictions that have developed guidelines for assessing risks of complex mixtures.

Environ does not provide a separate section on hazard identification. However, the chemicals of concern are identified under exposure assessment from the historical Liquor Burner stack emissions and the major hazards of concern for some of the chemicals identified in the toxicity assessment.

4.2. Section 3. - Exposure assessment

The exposure assessment is based on estimated or predicted concentrations of emissions from the Liquor Burner from two exposure sources:

- Estimates of mass emission data from the Liquor Burner before it was shut down in 2002 and the components identified in the emissions. The data were provided to Environ by Alcoa and are based on results from monitoring programs of stack emissions from the Liquor Burner at Kwinana over a period of 6 years from 1996 to 2002.
- Predicted or expected emissions after the Liquor Burner has been updated with new air emission control equipment.

1. Estimates from previous monitoring results

The compounds identified in the emissions have been grouped into the following generic groups (listed alphabetically):

- Aldehydes and ketones
- Carboxylic acids
- Metals

- Organo sulphides
- Particulates
- Products of combustion (CO, SO_2, NO_2)
- Semi-volatile organic compounds (SVOC)
- Volatile Organic Compounds (VOC)

Sixty individual compounds were identified within these groups and quantified by the analytical methods used. These were used in the health risk assessment.

An additional 24 VOC were present in the Liquor Burner emissions, but no health risk assessment was conducted on them because either their identification was uncertain or they were present at concentrations below the limit of quantification for the analytical techniques used. While this is consistent with good scientific principles in the absence of information, every effort should be made to characterise fully the emissions from the Liquor Burner.

2. Estimated emissions after new emission controls are instituted

The concentrations of emission components after the new emission control equipment is installed in the Liquor Burner are derived in two ways:

- Alcoa has defined the maximum concentrations to be emitted (to define mass emissions from the Liquor Burner) for some emission components as outlined in the following table and compared them with previous emissions.

Component	Available Data#	Upgraded Estimate	
	mg/Nm^3	mg/Nm^3	%*
Total Suspended Particulates (TPS)	24 – 200	10	41 -2
Carbon Monoxide (CO)	1,700 – 5, 000	200	12 - 4
Oxides of Nitrogen (as NO_2)	79 –135	135	170 - 100
Acetaldehyde	39	2	5
Acetone	63 – 148	5	8 - 3
Formaldehyde	4.1	0.4	10
Benzene	32 - 55	2	6 - 4
Toluene	5.9 – 6.2	0.5	8

#: Data from previous monitoring

*: Upgraded estimate as a percentage of available data.

- For the remainder of the emission components, Alcoa has accepted industrial experience or the advice of the manufactures of the emission controls to be instituted on the expected emissions (reduction by 99.5% for aldehydes and ketones and 98% for other VOC components).

4.2.1. Section 3.1.1 - Dioxins and Furans

The Liquor Burner stack was sampled for dioxins and furans in 2001. Two dioxins were identified and quantified, others were present but below the quantification limit. The chemicals identified have a Toxic Equivalency Factor (TEF) of zero; hence the Toxicity Equivalent Quotient (TEQ) is zero.

These were no longer considered in the health risk assessment. This is consistent with international approaches in assessing exposure to dioxins and furans.

Dioxins and furans consist of groups of closely related individual chemicals (congeners) with similar toxicological profiles (some of the congeners), but different toxicity potencies. For risk assessment purposes, it is assumed that all congeners act through a common mechanism and their toxicity potencies are

expressed as a ratio to the toxicity potency of a reference chemical (2,3,7,8-tetrachlorodibenzodioxin or TCDD, which is given a factor of 1). The TEF approach is applied to dioxins, furans and some dioxin like polychlorinated biphenyls (PCB).

The TEF ratios are used to calculate the relative contribution to the overall dose (TEQ) from the concentration of each congener in the medium. That is, the concentration of the congener in the medium (air) is multiplied by the TEF to give a TCDD equivalent concentration and the TEF for each congener present added to give an overall single concentration (TEQ) equivalent to TCCD concentration. Thus only one concentration (dose), equivalent to a dose of TCDD, is used in the risk assessment and compared to the toxicity profile and toxicity value for TCDD. As the congeners found in the emissions have a TEF of zero, the equivalent dose of TCDD (TEQ) was also zero.

4.2.2. Section 3.2 - Potential receptors

Alcoa has identified the population at risk of being exposed to the Liquor Burner emissions. It consists of individuals in 11 residences, one caravan park and the Naval Base hotel.

Four target sites are within the industrial area (EPP Area A), about 2-3 km from the Liquor Burner (estimated from Figure 1 in the Environ report), north and south east of the Liquor Burner. The remainder are in the buffer zone (EPP Area B). Receptors 1 and 6 within the industrial area are identified as the most likely exposed receptors and receptor 12 in the buffer zone as the least exposed.

4.2.3. Section 3.3 - Exposure routes considered

Inhalation was the only route of exposure considered. The reason given is that the majority of the components are volatile; hence inhalation is the most significant route of exposure.

Whether or not other routes of exposure (oral and dermal) are important depends on whether or not the emission components are deposited in any significant amount on soil, water or garden produce. The Office of Environmental Health Hazard Assessment in California (OEHHA, 2000)[1] has developed a list of compounds for which multi pathway exposure needs to be considered. Arsenic was the only chemical component of the emissions from the Liquor Burner found on the OEHHA list. The decision to consider only the inhalational route is based on this list (see Section 3.4.1 for additional comments on arsenic).

4.2.4. Section 3.4 – Estimated concentrations in air

The maximum and 99.5th percentile 1-h and 24-h average ground-level concentrations of the emission components (and the annual average ground-level concentration) at each of the receptor locations were estimated from the results of air dispersion modelling of oxides of nitrogen.

Environ does not provide a justification for the appropriateness of using such an approach to determine ambient air concentration of the emissions. Given that particles behave differently than gases in air and the half-life of different VOC can vary, a more comprehensive description would facilitate understanding

[1] Office of Environmental Health Hazard Assessment (OEHHA)(2000). Air Toxics "Hot Spots" Program Risk Assessment Guidelines Part IV Exposure Assessment and Stochastic Analysis Technical Support Document. October 27, 2000. http://www.oehha.ca.gov/air/hot_spots/finalStoc.html

and acceptance of the results of the air modelling. Sinclair Knight and Mertz undertook the air dispersion modelling and their report might provide the justification for the approach (not reviewed by BenchMark Toxicology Services).

It is not readily clear what is meant by the sentence: *NOx emissions comprise oxides of nitrogen (NO) and nitrogen dioxide NO_2.* Presumably the phrase *oxides of nitrogen* is meant to be nitrogen oxide. In addition, it is not readily clear whether the estimated NO_2 or total NOx ground-level concentration was used in equation 1.

4.2.5. Section 3.4.1 - Averaging period adjustment

The air guideline values for carbon monoxide, acrolein and styrene are for 8-h, 30 min and 1 week averages, respectively. These averaging periods do not correspond to the 1-h and 24-h averaging periods predicted in the modelling. Consequently, the predicted ground-level concentrations were adjusted to the appropriate averaging period to allow comparison with the reference guideline value. The Power Law of Hanna, Briggs and Hosker (equation 2) was used to make the conversion (this source requires a reference).

BenchMark Toxicology Services has not evaluated the appropriateness of using the Power law for adjusting averaging periods, as the reference could not be sourced readily.

4.3. Section 4. - Toxicity assessment

The approach described is consistent with national and international approaches to assessing toxicity.

For risk assessment purposes two models are used in deriving toxicity values: threshold and non-threshold models.

In this review, the term *toxicity value* is used generically to refer to estimates of Tolerable Intakes (TI) based on the threshold model named variably by different jurisdictions as Tolerable Daily Intakes (TDI), Acceptable Daily Intake (ADI), Tolerable Concentration (TC), Reference Dose (RfD), Reference Concentration (RfC), Maximal Risk Levels (MRL), and outcomes of probabilistic models (non-threshold model) such as unit risk (UR, the risk associated with exposure to a unit concentration such 1 $\mu g/m^3$), risk specific dose (RSD, risk associated with a particular dose), slope factors (the gradient – slope of the dose-response curve) or Virtually Safe Dose (VSD, the dose at an acceptable or negligible level of risk).

The underlying assumption in the threshold model is that there is a threshold dose, below which no adverse or toxic effect occurs. Toxicity values are expressed as the dose or concentration that is unlikely to cause any appreciable adverse health effects over a lifetime. This model is used in deriving toxicity values for substances that do not have carcinogenic properties or for non-cancer adverse effects for substances that do as well as for some substances that have carcinogenic properties.

The underlying assumption in the non-threshold model is that there is a finite probability of an adverse effect no matter how low the dose. Toxicity values are expressed as risk probabilities (eg, UR, slope factor) from which a dose or concentration (RSD, VSD) that poses a negligible or acceptable risk (eg, one in one million risk) can be determined. This model is used in deriving toxicity values for substances that have carcinogenic properties, particularly those that also exhibit genotoxic properties (damage to genetic material).

The outcomes of both models are toxicity values, which in essence are estimates of a safe or acceptable dose of the substance based on the knowledge available at the time. Both models are based on sets of assumptions, which are intentionally conservative to ensure overestimation of the likely risks posed by the substance; hence to be protective of human health. The non-threshold model generally gives more conservative estimates of risk than the threshold model.

The toxicity values so derived are then used to calculate guideline values or criteria in a particular medium (air, water, soil, food), which are the basis for regulating the levels of contaminants in the medium.

The document by Environ is not entirely clear on the distinction between a guideline value or criterion (referred to as health protective guideline) and a toxicity value (the dose or concentration to which one can be exposed for a defined period without any appreciable adverse health effects or a negligible risk). The derivation of guidelines is in the main based on toxicity values.

In the case of air quality, the guideline concentration may be the same as the inhalational toxicity value. However, this is not necessarily the case for all chemicals as the derivation of guidelines may take into account factors in addition to the toxicity value (eg, limitations of analytical techniques) or may be derived using endpoints other than traditional toxicity values; or take other factors into consideration, eg, criteria pollutants in the NEPM on ambient air quality (NEPC, 1998)[2], in which cost/benefit is also taken into account in deriving the criteria.

Environ sources air quality guidelines from a number of jurisdictions to assess whether or not the estimated levels of emission components pose a health risk. The sources are generally consistent with the hierarchy for sourcing toxicity values recommended in the national health risk assessment guidelines published by the National Environmental Health Council (enHealth, 2002)[3].

In cases where no air quality guidelines or inhalational toxicity values were available, tolerable concentrations (or health protective guidelines) in air have been derived from oral toxicity values. The method used for converting oral toxicity values to inhalational toxicity values is consistent with the US EPA default method for such conversions. However, additional analysis of the derivation of the oral toxicity factors and any known data on inhalational exposure (including relative bioavailability between the oral and inhalational route) would facilitate the understanding of the extrapolation and acceptance of the derived inhalational toxicity values. The chemicals for which this conversion was used are identified in Table A3 (Environ Document).

In cases where a major national or international jurisdiction has not established toxicity values or ambient air guideline for a substance for any route of exposure, the values have been sourced from other credible sources, such as state jurisdictions in the US.

The use of the PM_{10} NEPM standard of 50 µg/m^3 for TSP emitted from the Liquor Burner is supported. The PM_{10} fraction is likely to be less than the TSP measured (albeit only marginally in the case of emissions from the Liquor Burner), hence the risk estimates would be protective of human health.

[2] National Environment Protection Council (1998). National Protection Measure on Ambient Air Quality. http://www.ephc.gov.au/pdf/Air_Quality_NEPM/air_nepm0698.pdf

[3] enHealth (Environmental Health Council) (2002). Environmental Health Risk Assessment. Guidelines for assessing human health risks from environmental hazards. Commonwealth of Australia, 2002

4.3.1. Section 4.1 - Non-carcinogenic effects

The description of the methodology used in deriving toxicity values for non-carcinogenic effects is adequate.

It is not clear what the following statement *…a series of uncertainty factors representing experimental vs environmental exposure duration* means.

Toxicity values are derived using the No Observable Adverse Effect Level (NOAEL) or the Lowest Observable Adverse Effect Level (LOAEL) in experimental studies and a number of substance specific factors derived to account for inter and intra-species differences (species and human individual sensitivities), study duration and quality of the database (confidence in the experimental or epidemiological results used), severity of the effect, using a LOAEL when a NOAEL is not determined, and a substance specific factor for any other concerns that might arise.

Both short term (acute) and long term (chronic) exposure health protective guideline values are considered. These are intended to protect against a single or short duration, high emission event that may cause immediate or delayed adverse effects and on persistent or long duration emission events that may cause adverse effects after an extended period of exposure. Chronic toxicity values, from which chronic exposure guidelines are derived, are based on the assumption that exposure will be over a period of 70 years (a lifetime).

4.3.2. Section 4.2 - Carcinogenic effects

Using the WHO general rule for deriving toxicity values and guidelines for carcinogenic effects is appropriate. This is based on the International Agency for Research on Cancer (IARC) classification for substances with carcinogenic properties. The classification is based on the weight and strength of evidence (from experimental animal studies, epidemiology and other data) that the substance poses a carcinogenic risk to humans.

Consequently, air guideline values for arsenic and benzene (classified as known human carcinogens by IARC – Group I) are based on probabilistic (non-threshold) toxicity values. Whilst formaldehyde is classified as a probable human carcinogen by IARC (Group 2A), the air guideline value (same as the toxicity value) for irritancy is considered adequately protective of its carcinogenic properties because irritancy and tissue damage (cell death) precede the development of nasopharyngeal cancers. That is, cancer is a consequence of the tissue damage caused by formaldehyde. BenchMark Toxicology Services supports this approach. The approach is consistent with the approach by WHO and the Environmental Protection and Heritage Protection Council (EPHC) in deriving ambient air guidelines for formaldehyde.

It should be pointed out that NEHPC uses an additional factor of 2 to convert the 30 min health guideline of 0.08 ppm (100 µg/m^3) to the 24-h average monitoring investigation level of 0.04 ppm (50 µg/m^3).

Notwithstanding, Environ uses the inhalational MRL (toxicity value, exposure over a lifetime) derived by the US Agency for Toxic Substances and Disease Control (ATSDR) of 10.7 µg/m^3. This is about 10 times lower than the WHO and NEPM ambient air level (30 min average) for formaldehyde and about 4 times lower than the Air Toxics NEPM 24-h average for formaldehyde. Consequently, an additional level of safety and conservatism is introduced. Specifically, irritation is concentration dependent requiring exceedance of the threshold for the irritant effects to occur. Using a health protective guideline at least 4-times lower than recommended criteria is more than adequate protection against irritation.

Environ refers to 16.9 µg/m^3 as the 24-h average value for formaldehyde from the draft NEPM (page 13), which has bee superseded. However, the appropriate value of 0.04 ppm for formaldehyde as 24 h average in the NEPM is used for assessment of acute exposure.

The choice of 2 mg/m^3 and 0.05 mg/m^3 for the acute and chronic guideline values, respectively, for acetaldehyde is appropriate based on the same reasoning as for formaldehyde.

Fluoranthene and phenanthrene are two polycyclic aromatic hydrocarbons (PAH) detected in the emissions from the Liquor Burner. Both are classified as Group 3 carcinogens by IARC (*non-classifiable as to its potential for carcinogenicity in humans*), based on insufficient evidence being available – a criterion for classification in Group 3. The US EPA also used an equivalent classification.

Generally, toxicity assessment of substances assigned in Group 3 is based on the threshold model, even though their carcinogenic potential cannot be discounted. Therefore the guideline value would be derived using a TC of RfC, rather than the cancer unit risk factors.

If a chemical is classified as Group 3 carcinogen by IARC and a toxicity value for non-cancer effects is established, the toxicity value should be used in the risk assessment. This is the approach taken in Australia.

The Railroad Commission of Texas (RRC, 2001)[4] has published oral RfD values of 0.03 and 0.04 mg/kg/day (105 and 140 µg/m^3) for phenanthrene and fluoranthene, respectively. The latter is the same as the oral and inhalational RfD for fluoranthene published by the US EPA (2002)[5]. The US EPA has set an ambient air Provisional Remediation Goal (PRG) of 150 µg/m^3 for non-cancer effects based on the RfD.

The PRG is a screening value. If the concentration in air is lower than the PRG for the substance, no additional investigation is required, ie, the air does not pose a health risk and is not considered contaminated. It is derived using US EPA toxicity values (RfD, RfC or unit risk factors). As they are screening levels, they are relatively conservative.

Environ assesses fluoranthene using the cancer unit risk factor of 8.7-87 x 10^{-5} (µg/m^3)$^{-1}$ derived by WHO using the cancer unit risk factors for benzo(a)pyrene (8.7 x 10^{-2} (µg/m^3)$^{-1}$) and a potency factor for fluoranthene (TEF) of 0.001-0.01 relative to benzo(a)pyrene (ie, fluoranthene is 100-1000 times less potent than benzo(a)pyrene). This approach is similar to that used for dioxins and furans (see Section 4.2.1).

Benzo(a)pyrene is the most studied of the PAH congeners and is also a very potent animal carcinogen. Hence, it is used as a reference compound for other PAH compounds in assessing their relative potencies.

BenchMark Toxicology considers that it would have been appropriate to use the ambient air PRG of 150 µg/m^3 for non-cancer effects developed by the US

[4] Railroad Commission of Texas (RRC) (2001). Guidelines for Spills, Releases, and Risk Based Decision Making for Oil Field Related Sites in Texas. http://www.rrc.state.tx.us/divisions/og/riskguidelines/ (Table 4-4)

[5] US EPA (2002). Preliminary Remediation Goals On-Line Database. US Environmental Protection Agency Region 9, Sacramento, California. http://www.epa.gov/region09/waste/sfund/prg/index.htm

EPA in the screening assessment. Although inconsistent with Australian practices, the approach taken by environ is more conservative.

4.3.3. Section 4.3 - Chemicals lacking health protective guidelines

Twenty one of the chemicals identified in the Liquor Burner emissions have no toxicity values or air quality guidelines that have been published by national or international jurisdictions. In these cases, Environ sources guideline values – the Effects Screening Levels (ESL) - for ten of the chemicals from the Texas Commission on Environmental Quality (TCEQ). BenchMark Toxicology Services has been unable to verify the basis for the derivation of the ESL from the information on the TCEQ website, although they appear to be based on US EPA toxicity values.

A cursory analysis by BenchMark Toxicology Services for 9 of the chemicals identified in the emissions from the Liquor Burner indicates that the ESL values are comparable (generally within one order of magnitude) with the Provisional Remediation Goals (PRG) for air quality published by the US EPA Region 9 (US EPA, 2002)[6].

No reference toxicity values or air quality guidelines were identified for tartaric acid, malic acid, thiophene, n-butyl benzene, 1H-indole, n-propyl benzene, acenaphthylene, and 9H-Fluoren-9-one.

BenchMark Toxicology Services was able to identify the following toxicity values and information that might aid the screening assessment.

Tartaric acid and malic acid are used as food additives. The Joint FAO/WHO Expert Committee on Food Additives (JECFA, 1996)[7] established an ADI for tartaric acid, L(+) of 30 mg/kg/day. Applying the equation for converting an oral toxicity value to an inhalational toxicity value, this equates to an inhalational TC of 105 mg/m^3. JECFA (1999)[8] has not set and ADI for malic acid stating that there is *No safety concern at current levels of intake when used as a flavouring agent.* This suggests that the substance is of low toxicity, hence might not contribute significantly to the HI for the emissions.

The US EPA (2002)[9] has published ambient air PRG values for n-butyl benzene and n-propyl benzene each of 150 µg/m^3.

The Railroad Commission of Texas (RRC, 2001)[10] has published an oral RfD for acenaphthylene of 0.6 mg/kg/day. The derivation of the RfD or its source could not be identified. Using the default equation for converting oral RfD to inhalational RfC, an ambient air RfC of 2.1 mg/m^3 is obtained.

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[6] US EPA (2002). Preliminary Remediation Goals On-Line Database. US Environmental Protection Agency Region 9, Sacramento, California. http://www.epa.gov/region09/waste/sfund/prg/index.htm

[7] The Joint FAO/WHO Expert Committee on Food Additives (JECFA) (1996). Summary of Evaluations Performed by the joint FAO/WHO Expert Committee on Food Additives (JECFA). ILSI Press

[8] The Joint FAO/WHO Expert Committee on Food Additives (JECFA) (1999). Summary of Evaluations Performed by the joint FAO/WHO Expert Committee on Food Additives (JECFA). http://www.inchem.org/documents/jecfa/jeceval/jec_1136.htm

[9] US EPA (2002). Ibid

[10] Railroad Commission of Texas (RRC) (2001). Guidelines for Spills, Releases, and Risk Based Decision Making for Oil Field Related Sites in Texas. http://www.rrc.state.tx.us/divisions/og/riskguidelines/ (Table 4-4)

4.4. Section 5. - Risk characterisation

The potential for non-carcinogenic effects of the emissions as a whole is assessed by calculating the Hazard Quotient (HQ) for each component at each predicted ground level concentration (for acute effects, 1-h averages and 24-h averages, and chronic effects, annual averages), and the resulting HQ values summed to give an overall Hazard Index (HI) for the emissions.

For carcinogenic effects, the risks for each chemical at the predicted ground level concentration (annual averages) are added for all chemicals with carcinogenic properties assessed to give an overall incremental cancer risk over a lifetime.

Chemicals assessed on effects other than carcinogenic effects

Environ determines the HI by summing the HQ values for the individual chemicals identified in the emissions with identified toxicity values. The HQ compares the calculated exposure of each individual substance to its toxicity value (tolerable concentration) or health protective guideline. This is the usual approach taken to assess whether or not an environmental concentration is likely to pose a health risk.

The HI is calculated for both acute exposure (using the predicted 1-h and 24-h average concentrations, maximum and 99.5th percentile ground-level concentrations) and for chronic exposure (using the annual averages).

The 1-h averages are assumed (predicted) to occur once a year. However, the estimates of the risk apply equally to any isolated event through the year, as the acute effects are generally reversible and non-cumulative (eg, irritant effects). If maximum release occurs for a number of consecutive days or intermittently over short periods, they will be reflected in the 24-h averages.

It is generally agreed that a chemical present at a concentration that results in a HQ less than one does not pose a health risk. Similarly, if the HI for a group of substances is less than one, then the group of substances does not pose a heath risk. The HQ and HI are a measure of the margin of safety, which is reflected in the size of the HI or the HQ - the smaller the HQ or HI, the larger the margin of safety.

If the HQ or HI exceeds one, it does not necessarily mean that the chemical or group of chemicals poses a health risk. In these cases, it is necessary to review the scientific data on which the reference toxicity value is based to assess the likelihood of an adverse effect. For example, the reference toxicity value may have been based on a serious, debilitating and irreversible adverse effect with a steep dose response curve (marked increases in severity or incidence with small increases in dose), in which case only relatively small exceedances may be tolerable. On the other hand the reference toxicity value may have been based on a relatively trivial and reversible effect or the dose response curve is flat (small increases in severity or incidences of adverse health effects with large increases in dose), in which cases higher exceedances may be tolerated.

In the end the decision whether or not exceedances are likely to lead to adverse health effects is one of expert judgement based on the weight and strength of the scientific evidence. Notwithstanding, it is good practice to take appropriate steps to reduce levels that exceed health guideline values or criteria.

The interpretation of exceedances provided by Environ is reasonable, given the conservative nature of the approach taken for the screening assessment and the intentional conservatism (safety margin) inherent in the derivation of the reference toxicity values and the health protective guideline values.

Figure 2 to which Environ refers in the second last paragraph on page 16 could not be found in the document.

Substances considered to pose a carcinogenic risk.

Environ estimates the incremental risk associated with the predicted ground-level concentration for each substance and assesses total risk of cancer by adding the risks for each substance and comparing with a reference level of risk. The reference level of risk used is one in one million (10^{-6} risk), based on the US EPA *de minimis* or negligible risk level.

This is considered adequate and conservative. To put this risk level in context, a table outlining a number of everyday activities associated with a risk of one in a million is provided in Appendix I, as requested by the SRG.

4.4.1. Sections 5.2 to 5.4 – Results of the screening assessment

Acute and chronic non-carcinogenic effects and carcinogenic effects

The acute and chronic HI values for historical emissions were less than one. The highest HI calculated was 0.763 for chronic effects at the closest residence to the source (17 Lionel Street, Naval Base - receptor 1).

Consequently, exposure to the predicted ground-level concentrations for chemicals identified in the emissions from the Liquor Burner are highly unlikely to have caused any chronic adverse effects in the past in the most exposed target group.

Excluding fluoranthene, the highest calculated combined incremental carcinogenic risk from exposure to benzene and arsenic is 1.18 in 1,000,000 for receptor 1; this is considered a negligible risk. Benzene is the main contributor to the risk (1.14 in 1,000,000).

For fluoranthene, the ATSDR (1985) [11] has developed an inhalational MRL for intermediate exposure duration (15-364 days) of 0.4 mg/kg/day (equivalent to a concentration in air of 1400 µg/m^3). The US EPA (2002)[12] has derived a chronic inhalational toxicity value (RfD) of 0.04 mg/kg/day and an ambient air PRG of 150 µg/m^3. The highest predicted ground-level concentration for fluoranthene for receptor 1 is around 0.1 µg/m^3 (1-h average, monitoring results), which is around 14,000 lower that the intermediate MRL set by ATSDR and 1500 times below the US EPA ambient air PRG (HQ = 0.0007). Based on these comparisons, fluoranthene would contribute only slightly and insignificantly to the HI.

The predicted ground-level concentrations of the chemicals in the emissions when the Liquor Burner is upgraded are much lower than in the past. The resulting calculated HI values are also lower, (eg, 7-9 times and 99 times lower for acute and chronic effects, respectively, and the calculated carcinogenic risk for arsenic and benzene combined is about 3 in one hundred million in the case of receptor 1.

[11] ATSDR (1985). Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), August 1995 http://www.atsdr.cdc.gov/toxprofiles/tp69.html (p 327).

[12] US EPA 2002. Preliminary Remediation Goals On-Line Database. US Environmental Protection Agency Region 9, Sacramento, California. http://www.epa.gov/region09/waste/sfund/prg/index.htm

Arsenic was the only chemical for which multi pathway exposure was identified from the OEHHA list (OEHHA, 2000)[13]. However, Environ considers only inhalational exposure for arsenic. This is justifiable because of the low levels in air.

The highest risk from arsenic exposure in air calculated for receptor 1 was 4.13×10^{-8}, about 25 times lower that the reference negligible risk of 10^{-6}. In order to equal the reference risk level, the amount of arsenic taken orally or dermally from deposited airborne arsenic would need to be 25 times more than the amount inhaled.

BenchMark Toxicology Services considers that the predicted concentrations of arsenic in air are insufficient to increase the environmental load from deposition of emissions to soil, water and crops to achieve such a level of oral or dermal exposure. Therefore, oral and dermal exposures are not likely to contribute significantly to the risks.

4.4.2. Section 5.5 - Irritancy

The conclusion that ground-level concentrations that are protective of acute and chronic health effects are also protective of irritant effects is justified and supported.

4.4.3. Section 5.6 - Chemicals lacking health protective guidelines

The use of short-term and long-term Effects Screening Levels (ESL) from the Texas Commission on Environmental Quality (TCEQ) is appropriate, since no other nationally published values are available.

Comparing the predicted ground-level concentrations with the ESL indicate that the past and future emissions from the Liquor Burner are well below the ESL values, except for phenanthrene, the maximum 1-h average level for which at receptor 6 was 0.85 µg/m^3. If the short term ESL (1-h average) of 0.5 µg/m^3 is used as the air guideline value, the HQ is 1.7, ie, an exceedance of the HQ by 70%. The 95.5th percentile 1-h concentration for this receptor was 0.12 µg/m^3, which yields a HQ of 0.24. The maximum and 95.5th percentile 1-h average concentrations for phenanthrene at receptor 1 were 0.52 and 0.24 µg/m^3, respectively, which yield HQ values of about 1 and 0.5, respectively.

The State of Vermont in the US has an annual-average ambient air limit for phenanthrene of 130 µg/m^3 (ATSDR, 1985)[14]. The Railroad Commission of Texas (RRC, 2001)[15] has published oral RfD values for phenanthrene of 0.03 mg/kg/day (RfC = 105 µg/m^3). Thus the ESL values used by TCEQ appear to be much more conservative than other values used.

Overall, these observations would suggest that the amounts of phenanthrene in past emissions from the liquor burner have not impacted adversely on the health of residents.

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[13] Office of Environmental Health Hazard Assessment (OEHHA)(2000). Air Toxics "Hot Spots" Program Risk Assessment Guidelines Part IV Exposure Assessment and Stochastic Analysis Technical Support Document. October 27, 2000. http://www.oehha.ca.gov/air/hot_spots/finalStoc.html

[14] ATSDR (1985). Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs), August 1995 http://www.atsdr.cdc.gov/toxprofiles/tp69.html (p 343).

[15] Railroad Commission of Texas (RRC) (2001). Guidelines for Spills, Releases, and Risk Based Decision Making for Oil Field Related Sites in Texas. http://www.rrc.state.tx.us/divisions/og/riskguidelines/ (Table 4-4)

The predicted ground-level concentrations for emissions from the upgraded Liquor Burner are much lower than recorded in the past. Hence expected to be well within the ESL values.

4.4.4. Section 5.7 - Uncertainties

The uncertainties in the various steps of the assessment have been identified and a number of recommendations made to address them where it is feasible to do so. These include further work to identify and characterise the emissions' components that were not clearly identified and quantified previously. Achieving this will depend on the levels of chemicals in the emissions and the availability of appropriate analytical techniques to identify and quantify them. This applies to the unidentified VOC compounds and the dioxin and furans. BenchMark Toxicology Services supports these recommendations. Further, once identified and quantified, an assessment of health risk can be undertaken if scientific data are available.

The other uncertainties identified are inherent in monitoring, analytical techniques and risk assessment methodologies used; hence common to many other environmental issues in which risk assessment is used. It is unlikely that these could be addressed in the short to medium term. However, identifying and considering the uncertainties is important in interpreting the outcomes of the screening assessment.

There were 11 chemicals identified in the emissions for which no guidelines or toxicity values could be found because of the lack or scarcity of scientific data on their toxicological properties. BenchMark Toxicology Services has identified toxicity values or guidelines for 4 of these and for malic acid (a food additive) a toxicity value has not been set because there is no concern at the level in which it is used as a food additive.

Data on the remaining chemicals is unlikely to become available. Generally speaking, data for environmental chemicals are developed based on priorities assigned according to their importance or the level of concern because of potential output volume and toxicity (known, suspected or inferred from similarity with other chemicals) because of the time and cost involved. In addition, many environmental chemicals don't have an "owner" as such who might sponsor the studies.

Given the very low HI values and carcinogenic risks predicted for the upgraded Liquor Burner for the emission chemicals with known reference toxicity values, it is highly unlikely that the chemicals for which no or few data exist would contribute to any significant degree to the HI or the carcinogenic risks calculated in the screening assessment by Environ.

Environ has taken the approach of summing the HQ and carcinogenic risk to asses the likely impact of the group of substances in the emissions. This is consistent with the default approach usually taken to assess groups of chemicals.

On one hand, the approach is conservative because it adds the risks of chemicals with different target organs and different mechanisms of action, ie, the effects of the chemicals are mutually excusive - not interdependent - hence not additive. On the other hand, the approach does not take account of synergistic, potentiating or antagonistic interactions between the chemicals. These interactions are more difficult to define and to quantify, hence to consider in risk assessment.

It is extremely difficult, if not impossible, to study experimentally the effects of mixtures beyond simple mixtures of a few chemicals because of the number of

possible permutations and combinations that need to be investigated. It is also extremely difficult to predict exposure to the different combinations and concentrations in air (variations with time and three dimensionally in the medium). Hence, the most common approach of adding the effects and risks of the individual chemicals is the best approximation to the assessment of mixtures in practical terms.

4.5. Appendix A

The carcinogenic mechanisms of formaldehyde and acetaldehyde are briefly reviewed. The case is made that because the induction of cancer by these chemicals is preceded by irritation and cell death of the nasopharyngeal membranes, protection against irritation will also be protective against the development of cancer. This is consistent with current scientific consensus on the mechanism of action of these substances and approaches to regulation.

It is unclear what is meant by *biologically "motivated" case-specific model* in last paragraph on page A1 – should it be *biologically "based"?*

The tolerable concentration (TC) for acetaldehyde of 300 g/m^3 given in the last paragraph on page A2 should read 300 µg/m^3.

5. Conclusions

The screening assessment by Environ is consistent with national and international practices. The approach is conservative, with the calculated potential risks likely to be overestimated rather than underestimated. Importantly, the potential adverse health effects of the emissions as a whole are assessed as well as those of the individual components of the mixture.

Air dispersion modelling, based on historical stack emissions and predicted stack emissions from upgraded emission controls in the future, is used to predict ground level concentrations at 13 identified receptor locations within the industrial area and the buffer zone. Appropriate averaging times are used to predict ground level concentrations for acute and chronic screening assessment.

The outcomes indicate that the historical emissions are unlikely to have affected adversely the health of the identified receptors and the likelihood is even lower if the Liquor Burner emissions comply with predicted emissions in future.

Adequate monitoring of emissions and analytical techniques to identify and quantify the individual components of the emissions should ensure compliance with the set limits and verify the predicted emissions.

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21 July 2004

Appendix I
Lawrence Pringle (1989). Living in a Risky World. Marrow Junior Books, New York. Page 27.

Risks that Increase Chance of Death by One in a Million

Smoking 1.4 cigarettes	Cancer, heart disease
Drinking ½ liter of wine	Cirrhosis of the liver
Spending 1 hour in a coal mine	Black lung disease
Spending 3 hours in a coal mine	Accident
Living 2 days in New York or Boston	Air pollution
Traveling 6 minutes by canoe	Accident
Traveling 10 miles by bicycle	Accident
Traveling 30 miles by car	Accident
Flying 1,000 miles by jet	Accident
Flying 6,000 miles by jet	Cancer caused by cosmic radiation
Living 2 months in Denver on vacation from New York	Cancer caused by cosmic radiation
Living 2 months in average stone or brick building	Cancer caused by natural radioactivity
One chest X ray taken in a good hospital	Cancer caused by radiation
Living 2 months with a cigarette smoker	Cancer, heart disease
Eating 40 tablespoons of peanut butter	Liver cancer caused by aflatoxin
Drinking Miami drinking water for 1 year	Cancer caused by chloroform
Drinking 30 12-oz. cans of diet soda	Cancer caused by saccharin
Living 5 years at site boundary of a typical nuclear power plant in the open	Cancer caused by radiation
Living 150 years within 20 miles of a nuclear power plant	Cancer caused by radiation
Eating 100 charcoal-broiled steaks	Cancer from benzopyrene

Richard Wilson, an advocate of nuclear power, used statistical estimates of harm from different activities (activity on left, hazard on right) to devise a table that stressed the low risk from safely operated nuclear reactors.