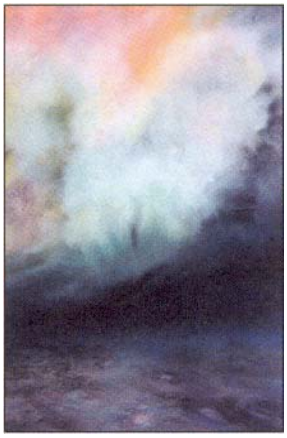

Katestone Environmental

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**REPORT FROM KATESTONE ENVIRONMENTAL
TO ALCOA WORLD ALUMINA AUSTRALIA**

DESKTOP REVIEW OF AIR DISPERSION MODELLING OF DIFFUSE AREA SOURCE EMISSIONS FOR THE WAGERUP REFINERY EXPANSION PREPARED BY AIR ASSESSMENTS

May 2005

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1. Scope of Expert Review

Katestone Environmental has been commissioned by Alcoa to supply independent expert advice, in the form of a desktop review of project studies related to Alcoa's Wagerup 3 refinery expansion, in order to assist the Emissions and Health Working Group. In addition the desktop review may be used by Alcoa to provide additional information to regulatory agencies and the public.

The terms of reference for the desktop review are as follows:

- Comment on the completeness of the information presented;
- Comment on the suitability of the measurements performed for assessing the project impacts;
- Comment on the correctness of the analysis performed on the data presented;
- Comment on the suitability of methodology used to make predictions.
- Comments in relation to conclusions reached in the report being reviewed.

Generally this means that the work presented in the various reports will be reviewed to determine if the information is sufficient, whether the methodologies used are adequate in determining the impacts on air quality due to the refinery and whether the conclusions drawn from the work are appropriate. This review is not intended as an audit of the provided input information (eg. the completeness of the emissions inventory), an evaluation of the process or technology, or an assessment of the air quality impacts of the project; these tasks are for the governing environmental authorities. This review focuses on the modelling methodology and the conclusions drawn from it.

The project report to be reviewed in this report is:

"Air Dispersion Modelling of Fugitive Emissions Wagerup Refinery" Prepared for Alcoa World Alumina Australia by Air Assessments, April 2005. – Draft report

Other reports and information that have been referred to in the Air Assessment report have been supplied by Alcoa to help clarify the information in the above reports and understanding of plant operations. Where appropriate, additional literature not cited in the reports to Alcoa has been sought to help clarify some of the more complex technical issues. Air Assessments has also been very co-operative in explaining their detailed calculations and in providing spreadsheets and Fortran code developed as part of this project. A list of reports used in this assessment is included in the references.

2. Introduction

Alcoa has made a public commitment to achieving certain air quality objectives for the expansion project. They have committed to no increase in emission impacts (short-term and long-term), odour, dust and noise impacts on residents and to meet world-class health risk criteria. The emphasis is therefore on the change in impacts that is likely to occur as a result of the expansion, rather than a simple comparison with regulatory guidelines for health or amenity.

The refinery complex has a wide variety of emission sources of dust, odour or VOCs:

(i) Elevated refinery stacks;
(ii) Low refinery stacks;
(iii) Fugitive emissions at the refinery; and
(iv) Fugitive emissions from the RDA and cooling pond areas.

Tall stack emissions for the calciner multiflue, calciner 4, boiler and GT stacks have a high enough temperature to achieve a plume rise of the order of the stack height (see CSIRO Phase 3 report) and hence give rise to very intermittent ground-level impacts (especially as these plumes are not affected by building wakes to any degree). Intermittency refers to the infrequent grounding of the plume that may only impact on a very small area, i.e. impacts can vary significantly over a small area and can also change significantly over a small time period (typically less than 1 hour average). It is common to use peak-to-mean concentration ratios to estimate the short-term impacts from hourly averages generated by the dispersion modelling; for these sources, peak-to-mean ratios would be high.

Low refinery stack sources (such as the cooling towers and various types of vent sources) are generally less than 20 m high and are much less buoyant than the tall stack plumes. They are likely to be wake-affected and to give rise to a less intermittent plume impact and at shorter downwind distances compared to the tall stack plumes. This means that the plumes are generally wider, of lower concentrations and there are smaller differences between the peaks and lows in concentration across the plume. The peak-to-mean ratios for less intermittent plumes are smaller.

Fugitive emissions from the refinery are increasingly unlikely as the emission controls improve but may include near-surface releases of various buoyancies but again giving low intermittency plumes.

The diffuse emission rates from the RDA and cooling pond areas are likely to be strongly dependent on current meteorological conditions and the recent climatic history (e.g. hot and dry conditions following days of no rainfall will dry out surfaces and can lead to elevated dust emissions). Key variables are likely to be near-surface windspeeds (for dust and odour/VOC emissions from liquid or very moist surfaces), temperature differences between near-surface air and the surface temperature of the underlying soil or water surface, solar radiation (for odour/VOCs) and relative humidity (for some compounds or hygroscopic dusts).

The cooling pond is used to cool the hot tailings from the process and has a temperature in the range 27-55ºC. The pond is rectangular for which the buoyant plume lift-off effects will vary with wind direction. Some other RDA sources are also hotter than ambient air and hence may give rise to buoyant plumes detaching from the surface in light winds. If buoyant plume lift-off is significant, the plume impacts will become more similar to those from a stack source (e.g. intermittent grounding of the plume resulting in higher concentrations over a short time period) rather than a typical area source plume that is more consistent with concentrations over a short time period (e.g. 3 minutes) being similar to longer time periods (e.g. 1 hour).

The above summary suggests that the physical processes that give rise to fugitive emissions are quite complex and challenging to characterise within a mathematical modelling system. More detailed site-specific monitoring data will be required to confirm the estimates used in this study. Whilst the various projects conducted for Alcoa are extensive and use very novel techniques, their extent (spatially and seasonally) is currently too sparse to give a good description of emission variability. It is not surprising that different techniques quite often give disparate or conflicting results. For some emissions, the uncertainties may be an order of magnitude; it is therefore necessary to judge whether the main impacts are sensitive to the various types of uncertainty (e.g. measurement errors or biases, emission variability, meteorological and spatio-temporal variability, model prescription errors and the uncertainties in tying up concentration measures with community response). For the current analysis, these uncertainties are less important if differences in impact are the main focus as long as:

- The main sources (from an impact viewpoint) are well and consistently described and the differing control efficiencies can be substantiated by site measurements or accepted literature;

- Any new emission sources added in the expansion have similar characteristics/dependencies as existing sources or can be reliably described in terms of emission rate and characteristics; and

- There are no major changes in the location of emission sources with respect to the most affected receptors.

In the time available for the current review, it has not been possible to check all the emission characteristics and dependencies from the available field data. Wherever possible, the modelling approach to the main sources has been evaluated, with most attention given to those sources that are likely to dominate impacts at the most affected receptors.

The Air Assessment report reviewed here deals only with the diffuse sources of the RDA; the refinery sources are treated in the CSIRO reports and the concentration predictions have been combined with the RDA results by Environ on an hour-by-hour basis at each receptor, using the same TAPM windfields as inputs. This is a reasonable procedure for hourly or longer averaging periods. For very short-term concentrations for odour assessments, some account of the differing peak-to-mean ratios should be included, not just for tall stack sources like the main multiflue odour source but for any near-surface sources that achieve lift-off to any marked degree, such as the cooling pond.

Finally, we note that the modelling of fugitive sources is complex and often difficult; indeed the CFD modelling of the RDA/cooling pond sources is very appropriate and novel. We know of no other refineries where such a detailed modelling exercise has been attempted. We note that this and other studies such as the field odour measurement campaign produced results at the end of the project that gave little time to Air Assessments for as full a consideration/critique as would normally be necessary in any complex scientific investigation. The work program overall is very commendable; the lack of evaluation time by the consultants and reviewers is unfortunate and risks some important issues in the detailed modelling being overlooked. Furthermore, the importance of many issues can only be properly judged once the impacts of all sources combined are compared at given receptors. We did not have the detailed files or time to undertake such comparisons.

3. Background

3.1 Community impacts

At Wagerup there is a considerable history of complaints about odours, fumes, dust and health impacts. The complaint statistics have been collated by month and time of day by various reviewers and their association with relevant site meteorology and refining operations has been investigated. It appears that the main odour complaints have occurred during the daytime period especially in the mid-morning. These complaints have been attributed to the refinery sources but have reduced considerably in frequency of occurrence in the last year as a result of the major odour reduction programme. Whilst complaints have been registered from residents in all three nearby townships, the most frequent complaints have originated from the town of Yarloop, to the south of the refinery, and have occurred in light to moderate north-westerly to north-easterly winds.

The odour reduction programme undertaken by Alcoa has achieved dramatic reduction of volatile organic emissions from the digestion system and other non-stack sources and a better quantification of the nature of the emitted odour. This ongoing programme and the difficulties in undertaking standardised and repeatable odour measurements in a dynamic environment have resulted in some uncertainty in the odour emission rates and different distributions of the odour emissions between various sources. These odour aspects are important as the major community concerns have been about odours and their association with temporary health ailments.

Dust complaints have also been received and are thought to be mainly due to windborne dust from the RDAs located to the west of the refinery complex.

One of the problems with focusing on differences between existing odour impacts and future impacts (after some change in activity), is that the dominant existing odour sources may mask the effects of other less dominant but important odours. Similar effects are also noticed with other environmental stressors such as noise. The successful mitigation of a dominant odour source may make the more secondary sources more noticeable. Odour amenity assessments need to include the consideration of time of exposure, hedonic tone and community sensitivities, in a similar fashion to the requirements to consider noise frequencies, impulsiveness, disturbance to sleep and susceptibility to noise of some groups within a broader community.

When dealing with community impacts, it is therefore wise to undertake multiple assessments that deal with compliance both with ambient guidelines, the various risk measures of modern health risk assessment methodologies and a detailed consideration of both odour annoyance guidelines and the potential for odour-induced health impacts. The latter aspects are much more difficult to quantify but could still be kept in mind, especially when dealing with comparative impacts of current and expanded operations.

4. Review of reports

4.1 General comments

As the techniques for assessing both the current emissions and proposed expansion are the same, the relative difference in impacts is the key outcome. From a brief inspection of the HRA outcomes it is evident that dust is a major contributor to the overall health risk in the region and the VOC emissions and predicted impacts from the RDA diffuse sources are considerably lower than those due to the refinery sources for current operations. Odour from the diffuse sources is less significant for the current operations; however, due to the considerable reduction in odour emissions from the refinery sources, odours from the RDA will be more important after the expansion. Therefore this review has concentrated on dust and odour impacts and the associated modelling techniques.

The Air Assessments report is very complex and at times difficult to follow. This review has attempted to understand all the input parameters and assumptions in the modelling and to assess exactly what options were used in the HRA modelling. At times this was not possible due to limited information presented in the report. During the review process Dr Owen Pitts, the author of the Air Assessments report, was contacted to clarify some points raised by the reviewers and to help understand some of the methodologies and assumptions used in the report. Additional information was supplied to the reviewers, particularly on dust emission rates.

This review has been separated into three distinct sections to make understanding of the information easier for the reader. The review has been separated into dust, odour and VOC and each section will deal with the pollutants from emissions estimation, to modelling and impacts. General comments on the appropriateness of the dispersion model setup and meteorology will be dealt with in the following sections.

4.2 Meteorology

4.2.1 Regional flows

The meteorology in the region is quite complex due to the location of the site at the foothills of the Darling Escarpment. Information presented by Air Assessments identifies the presence of rotors, gully winds, channeling winds and drainage flows. Most of these features are difficult to characterise using a prognostic model such as TAPM and the use of a diagnostic model such as Calmet could only be possible with very detailed measurements for surface and upper-level wind and temperature. As the monitoring network lacks the coverage for Calmet to reproduce the complexities in the wind fields and TAPM does not contain the physical parameterisation to enable the model to generate such complexities, we are left with wind fields that will never represent, to the full extent, the complex flows in the region.

Therefore it is important to determine the importance of such deficiencies on the predicted outcomes of the modelling.

Gully winds are generated in the early morning and result in strong easterly winds across the region. TAPM has actually overestimated the frequency of strong easterly winds; however, the time of day of the predicted strong easterlies is not known (data were not supplied in the Air Assessments report or the CSIRO Phase 1 report). The presence of strong easterly winds would result in higher dust emissions generated from the RDAs and elevated impacts to the west of the refinery. As the major communities are to the south and north of the refinery and the closest receptor to the west is some distance away, the deficiency of gully winds in the predicted wind fields is not a significant issue.

Rotors or wind reversals near the foothills are generated at night during easterly flows. The presence of rotors may result in better dilution of plumes and mixing due to increased turbulence, or in some circumstances, the premature grounding of any tall stack plumes. Drainage flows down the escarpment are also nighttime flows increasing the frequency of easterly winds. Again, as for the gully winds, the rotors and drainage flows would impact on areas to the east or west of the refinery, and, as they occur infrequently, this is not a significant issue to the outcomes of the modelling.

Channeling of the winds along the base of the foothills would result in a greater frequency of winds that may take emissions from the refinery to either the north or south and hence towards the closest residential areas. These winds would generally be light and occur during the nighttime or early morning. It is possible that the channeling of winds could transport emissions from the refinery to the townships of Hamlet and Yarloop more frequently than the model has predicted. For emissions from the RDAs that are a further distance from the foothills (and as such less likely to be influenced by the channeling winds), this possible under-prediction is less of a problem. The comparison of contour plots of VOC impacts generated by TAPM wind fields and those generated using observations (which would include any channeling) indicate that there is not a significant difference in the impacts.

The significant work undertaken to correct the poor quality wind data from the RDA monitoring network is commendable; however, as noted above, the impact on the final outcome is unlikely to be significant. It would be wise to check from existing recent acoustic sounder monitoring (and perhaps by supplementary electromagnetic radar measurements) whether the rotors when they form do indeed produce extra downdrafts/updrafts and stronger turbulence and/or flow deviations for the heights of relevance to the refinery and diffuse emissions.

4.2.2 Generation of Wind fields

There are many ways to generate winds fields using Calmet and the use of various factors and radii of influence is site dependant and presumably this has been tested during the process. There are a few points below that may need clarification in the final report to help the reader understand exactly what was done.

- For the Calmet wind fields based on TAPM only, there is a slight contradiction as to the location of the upper-level file - is it “set to way off the grid” or extracted at the RDA?

- For the observation-based wind fields it is assumed that parameters other than winds required by Calmet, such as temperature, relative humidity and pressure are based on local observations, except for cloud, which is generated by TAPM. As an alternative method for generating the cloud cover (as TAPM is sometimes highly sensitive and produces too much cloud), the local net radiation measurements can be used to back-calculate the cloud amount, using the same parameterisation used in Calmet to generate net radiation from cloud.

4.3 Dispersion model

No model setup files were supplied for review, therefore the information presented in the report was used to determine the method used in the modelling. All information presented in the report indicates a standard model setup except for the following points:

- Pasquill-Gifford dispersion curves were used instead of the typically recommended option of micro-meteorological dispersion algorithms. Although the sensitivity to this assumption was not presented in the report, comments made by Dr Pitts indicate that this was investigated and, due to limitations in the parameterisation for very smooth areas (such as the RDA), the micro-meteorological option did not give a sensible frequency of E and F class stability. Therefore, although this is not the typically recommended option, the justification is accepted.

- The terrain adjustment scheme selected was the Calpuff scheme. This scheme is still under development and should be used with caution; however, as terrain is not an important feature for the diffuse source modelling, this is not a significant issue needing attention.

4.4 Dust

Estimating dust emissions is a very difficult problem as there are many variables that influence the emission rate such as operational activities or management activities, meteorological conditions and the condition of the source (e.g. moisture content). All of these factors can vary significantly across a given day; therefore using hourly averaged parameters to generate emission rates is critical. Air Assessments has used this approach to estimate emissions from the RDAs and stockpiles.

Dust impacts are generally assessed from a human health viewpoint on a 24-hour average timeframe. Peak short-term dust events (sub 1 hour averages) are those likely to result in dust complaints. These have not been addressed in the assessment and from a community amenity viewpoint should be considered.

Controlling dust emissions from such large surfaces as the RDAs will be a continuing challenge for Alcoa. The proposed and current management practice of forecasting high wind events and applying water to the RDAs using water cannons should control the dust emissions so long as the areas are wetted sufficiently prior to the high wind events and the forecasting procedures are adequate. Ironically, the purpose of spreading the residue out is to dry it out. At various stages of the drying process the residue is turned to bring the wet material to the surface. This has been taken into account using a flat emission rate for the time when activities could be undertaken (daytime). It is not clear if this factor will increase during the expansion project or if it is limited due to the number of vehicles available.

The process used to estimate the emission rates for the RDAs is presented below:

1. Emission rate is generated from hourly wind speed corrected by gustiness factor during the daytime, and rain correction factor (using equation 5.3) and the original k factor from the Pinjarra refinery modelling.
2. The emissions are then modelled using Calpuff and the predicted 24-hour average concentrations have been compared to the measurements (less background level, which is taken as the lowest 24-hour average for any monitor for that particular day).
3. The emissions are then corrected by using the k factor to better represent the measurements for Wagerup for the current operations (note that this is very sensitive to the windspeed and as such different factors are determined for the TAPM and observed datasets).
4. The total emission rate determined for the current operations of the RDA has been split into 15% sand stockpile, 6% ROCP1, 10% RDA2 sand areas and 69% RDA dry stacked area. This means that the total dust emission rate from the RDA is determined for each hour based on a wind speed and the site-specific coefficient (k factor).
5. The RDA dry stacked area is then split up, firstly based on the area and then the estimated area controlled by water cannons (44-61% controlled area for current operations).
6. The areas controlled by water cannons are assumed to have zero emissions; therefore all the emissions are from the “non-wetted” areas, which is roughly 78 ha for the current operations (base case).
7. For the expansion the new water cannon configuration and upgrade of the piping to reduce the failure rate will increase the area controlled by water cannons to 75%.
8. The new area that is “non-wetted” is actually smaller than the current operations (68 ha) due to the better coverage of the water cannons.
9. The emission rate of dust is then scaled based on the corresponding areas that are non-wetted for the expansion (e.g. 68/78 ha or 87% of emissions for expanded RDA dry stacked areas compared to current emissions).

One significant assumption made to estimate the emissions for the expansion is that no emissions occur from the areas controlled by water cannons. It would be wise to investigate an alternative and more conservative method by assuming a split between the areas controlled by water cannons and those not as the dust emission rate is very sensitive to this assumption. If a split of 90% of emissions from non-wetted areas and 10% from wetted was assumed, the emissions from the dry stacked RDA would increase by 5% (rather than decrease by 12%) from current operations. For haul road, stockpiles and other dust generating activities, the application of water gives at best a control factor of 75% (NSW Minerals Council, 2000). Based on a split of 75% and 25% for uncontrolled/controlled areas, the dust emission from the RDA dry stacked areas could increase by almost 30% for the expansion. These figures are also very sensitive to the assumption of the percentage of area controlled by the water cannons; should the 75% water cannon coverage assumed reduce by 5%, the emission rates of dust from the RDA dry stack areas would increase by as much as 40% (assuming 75% and 25% for uncontrolled/controlled split).

It is noted that the HRA is sensitive to the level of dust predicted which is directly related to the level of emissions and assumptions made to estimate the emission rates for the expansion. We recommend that a sensitivity analysis be undertaken to determine the impacts on the HRA outcomes.

The bauxite stockpile emissions were determined in a similar fashion (items 1-3 above) and then scaled up based on throughput. As there is a significant increase in throughput for this source the emission rate from the Bauxite stockpiles is important for the expansion scenario.

For receptor 16 (to the north of the refinery), the emissions from the nearby bauxite stockpiles will dominate the impacts. There will be some shielding provided to the northern stockpile by the southern one for the important southerly winds. Theoretical considerations (e.g. see Parrett 1992) suggest a robust method for reducing the incident windspeed on the sheltered stockpile. The Air Assessments report does not include this and hence may overstate the worst-case statistics for receptor 16.

A comparison of the dust emission rates (note that the units presented in equations 1 and 2 are incorrectly stated and should be $g/m^2/s$) with basic emission factors for exposed surfaces indicates that the emissions estimated for the RDAs are comparable to other estimation methods.

It would be useful for the reader to have a better understanding of the conditions driving the peak impacts. Are they driven by the high emission events during extreme wind conditions or are they dispersion dependent? Are the peak short-term impacts predicted during the daytime or at night? This would also help in determining impacts during the worst year by identifying the frequency of particular meteorological conditions.

The equations for generation of dust emissions are very sensitive to wind speed, particularly high wind speeds. Will the height of the RDA increase significantly as they are used more in the future? And if so, should the wind speed be corrected for higher surfaces, and hence higher wind speeds for the future scenario?

Overall the assessment of dust impacts is very detailed and has used appropriate methodologies but a sensitivity analysis into the method used to estimate the emissions for the expansion is recommended and would provide more confidence in the final outcomes of the HRA. When assessing the overall impact of the refinery (diffuse plus refinery sources) against ambient air quality guidelines, it is important to add the background level of dust for region, as it can be significant.

4.5 Odour and VOCs

Odour complaint data have not been sighted in our review. The CSIRO Phase 2 report notes that TAPM modelling of the calciner multiflue and calciner 4 stacks gave good agreement between the diurnal variability of predicted short-term odour concentrations with the recent complaint data. No quantitative validation for odour concentration or intensity was undertaken. The intensity-concentration relationship for stack emissions is also not available whilst those for fugitive sources have been assumed from previous work for Kwinana (i.e. I = 3 corresponds to 4.8 OU). We consider that the absence of site-specific intensity-concentration measurements for the main sources from the refinery and diffuse sources makes the addition of odour concentrations from each source problematic and may invalidate any comparison of total odour statistics with the Western Australian default guidelines. If intensity and hedonic tone measurements had been undertaken, more use could have been made of the available field measurements and complaint information to confirm the main sources that give rise to odour annoyance to most people.

Field measurements of odour intensity by Environmental Alliances have been conducted twice, with the current report relying on the more recent campaign. These measurements indicate that recognisable odour is unlikely due to the RDA/pond sources at distances over 2.5 km and that the plumes were “generally undetectable beyond 3000 m”. It is understood that local residents believe that the annoying odours are due to refinery sources, not the fugitives from the RDA/pond areas.

Whilst the refinery odour emission rates have been based on a correlation of VOC emissions and measured odour levels, the diffuse sources from the RDA/pond areas have been characterised by fluxhood measurements for a summer period (with some meteorological dependencies identified). It is claimed that the emission rates have been validated with ambient, CFD and back trajectory modelling. This claim is examined below.

For comparison purposes, Table 1 gives the current and future odour emission rates for the refinery sources[1] and for the RDA/pond sources[2]. Table 1 also includes a description of the sources and an estimate of the maximum complaint distance for each individual source operating at peak emissions, based on an adaptation of the semi-empirical approach of Williams and Thompson (1986) to the new odour measurement standard and an allowance for the influence of plume height and different peak-to-mean ratios. The main impacting sources are expected to be the calciners, cooling pond, cooling towers and RDA2 liquor sources (the latter being removed in the expansion). For the expansion, this formulation suggests that the calciners and cooling pond emissions are likely to be the main contributors. The modeling of these sources therefore deserves careful attention.

For the pre-expansion odour emissions, complaints are possible at 3 km downwind due to the cooling pond, refinery vent and cooling tower emissions (depending on their inherent offensiveness).

[1] Information provided by Alcoa and summarised in the forthcoming Environ report
[2] Information provided in the Air Assessment report

Table 1: Characteristics of the various important odour sources before and after expansion

Source Name	Source Nature	Approx. plume height (m)	Q^{peak} pre (OU/s)	Q^{peak}post (OU/s)	Complaint distances (m)		Characteristics/comments
					Pre	Post	
Cooling pond	Heated area 15.5 ha	5-50	666,500	999,800	3360	4210	27-55ºC, spatial varying. Q met dependent and uncertain
RDA Liquor south	8 ha area	10 (estimate)	298,700	0	2040	-	Dry stacking only after expansion
Sand Lake	4.3 – 4.6 ha area	5 (estimate)	152,100	156,460	1360	1385	Little change
Dry stacked area	186-275 ha	5 (estimate)	37,830-48,800	63,430-79,630	690	920	Temperature/moisture dependent
Calciners	Multiflue stacks, hot	150-200	302,532	555,315	1190	1700	Stronger hedonic tone?
Cooling towers	Warm low plumes	20-50	448,052	190,000	2260	960	Considerable uncertainty in emission characteristics
Refinery vents	Warm low level plumes	20	438,221	88,772	3350	680	Difficult to quantify and may increase in upset conditions
Power station boilers	Tall stack, hot	200	N/A	N/A	N/A	N/A	Probably low

These results are only indicators but do give a basis on which to focus attention for this review.

The "average" refinery source emission rates are predicted to decline from the current 1,356,000 OU/s to 965,000 OU/s, with the main changes being an increase in calciner emissions by 83% but a drastic reduction in vent emissions by 80% and in cooling tower emissions by 58%. The total emission rates of the refinery go from being dominated by near-surface sources (65%) to being dominated by stack sources (57%).

The fugitive emissions from the diffuse sources at 25ºC and in light winter winds are predicted to increase from 303,000 OU/s to 336,000 OU/s, with the cooling pond emissions increasing from 110,200 OU/s to 165,000 OU/s and being the dominant source (followed by the dry stack areas at 74,000 OU/s and 117,000 OU/s respectively for current and future operations).

Peak emission rates from the diffuse sources are much higher, being 1,306,000 OU/s for the current case (i.e. 37% of the total Wagerup odour emissions) and 1,384,000 OU/s (42% of the total future emissions).

The refinery non-stack emissions are assumed to be emitted continuously whilst there is a 4-fold variation in fugitive emissions from the RDA/ponds due to meteorological factors. The probability of off-site odour after the expansion will therefore become much more dependent on meteorological conditions than in the past when non-stack refinery sources have likely dominated (these views should be easily checked from the overall Environ calculations when available). This conclusion does depend on whether the calciner emissions are thought to give much more intermittent impacts than suggested by the CSIRO analysis (e.g. CSIRO recommend a maximum 3 minute to 1 hour factor of 2.05 for $p = 0.24$, rather than the value of 3.31 expected for the tall stack convection with $p = 0.4$).

4.5.1 Odour emission rates for diffuse sources

Odour emissions from water surfaces can be expected to depend on windspeed, temperature and solar radiation (as for any water droplet-borne emissions).

The current study assumes only a windspeed dependence and finds that satisfactory agreement between flux chamber results and back calculations (based on field odour surveys with an assumed concentration-intensity relationship) can only be achieved by using a power law exponent of 0.78, not the usual 0.5 value used elsewhere in Australian odour assessments. Nevertheless, some of the Alcoa calculation of odour emission rates have used the 0.5 rather than 0.78 factor whilst the Air Assessment's estimation of cooling pond emissions has used the higher value. These matters are unclear in the various reports and lead to some uncertainty in the reader. Air Assessments (p94-95) note that the choice of exponent may yield odour estimates that differ by a factor of 2-4. Other references (e.g. Huang 1996) also favour an exponent of around 0.75 – 0.90 for water surfaces and shows a near-linear dependence on fetch. We would recommend the use of an exponent of around 0.75 for all water surfaces and do not yet understand why the 0.5 factor has been used in the final calculations for some sources.

For soil surfaces, the available data on windspeed dependence is poor and interim reliance has been placed on American measurements that assume no dependence on windspeed. We draw attention here to some relevant and fairly recent work:

(a) Blight (2002) has summarised South African work on evaporation from mining tailing dams that suggests little windspeed dependence for wetted soils compared to dry surfaces.

(b) Most researchers looking at fluxes of gas or vapour from soil surfaces use an energy balance method that has the role of incoming radiation as important (e.g. the OASIS experiments of CSIRO, the engineering design procedures for South Australia). Fluxhoods can cause a shading of surfaces and a reduction in this volatilisation component.

(c) Wind profiles over the surfaces of soil or water are important and should be represented by the full stability-dependent Monin-Obukov similarity functions, not simplistic power law formulas that give little indication of near-surface characteristics.

(d) Reichman and Rolston (2002) review the design and performance of dynamic flux chambers for measuring emissions from soil surfaces, and note the conditions under which significant errors can occur. They note that volatilisation rates may be affected by chamber-induced reduction of soil temperatures.

It might therefore be expected that radiation inputs would be important for odour/VOC emissions from various types of surface. Under some circumstances this may be captured by a dependency on soil (or ambient) temperature. Alcoa has suggested a linear relationship with temperature for wet residue, with zero emissions predicted below 11ºC (at least for the summer campaign – this may not be the case in winter). It is not clear to the reviewer why emissions would be zero on a sunny winter day with ambient temperatures around 10ºC as the surface is going through a period of rapid heat gain and evaporation may be quite substantial even in the absence of wind.

4.5.2 Buoyancy-affected plume rise and dispersion

Warm surface sources include the cooling ponds, superthickener and RDA2 liquor lake. Air Assessment's commissioning of CFD work to investigate the potential for plume lift-off in light winds is admirable as the available literature (Hanna, Briggs and Chang 1998, Ramsdale and Tickle 2001) gives only indications of what might happen as the air flows over a heated extended surface of non-uniform temperature. The CFD work (PAE 2005) idealises the situation into a rectangular area with a quadratic temperature pattern (inlet 55ºC, outlet 27ºC) for the cooling pond with ambient temperatures at 11ºC in daytime and 4ºC at night. This would be an optimistic view of what might happen in summer. The CFD simulations for the cooling pond are for a southerly wind when the incident air meets the warmer part of the pond first. It is not obvious whether the same degree of plume lift-off in light winds will occur for the more important northerly winds that take the emissions towards Yarloop.

The CFD work is important in showing that the flow of surface air into the ponds and subsequent formation of coherent structures are important in encouraging plume lift-off. The CFD work does not extend to the parameterisation of evaporation/volatilisation or the importance of saturation processes as the wind fetch across the pond increases. The simulations confirm the expectations from previous literature that plume lift-off will only be significant for light wind conditions and for low ratios of pond width to along-wind length. For westerly winds, the simulations suggest that the pond plume becomes more restricted in the lateral extent and that there are likely to be strong odour gradients at the “edge” of the pond – this seems to have been noted in some of the field intensity observations.

We doubt the validity of equations 7.1 – 7.4 for very light northerly winds and note the paucity of data points for non-stable light winds.

The dispersion modeling of the ponds appears to have used “elevated” area sources with a height given by equations 7.1 – 7.4 supplemented by a tentative linear dependence on wind direction with respect to the main axis of the pond and an initial vertical spread given by equation 7.5. This latter relationship is very tenuous whilst the wind direction dependence is speculative. The contours for various scenarios (Figures 7.10 – 7.11) and overall statistics for a 1 year period (Figures 8.15 – 8.18) show a pronounced reduction in concentrations for any winds with a dominant north/south component. This feature may not be robust once more sensitivity analysis is undertaken, as recommended in the PAE report.

4.5.3 Summary of odour assessment

In summary, our current view of the odour assessment is:

(a) The information provided is not complete without detailed reference to the many other reports.

(b) The measurements and simulations undertaken were quite appropriate and the remaining uncertainties are a result of limited time in measurement and evaluation.

(c) There are some technical issues about the analysis of emission rates that deserve further attention.

(d) Most of the modelling appears soundly based but there is some lack of consistency in the treatment of various sources.

(e) The conclusions of the odour sections are reasonable. We would expect that the overall analysis of odour impacts (combined diffuse and refinery sources) should carefully consider the relative impact of the various sources.

4.5.4 VOCs

Unfortunately, due to time constraints it was not possible to undertake an in-depth analysis of the VOC modelling and emission rate assumptions as has been undertaken for odour. As the VOC components from the diffuse sources are less significant in the final outcomes of the HRA, this is not seen as a major limitation to the review. Our general view is that the methodologies used to estimate VOC emissions are reasonably justified but that on-going sampling would provide a useful means of validating the approaches taken. Similar uncertainties identified in the estimation of the odour emission rates apply to the VOCs; therefore as the emissions for odour are refined so will the VOC emission rates. The final modelling presented for VOC and used in the HRA conservatively assumed no plume lift-off from the cooling pond. As this is the major source of most of the VOC emissions the conservatism should outweigh the uncertainties in the results.

4.6 Summary of review

This review has been conducted over a relatively short time with the information coming to hand only recently. As for other investigators, we note that the refinery presents a very complex emission situation that requires considerable testing and evaluation and the use of supplementary and perhaps non-standard techniques to resolve many of the issues. The assessment of odour and VOC emissions from area sources such as ponds and evaporation from surface sources is very complex and current practice for assessing emissions is in current scientific debate.

Overall the assessment of dust impacts is very detailed and has used appropriate methodologies. A sensitivity analysis into the method used to estimate the emissions for the expansion is recommended and would provide more confidence in the final outcomes of the HRA.

The conclusions drawn from the odour assessment seem reasonable. We have made some comments on various technical issues relating to the modelling and emission estimation techniques that should be addressed over time, but their resolution is unlikely to change the outcomes of the assessment.

A detailed list of uncertainties is included in the Air Assessments report. This list should be referred to and if possible activities undertaken in the future to reduce the uncertainty. A list of detailed recommendations for further work is also presented in Section 10; we concur with all items listed and recommend that all actions are undertaken to complete these recommendations and those presented in other reports such as the CFD modelling.

5. Specific expertise of the review team

Christine Killip and Dr Peter Best of Katestone Environmental have compiled this report. Katestone Environmental has particular experience and technical expertise in the following areas of relevance to the current review:

- Coastal dispersion and meteorology.
- Performance of advanced air quality dispersion models for near-coastal sites (including Calpuff).
- Performance of TAPM-type models in simulating meteorology in a wide range of conditions and countries.
- The air quality impact assessments of a wide range of industrial developments including refineries, power stations and major dust generating activities.
- The odour assessment of industries, with particular emphasis on community impacts.
- Assessment of industrial projects in Western Australia such as at Kwinana, Kalgoorlie, Collie and Hill River.
- Community impact assessments of roadway projects and odour impacts from intensive agricultural and major industries.

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