Wagerup Ambient Air Quality Monitoring Programme

Intensive Ambient Air Quality Study
Phase 2: August to October 2004

REPORT

April 2005

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Executive Summary

This report summarises and analyses the results of the second phase of an extensive air quality monitoring campaign carried out in the winter and spring months of 2004. Phase 2 included more intensive sampling at selected locations over a six week period from 23 August to 1 October 2004 in the region surrounding the Wagerup alumina refinery. The work was conducted on behalf of Alcoa World Alumina Australia (Alcoa) and the local community by independent, NATA accredited sampling and analytical specialist laboratories using USEPA or other applicable standard techniques[1]. Air samples were analysed for a broad spectrum of organic and inorganic species, including Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), inorganic anions, acids, and metals. Products of combustion (CO_2, CO, NO_x, SO_x) were not included in this study.

A total of 274 volatile chemical compounds were analysed for. Of these, a total of 35 were identified at quantifiable levels, and a further 31 were indicated in some samples at levels too low to quantify.

The overall air quality was found to be typical of rural environments in both the nature and the levels of chemical compounds detected, except for acetaldehyde which was at levels more typical of urban environments (refer to Table 5 in the text). All of the compounds detected were at levels well below applicable environmental and health standards. These most commonly detected compounds were formaldehyde, acetaldehyde and acetone, which were found at levels similar to those measured in the DoE study in 2003[2]. Most samples also showed the presence of lower levels of other aldehydes and ketones, as well as benzene and toluene.

The main chemical compounds detected are all known to be present in refinery emissions. The levels found in the ambient environment are generally many times greater than the calculated refinery influence for each compound. There was a lack of any clear spatial distribution that would indicate a refinery influence on the levels of the compounds detected. This is consistent with the proposition that the levels of chemicals in the ambient atmosphere are dominated by human and natural processes other than the refinery operation.

The chemical compounds detected and their levels in the atmosphere showed little spatial variation and for the most part appeared to be randomly distributed, limiting the ability to attribute specific sources. Elevated levels of both carbonyls and VOCs were found at the Waroona and Yarloop township sites, consistent with the effects of human activities associated with the use of fossil fuels. Sampling sites closest to the refinery generally showed lower concentrations of the compounds detected, although indications of higher than average levels of carbonyls at the Boundary Rd and to a lesser extent the Hoffman Rd sites could warrant further investigation.

The study provides quality assured information on the overall air quality on a daily and weekly average basis over the study period (late winter to early spring). No clear evidence was found of an influence of the refinery on overall air quality of the study region for averaging times of 8 hours to one week. Similar results were found in the earlier study (Phase 1), carried out over a fifteen week period from

[1] All sampling was carried out by Environmental Consulting Services (ECS), Unit 4, 7 Day Road, Rockingham, WA 6168, and all analysis was carried out by Leeder Consulting, Unit 5, 18 Redland Drive, Mitcham, Victoria 3132.

[2] "Results of Carbonyl Sampling at Wagerup", WA Department of Environment, January 2004.

May to August 2004. This is consistent with the results of recent dispersion modelling, which indicates that the contribution of the refinery to the levels of the VOCs detected in the ambient air is in general far lower than the background concentrations present from other sources. It is therefore to be expected that refinery influence will be difficult if not impossible to detect by examining the regional distribution VOC concentrations.

Recommendations are made regarding additional work to further clarify the contributions of the refinery and other sources of chemical emissions to air quality in the region.

1 Introduction

An intensive sampling and analysis programme has been conducted to assess air quality in the region around the Wagerup alumina refinery. The programme was developed using information from previous studies, in particular the 15-week Phase 1 Study carried out from May to September 2004. The Phase 2 Study scope was developed by Alcoa with input from the community, DoE, the Chemistry Centre and CSIRO. The independent specialists contracted to perform the sampling and analysis were chosen through a formal, open competitive bidding process managed by Alcoa on behalf of the stakeholders and with direct input from community representatives. NATA accreditation of procedures was a condition of the selection process. USEPA methods were used wherever possible, otherwise applicable Australian Standard or International Standard methods were used.

This report is an analysis of the data as presented, and while all due care was taken in relation to data integrity, the authors are not responsible for any errors in the original data. The methodology and data were not derived or directly audited by the authors.

2 Sampling and Analysis

2.1 Sampling and analysis: an overview of methods

The three main sampling techniques used were:

- Passive sampling for aldehydes, ketones and VOCs using the Radiello[3] sampling technique, in which samples were collected weekly at 11 locations, in duplicate;
- Active sampling for aldehyde and ketones using the USEPA methods TO-11A & TO-5A, VOCs using USEPA method TO-17, SVOCs using USEPA method TO-13, inorganic acids using NIOSH 7903, and halogens using NIOSH 6011. Samples were collected at 5 locations in duplicate, 3 times per week for 8 hours starting about 8:00am;
- Active sampling for metals associated with particulates. Method AS 2800-1985, which is for the determination of lead, was the sampling method used for all metals. The sample is collected using a High Volume Sampler. Samples were collected at four sites, each sample being taken over a period of one week. Between one and six samples were taken at each site. The lead component was determined as by Atomic Flame Mass Spectroscopy (AFMS), as per AS 2800-1985. The additional metals were analysed by the method most appropriate for each particular metal, using either AFMS or vapour generation and Inductively Coupled Plasma Spectroscopy (ICP).

Radiello sampling is a proprietary method for the passive collection of VOCs from ambient air using cylindrical cartridges containing an inner adsorbent and outer radial diffusion layer[1]. It has the advantage of requiring no pumping or metering of air, and no power supply. Radiello sampling can be used to collect under ambient conditions over a long period of time, and so can be used where the concentration of VOCs is below the normal detection limits for active sampling over a shorter time. Any transient excursions in the concentrations of VOCs are captured by this sampling method and included in the overall average concentrations.

The USEPA TO-11A methodology for monitoring air with low carbonyl content requires a calibrated pumping system to sample ambient air for a known time between 1 and 24 hours. The ambient air flow can be between 100 mL/minute and 2000 mL/minute, depending on the concentration of organics present. The ambient air is passed through a cartridge containing an adsorbent such as silica coated with 2,4-dinitrophenylhydrazine (DNPH) and a strong acid catalyst. The hydrazones resulting from reaction with airborne aldehydes and ketones are later analysed using high performance liquid chromatography. Before contacting the DNPH adsorbent, the ambient air is passed through granular potassium iodide to remove ozone, necessary to prevent loss of the DNPH product prior to analysis. Using TO-11A, low molecular weight carbonyl compounds including benzaldehyde are commonly measured to less than 0.5 ppb by volume.

The USEPA TO-5A method is an older operating procedure in which air is passed through an impinger containing solutions of DNPH, so that the solutions capture the ambient aldehydes and ketones. As with TO-11A, the hydrazones formed are analysed using HPLC. The accuracy of the TO-5A method can allow measurements down to 1-2 ppb by volume.

A USEPA TO-17 sampling protocol collects ambient VOCs by passing a known volume of air through suitable media, followed by thermal desorption, then gas chromatography and mass spectrometry for analysis. The method is considered capable of measuring VOC concentrations of 0.5 ppb to 25 ppb in ambient air.

[3] For further details visit the web page at: http://www.radiello.it/english/

The USEPA TO-13A technique utilises the collection of polyaromatic hydrocarbons (PAHs), typically onto polyurethane foam (PUF) or a similar adsorbent, followed later by desorption and analysis of the PAHs. Analysis is achieved by separation of components by gas chromatography followed by detection by mass spectrometry. A known volume of approximately 300,000 litres of air is typically drawn through the PUF adsorbent filters during rapid flow sampling (220 litres/minute). The TO-13A method is applicable to the measurement of easily condensed PAHs containing three or more aromatic rings.

2.2 Sampling sites

Passive sampling was conducted at the following 11 locations throughout the 6 weeks of the comprehensive programme: Boundary Road, Hoffman Road; Bremnar Road, Hamel Training Centre, the Yarloop Lawn Bowls, Residue Area, Residue South, Hamel Neighbour, Yarloop Neighbour, the Waroona Lawn Bowls and the Willowdale Mine. Refer to Appendix 1 for the location of each sampling point on the aerial photograph.

Active sampling was conducted at the following 5 locations throughout the 6 weeks of the comprehensive programme: Boundary Rd 2 (8), Hoffman Road (10), Bremnar Road (11), Hamel Training Centre (2), and the Yarloop Lawn Bowls (5). Refer to Appendix 1 for the location of each sampling point.

3 Results

3.1 Background aldehyde and ketones by passive sampling

Over the 6 week period of passive sample collection at 11 locations, five compounds: formaldehyde, acetaldehyde, propanal, butanal and benzaldehyde, were measured at concentrations above their respective method detection limits (see Appendix 2A&B). Formaldehyde and acetaldehyde concentrations are frequently above their detectable limit and show measurable variation between the different sampling sites (see Appendix 3). Figure 1 shows the mean and maximum weekly (background) formaldehyde and acetaldehyde concentrations at the 11 different sites during the 6 week period from 23rd August to 1st October 2004 (source data is in Appendix 3).

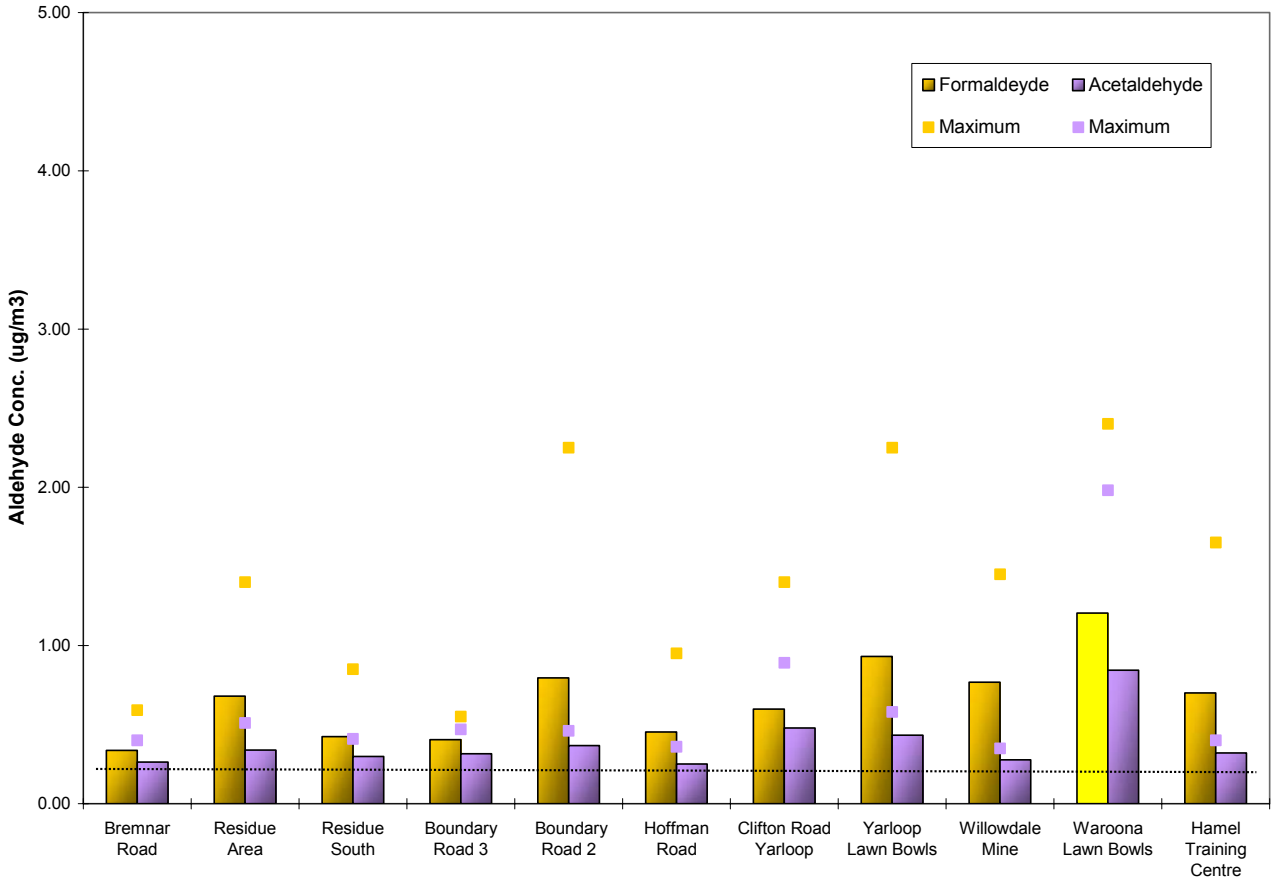

Figure 1 *Mean and maximum concentrations of formaldehyde and acetaldehyde at 11 locations over the 6 weeks as determined by passive sampling. Both compounds are well below applicable health limits (11 and 50ug/m^3 respectively for chronic health effects) and their odour thresholds (60 to 1230 for formaldehyde and 380 for acetaldehyde) – see Table 4.*

The highest concentration of formaldehyde and acetaldehyde (8 to 10 times the Method Detection Limit (MDL – see Appendix 4 for definition) occurs at Waroona Lawn Bowls (Sample Point 1) some 10 km north of the refinery (see Figure 1 and Appendix 1). This is attributable to sources associated with various localized activities including emissions from vehicles and other combustion engine devices, domestic and other wood fires, tobacco smoke, domestic chemicals and building products (Table 6), which are expected to be more concentrated in the town than in the surrounding rural environment. Bremnar Road (Sample Point 11) and Hamel Neighbour (Sample Point 9) (labeled "Point 1 Boundary Road" on aerial photo) sample points had the lowest mean background concentration of these 2 compounds. At the latter sites the mean values are only 2 - 4 times the average MDL (indicated by the dashed line in Figure 1).

The concentration of propanal, butanal and benzaldehyde was frequently measured at below the method detection limits. This makes averaging of duplicate results unreliable, in which case they are recorded as "D" (when detected but not quantified) or "nd" (not detected) in Appendix 2.

3.2 Concentrations of aldehydes and ketones at 5 key sites by active sampling

A total of twelve different aldehyde and ketone (carbonyl) compounds: formaldehyde, acetone, acetaldehyde, benzaldehyde, hexanal, butanal/isobutyraldehyde, propanal, acrolein, methacrolein, pentanal, 2-pentanone/3-methyl-2-butanone and methyl ethyl ketone, were measured at concentrations above their respective detection limits (by USEPA TO-11A), though only the first three were present in the majority of samples. The formaldehyde and acetaldehyde concentrations are consistently above

their MDLs at each of the 5 sampling locations (see Figures 2–6 & Appendix 5). All the concentrations recorded were well below the applicable 24 hour health standards (Table 4).

The concentrations of carbonyls at the 5 key sampling sites are also shown in Figures 2 to 6. Yarloop Lawn Bowls and Bremnar Road sites recorded several higher propanal concentrations, while the other six compounds generally lower than at the other four sites (see Figures 2 to 6). Propanal is associated with vegetative and fossil fuel burning, wood heaters, tobacco smoke, and burning plastics, and is emitted naturally from trees and shrubs (Table 6). The Hoffman Road site reports several mean duplicate benzaldehyde concentrations that are well above the MDL and higher than the other sites (see Figure 3).

The other 5 compounds (not displayed in Figures 2 to 6) are detected infrequently at the 5 sampling points (see Appendix 6). There are no significant differences in the concentration levels of these compounds at the 5 different sites.

Recent dispersion modelling (CSIRO, 2005) indicates that the observed concentrations of these compounds in the ambient air are not explained by their presence in refinery emissions, because the calculated contribution of the refinery is in every case many times less than the concentrations observed. This indicates that the measured levels are dominated by other natural and anthropomorphic processes (Table 6).

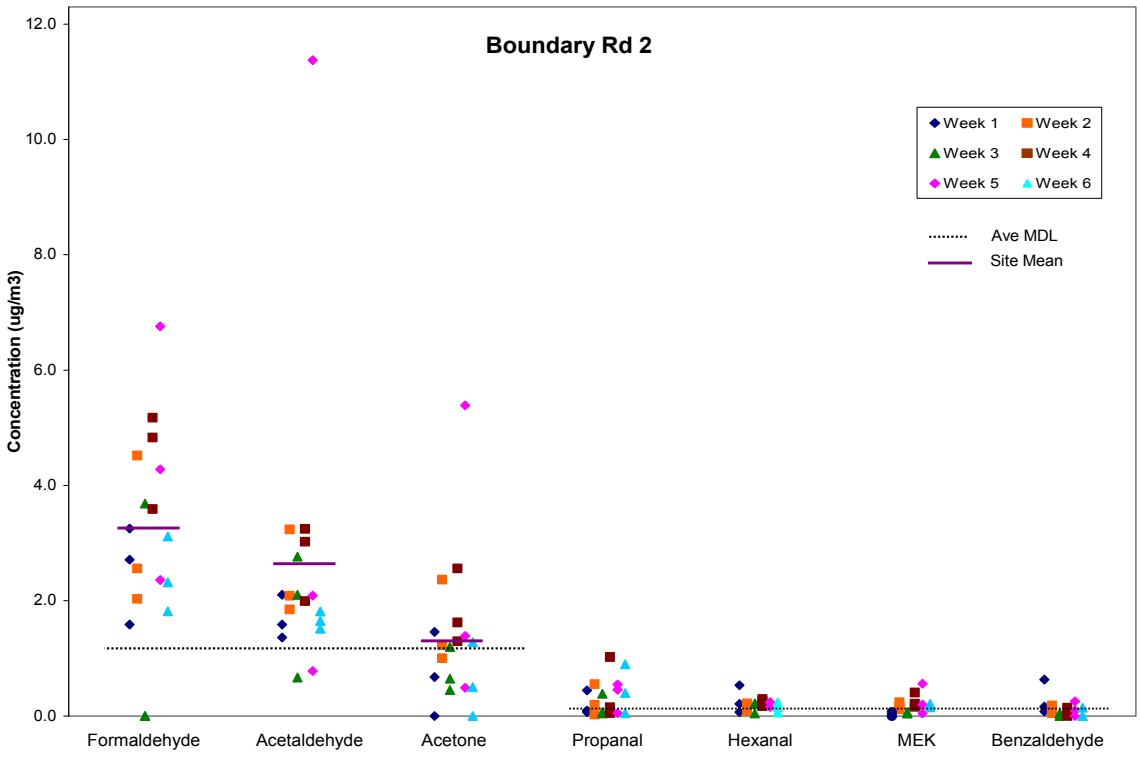

Figure 2 *Concentrations of aldehyde and ketone compounds at the Boundary Rd 2 sampling site over the 6 week programme around the Wagerup region. All concentrations are well below applicable health standard levels (Table 4). Each point represents the average of duplicates on a given day.*

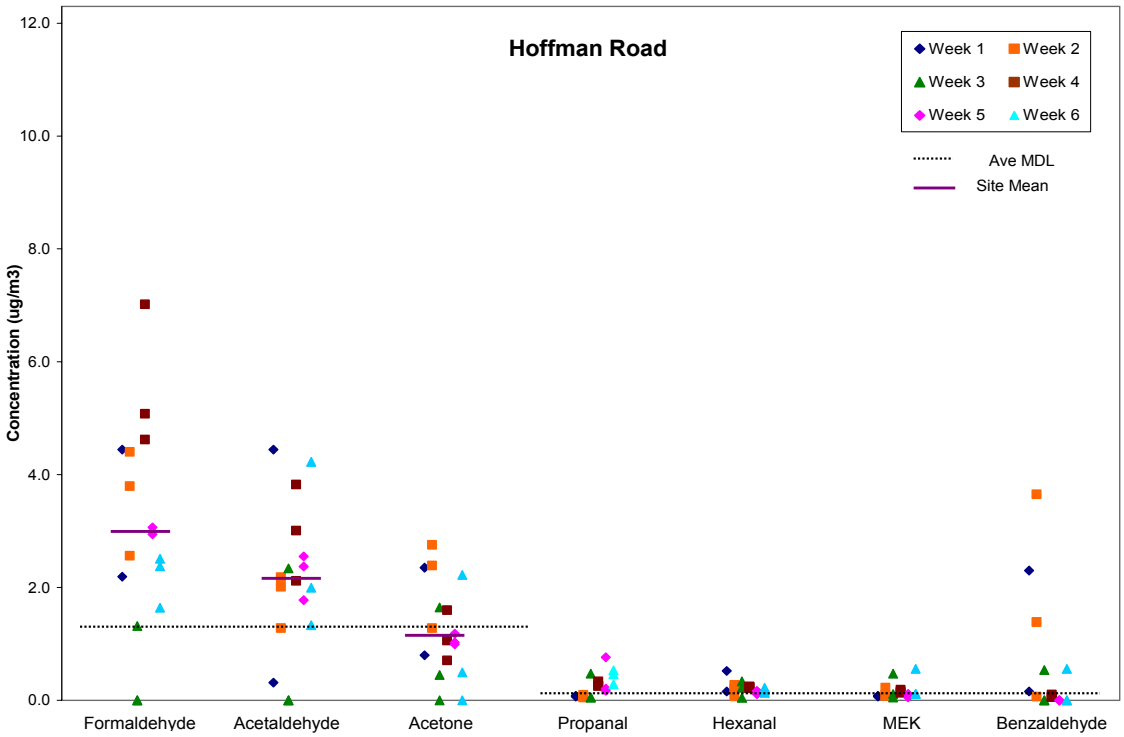

Figure 3 *Concentrations of aldehyde and ketone compounds at Hoffman Road over the 6 week sampling programme around the Wagerup region. All concentrations are well below applicable health standard levels (Table 4). Each point represents the average of duplicates on a given day.*

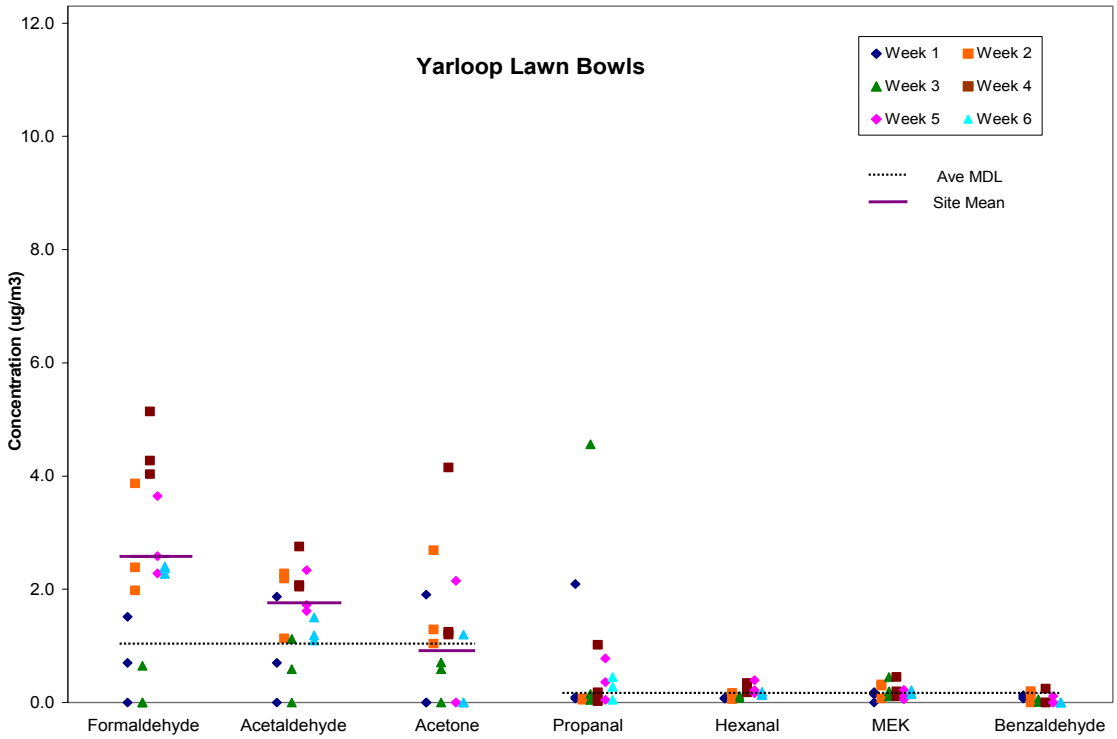

Figure 4 *Concentrations of aldehyde and ketone compounds at the Yarloop Lawn Bowls over the 6 week sampling programme around the Wagerup region. All concentrations are well below applicable health standard levels (Table 4). Each point represents the average of duplicates on a given day.*

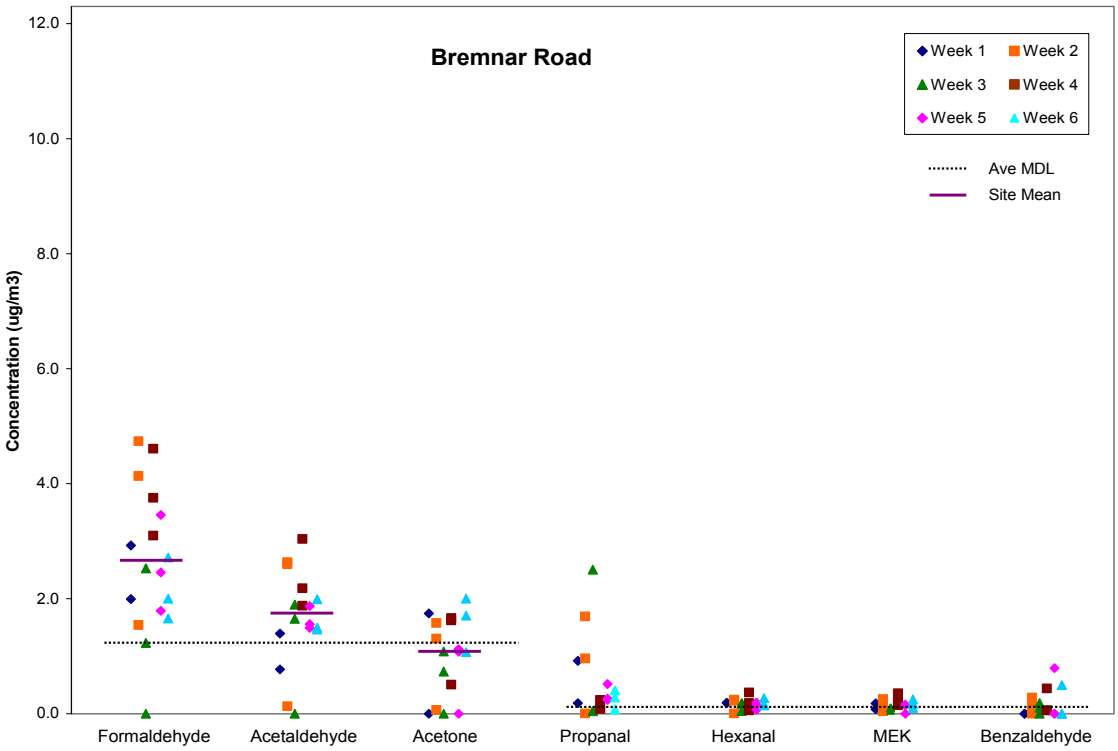

Figure 5 *Concentrations of aldehyde and ketone compounds at Bremnar Road over the 6 week sampling programme around the Wagerup region. All concentrations are well below applicable health standard levels (Table 4). Each point represents the average of duplicates on a given day.*

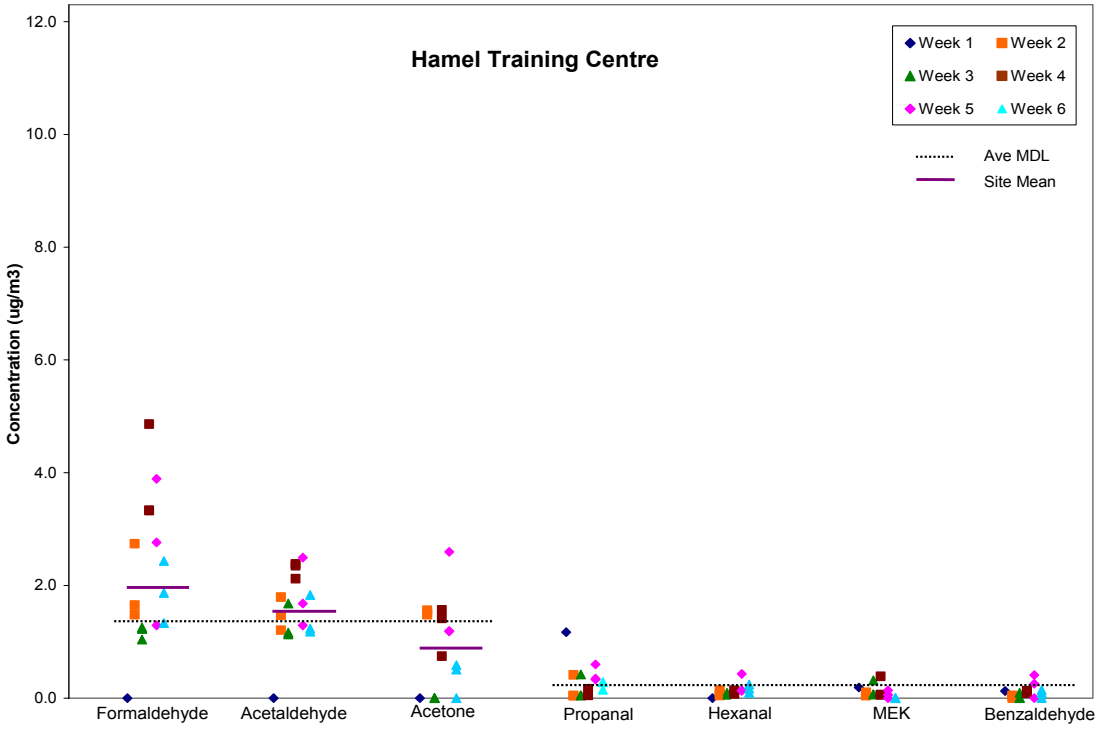

Figure 6 *Concentrations of aldehyde and ketone compounds at the Hamel Training Centre over the 6 weeks sampling programme around the Wagerup region. All concentrations are well below applicable health standard levels (Table 4). Each point represents the average of duplicates on a given day.*

The mean concentration of formaldehyde in week four (4.4 ug/m^3), is higher than all other weeks at each of the 5 sample collection points. Reliable mean (duplicate) values are obtained during this week since they are frequently more than twice the average detection limit (MDL - see Figure 7 & Appendix 5). The concentration of formaldehyde at all 5 sites in week 3 is lower than for the other 5 weeks (see Figures 7 & 8). The concentrations of formaldehyde and acetaldehyde during this week were often less than 1.5 times their MDLs. The calculated mean concentrations are therefore less reliable (see Appendix 4 & 5).

The highest weekly formaldehyde concentrations occurred at the Boundary Rd 2 and Hoffman Road sampling points, but the differences between these and the other sites are small and the weekly variation in mean formaldehyde concentration is greater than the differences between the 5 sampling points (see Figure 7).

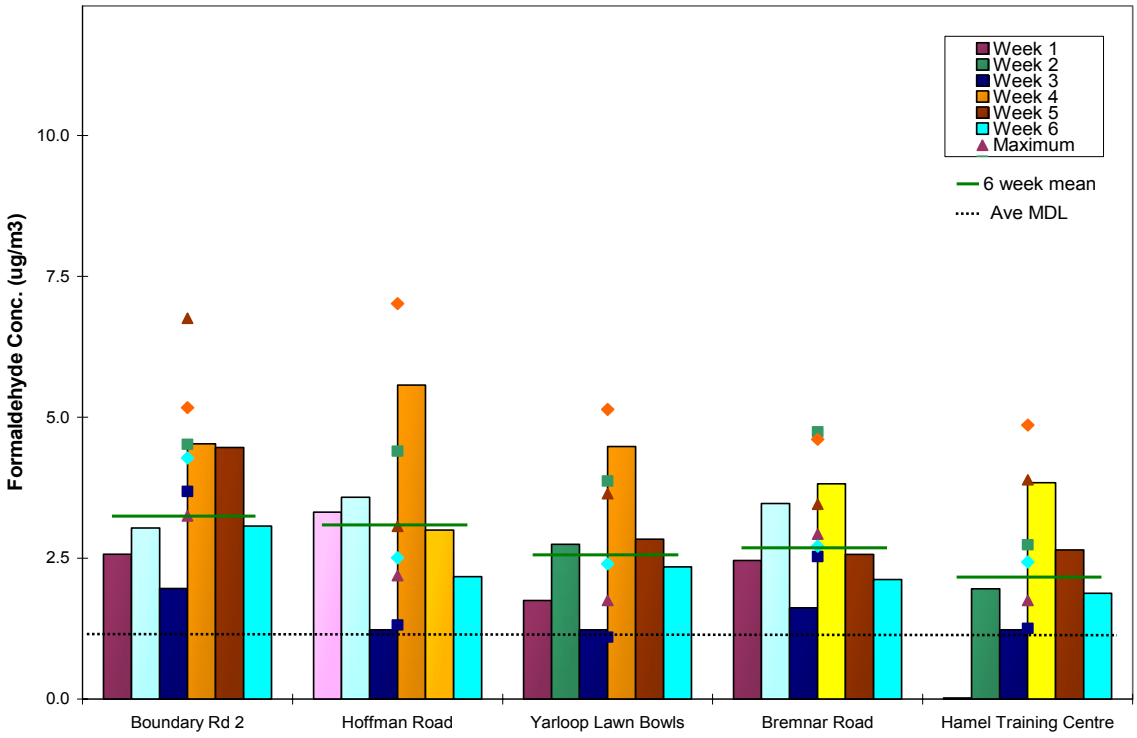

Figure 7 *Weekly average formaldehyde concentrations at the 5 key sampling points around Wagerup as determined by TO-11A active sampling. The bars show weekly average values. The points show the highest value recorded each week, with the week identified by the colour of the symbol. All concentrations are well below applicable health standard levels (Table 4).*

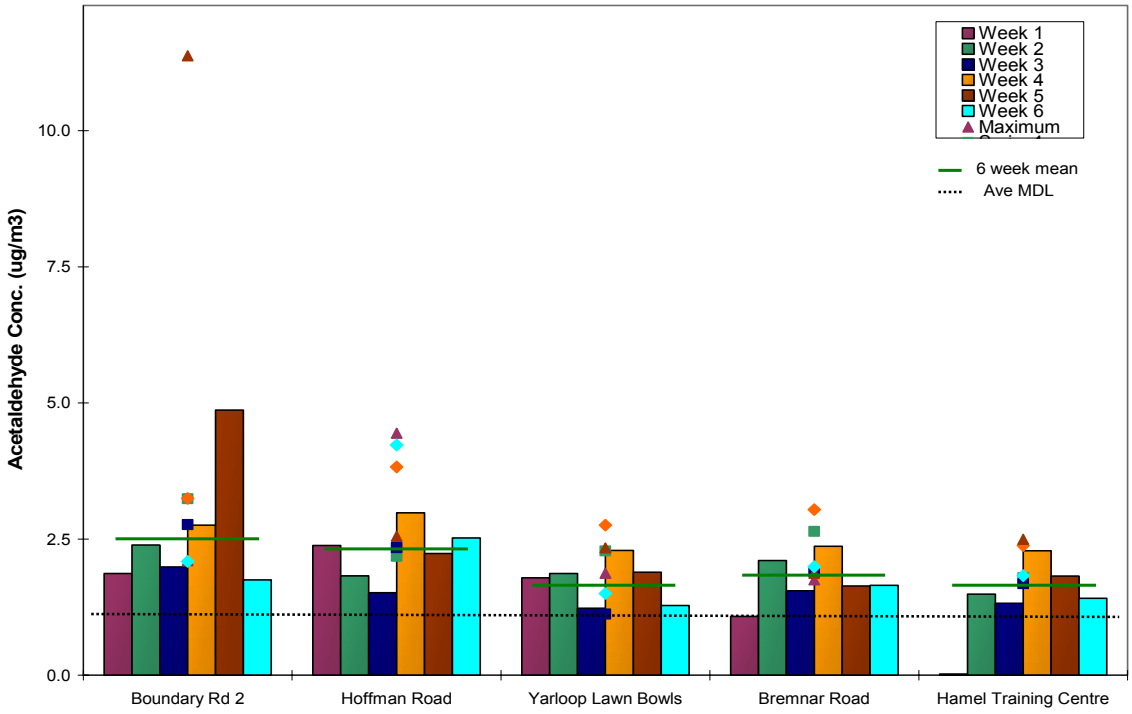

Figure 8 *Weekly average acetaldehyde concentrations at the 5 key sampling points around Wagerup as determined by TO-11A active sampling. The bars show weekly average values. The points show the highest value recorded each week, with the week identified by the colour of the symbol. All concentrations are well below applicable health standard levels (Table 4).*

The highest weekly mean concentration of acetaldehyde over all sites for the 6 week programme was 2.5 ug/m^3 (Appendix 5), and this occurred in weeks 4 & 5. The highest individual weekly value of 4.9 ug/m^3 was recorded in week 5 at Boundary Rd. (see Figure 8 & Appendix 5). Week 3 has the lowest mean concentration of acetaldehyde (1.5 ug/m^3), although the difference with other weeks is smaller than for formaldehyde.

The average differences between sites do not appear to be statistically significant because the weekly variation in mean acetaldehyde concentration (1.5 – 2.5 ug/m^3) is similar to the differences between the 5 sampling points.

The mean concentrations of acetone in weeks two and four (1.5 - 1.6 ug/m^3) are higher than for the other weeks (0.5 – 1.3 ug/m^3) (see Appendix 5). Week three has the lowest mean concentration, at approximately half the average method detection limit (see Appendix 4). The highest weekly acetone concentrations appear to be at the Boundary Rd 2 and Hoffman Road sampling points, although it is doubtful that this is statistically significant because they lie only slightly above the average six-week MDL. Hamel Training Centre records the lowest mean acetone concentrations, with no acetone detected in weeks one and three[4]. The weekly variation in mean acetone concentration is greater than the differences between the 5 sampling points (see Figure 9).

While the variations between sites are too small in relation to overall variability to be definitive, the average values appear to be marginally higher at the Boundary Rd and Hoffman Rd sites, and these sites also show the majority of highest individual results for the carbonyl compounds. No comparative data are available for Waroona, which would be expected to be higher based on the Radiello results.

[4] Only one duplicate run was performed at Hamel Training Centre during week one.

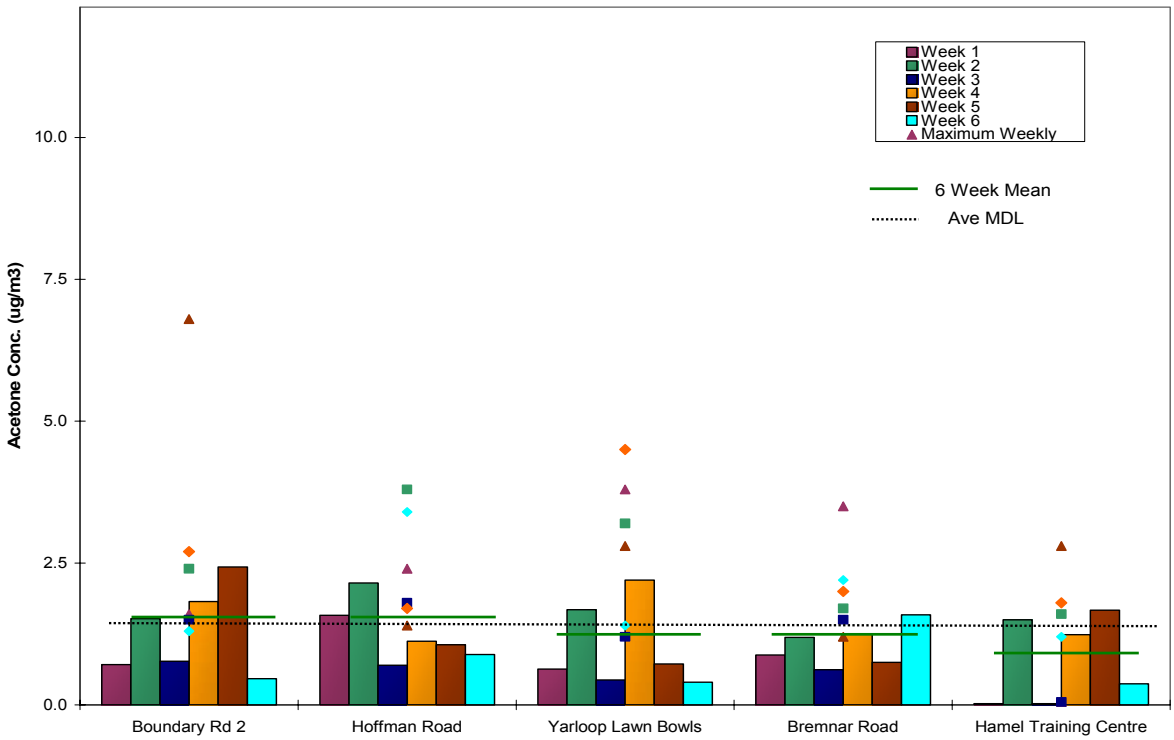

Figure 9 *Weekly average acetone concentrations at the 5 key sampling points around Wagerup as determined by TO-11A active sampling. The bars show weekly average values. The points show the highest value recorded each week, with the week identified by the colour of the symbol. All concentrations are well below applicable health standard levels (Table 4).*

Ambient air samples were also collected by an alternative active sampling method, USEPA Method TO-5A, for aldehyde and ketone analysis. Formaldehyde, acetone, acetaldehyde, butanal/isobutyraldehyde, hexanal, and 2-pentanone/3-methyl-2-butanone were detected by this method. However the results are less useful than from TO-11A because of the lower sensitivity of TO-5A, which meant that most results failed to satisfy reporting quality criteria (see Appendices 4 & 7).

3.3 VOCs collected by passive sampling at 11 different sites

A total of eleven VOC compounds were detected by passive sampling at the 11 passive sampling points: benzene, toluene, xylenes, n-decane, n-hexane, n-heptane, isooctane, isobutanol, 2-methyl pentane, 3-methyl pentane and cylcohexane. All of these compounds were measured at low concentrations and often were not detected in individual samples (see Appendix 8). Benzene and toluene were the species most frequently detected at the 11 sampling points over the 6 week programme.

The mean concentration of benzene and toluene is highest in ambient air sampled at the Waroona and Yarloop Lawn Bowls sampling locations (see Figure 10). These sample points are the only ones to have mean concentrations of any VOC above the average MDL (see Figure 10 & Appendix 8). It is therefore not possible to present a true average concentration for these compounds for each site, and the values shown below the MDL in Figure 10 are indicative only.

A greater proportion of samples from Waroona and Yarloop Lawn Bowls record individual VOC concentrations above their MDLs (see Appendix 8). The higher concentrations of VOCs recorded at the township sites are consistent with the presence of general fuel burning activities (vehicles, wood fires, etc – see Table 6). All values recorded are well below applicable health standard levels (Table 4).

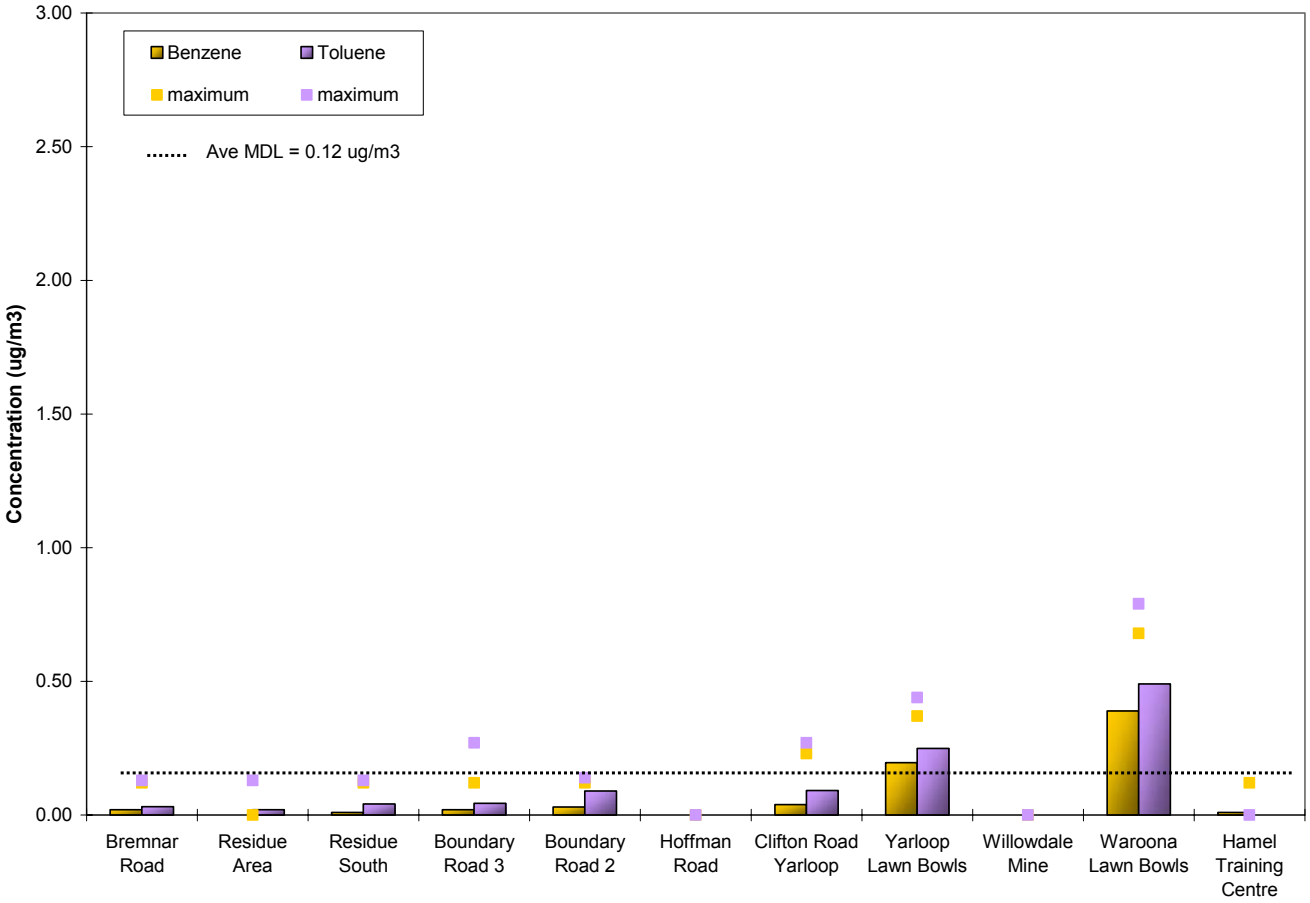

Figure 10 *Average and maximum concentrations of benzene and toluene at 11 locations over the 6 week programme as determined by passive sampling. The influence of fuel burning activities in townships is evident. All concentrations are well below applicable health standard levels (Table 4).*

3.4 Concentration of VOCs at the 5 key sampling sites

Benzene, toluene, xylene and carbon tetrachloride were the only VOCs collected by active sampling with ambient concentrations above detection limits. However it is not possible to report a reliable mean concentration for these compounds since most values were below the MDLs (see Appendix 9A). There are no clear differences between VOC concentrations in a particular week or between sampling locations.

The following VOCs were detected but not quantified by USEPA TO-17 during the 6 week period: n-hexane, n-pentane, iso-pentane, 2-methyl pentane, 3-methyl pentane and methyl cyclopentane. They were detected most frequently at the Yarloop Lawn Bowls site (see Appendix 9B). All concentrations are well below applicable health standard levels (Table 4).

3.6 Concentration of SVOCs the 5 key sampling sites

The following SVOCs were detected and quantified using USEPA Method TO-13A during the 6 week sampling programme at the five key sampling sites: fluorene, naphthalene, phenanthrene, dibenzofuran, 1-methyl naphthalene, 2- methyl naphthalene, m&p-cresol, o-cresol, phenol, 2,4-dimethylphenol, 1,4 dichlorobenzene, fluoranthene, pyrene and benzyl alcohol (see Appendix 10A&B). These compounds were at the greatest concentration, and most frequently detected at Yarloop Lawn Bowls where three or more were detected on most sampling days (see Appendix 10B)[5]. All concentrations are well below applicable health standard levels (Table 4).

[5] No samples were collected by TO-13A at Boundary Rd 2 or Waroona during the 6 weeks.

3.7 Trace metal concentrations in suspended particulates

Samples of ambient air were collected at the Hoffman Road, Hamel Training Centre, Bremnar Road and Boundary Rd 2 sites to determine the lead and other metals content on solid particulates. The results of the weekly samples show levels of lead, mercury and other heavy metals (see Appendix 11). All concentrations measured are at very low levels. Examples of comparisons with applicable health standard levels are shown in Table 4A.

3.8 Inorganic acid concentrations at the 5 key sites

Samples of ambient air were collected at the 5 key sampling sites to determine the concentration of six different inorganic acids. The results of weekly 6 hour samples collected at each site showed the absence of all inorganic acids except for occasional traces of sulphuric acid at the Bremnar Road and Hamel Training Centre sites at different times (see Appendix 12). The highest value recorded was 130ug/m^3, well below the NPI 8 hour TWA standard of 1000ug/m^3. All other samples were below 110ug/m^3. No source of the traces of sulphuric acid was identified.

3.9 Chlorine and bromine concentrations at the 5 key sites

Samples of ambient air were collected at the Boundary Rd 2, Hoffman Road, Bremnar Road and Hamel Training Centre sites for determination of bromine and chlorine. The results of the weekly samples show traces of both bromine and chlorine at each site on occasions (Appendix 13). Two samples showed quantifiable levels of chlorine, at 170 and 150 ug/m^3, and all other samples were below these levels. These results are well below the 8 hour TWA of 1500 ug/m^3 according to NIOSH and OSHA. No specific source was identified for either element.

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4 Discussion

4.1 Comparison between passive and active sampling results: Carbonyls

The passive sampling apparatus adsorbs sample over an entire week which results in averaging of air concentration over this period. This type of sampling results in high sensitivity (low method detection limits) because a larger quantity of compound can be collected over the longer sampling periods made available by this method. Transient peaks occurring within the period are captured and included in the average concentration recorded. The aldehyde and ketone data acquired by this technique are different to the data from samples collected by active sampling over of 8 hour periods during daylight hours.

A comparison of formaldehyde and acetaldehyde concentrations determined by passive (Radiello) and active sampling (TO-11A) is shown in Table 1. Both formaldehyde and acetaldehyde concentrations are recorded higher at all sites when sampled and analysed by TO-11A. The aldehyde and ketone contributions to ambient air from human activity (in particular vehicular traffic and other fuel burning activities) may be expected to be greatest during daylight hours, which may at least partly explain the observed difference. However no investigation of method biases was done, so artefacts due to the differences between the sampling techniques cannot be discounted.

The weekly average concentrations measured by passive sampling showed that the average and individual highest values were greatest at the Waroona Lawn Bowls site. The lowest values were recorded at Residue South, the closest site to the refinery, and Bremnar Rd, which is farthest from both the refinery and the towns (Fig 1). This indicates that the influence of general human activities associated with the town (principally fuel burning) have a significant influence on the overall levels of carbonyls in the atmosphere, whereas a refinery influence could not be discerned. The results of the active sampling show indications of higher values at the Boundary Rd and Hoffman Rd sites than at the other key sites sampled. Whether this could be indicative of a refinery influence is unclear, and no comparison with Waroona can be drawn because it was not included in the group of key sites for active sampling.

Table 1. Mean formaldehyde and acetaldehyde concentration at each of the 5 key sampling sites determined by TO-11A and Radiello

Location	Formaldehyde (ug/m^3)		Acetaldehyde (ug/m^3)	
	Active (8 hrs)	Passive (1 week)	Active (8 hrs)	Passive (1 week)
Boundary Rd 2	3.27	0.80	2.60	0.37
Hoffman Road	3.15	0.45	2.36	0.25
Yarloop Lawn Bowls	2.57	0.93	1.73	0.43
Bremnar Road	2.68	0.34	1.84	0.26
Hamel Training Centre	2.22	0.70	1.68	0.32
All sites	2.8	0.6	2.0	0.3

4.2 Comparison between passive and active sampling results: VOCs

The results from passive and active sampling for VOCs show a similar pattern to the aldehydes and ketones discussed above. This is illustrated in Table 1a, which shows the maximum concentrations recorded for benzene and toluene at the same sites (maximum values are given because it was not possible to determine averages due to the large number of non-detects – see Appendices 7&8). The maximum concentrations of benzene and toluene (4.6 & 1.7 ug/m^3) obtained by active sampling are higher than the weekly maximum VOC concentrations at the corresponding 5 sites determined by passive sampling (0.37 & 0.41 ug/m^3). A larger number of different VOCs were detected by passive sampling due to the lower method detection limits (see Appendices 7&8).

The results of passive sampling show the highest concentrations of benzene and toluene at the Waroona and Yarloop township sampling sites, with Waroona the greater. The Residue sites, which are the closest sampling sites to the refinery, show among the lowest concentrations. This again indicates that fuel burning activities in the towns are the most notable influence on the overall concentrations of the measured compounds in the atmosphere. The pattern is similar for active sampling, with the Yarloop site showing the highest levels of benzene and toluene, and also the largest number of individual VOCs detected. Comparison with Waroona could not be made because it was not included in the group of key sites. An exception is the single high benzene result recorded at Hoffman Rd.

Table 1a. Maximum benzene and toluene concentration at each of the 5 key sampling sites determined by TO-17 and Radiello

	Benzene (ug/m^3)		Toluene (ug/m^3)	
Location	Active (8 hrs)	Passive (1 week)	Active (8 hrs)	Passive (1 week)
Boundary Rd 2	0.58	0.12	nd	0.14
Hoffman Road	4.6	nd	nd	nd
Yarloop Lawn Bowls	0.62	0.37	1.7	0.41
Bremnar Road	0.62	0.12	nd	0.13
Hamel Training Centre	0.73	0.12	0.60	0.27

4.3 Summary of all compounds detected during ambient study

A total of 66 different volatile compounds were detected (at least once) using both active and passive sampling techniques during the 6 week ambient programme. The compound types identified were: aldehyde and ketones (29 different compounds), aromatics (9), alkanes & cycloalkanes (14), alcohols, phenols & cresols (8), heterocycles (2), organohalides & halides (3) and others (1) (see Table 2).

Table 2. Comprehensive list of all VOCs detected by active ambient sampling in this study of the region surrounding the Wagerup Refinery.

Compound detected	Ambient Concentration (ug/m3)	Active	Passive	Molecular Weight	CAS
Aldehydes and Ketones					
Formaldehyde	nd - 7.0	TO-11A, TO-5	Radiello	30.0	50-00-0
Acetaldehyde	nd - 11.4	TO-11A, TO-5	Radiello	44.0	75-07-0
2-Propenal (Acrolein)	nd - 0.25	TO-11A, TO-5		56.1	107-22-2
Acetone	nd - 5.4	TO-11A, TO-5		58.1	67-64-1
Propanal	nd - 4.6	TO-11A, TO-5	Radiello	58.1	123-38-6
2-methylPropenal (Methacrolein)	nd - 0.56	TO-11A, TO-5		70.1	78-85-3
Butenal	nd - 0.096	TO-11A, TO-5		70.1	4170-30-3
Methyl Vinyl ketone	D, SQ	TO-11A, TO-5		70.1	78-94-4
2-Butanone (MEK)	nd - 0.56	TO-11A, TO-5		72.1	78-93-3
Butanal*	nd - 0.52	TO-11A, TO-5	Radiello	72.1	123-72-8
Methylglyoxal	D, SQ	TO-11A, TO-5		72.1	78-98-8
3-Penten-2-one	D, SQ	TO-5		86.1	96-22-0
Pentanal	nd - 0.95	TO-11A, TO-5		86.1	110-62-3
2-Pentanone**	nd - 0.89	TO-11A, TO-5		86.1	107-87-9
3-Methyl-2-butanone**	D, SQ	TO-11A, TO-5		86.2	563-80-4
Cyclohexanone	D, SQ	TO-11A, TO-5		98.1	108-94-1
trans-2-Hexenal	D, SQ	TO-11A, TO-5		98.1	6728-26-3
3,3-Dimethyl-2-butanone	D, SQ	TO-11A, TO-5		100.1	75-97-8
Hexanal	nd - 0.54	TO-11A, TO-5		100.2	66-25-1
Benzaldehyde	nd - 3.6	TO-11A, TO-5	Radiello	106.1	100-52-7
Heptanal	D, SQ	TO-11A, TO-5		114.2	111-71-7
Tolualdehyde	nd - 0.15	TO-11A, TO-5		120.1	1334-78-7
6-Methyl-5-hepten-2-one	D, SQ	TO-11A, TO-5		126.2	110-93-0
Octanal	D, SQ	TO-11A, TO-5		128.2	124-13-0
Nonanal	D, SQ	TO-11A, TO-5, TO-13A		142.1	124-19-6
Vanillin	D, SQ	TO-11A		152.1	121-33-5
Decanal	D, SQ	TO-11A, TO-5, TO-13A		156.1	112-31-2
Undecanal	D, SQ	TO-11A, TO-5		170.1	112-44-7
Dodecanal	D, SQ	TO-11A, TO-5		184.1	112-54-9
Alcohols, Phenols & Cresols					
isoButanol	nd - 1.8		Radiello	74.1	75-65-12
Phenol	nd - 0.0099	TO-13A		94.1	108-95-2
Benzyl Alcohol	nd - 0.068	TO-13A		108.1	100-51-6
2 methylPhenol (o-Cresol)	nd - 0.0092	TO-13A		108.2	95-48-7
3&4 methylPhenol (m&p-Cresol)	nd - 0.018	TO-13A		108.2	106-44-5
2,4 Dimethyl Phenol	nd - 0.013	TO-13A		122.2	105-67-9
2-ethylHexanol	T, SQ		Radiello	130.3	104-76-7
Eucalyptol	T, SQ	TO-13A		154.1	470-82 to 6

Table 2. (cont.)

Compound detected	Ambient Concentration (ug/m3)	Active	Passive	Molecular Weight	CAS
Alkanes and Cycloalkanes					
n-Pentane	T, SQ	TO-17		72.2	109-66-0
Isopentane	T, SQ	TO-17		72.2	78-78-4
methylCyclopentane	T, SQ	TO-17		84.2	96-37-7
2-methyl-Pentane	T, SQ	TO-17	Radiello	86.2	107-83-5
3-methyl-Pentane	T, SQ	TO-17	Radiello	86.2	96-14-0
n-Hexane	nd - >L, SQ	TO-17		86.2	1120-21-4
n-Decane	T, SQ	TO-17		142.3	124-18-5
Undecane	T, SQ	TO-13A		156.3	1120-21-4
Dodecane	T, SQ		Radiello	170.3	112-40-3
Tridecane	T, SQ		Radiello	184.4	629-50-5
Tetradecane	T, SQ		Radiello	198.4	629-59-4
Hexadecane	T, SQ	TO-13A		226.5	544-76-3
Heptadecane	T, SQ	TO-13A		240.2	
Octadecane	T, SQ	TO-13A			
Aromatics					
Benzene	nd - 4.6	TO-17		78.1	71-13-2
Toluene	nd - 1.7	TO-17		92.1	108-88-3
Xylenes	nd - 1.1	TO-17		106.2	108-38-3
Naphthalene	nd - 0.030	TO-13A		128.2	91-20-3
1-Methyl Naphthalene	nd - 0.0099	TO-13A		142.2	90-12-0
2-Methyl Naphthalene	nd - 0.02	TO-13A		142.2	91-57-6
Flourene	nd - 0.0033	TO-13A		166.2	86-73-7
Phenanthrene	nd - 0.0066	TO-13A		178.2	85-01-8
Fluoanthene	nd - 0.0011	TO-13A		202.3	206-44-0
Heterocycles					
Dibenzofuran	nd - 0.0033	TO-13A		168.2	132 to 64-9
Pyrene	nd - 0.0032	TO-13A		202.2	129-00-0
Organo Halides & Halides					
Chlorine	nd - 170	NIOSH-6011		70.9	7782-50-5
1,4 Dichlorobenzene	nd - 0.0099	TO-13A		147.0	106-46-7
Carbon tetrachloride	nd - 0.73	TO-17		153.8	56-23-5
Others					
Sulphuric acid	nd - 360	NIOSH-7903		98.1	7664-38-2

Notes: nd: not detected T, SQ: tentative assignment & semi –quantitative
D, SQ: assigned but semi-quantitative only >L, SQ: exceeds calibration limit so semi-quantitative results.

Shading indicates the compounds are not present in Wagerup Refinery emissions, according to the Wagerup Refinery Air Emissions Inventory Final Report, 2002.
Source Alcoa TDG

Of the 66 species detected, just over half (35), have been determined quantitatively in this study (see Table 3 for more details). The remaining compounds were recorded with tentative assignments and semi-quantitative values only, due to low levels and/or lack of appropriate standards and accreditation for the analysis .

Table 3 Summary of sampling methods and detection limits used to identify all compounds throughout the programme.

Compound/ type	Sampling method	Passive or active	Collection time	Ave MDL ug/m3	# Species analysed for	# Species quantified	# Species detected only
Aldehyde or ketone acetone propanal, hexanal etc	TO-11A TO-11A	Active Active	8 hours 8 hours	1.2 0.12	29	14	15
Aldehyde or ketone formaldehyde, acetaldehyde & acetone including propanal, hexanal etc	TO-5A	Active	12 hours	13	27	6	13
Aldehydes formaldehyde, acetaldehyde & benzaldehyde propanal butanal	Radiello Radiello Radiello	Passive Passive Passive	1 week 1 week 1 week	0.11 0.25 0.87	9	5	0
VOC benzene, toluene & carbon tetrachloride etc	TO-17	Active	2 hours	0.6 - 1.2	52	4	6
VOC benzene, toluene, xylenes & n-hexane etc	Radiello	Passive	1 week	0.11 - 0.16	35	11	4
SVOC naphthalene, phenol & o-cresol etc	TO-13A	Active	1-3 days	0.001 - 0.004	212	14	6
Inorganics sulphuric acid, hydrochloric acid, hydrogen fluoride	NIOSH-7903 NIOSH-7903	Active Active	6 hours 6 hours	90 - 130 45 - 64	6	1	0
Metals lead, aluminium, arsenic, boron,barium, beryllium, cadmuim, cobalt, copper, gallium, mercury, lithium, molybdenum, nickel, selenium, thalium, vanadium	AS-2800	Active	1 week	0.000001-0.0001	18	17	0
Halogens chlorine & bromine	NIOSH-6011	Active	3 1/2 hours	130 - 170	2	1	0

4.4 Comparison of concentrations of species at the 5 key sampling sites with odour thresholds, ambient guidelines, and typical rural air quality

The peak concentrations of the VOCs measured are well below ambient air guideline levels (Table 4). This is also true for odour thresholds, with the possible exception of benzaldehyde which was occasionally measured at the lower end of its range of reported odour threshold values and has a pleasant, fruity smell.

Table 4: Ambient Air Quality Guidelines and Odour Thresholds

Species	Maximum Concentration Measured	Acute Health Effects			Chronic Health Effects			Carcinogenic Effects		Odour Threshold	Odour Guideline	
		Value	Averaging		Value	Averaging		Probability				
	(ug/m3)	(ug/m3)	Period	Reference	(ug/m3)	Period	Reference	(per ug/m3)	Reference	ug/m3	ug/m3	Reference
Formaldehyde	7.0	54	24 h	NEPC(AT)	11	Annual	NEPC(AT)	1.30E-05	NEPC(AT)	60 -1,230	-	-
Acetaldehyde	11.4	2,000	24hr	WHOa	50	Annual	WHOa	9.00E-07	WHOa	380	-	-
Acetone	5.4	66,000	24hr	ATSDR	33,000	Annual	ATSDR	-	-	47,300	-	-
Propanal	4.6	3	24hr	OAQC	2	Annual	TCEQ	-	-	22 - 400	20	TCEQ
Benzaldehyde	3.6	-	-	-	2.2	Annual	TCEQ	-	-	0.8 - 180	22	TCEQ
2-Butanone (MEK)	0.56	13,000	1hr	OEHHA	5,000	Annual	IRIS	-	-	15,900	-	-
Hexanal	0.54							-	-	19	-	-
Methacrolein	0.56	4	1 h	TCEQ	0.4	Annual	TCEQ	-	-	-	-	-
Acrolein	0.25	0.2	1 h	OEHHA	0.06	Annual	OEHHA	-	-	-	-	-
Butanal	0.52							-	-	-	-	-
Butenal	0.10							-	-	-	-	-
Pentanal	0.95	100	Odour	TCEQ	10	Odour	TCEQ	-	-	-	-	-
Tolualdehyde	0.15							-	-	-	-	-
2-Pentanone	0.89	530	1 h	TCEQ	5300	Annual	TCEQ	-	-	-	-	-
					705000	TWA	NOHSC	-	-	-	-	-
					410000	TWA	OSHA (STL)	-	-	-	-	-
					250	TWA	NIOSH (REL)	-	-	-	-	-
Carbon Tetrachloride	0.73	1900	7 h	OEHHA	40		OEHHA	-	-	>300,000	-	-
		130	1 h	TCEQ	13		TCEQ	-	-	-	-	-
					0.2 (0.03 ppm)		ATSDR	-	-	-	-	-
Benzene	4.6	174	24hr	ATSDR	60	Annual	OEHHA	6.00E-06	WHO	-	-	-
		1,300	6 h	OEHHA						-	-	-
Dibenzofuran	0.0033	-	-	-	20 pg/m3 based on TGA TMI of 70 pg/kg/day for dioxin						-	-
1,4-Dichloro Benzene)	0.0099	150	8hr	ACGIH	-	-	-	-	-	-	-	-
		600		TCEQ	60	-	TCEQ	-	-	-	-	-
		12000		ATSDR	120	-	ATSDR	-	-	-	-	-
Toluene	2.3	4,113	24hr	NEPC(AT)	411	Annual	NEPC(AT)	-	-	>8,000	-	-
Xylenes	1.1	1,083	24hr	NEPC(AT)	946	Annual	NEPC(AT)	-	-	-	-	-
iso-Butanol	1.8	152	1 h	TCEQ	1520	Annual	TCEQ	-	-	-	-	-
Phenol	0.0099	19,000	8hr	OSHA	150	Annual	TCEQ	-	-	150	-	-
		5,800	1 h	OEHHA	200		OEHHA	-	-	-	-	-
2,4-Dimethyl Phenol	0.0130	-	-	-	73		US EPA PRG	-	-	-	-	-
Benzyl Alcohol	0.068	500	1 h	TCEQ	50	Annual	TCEQ	-	-	-	-	-
m&p-Cresol	0.018	-	-	-	-	-	-	-	-	-	-	-
o-Cresol	0.0092	22,000	8hr	OSHA	-	-	-	-	-	-	-	-
Cresol mixtures				OEHHA	0.5	Annual	TCEQ	-	-	-	5	TCEQ
The following should all be handled as PAH using TEF for chronic effects								-	-	-	-	-
Pyrene	0.0032	-	-	-	-	-	-	-	-	-	-	-
1-Methyl Naphthalene	0.0099	-	-	-	-	-	-	-	-	-	-	-
2-Methyl Naphthalene	0.020	-	-	-	-	-	-	-	-	-	-	-
Naphthalene	0.03	-	-	-	4	Annual	ATSDR	-	-	440	-	-
Total Naphthalenes	**0.06**	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	0.0066	100	10hr	NIOSH	-	-	-	-	-	-	-	-
Fluorene	0.0033	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	0.0011	-	-	-	-	-	-	-	-	-	-	-

Indicates values close to a known exposure standard

References:

NEPC(AT)	National Environmental Protection (Air Toxics) Measure (NEPC, 2004)
WHOa	World Health Organisation Guidelines for Air Quality (2000a)
OEHHA	California Office of Environmental Health Haxard Assessment (OEHHA) Toxicity Criteria Database
ATSDR	U S Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs) for Hazardous Substances
OAQC	Ontario Air Quality Criteria
NIOSH	National Institute for Safety and health
ACGIH	American Conference of Governmental Industrial Hygenists

Table 4A: Exposure Guidelines for Metals in Airborne Particulates[1]

Note that in this table short term values are compared with annual average guidelines, which is an extremely conservative comparison, ie the safety margin is very large.

Metal	Speciation	Guideline Value ug/m^3	Averaging Period	Max Found ug/m^3
Lead	Metal	0.2	3 months	0.00080
Mercury	Metal	0.33	Annual	<0.00001
Chromium	V	0.0011	Annual	-[2]
Chromium	0 & III	0.11	Annual	0.0023
Arsenic	Inorganic	0.0055	Annual	0.00014

[1] New Zealand Ambient Air Quality Guidelines, AQ Report No 32, NZ Ministry for the Environment, May 2002.

[2] It is highly unlikely that the Cr(VI) is present, however even if all were in that form the highest spot sample recorded would still be below the annual average guideline value.

The concentrations observed for the organic compounds quantified are comparable values for rural air elsewhere, and significantly lower than typically observed in urban and residential situations (see Table 5). An exception is acetaldehyde, which is in the range normally associated with urban environments. The highest average and peak concentrations of most carbonyls were found at the Boundary Rd and Hoffman Rd sites. While the differences involved are of the same order as the variability between sites, nevertheless this could be worthy of further investigation in that these carbonyls are components of the refinery emissions. The highest level of propanal was found at the Yarloop site, and was not associated with maxima in any of the other key compounds.

Table 5 Comparison of Ambient Air Quality determined in this study to others.

All concentrations in micrograms/cubic metre (ug/m^3)

	Typical Concentrations of VOCs in Ambient Air			*Concentrations in this study*	
Compound	**Rural Ambient**	**Urban Ambient**	**Indoor Residential**	**6 Week Mean**	**Weekly Max**
Formaldehyde	1 – 6[(1)]	2 – 20[(1)]	30 – 100[(1,2)]	2.7	5.6
Acetaldehyde	0.0 – 1.4[(3)]	1.6 – 44[(3)]	30 – 100[(3)]	1.9	4.9
Acetone	0.5 – 5[(4)]	10 – 100[(4)]	5 – 27[(3)]	1.1	2.4
Propanal	0.1 – 0.2[(6)]	0.5 – 10[(5,6)]	-	0.4	4.6
Hexanal	0.00 – 0.25[(6)]	0.06 – 1.55[(6)]	-	0.17	0.54
MEK	0.2 – 2.3[(6)]	0.6 – 6.5[(6)]	-	0.15	0.56
Benzaldehyde	0.00 – 0.15[(6)]	0.1 – 0.7[(6)]	-	0.19	3.65

References:

1. International Programme on Chemical Safety Bulletin EHC89, 1989

2. State of Knowledge report: Air Toxics and Indoor Air Quality in Australia, Environment Australia 2001
3. Acetaldehyde as a Toxic Air Contaminant, California EPA, November 1993
4. International Programme on Chemical Safety Bulletin EHC207, 1998
5. Characterisation and identification of Sources of Volatile Organic Compounds in an Industrial Area in Brisbane, O Hawas et al, ANSTO, 1991
6. Tilson Air Quality Study, Manitoba Environmental, August 2000

4.5 Sampling techniques and detection limits

The various sampling methods used have differing collection times and hence also detection limits. Aldehydes, ketones and VOCs concentration determined by passive sampling generally have lower detection limits due to the considerably longer collection time (see Table 3). A low method detection limit allows compounds to be measured to a lower concentration and with greater reliability.

The less concentrated aldehydes and ketones such as propanal and hexanal have lower method detection limits when determined by the active sampling method TO-11A, as indicated in Table 3. This appears to be due to species-specific difficulties in analysis of samples collected by the Radiello technique.

4.6 Common origins and source of ambient species

The likely sources for the species most frequently detected in ambient air in this programme are given in Table 6.

Table 6 Common origins of VOCs detected in ambient air in the current programme.

Formaldehyde[1,2]	Vegetative fires & fossil fuel burning, wood heaters, tobacco smoke, combustion engines, natural decomposition processes including atmospheric oxidation of hydrocarbons, glues, detergents, cosmetics, building products. The most common aldehyde in the environment.
Acetaldehyde[1,2]	Vegetative fires & fossil fuel burning, wood heaters, tobacco smoke, combustion engines, atmospheric conversion of other compounds, respiration of plants, ripening of fruit.
Acetone[3]	Vegetative fires & fossil fuel burning, evaporation from living plants and trees, breakdown of body fats, solvents, tobacco smoke, landfill sites, vehicle exhaust.
Propanal[4]	Vegetative & fossil fuel burning, wood heaters, tobacco smoke, combustion engines, burning plastics, natural emissions from trees and bushes.
Benzaldehyde[5]	Natural emissions from plants and grasses, decomposition of leaf litter, common flavouring in foods, combustion processes, atmospheric photo-oxidation of toluene and other aromatic hydrocarbons.
MEK[1]	Vegetative fires & fossil fuel burning, wood heaters, biological degradation processes, veneer & plywood manufacture, varnishes & lacquers, paints & primers, tobacco smoke, vehicle exhaust, cleaners, dyes, inks, insecticides, laundry starches, lubricants, nail polish & remover, shoe polish, furniture, particle board.
Hexanal[6,7]	Natural degradation of plant matter, storage and drying of wood, food flavouring.
Benzene[1]	Vegetative fires & fossil fuel burning, oil and coal, landfills, service stations and all machinery using liquid fuel, burning crop residues and forest management burning, tobacco smoke.
Toluene[1]	Vegetative fires & fossil fuel burning, service stations and all machinery using liquid fuel, burning crop residues and forest management burning, tobacco smoke, consumer products including adhesives, polishes, varnish removers & thinners, coatings, particle board, leather dressings, lubricating oils, pens and markers, furniture, vinyl products.
Acrolein (2 Propenal)[1]	Fuel and vegetative burning, tobacco smoke, livestock feeds, pesticides

References:

1. State of Knowledge Report: Air Toxics and Indoor Air Quality in Australia, Environment Australia, 2001
2. WHO Air Quality Guidelines 2002
3. eco-usa.net, extract from Toxicological Profile of Acetone, Agency for Toxic Substances & Disease Registry, US Public Health Service, May 1994

4. Spectrum Chemical Fact Sheet for Propanal, www.speclab.com
5. Spectrum Chemical Fact Sheet for Benzaldehyde, www.speclab.com
6. Spectrum Chemical Fact Sheet for Hexanal, www.speclab.com
7. "Emission of Hexanal and CO from Storage of Wood Pallets", U Svedberg et al, Ann Occup Hyg, Vol 48, pp339-349, 2004

4.7 Calculated Refinery Contributions to Ambient Concentrations of Key Compounds

Table 7 outlines the levels of the most prevalent Volatile Organic Compounds detected at Boundary Road. All compounds were detected at concentrations typical of rural environments and well below levels of concern. The same compounds are present in refinery emissions and the Ground Level Concentrations GLCs) resulting from those emissions have been calculated by CSIRO using the TAPM model. It is therefore possible to estimate the contribution of the refinery emissions to the GLCs of each compound. In all cases it can be seen that the contribution from the refinery is small in comparison to the background concentrations from other sources, which are a combination of natural and anthropogenic sources.

Table 7 Ambient VOC Concentrations at Boundary Rd

	Measured Ambient Levels		Refinery Contribution		
	ug/m3	ug/m3	ug/m3	%	ug/m3
	Average	Max Detected	Average[1]		24hr 95%[2]
Formaldehyde	3.3	6.8	0.00340	0.1%	0.05
Acetaldehyde	2.6	11.4	0.01000	0.4%	0.10
Acetone	1.3	5.4	0.06100	4.7%	0.64
Propanal	0.31	1.0	*0.00272*[1]	0.9%	
Hexanal	0.2	0.5	*<0.00003*[1]		
MEK	0.16	0.6	0.00660	4.1%	0.06
Benzaldehyde	0.14	0.6	*0.00080*	0.7%	
Benzene	-[3]	0.58	0.00085		0.02
Toluene	-[3]	-[4]	0.00580		0.05
Acrolein	-[3]	0.25	*0.0019*[1]		

[1] Numbers in italics are estimated as ratio to acetone on basis of emission rates

[2] 95th percentile 24-hour maximum values

[3] Insufficient data to calculate averages

[4] Toluene was not detected at Boundary Rd above the average MDL (0.60 ug/m^3) by the TO17 method. The maximum value detected over all sites was 1.7ug/m^3 at the Yarloop Lawn Bowls site.

5 Conclusions

This study provides detailed knowledge of the ambient air quality in the region surrounding the Wagerup alumina refinery, including the townships of Waroona and Yarloop and the associated rural environment. The study was carried out over a six week period and built on data and information gathered in the previous fifteen week preliminary study. A variety of recognised sampling and analytical techniques were employed, including USEPA methods for determining volatile organic compounds (VOCs), carbonyls, metals and inorganic compounds. A total of 274 volatile chemical compounds were analysed for. Of these, 35 were detected and quantified, a further 31 were detected at levels too low to quantify, and the remainder were not detected.

The main chemical compounds detected are all known to be present in refinery emissions. The levels found in the ambient environment are generally many times greater than the calculated refinery influence for each compound. There was a lack of any clear spatial distribution that would indicate a refinery influence on the levels of the compounds detected. This is consistent with the proposition that the levels of chemicals in the ambient atmosphere are dominated by human and natural processes other than the refinery operation.

All chemical compounds detected were found to be at levels well below applicable limits set for the protection of human health, and were generally within the ranges expected for rural environments. An exception to the latter is acetaldehyde, which was found at levels more typical of urban environments. This could warrant further investigation to establish the source, but the distribution, levels and relativity to other compounds mean that the refinery is unlikely to be the cause.

The chemical compounds detected and their levels in the atmosphere showed little spatial variation and for the most part appeared to be randomly distributed, limiting the ability to attribute specific sources. Elevated levels of both carbonyls and VOCs were found at the Waroona and Yarloop township sites, consistent with the effects of human activities associated with the use of fossil fuels. Sampling sites closest to the refinery were generally showed lower concentrations of the compounds measured, although indications of higher than average levels of carbonyls at the Boundary Rd and to a lesser extent the Hoffman Rd sites could warrant further investigation.

The exclusion of sampling sites at Waroona and close to the refinery in the group of key sites for intensive monitoring is a weakness of the study, as comparisons between Waroona and close to the refinery could be expected to be informative on the basis of the Radiello passive sampling results.

Significant differences were observed between the weekly results from Radiello passive sampling and the USEPA methods for VOCs and carbonyls. It is not clear to what extent this is due to differences in sampling technique or real differences in ambient concentrations between day and night, and between workdays and weekends. It would be useful to resolve this by parallel sampling and analysis.

6 Recommendations

To resolve the issues raised by this study and further investigate the possibility of detecting influences of the refinery on ambient air quality, the following recommendations are made:

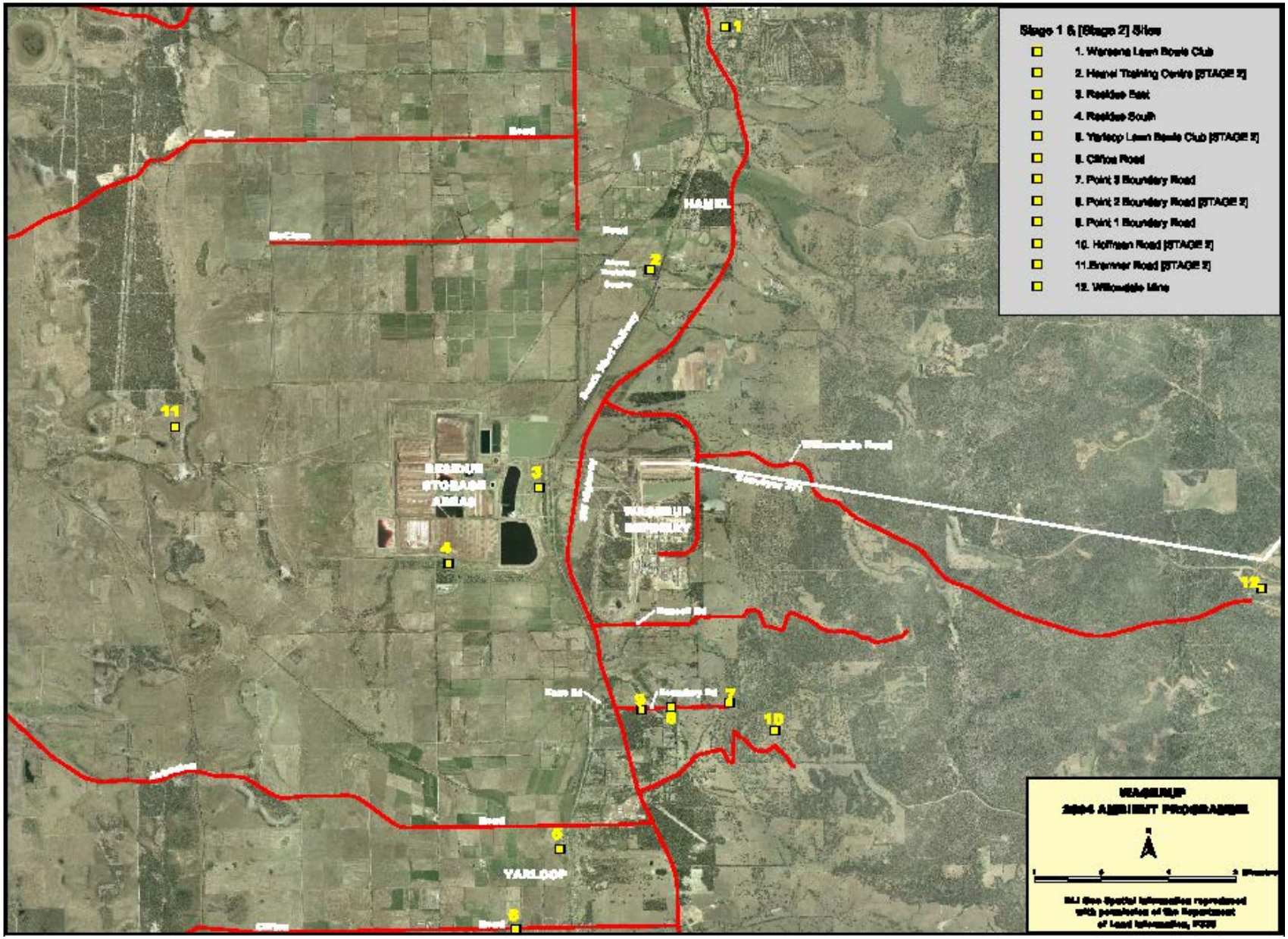
1. A comparative study of Radiello and USEPA sampling techniques over the same time periods should be carried out to investigate the apparent bias between the techniques and indicate possible reasons;
2. An investigation of the cause of the apparent elevated levels of carbonyls at Boundary Rd could be informative;
3. Investigation of techniques for monitoring short-term concentrations of compounds of interest should be progressed, preferably by continuous monitoring techniques such as the Opsis that is currently being trialed for formaldehyde and benzene. This should attempt to correlate variations in

concentrations with short term influences of refinery emissions on the ambient atmosphere indicated by marker compounds, in particular NO_x.

4. Information from 3 should be used in combination with dispersion modeling and emission source measurements to improve knowledge of the influences of the refinery on ambient air quality. This provides a practical alternative to the approach of event monitoring with ultra-trace analysis, which is not recommended due to the difficulties involved in identifying and capturing events, the high dilution from dispersion, and the background levels of chemicals existing in the atmosphere from other natural and anthropogenic sources.
5. An investigation of the hexanes, pentanes and PAHs detected at the Yarloop site could be carried out to confirm their concentrations and identify likely sources.

APPENDICES

Appendix 1: Aerial Photo showing the location of the 11 sampling points used in the comprehensive Wagerup ambient air program.



Appendix 2: Aldehyde and ketones concentration at 11 sampling points around Wagerup as determined by passive sampling (Radiello).

Formaldehyde	Waroona Lawn Bowls		Yarloop Lawn Bowls		Clifton Rd Yarloop		Residue South		Hoffman Road		Bremnar Road	
ug/m3	run 1	run 2	run 1	run 2	run 1	run 2	run 1	run 2	run 1	run 2	run 1	run 2
1	1.0	1.2	0.57	0.47	0.38	0.47	0.19	0.19	0.20	0.20	0.37	0.37
2	1.5	3.3	2.1	2.4	1.2	1.6	0.59	0.39	0.90	1.0	0.49	0.68
3	0.87	0.97	0.58	0.58	0.19	0.097	0.30	0.30	0.29	0.29	0.19	0.19
4	0.93	1.1	0.41	0.91	0.74	0.41	0.25	0.68	0.33	0.58	0.17	0.25
5	1.1	1.3	0.96	0.77	0.58	0.39	0.94	0.75	0.48	0.77	0.57	0.57
6	0.59	0.59	0.61	0.81	0.51	0.61	0.30	0.20	0.31	0.10	0.099	0.099
Mean	1.00	1.41	0.87	0.99	0.60	0.60	0.43	0.42	0.42	0.49	0.31	0.36
Acetaldehyde												
1	0.36	0.36	0.22	0.11	0.11	0.22	0.055	0.055	0.12	0	0.055	0.22
2	0.85	3.1	0.58	0.58	0.58	0.70	0.35	0.46	0.35	0.35	0.34	0.34
3	0.80	0.80	0.46	0.46	0.34	0.23	0.23	0.35	0.11	0.11	0.23	0.23
4	0.50	0.60	0.29	0.39	0.39	0.48	0.30	0.40	0.29	0.39	0.20	0.30
5	0.68	0.90	0.45	0.57	0.46	0.46	0.33	0.33	0.34	0.23	0.34	0.45
6	0.70	0.47	0.48	0.60	1.3	0.48	0.36	0.36	0.48	0.24	0.23	0.23
Mean	0.65	1.04	0.41	0.45	0.53	0.43	0.27	0.33	0.28	0.22	0.23	0.30
Propanal												
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	1.2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	0.25	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	0.21	0.21	nd	0.21	0.21	nd	nd	0.21	nd	0.21	nd	nd
5	0.24	0.49	0.49	0.24	0.25	0.25	0.48	0.24	0.25	0.25	0.24	0.24
6	0.5	0.5	0.52	0.26	0.26	0.26	0.51	0.51	0.26	nd	0.50	0.50
Butanal												
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	0.87	1.7	0.87	0.87	nd	0.88	nd	0.89	nd	0.87	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzaldehyde												
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	0.20	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Appendix 2 (cont.)

Formaldehyde ug/m3	Boundary Rd 3		Boundary Road 2		Willowdale Mine		Hamel Training Centre		Residue Area	
	run 1	run 2	run 1	run 2	run 1	run 2	run 1	run 2	run 1	run 2
1	0.38	0.38	0.29	0.29	0.67	0.48	0.40	0.40	0.38	0.57
2	0.60	0.50	2.1	2.4	1.2	1.7	1.8	1.5	1.7	1.1
3	0.48	0.39	0.19	0.19	0.29	0.29	0.29	0.097	0.39	0.3
4	0.41	0.25	na	na	0.86	1.2	0.84	na	0.76	1.0
5	0.48	0.48	0.58	0.58	0.47	0.65	0.48	0.57	0.57	1.0
6	0.31	0.20	0.82	0.51	1.2	0.20	0.99	0.20	0.20	0.20
Mean	0.44	0.37	*0.80*	*0.79*	0.78	0.75	0.80	0.55	0.67	0.70
Acetaldehyde										
1	0.11	0.055	0.11	0.22	0.11	0.11	0.12	0.12	0.23	0.055
2	0.47	0.47	0.35	0.35	0.23	0.34	0.32	0.43	0.35	0.46
3	0.23	0.34	0.57	0.34	0.35	0.23	0.34	0.34	0.35	0.23
4	0.29	0.29	na	na	0.20	0.40	0.40	na	0.30	0.30
5	0.34	0.34	0.45	0.45	0.33	0.33	0.34	0.34	0.44	0.33
6	0.48	0.36	0.36	0.48	0.35	0.35	0.47	0.23	0.51	0.51
Mean	0.32	0.31	*0.37*	*0.37*	0.26	0.29	0.33	0.29	0.36	0.31
Propanal										
1	nd	nd	nd	nd	nd	0.24	nd	nd	0.24	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	0.24	nd	nd	nd	0.25	nd	nd	nd
4	0.21	nd	na	na	nd	0.22	nd	na	nd	0.21
5	0.24	0.24	0.24	nd	nd	0.24	0.25	nd	0.24	0.48
6	0.26	0.52	0.52	0.26	0.51	0.51	0.50	0.25	0.51	0.51
Butanal										
1	nd	nd	nd	nd	nd	1.7	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	1.7	0.87	0.88	nd	0.88	0.88	0.89	0.89
4	nd	nd	na	na	nd	nd	nd	na	nd	nd
5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Benzaldehyde										
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	na	nd	nd
5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Appendix 3: Formaldehyde and acetaldehyde concentration at 11 sampling points around Wagerup as determined by passive sampling (Radiello).

Formaldehyde

Sampling Sites	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Combined 1 - 6	
	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error
Boundary Road	0.29	0.00	2.25	0.42	0.19	0.00	No samples		0.58	0.00	0.67	0.44	0.80	0.17
Willowdale Mine	0.58	0.27	1.45	0.71	0.29	0.00	1.03	0.48	0.56	0.25	0.70	1.41	0.77	0.52
Hamel Training Centre	0.40	0.00	1.65	0.42	0.19	0.27	0.84	0.00	0.53	0.13	0.60	1.12	0.70	0.39
Residue Area	0.48	0.27	1.40	0.85	0.35	0.13	0.88	0.34	0.79	0.61	0.20	0.00	0.68	0.37
Waroona Lawn Bowls	1.10	0.14	2.40	0.42	0.92	0.00	1.02	0.71	1.20	0.27	0.59	0.28	1.20	0.30
Yarloop Lawn Bowls	0.52	0.14	2.25	0.42	0.58	0.00	0.66	0.71	0.87	0.27	0.71	0.28	0.93	0.30
Clifton Road Yarloop	0.43	0.13	1.40	0.57	0.14	0.13	0.58	0.47	0.49	0.27	0.56	0.14	0.60	0.28
Residue South	0.19	0.00	0.49	0.28	0.30	0.00	0.47	0.61	0.85	0.27	0.25	0.14	0.42	0.22
Hoffman Road	0.20	0.00	0.95	0.14	0.29	0.00	0.46	0.35	0.63	0.41	0.21	0.30	0.45	0.20
Bremnar Road	0.37	0.00	0.59	0.27	0.19	0.00	0.21	0.11	0.57	0.00	0.10	0.00	0.34	0.06
Boundary Road 3	0.38	0.00	0.55	0.14	0.44	0.13	0.33	0.23	0.48	0.00	0.26	0.16	0.41	0.11
ALL 11 sites	0.45	0.09	1.40	0.42	0.35	0.06	0.65	0.40	0.68	0.22	0.44	0.39	0.66	0.27

Acetaldehyde

Sampling Sites	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Combined 1 - 6	
	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error	mean	Std Error
Boundary Road	0.17	0.16	0.35	0.00	0.46	0.33	No samples		0.45	0.00	0.42	0.17	0.37	0.13
Willowdale Mine	0.11	0.00	0.29	0.16	0.29	0.17	0.30	0.28	0.33	0.00	0.35	0.00	0.28	0.10
Hamel Training Centre	0.12	0.00	0.38	0.16	0.34	0.00	0.40	0.00	0.34	0.00	0.35	0.34	0.32	0.10
Residue Area	0.14	0.25	0.41	0.16	0.29	0.17	0.30	0.00	0.39	0.16	0.51	0.00	0.34	0.12
Waroona Lawn Bowls	0.36	0.00	1.98	3.18	0.80	0.00	0.55	0.14	0.79	0.31	0.59	0.33	0.84	0.66
Yarloop Lawn Bowls	0.17	0.16	0.58	0.00	0.46	0.00	0.34	0.14	0.51	0.17	0.54	0.17	0.43	0.11
Clifton Road Yarloop	0.17	0.16	0.64	0.17	0.29	0.16	0.44	0.13	0.46	0.00	0.89	1.16	0.48	0.29
Residue South	0.06	0.00	0.41	0.16	0.29	0.17	0.35	0.14	0.33	0.00	0.36	0.00	0.30	0.08
Hoffman Road	0.06	0.17	0.35	0.00	0.11	0.00	0.34	0.14	0.29	0.16	0.36	0.34	0.25	0.13
Bremnar Road	0.14	0.23	0.34	0.00	0.23	0.00	0.25	0.14	0.40	0.16	0.23	0.00	0.26	0.09
Boundary Road 3	0.08	0.08	0.47	0.00	0.29	0.16	0.29	0.00	0.34	0.00	0.42	0.17	0.32	0.07
ALL 11 sites	0.14	0.11	0.56	0.36	0.35	0.10	0.36	0.11	0.42	0.09	0.46	0.24	0.38	0.17

Summary

Site No.	Sampling Site	Formaldeyde			Acetaldehyde		
		mean	Min	Maximum	mean	Min	Maximum
11	Bremnar Road	0.34	0.10	0.59	0.26	0.14	0.40
3	Residue Area	0.68	0.20	1.40	0.34	0.14	0.51
4	Residue South	0.42	0.19	0.85	0.30	0.06	0.41
9	Boundary Road 3	0.41	0.26	0.55	0.32	0.08	0.47
8	Boundary Road	0.80	0.19	2.25	0.37	0.17	0.46
10	Hoffman Road	0.45	0.20	0.95	0.25	0.06	0.36
6	Clifton Road Yarloop	0.60	0.14	1.40	0.48	0.17	0.89
5	Yarloop Lawn Bowls	0.93	0.52	2.25	0.43	0.17	0.58
12	Willowdale Mine	0.77	0.29	1.45	0.28	0.11	0.35
1	Waroona Lawn Bowls	1.20	0.59	2.40	0.84	0.36	1.98
2	Hamel Training Centre	0.70	0.40	1.65	0.32	0.12	0.40
	ALL 11 sites	0.66	0.28	1.43	0.38	0.14	0.62

Appendix 4: Method Detection Limit defined, and low concentration assignments, used in this study.

The Method Detection Limit (MDL) refers to the lowest concentration a detected compound can be reliably reported. The value equates to 4 times the compound concentration of a method blank sample.

"D" is assigned to a single value or mean duplicate (for recording purposes) if: ½ MDL < x_1 < MDL. To obtain representative averages (at a sampling site or for a given week) the measurements were allocated a value equal to ½ MDL.

"nd" is assigned to a single value or mean duplicate where x_2 < ½ MDL. A value of zero ("0") was chosen for these measurements when averaging.

Duplicate values are considered "reportable" if both of the conditions below are met:

(a) One value x_1 > 2 MDL, and the other value x_2 > MDL &

(b) $\left| x_1 - x_2 \right|$ < ¼ mean.

Appendix 5: Formaldehyde, acetaldehyde and acetone concentrations at 5 key sampling points around Wagerup determined by the active sampling USEPA method TO-11A.

Formaldehyde	Week number and commencement date						
	1	**2**	**3**	**4**	**5**	**6**	**Site**
	23rd Aug 2004	30th Aug 2004	6th Sept 2004	13th Sept 2004	20th Sept 2004	27th Sept 2004	**Ave**
Boundary Rd 2	2.57	3.04	1.96	4.53	4.46	3.07	3.27
Hoffman Road	3.32	3.58	1.23	5.57	3.00	2.17	3.15
Yarloop Lawn Bowls	1.75	2.75	1.23	4.48	2.84	2.35	2.57
Bremnar Road	2.46	3.47	1.62	3.82	2.57	2.12	2.68
Hamel Training Centre	0.00	1.96	1.23	3.84	2.65	1.88	1.93
Weekly Ave	2.02	2.96	1.45	4.45	3.10	2.32	2.72
Acetaldehyde	Week number						**Site**
	1	**2**	**3**	**4**	**5**	**6**	**Ave**
Boundary Rd 2	1.87	2.39	1.99	2.75	4.87	1.75	2.60
Hoffman Road	2.38	1.82	1.51	2.98	2.23	2.52	2.24
Yarloop Lawn Bowls	1.79	1.87	1.23	2.29	1.89	1.28	1.73
Bremnar Road	1.08	2.11	1.55	2.37	1.64	1.65	1.73
Hamel Training Centre	0.00	1.49	1.32	2.28	1.82	1.41	1.39
Weekly Ave	1.42	1.94	1.52	2.54	2.49	1.72	1.94
Acetone							**Site**
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	**Ave**
Boundary Rd 2	0.71	1.52	0.77	1.82	2.43	0.46	1.29
Hoffman Road	1.58	2.15	0.70	1.12	1.06	0.89	1.25
Yarloop Lawn Bowls	0.63	1.68	0.44	2.20	0.72	0.40	1.01
Bremnar Road	0.88	1.19	0.62	1.25	0.75	1.59	1.05
Hamel Training Centre	0.00	1.50	0.00	1.24	1.67	0.37	0.80
Weekly Ave	0.76	1.61	0.51	1.53	1.33	0.74	1.08

Appendix 6: Aldehyde and ketones concentration at the 5 key sampling points around Wagerup as determined by USEPA TO-11A.

	Boundary Rd 2 (Weeks)						
	Day #	**1**	**2**	**3**	**4**	**5**	**6**
Acetone	**1**	nd (1.9)	2.0 (1.8)		*2.7 (0.96)*	*6.8 (0.97)*	1.3 (0.92) *
	2	D (2.7)	1.3 (0.95)	D (1.8)			
	3		**2.4 (1.1)**	1.3 (0.92)			
	4			1.5 (0.93)	1.8 (1.0)	0.98 (0.98)	nd (1.0)
	5	1.6 (1.4)			1.4 (1.0)	1.4 (1.0)	1.0 (1.0)
Propanal	**1**	D (0.19)	*1.1 (0.18)*		*1.5 (0.19)*	*0.81 (0.097)*	D (0.092)
	2	*0.64 (0.27)*	*0.34 (0.094)*	D (0.18)			
	3		D (0.11)	D (0.092)			
	4			*0.72 (0.093)*	*0.20 (0.10)*	D (0.099)	*1.2 (0.20)*
	5	D (0.14)			D (0.10)	*0.62 (0.10)*	*0.58 (0.10)*
Butanal/ Isobutyraldehyde	**1**	nd (0.19)	0.20 (0.18)		0.13 (0.096)	*0.37 (0.097)*	0.099(0.092) *
	2	D (0.27)	0.11 (0.094)	0.19 (0.18)			
	3		D (0.11)	D (0.090)			
	4			0.13 (0.093)	0.15 (0.10)	nd (0.098)	0.10 (0.10)
	5	D (0.14)			nd (0.099)	0.17 (0.10)	nd (0.10)
Acrolein	**1**	nd (0.19)	nd (0.094)		nd (0.096)	nd (0.097)	nd (0.092) *
	2	nd (0.14)	nd (0.094)	nd (0.095)			
	3		nd (0.11)	nd (0.090)			
	4			nd (0.091)	nd (0.10)	0.12 (0.098)	nd (0.10)
	5	nd (0.13)			nd (0.095)	**0.25 (0.10)**	nd (0.10)
Methacrolein	**1**	nd (0.19)	D (0.18)		0.12 (0.096)	0.15 (0.097)	nd (0.092) *
	2	D (0.27)	0.15 (0.095)	nd (0.095)			
	3		0.13 (0.11)	nd (0.090)			
	4			0.11 (0.093)	*0.38 (0.10)*	0.12 (0.098)	nd (0.10)
	5	nd (0.13)			0.12 (0.10)	*0.24 (0.10)*	nd (0.10)
Methyl Ethyl Ketone	**1**	nd (0.19)	0.24 (0.18)		0.41 (0.15)	*0.64 (0.097)*	0.18 (0.092) *
	2	D (0.27)	0.17 (0.095)	D (0.18)			
	3		*0.28 (0.11)*	D (0.092)			
	4			D (0.091)	0.21 (0.10)	0.098(0.098)	0.30 (0.20)
	5	D (0.14)			0.18 (0.10)	**0.20 (0.10)**	0.16 (0.10)
Pentanal	**1**	nd (0.19)	nd (0.094)		0.12 (0.096)	nd (0.097)	nd (0.092) *
	2	nd (0.14)	nd (0.094)	nd (0.095)			
	3		nd (0.11)	nd (0.090)			
	4			0.093(0.093)	0.12 (0.10)	nd (0.098)	nd (0.10)
	5	nd (0.13)			nd (0.099)	0.16 (0.10)	nd (0.10)
Hexanal	**1**	**0.54 (0.19)**	0.31 (0.18)		**0.30 (0.15)**	*0.37 (0.097)*	*0.24 (0.092)**
	2	0.14 (0.14)	0.095(0.095)	*0.42 (0.18)*			
	3		nd (0.11)	0.090(0.090)			
	4			**0.22 (0.092)**	*0.32 (0.10)*	*0.20 (0.098)*	*0.22 (0.10)*
	5	0.23 (0.13)			*0.20 (0.10)*	**0.24 (0.10)**	0.12 (0.10)
2-Pentanone/ 3-Methyl-2-butanone	**1**	nd (0.19)	*0.37 (0.18)*		**0.47 (0.15)**	*0.44 (0.097)*	*0.20 (0.092)*
	2	0.35 (0.27)	**0.26 (0.095)**	*0.35 (0.18)*			
	3		**0.24 (0.11)**	D (0.092)			
	4			0.091(0.091)	*0.30 (0.10)*	0.15 (0.098)	0.10 (0.10)
	5	0.22 (0.14)			0.18 (0.10)	*0.34 (0.10)*	0.18 (0.10)
Benzaldehyde	**1**	**0.63 (0.19)**	0.24 (0.18)		0.19 (0.096)	*0.31 (0.097)*	0.15 (0.092) *
	2	0.19 (0.14)	0.095(0.095)	D (0.18)			
	3		0.19 (0.11)	nd (0.090)			
	4			0.091(0.091)	0.12 (0.10)	nd (0.098)	nd (0.10)
	5	0.16 (0.14)			nd (0.099)	0.14 (0.10)	nd (0.10)

* Value is for run 2 only.

Shaded cells show days when no samples were collected.

Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 6 (cont.)

		Hoffman Road (Weeks)					
	Day #	1	2	3	4	5	6
Acetone	1		*3.8 (1.9)*	D (1.8)			
	2	D (1.6) *			1.4 (1.0)	0.98 (0.98)	*3.4 (0.96)*
	3	None			1.2 (0.97)	1.4 (1.0)	0.94 (0.94)
	4	2.4 (1.3)	2.5 (1.3)	*1.8 (0.99)*	1.7 (0.95)	1.1 (0.95)	nd (1.0)
	5		1.4 (0.99)	nd (0.93)			
Propanal	1		D (0.19)	D (0.18)			
	2	D (0.16) *			0.47 (0.20)	*1.2 (0.20)*	**0.53 (0.20)**
	3	None			**0.26(0.097)**	*0.32 (0.10)*	*0.45 (0.094)*
	4	D (0.13)	D (0.13)	D (0.099)	**0.26(0.095)**	0.17 (0.095)	**0.46 (0.10)**
	5		D (0.099)	D (0.095)			
Butanal/ Isobutyraldehyde	1		D (0.19)	0.13 (0.096)			
	2	D (0.16) *			0.12 (0.10)	nd (0.098)	nd (0.096)
	3	None			0.11 (0.095)	nd (0.096)	nd (0.094)
	4	D (0.13)	0.15 (0.13)	D (0.099)	0.12 (0.095)	nd (0.092)	nd (0.10)
	5		D (0.099)	nd (0.093)			
Acrolein	1		nd (0.094)	nd (0.096)			
	2	nd (0.16) *			nd (0.10)	nd (0.098)	nd (0.096)
	3	None			nd (0.095)	nd (0.096)	nd (0.094)
	4	nd (0.13)	nd (0.13)	nd (0.094)	nd (0.093)	nd (0.092)	nd (0.10)
	5		nd (0.098)	nd (0.093)			
Methacrolein	1		*0.21 (0.094)*	nd (0.096)			
	2	nd (0.16) *			0.14 (0.10)	D (0.20)	nd (0.096)
	3	None			0.16 (0.097)	nd (0.096)	nd (0.094)
	4	nd (0.13)	nd (0.13)	nd (0.094)	**0.27 (0.095)**	0.095(0.095)	nd (0.10)
	5		0.12 (0.098)	nd (0.093)			
Methyl Ethyl Ketone	1		D (0.19)	D (0.18)			
	2	D (0.16) *			0.16 (0.10)	D (0.20)	*0.84 (0.096)*
	3	None			0.16 (0.097)	0.12 (0.10)	0.11 (0.094)
	4	D (0.13)	0.25 (0.13)	D (0.099)	0.21 (0.095)	0.11 (0.095)	0.12 (0.10)
	5		0.099 (0.099)	0.11 (0.095)			
Pentanal	1		D (0.19)	0.096 (0.096)			
	2	nd (0.16) *			nd (0.10)	nd (0.098)	0.13 (0.096)
	3	None			nd (0.095)	nd (0.096)	nd (0.094)
	4	0.13 (0.13)	nd (0.13)	nd (0.094)	nd (0.093)	nd (0.092)	nd (0.10)
	5		nd (0.098)	nd (0.093)			
Hexanal	1		*0.40 (0.19)*	*0.40 (0.18)*			
	2	0.16 (0.16) *			0.24 (0.10)	0.12 (0.098)	*0.25 (0.096))*
	3	None			0.25 (0.095)	0.18 (0.10)	0.17 (0.096)
	4	**0.52 (0.13)**	*0.28 (0.13)*	*0.26 (0.099)*	*0.30 (0.095)*	0.16 (0.092)	0.14 (0.10)
	5		0.14 (0.098)	0.093 (0.093)			
2-Pentanone/ 3-Methyl- 2-butanone	1		D (0.19)	0.096 (0.096)			
	2	D (0.16) *			D (0.21)	0.10 (0.098)	*0.41 (0.096)*
	3	None			D (0.097)	0.10 (0.096)	0.16 (0.094)
	4	**0.89 (0.13)**	0.18 (0.13)	0.14 (0.099)	0.19 (0.095)	0.16 (0.095)	0.14 (0.10)
	5		0.18 (0.099)	D (0.095)			
Benzaldehyde	1		0.13 (0.094)	*0.17 (0.096)*			
	2	0.16 (0.16) *			0.12 (0.10)	nd (0.098)	0.78 (0.096)
	3	None			0.12 (0.097)	0.10 (0.096)	nd (0.094)
	4	**2.3 (0.13)**	**3.65 (0.13)**	nd (0.094)	0.11 (0.095)	nd (0.092)	nd (0.10)
	5		*2.4 (0.098)*	nd (0.093)			

Shaded cells show days when no samples were collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 6 (cont.)

		Yarloop Lawn Bowls (Weeks)					
	Day #	1	2	3	4	5	6
Acetone	1	nd (1.4)		D (1.9)	**4.0 (1.0)**	2.8 (1.9)	1.4 (0.99)
	2	*3.8 (2.4)*	1.1 (0.94)	1.2 (0.99)	1.2 (0.99)	nd (0.94)	nd (0.98)
	3	nd (1.7)	1.4 (0.99)	nd (0.97)	1.3 (0.95)	nd (0.95)	nd (1.0)
	4		*3.2 (0.99)*				
	5						
Propanal	1	D (0.15)		**4.6 (0.15)**	*1.4 (0.20)*	**0.78 (0.15)**	*0.32 (0.099)*
	2	*3.5 (0.24)*	D (0.19)	*0.26 (0.099)*	**0.20 (0.098)**	*0.59 (0.094)*	D (0.099)
	3	D (0.20)	D (0.099)	D (0.097)	D (0.10)	D (0.096)	*0.52 (0.10)*
	4		D (0.10)				
	5						
Butanal/ Isobutyraldehyde	1	nd (0.14)		D (0.19)	0.29 (0.20)	nd (0.093)	nd (0.099)
	2	0.33 (0.24)	D (0.19)	0.14 (0.099)	0.12 (0.098)	0.11 (0.094)	nd (0.098)
	3	nd (0.20)	D (0.099)	D (0.099)	0.14 (0.095)	nd (0.095)	nd (0.10)
	4		0.16 (0.099)				
	5						
Acrolein	1	nd (0.14)		nd (0.093)	nd (0.099)	nd (0.093)	0.18 (0.099)
	2	nd (0.11)	nd (0.094)	nd (0.093)	nd (0.098)	nd (0.094)	nd (0.098)
	3	nd (0.17)	nd (0.099)	nd (0.097)	0.11 (0.095)	nd (0.095)	nd (0.10)
	4		nd (0.099)				
	5						
Methacrolein	1	nd (0.14)		nd (0.093)	0.20 (0.20)	nd (0.093)	nd (0.099)
	2	0.31 (0.24)	nd (0.094)	nd (0.093)	nd (0.098)	nd (0.094)	nd (0.098)
	3	nd (0.17)	nd (0.099)	nd (0.097)	nd (0.095)	nd (0.095)	nd (0.10)
	4		nd (0.099)				
	5						
Methyl Ethyl Ketone	1	nd (0.14)		D (0.19)	*0.57 (0.20)*	0.26 (0.19)	0.24 (0.20)
	2	0.29 (0.24)	D (0.19)	D (0.099)	**0.20 (0.099)**	0.11 (0.094)	0.18 (0.099)
	3	0.20 (0.20)	**0.30 (0.099)**	D (0.099)	0.12 (0.10)	0.13 (0.095)	0.16 (0.10)
	4		**0.32 (0.10)**				
	5						
Pentanal	1	nd (0.14)		D (0.19)	0.25 (0.20)	0.13 (0.093)	0.099(0.099)
	2	nd (0.11)	nd (0.094)	nd (0.093)	0.14 (0.098)	0.11 (0.096)	nd (0.098)
	3	nd (0.17)	nd (0.099)	nd (0.097)	nd (0.095)	nd (0.095)	nd (0.10)
	4		nd (0.099)				
	5						
Hexanal	1	D (0.15)		D (0.093)	*0.51 (0.20)*	**0.40 (0.15)**	0.18 (0.099)
	2	D (0.24)	0.15 (0.094)	0.20 (0.099)	*0.24 (0.098)*	0.11 (0.096)	*0.20 (0.098)*
	3	0.17 (0.17)	0.12 (0.099)	0.16 (0.099)	*0.19 (0.095)*	0.17 (0.096)	0.16 (0.10)
	4		*0.22 (0.099)*				
	5						
2-Pentanone/ 3-Methyl- 2-butanone	1	D (0.15)		D (0.19)	*0.76 (0.20)*	*0.39 (0.19)*	0.20 (0.20)
	2	*0.71 (0.24)*	0.094(0.094)	D (0.099)	0.13 (0.099)	0.15 (0.096)	0.11 (0.099)
	3	0.23 (0.17)	0.14 (0.099)	D (0.099)	0.18 (0.095)	0.14 (0.096)	D (0.10)
	4		**0.33 (0.10)**				
	5						
Benzaldehyde	1	D (0.15)		D (0.19)	0.31 (0.20)	0.13 (0.093)	nd (0.099)
	2	0.14 (0.11)	nd (0.094)	nd (0.093)	nd (0.098)	nd (0.094)	nd (0.098)
	3	0.20 (0.17)	*0.20 (0.099)*	nd (0.097)	nd (0.095)	nd (0.095)	nd (0.10)
	4		**0.20 (0.099)**				
	5						

Shaded cells show days when no samples were collected.

Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 6 (cont.)

		Bremnar Road (Weeks)					
	Day #	1	2	3	4	5	6
Acetone	1	None	1.7 (0.93)	1.5 (1.0)	2.0 (1.3)	1.2 (0.96)	2.2 (2.0)
	2		1.6 (0.94)	nd (0.94)	1.0 (1.0)	nd (0.99)	1.2 (0.99)
	3			1.1 (0.91)		1.2 (0.99)	
	4	nd (1.5)					
	5	*3.5 (1.7)*	D (0.13)		1.9 (0.97)		**2.0 (0.90)**
Propanal	1	None	*2.5 (0.19)*	**2.5 (0.20)**	D (0.24)	*0.98 (0.20)*	D (0.20)
	2		*1.4 (0.092)*	D (0.096)	*0.32 (0.10)*	0.48 (0.099)	**0.40 (0.10)**
	3			D (0.091)		0.30 (0.089)	
	4	0.22 (0.15)					
	5	*1.7 (0.17)*	D (0.013)		0.12 (0.097)		**0.28 (0.09)**
Butanal/ Isobutyraldehyde	1	None	360	0.15 (0.10)	0.15 (0.13)	nd (0.096)	nd (0.098)
	2		**0.20 (0.09)**	nd (0.094)	nd (0.098)	nd (0.099)	nd (0.096)
	3			nd (0.090)		0.12 (0.099)	
	4	nd (0.15)					
	5	*0.38 (0.17)*	D (0.013)		0.11 (0.097)		0.092 (0.092)
Acrolein	1	None	nd (0.093)	nd (0.10)	nd (0.13)	nd (0.096)	0.12 (0.098)
	2		nd (0.092)	nd (0.094)	nd (0.098)	nd (0.099)	nd (0.096)
	3			nd (0.090)		nd (0.089)	
	4	nd (0.15)					
	5	nd (0.17)	nd (0.013)		nd (0.097)		nd (0.089)
Methacrolein	1	None	0.11 (0.093)	nd (0.10)	0.13 (0.13)	nd (0.096)	0.35 (0.20)
	2		0.15 (0.094)	nd (0.094)	nd (0.098)	nd (0.099)	D (0.099)
	3			nd (0.090)		0.16 (0.099)	
	4	0.15 (0.15)					
	5	nd (0.17)	nd (0.013)		0.21 (0.097)		nd (0.089)
MEK	1	None	*0.32 (0.19)*	0.10 (0.10)	0.38 (0.24)	0.21 (0.096)	0.33 (0.20)
	2		0.21 (0.094)	0.11 (0.096)	0.15 (0.10)	nd (0.099)	0.17 (0.096)
	3			0.11 (0.090)		0.16 (0.099)	
	4	0.15 (0.15)					
	5	0.19 (0.19)	0.075 (0.013)		**0.20 (0.10)**		0.11 (0.089)
Pentanal	1	None	D (0.19)	0.10 (0.10)	0.13 (0.13)	nd (0.096)	nd (0.098)
	2		0.13 (0.094)	nd (0.094)	nd (0.098)	nd (0.099)	nd (0.096)
	3			nd (0.090)		nd (0.089)	
	4	nd (0.15)					
	5	0.21 (0.17)	nd (0.013)		0.12 (0.097)		nd (0.089)
Hexanal	1	None	*0.28 (0.093)*	*0.27 (0.10)*	0.26 (0.13)	*0.19 (0.096)*	*0.41 (0.20)*
	2		*0.26 (0.094)*	0.096(0.096)	0.12 (0.098)	0.14 (0.099)	0.16 (0.099)
	3			0.18 (0.090)		0.20 (0.099)	
	4	0.22 (0.15)					
	5	*0.38 (0.17)*	D (0.013)		**0.38 (0.10)**		0.17 (0.092)
2-Pentanone/ 3-Methyl- 2-butanone	1	None	0.19 (0.19)	0.46 (0.10)	0.26 (0.13)	0.31 (0.20)	0.31 (0.20)
	2		**0.30 (0.09)**	*0.38 (0.096)*	0.17 (0.098)	0.13 (0.099)	**0.24 (0.10)**
	3			0.23 (0.090)		0.18 (0.089)	
	4	D (0.15)					
	5	D (0.19)	D (0.013)		*0.21 (0.097)*		0.18 (0.092)
Benzaldehyde	1	None	0.30 (0.19)	*0.27 (0.10)*	*0.59 (0.24)*	*1.6 (0.20)*	*1.0 (0.20)*
	2		0.13 (0.094)	0.21 (0.096)	0.12 (0.10)	nd (0.099)	nd (0.096)
	3			nd (0.090)		nd (0.089)	
	4	nd (0.15)					
	5	nd (0.17)	nd (0.013)		0.12 (0.097)		nd (0.089)

Shaded cells show days when no samples were collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 6 (cont.)

		Hamel Training Centre (Weeks)					
	Day #	1	2	3	4	5	6
Acetone	1						
	2						
	3	None	1.5 (1.9)	nd (0.94)	D (2.0)	1.4 (0.99)	1.0 (1.0)
	4	None	1.6 (0.91)	nd (0.92)	1.8 (0.98)	1.2 (1.0)	nd (1.0)
	5	nd (1.3)	1.5 (0.95)	nd (0.96)	1.4 (1.0)	**2.6 (1.0)**	1.2 (0.98)
Propanal	1						
	2						
	3	None	*0.73 (0.094)*	*0.80 (0.19)*	0.28 (0.20)	**0.34 (0.15)**	*0.45 (0.21)*
	4	None	D (0.093)	D (0.097)	D (0.098)	**0.34 (0.10)**	*0.25 (0.10)*
	5	*1.5 (0.25)*	D (0.095)	D (0.096)	D (0.10)	*0.76 (0.10)*	**0.28 (0.10)**
Butanal/ Isobutyraldehyde	1						
	2						
	3	None	0.17 (0.094)	nd (0.094)	D (0.20)	nd (0.099)	nd (0.10)
	4	None	D (0.093)	D (0.097)	nd (0.097)	0.12 (0.097)	nd (0.10)
	5	0.15 (0.13)	D (0.095)	D (0.096)	nd (0.10)	*0.32 (0.10)*	nd (0.098)
Acrolein	1						
	2						
	3	None	nd (0.094)	nd (0.094)	nd (0.099)	nd (0.099)	nd (0.10)
	4	None	nd (0.091)	nd (0.092)	nd (0.097)	nd (0.097)	nd (0.10)
	5	nd (1.3)	nd (0.090)	nd (0.096)	nd (0.10)	**0.20 (0.10)**	nd (0.098)
Methacrolein	1						
	2						
	3	None	nd (0.094)	nd (0.094)	D (0.20)	nd (0.099)	nd (0.10)
	4	None	nd (0.091)	nd (0.092)	**0.22 (0.098)**	0.14 (0.097)	nd (0.10)
	5	nd (0.13)	nd (0.090)	nd (0.096)	0.16 (0.10)	**0.29 (0.10)**	nd (0.098)
Methyl Ethyl Ketone	1						
	2						
	3	None	0.19 (0.094)	D (0.19)	0.22 (0.20)	0.18 (0.099)	0.30 (0.21)
	4	None	0.11 (0.091)	D (0.097)	0.16 (0.097)	0.14 (0.097)	0.18 (0.10)
	5	nd (0.13)	D (0.090)	0.12 (0.098)	0.10 (0.10)	**0.43 (0.10)**	*0.20 (0.098)*
Pentanal	1						
	2						
	3	None	nd (0.094)	nd (0.094)	nd (0.099)	nd (0.099)	nd (0.10)
	4	None	nd (0.091)	nd (0.092)	nd (0.097)	nd (0.097)	nd (0.10)
	5	nd (0.13)	nd (0.090)	nd (0.096)	nd (0.10)	0.14 (0.10)	nd (0.098)
Hexanal	1						
	2						
	3	None	nd (0.094)	0.094(0.094)	D (0.20)	nd (0.099)	nd (0.10)
	4	None	D (0.093)	nd (0.092)	0.14 (0.097)	**0.26 (0.10)**	0.14 (0.10)
	5	0.25 (0.25)	D (0.090)	nd (0.096)	0.14 (0.10)	*0.48 (0.10)*	0.18 (0.098)
2-Pentanone/ 3-Methyl-2-butanone	1						
	2						
	3	None	0.25 (0.19)	0.11 (0.094)	D (0.20)	0.16 (0.099)	0.34 (0.21)
	4	None	D (0.093)	D (0.097)	0.15 (0.098)	**0.30 (0.10)**	0.14 (0.10)
	5	0.33 (0.25)	D (0.095)	0.12 (0.098)	0.10 (0.10)	*1.0 (0.10)*	*0.27 (0.098)*
Benzaldehyde	1						
	2						
	3	None	0.11 (0.094)	*0.63 (0.19)*	*0.78 (0.20)*	nd (0.099)	nd (0.10)
	4	None	0.091(0.091)	0.14 (0.097)	0.12 (0.098)	0.12 (0.10)	nd (0.10)
	5	0.25 (0.25)	0.095(0.095)	0.13 (0.096)	0.12 (0.10)	0.16 (0.10)	nd (0.098)

Shaded cells show days when no samples were collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 7: Aldehyde and ketones concentration at the 5 key sampling points around Wagerup as determined by USEPA TO-5A.

		Boundary Rd 2 (Days)					Bremnar Road (Days)					Hamel Training Centre (Days)					Hoffman Road (Days)					Yarloop Lawn Bowls (Days)				
	Week #	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Formaldehyde	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	14 (14)	13 (13)				**25 (12)**							nd (12)	13 (13)					None			None	None		
	3		Invalid				None							None	None					None		None	nd (14)			
	4				None		nd (15)							13 (13)	nd (10)			nd (11)	nd (14)			nd (14)	14 (14)			
	5				nd (13)		nd (13)							nd (14)	nd (14)			None	nd (12)			None	nd (13)			
	6				None		13 (13)							nd (11)	None			nd (14)	nd (13)			nd (13)	nd (14)			
Acetaldehyde	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	D (14)	13 (13)				D (12)							D (12)	D (13)					None			None	None		
	3		Invalid				None							None	None					None		None	14 (14)			
	4				None		D (15)							D (13)	D (10)			D (11)	**28 (14)**			D (14)	14 (14)			
	5				13 (13)		D (13)							14 (14)	14 (14)			None	D (12)			None	D (13)			
	6				None		nd (13)							nd (11)	None			D (14)	D (13)			nd (13)	nd (14)			
Acetone	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	D (14)	13 (13)				*D (12)*							D (12)	D (13)					None			None	None		
	3		Invalid				None							None	None					None		None	D (14)			
	4				None		D (15)							25 (13)	**280 (10)**			D (11)	D (14)			D (14)	D (14)			
	5				D (13)		D (13)							D (14)	D (14)			None	D (12)			None	D (13)			
	6				None		D (13)							D (11)	None			D (14)	D (13)			D (13)	D (14)			
Butanal/ Isobutyraldehyde	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	D (14)	22 (13)				D (12)							D (12)	D (13)					None			None	None		
	3		Invalid				None							None	None					None		None	nd (14)			
	4				None		D (15)							**51 (13)**	**25 (10)**			nd (11)	nd (14)			nd (14)	nd (14)			
	5				nd (13)		D (13)							nd (14)	nd (14)			None	nd (12)			None	nd (13)			
	6				None		14 (13)							nd (11)	None			20 (14)	nd (13)			nd (13)	nd (14)			
Hexanal	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	nd (14)	nd (13)				nd (12)							nd (12)	nd (13)					None			None	None		
	3		Invalid				None							None	None					None		None	nd (14)			
	4				None		nd (15)							13 (13)	nd (10)			nd (11)	nd (14)			nd (14)	nd (14)			
	5				nd (13)		D (13)							nd (14)	nd (14)			None	nd (12)			None	nd (13)			
	6				None		14 (13)							nd (11)	None			nd (14)	nd (13)			nd (13)	nd (14)			
2-Pentanone/ 3-methyl-2-butanone	1	None			None	None	None							None	None			None	None	None		None	None	None		
	2	D (14)	**39 (13)**				**34 (12)**							D (12)	D (13)					None			None	None		
	3		Invalid				None							None	None					None		None	D (14)			
	4				None		D (15)							**59 (13)**	**34 (10)**			D (11)	D (14)			D (14)	D (14)			
	5				18 (13)		D (13)							D (14)	D (14)			None	D (12)			None	D (13)			
	6				None		D (13)							D (11)	None			D (14)	D (13)			nd (13)	nd (14)			

Only run 2 analysed. Collection flow rate at end many times higher than at start.
No sample collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 8: VOCs concentration at 11 sampling points around Wagerup as determined by passive sampling (Radiello).

	Week #	Benzene	Toluene	Xylenes	n-Hexane	n-decane	n-Heptane	Isooctane	Cyclohexane	Others
	1	nd (0.11)	nd (0.12)	nd (0.16)	nd (0.14)	nd (0.21)	0.16 (0.16)	nd (0.17)	nd (0.17)	nd
	2	0.12 (0.12)	nd	nd	0.15 (0.15)	nd	nd	nd	*0.36 (0.18)*	nd
Bremnar	**3**	0.12 (0.12)	0.12 (0.12)	nd	nd	*0.89 (0.22)*	nd	nd	nd	nd
Road (11)	**4**	nd	nd	nd	nd	nd	nd	nd	nd	nd
	5	nd	0.13 (0.13)	nd	0.14 (0.14)	nd	nd	0.17 (0.17)	nd	nd
	6	nd	nd	nd	nd	nd	nd	nd	nd	nd
	1	nd (0.12)	nd (0.13)	nd (0.16)	nd (0.14)	nd (0.22)	nd (0.16)	nd (0.17)	nd (0.19)	nd
Residue	**2**	nd	nd	nd	0.59 (0.15)	nd	nd	nd	nd	nd
Area (3)	**3**	nd	nd	nd	nd	D (0.23)	nd	nd	nd	nd
	4	nd	0.11 (0.11)	nd	nd	nd	nd	nd	nd	nd
	5	nd	nd	nd	nd	nd	nd	nd	nd	nd
	6	nd	0.13 (0.13)	nd	nd	nd	nd	nd	nd	nd
	1	nd (0.12)	nd (0.13)	nd (0.16)	*0.29 (0.14)*	nd (0.22)	0.16 (0.16)	nd (0.17)	0.18 (0.18)	nd
Residue	**2**	0.12 (0.12)	nd	nd	0.15 (0.15)	nd	nd	nd	nd	nd
South (4)	**3**	nd	nd	nd	nd	D (0.23)	nd	nd	nd	nd
	4	nd	nd	nd	nd	nd	nd	nd	nd	nd
	5	nd	nd	nd	nd	nd	nd	nd	nd	nd
	6	nd	0.13 (0.13)	nd	nd	nd	nd	nd	nd	nd
	1	0.12 (0.12)	0.13 (0.13)	nd (0.15)	*0.57 (0.14)*	0.22 (0.22)	**0.65 (0.16)**	nd (0.17)	*0.52 (0.17)*	nd
	2	nd	*0.27 (0.13)*	nd	0.15 (0.15)	0.23 (0.23)	**0.51 (0.17)**	nd	nd	nd
Boundary	**3**	0.12 (0.12)	0.12 (0.12)	nd	nd	D (0.22)	nd	nd	nd	nd
Road 3 (7)	**4**	nd	nd	nd	nd	nd	*0.56 (0.14)*	nd	nd	nd
	5	nd	nd	nd	nd	nd	**0.26 (0.13)**	nd	nd	nd
	6	nd	nd	nd	nd	nd	**0.35 (0.17)**	nd	nd	nd
	1	nd (0.12)	nd (0.13)	nd (0.15)	*4.1 (0.14)*	nd (0.22)	0.16 (0.16)	0.17 (0.17)	nd (0.19)	nd
Boundary	**2**	nd	nd	nd	nd	nd	nd	nd	nd	nd
Road 2 (8)	**3**	0.12 (0.12)	0.13 (0.13)	nd	nd	D (0.22)	nd	nd	nd	nd
	4	nd	0.14 (0.14)	nd	nd	nd	nd	nd	0.20 (0.20)	**Y 1**
	5	0.12 (0.12)	0.13 (0.13)	nd	nd	nd	nd	nd	nd	nd
	6	nd	0.14 (0.14)	nd	nd	nd	nd	nd	nd	nd
	1	nd (0.12)	nd (0.13)	nd (0.16)	*12 (0.15)*	nd (0.23)	0.33 (0.17)	*0.53 (0.18)*	nd (0.18)	nd
Hoffman	**2**	nd	nd	nd	nd	nd	nd	nd	nd	nd
Road (10)	**3**	nd	nd	nd	nd	D (0.22)	nd	nd	nd	nd
	4	nd	nd	nd	nd	nd	nd	nd	nd	nd
	5	nd	nd	nd	nd	nd	nd	nd	nd	nd
	6	nd	nd	nd	nd	nd	nd	nd	nd	nd

Note : **Y 1 :** Isobutanol *1.8 (0.14)*

Appendix 8 (cont.)

	Week #	Benzene	Toluene	Xylenes	n-Hexane	n-decane	n-Heptane	Isooctane	Cyclohexane	Others
Clifton Road (6)	**1**	0.23 (0.12)	nd (0.13)	nd (0.15)	nd (0.14)	nd (0.22)	nd (0.16)	nd (0.17)	0.17 (0.17)	nd
	2	nd	nd	nd	nd	nd	nd	nd	nd	nd
	3	0.12 (0.12)	0.13 (0.13)	nd	nd	D (0.22)	nd	nd	nd	nd
	4	nd	0.11 (0.11)	nd	nd	nd	nd	nd	nd	nd
	5	nd	nd	nd	nd	nd	nd	nd	nd	nd
	6	nd	0.27 (0.14)	nd	nd	nd	nd	nd	nd	nd
Yarloop Lawn Bowls (5)	**1**	0.12 (0.12)	0.25 (0.13)	nd (0.15)	nd (0.14)	nd (0.22)	D (0.16)	nd (0.17)	nd (0.17)	nd
	2	*0.37 (0.12)*	nd	nd	nd	nd	nd	nd	nd	nd
	3	**0.24 (0.12)**	**0.26 (0.13)**	nd	nd	D (0.22)	nd	nd	nd	nd
	4	**0.20 (0.10)**	**0.22 (0.11)**	nd	0.12 (0.12)	nd	0.14 (0.14)	nd	*0.30 (0.15)*	nd
	5	0.12 (0.12)	*0.26 (0.13)*	nd	nd	nd	nd	nd	nd	nd
	6	0.25 (0.13)	**0.41 (0.14)**	0.16 (0.16)	nd	nd	nd	nd	nd	nd
Willowdale Mine (12)	**1**	nd (0.12)	nd (0.13)	nd (0.15)	*0.43 (0.14)*	nd (0.22)	nd (0.16)	nd (0.17)	nd (0.19)	nd
	2	nd	nd	nd	nd	nd	nd	nd	nd	nd
	3	nd	nd	nd	nd	D (0.23)	nd	nd	nd	nd
	4	nd	nd	nd	nd	nd	nd	nd	nd	nd
	5	nd	nd	nd	nd	nd	nd	nd	nd	nd
	6	nd	nd	nd	nd	nd	nd	nd	nd	nd
Waroona Lawn Bowls (1)	**1**	0.63 (0.13)	**0.41 (0.12)**	0.16 (0.16)	**0.30 (0.15)**	nd (0.23)	0.17 (0.17)	nd (0.18)	nd (0.19)	nd
	2	*0.22 (0.11)*	**0.36 (0.12)**	0.29 (0.15)	*0.68 (0.14)*	nd	nd	nd	nd	nd
	3	**0.48 (0.12)**	**0.39 (0.13)**	nd	nd	D (0.22)	nd	nd	nd	nd
	4	**0.42 (0.10)**	**0.68 (0.11)**	0.27 (0.14)	0.25 (0.13)	nd	0.14 (0.14)	nd	**0.31 (0.15)**	nd
	5	**0.36 (0.12)**	**0.38 (0.13)**	nd	nd	nd	nd	nd	nd	nd
	6	*0.49 (0.12)*	**0.72 (0.13)**	**0.32 (0.16)**	nd	nd	nd	nd	nd	nd
Hamel Training Centre (2)	**1**	nd (0.12)	nd (0.14)	nd (0.15)	nd (0.15)	nd (0.23)	nd (0.17)	nd (0.18)	nd (0.19)	nd
	2	nd	nd	nd	nd	*0.42 (0.21)*	nd	nd	nd	nd
	3	0.12 (0.12)	nd	nd	nd	D (0.22)	nd	nd	nd	nd
	4	nd	nd	*2.2 (0.16)*	nd	nd	nd	*0.57 (0.19)*	*0.39 (0.19)*	**Y 2**
	5	nd	0.13 (0.13)	nd	**0.43 (0.14)**	nd	nd	0.17 (0.17)	nd	nd
	6	nd	nd	nd	nd	nd	nd	nd	nd	nd

Note : **Y 2** : 2-Methylpentane: 0.74 (0.15) & 3-Methylpentane: 0.74 (0.15)

Appendix 9A: VOCs concentration at the 5 key sampling points around Wagerup as determined by active sampling method USEPA TO-17.

		Carbon tetrachloride (Days)					Benzene (Days)					Toluene (Days)				
	Week #	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Boundary Rd 2	**1**	nd	nd			nd	0.58 (0.58)	nd			nd	nd	nd			nd
	2	nd	nd	nd			D (1.2); D (0.59)	D (1.2); D (0.60)	D (1.2); D (0.60)			nd	nd	nd		
	3		nd	nd	nd			nd	nd	nd			nd	nd	nd	
	4	nd			nd	nd	nd			nd	nd	nd			nd	nd
	5	nd			nd	nd	nd			nd	nd	nd			nd	nd
	6	nd			nd	0.62 (0.62)	nd			nd	nd	nd			nd	nd
Hoffman Road	**1**		1 Lost	nd	nd			1 Lost	nd	*4.6 (1.2)*			1 Lost	nd	nd	
	2	nd			nd	nd	nd			nd	0.86 (0.62)	nd			nd	nd
	3	nd			nd	nd	nd			nd	nd	nd			nd	nd
	4		nd	nd	nd			nd	nd	nd			nd	nd	nd	
	5		nd	nd	nd			nd	nd	nd			nd	nd	nd	
	6		nd	nd	nd			nd	nd	nd			nd	nd	nd	
Yarloop Lawn Bowls	**1**	2 Lost	nd	1 Lost			2 Lost	nd	1 Lost			1.7 (1.2)	nd	nd		
	2		D	nd	nd			nd	nd	nd			nd	nd	0.74 (0.62)	
	3	nd	nd	nd			nd	nd	nd			nd	nd	nd		
	4	0.62 (0.62)	nd	nd			nd	nd	nd			0.95 (0.59)	0.73 (0.61)	nd		
	5	nd	nd	nd			nd	nd	nd			nd	**Y**	nd		
	6	nd	nd	nd			nd	nd	nd			nd	nd	nd		
Bremnar Road	**1**	nd			nd	nd	1.6 (1.6); 0.85 (0.85)			1.3 (1.3)	nd	nd			nd	nd
	2	nd	nd			0.62 (0.62)	*	0.79 (0.57)*			*	nd	nd			nd
	3	0.62 (0.62)	nd			nd	nd	nd			nd	nd	nd			nd
	4	nd	nd			nd	nd	nd			nd	nd	nd			nd
	5	nd	nd			nd	nd	nd			nd	nd	D (0.62)			nd
	6	1 Lost	nd			nd	1 Lost	nd			nd	1 Lost	nd			nd
Hamel Training Centre	**1**			nd	nd	nd			nd	nd	nd			nd	nd	nd
	2			nd	nd	0.73 (0.61)			nd	nd	nd			0.60 (0.60)	nd	nd
	3			nd	nd	nd			nd	nd	nd			nd	nd	nd
	4			nd	nd	nd			nd	nd	nd			nd	nd	nd
	5			nd	nd	nd			nd	nd	nd			nd	nd	nd
	6			nd	nd	nd			nd	nd	nd			nd	nd	nd

Y Toluene 2.3 ug/m3 and Xylene 1.1 on Run 1/AM (MDLs 0.60 ug/m3)

Shaded cells show days when no samples were collected

***** S-B-benzene: 360.0 ug/m3 on Run 1/AM (MDL 1.2 ug/m3)

Italic typeface indicates <u>one</u> run has measured value more than 2 times the MDL.

Appendix 9B: Additional VOCs at the 5 key sampling points as determined by USEPA TO-17.

		Additional Compounds (Days)				
	Week #	1	2	3	4	5
Boundary Rd 2	**1**	nd	nd			nd
	2	MCP, Hexane	nd	nd		
	3		nd	nd	nd	
	4	nd			nd	nd
	5	nd			nd	nd
	6	nd			Hexane	nd
Hoffman Road	**1**		1 Lost	nd	Hexane	
	2	Hexane			Hexane	**D**
	3	nd			nd	Hexane
	4		nd	nd	nd	
	5		nd	nd	nd	
	6		nd	2-MP	nd	
Yarloop Lawn Bowls	**1**	2 Lost	nd	1 Lost		
	2		**D**	nd	**D**	
	3	2-MP, Pentane	2-MP, Pentane	2-MP, Pentane		
	4	Iso-Pentane	nd	nd		
	5	nd	nd	nd		
	6	**D**	nd	nd		
Bremnar Road	**1**	nd			nd	nd
	2	Hexane	nd			nd
	3	**D**	2-MP, Pentane			2-MP, Pentane
	4	nd	nd			nd
	5	nd	nd			Hexane
	6	1 Lost	nd			nd
Hamel Training Centre	**1**			nd	nd	nd
	2			nd	Hexane	2-MP, Pentane
	3			nd	nd	nd
	4			nd	nd	Hexane
	5			nd	nd	nd
	6			nd	nd	nd

D More than 3 additional compounds found - semi-quantative analysis only
MCP: methyl cyclopentane 2-MP: 2-methylpentane

Appendix 10 A: VOCs concentration at 4 key sampling points as determined by USEPA TO-13A.

		(Days)				
	Week #	1	2	3	4	5
Boundary Rd 2	**1 - 6**	***No samples collected over 6 week period.***				
Hoffman Road	**1**					
	2	None	Naphthalene 0.0034 1-Mnaph 0.0033 2-Mnaph 0.0033	nd	nd	nd
	3	Benzyl Alcohol 0.068	Benzyl Alcohol 0.0063	nd	nd	Naphthalene 0.0061 1-Mnaph 0.0041 2-Mnaph 0.0081 m&p Cresol 0.0051 o-Cresol 0.0010
	4	Naphthalene 0.0033 Benzyl Alcohol 0.0033	nd	Addnl	Addnls	Addnls
	5	nd	nd	Addnls	Addnl	2-Mnaph 0.0010 Addnl
	6	nd	m&p Cresol 0.0032	Pyrene 0.0032 m&p Cresol 0.016	nd	2-Mnaph 0.00078 m&p Cresol 0.0016 Addnls
Yarloop Lawn Bowls **	**1**					
	2		None	**10**	**11**	**7**
	3	**6 plus** Addnls	**6 plus** Addnls	**6**	**3**	**6 plus** Addnls
	4	Naphthalene 0.0034	nd	Naphthalene 0.0036 Addnl	**5 plus** Addnl	**7 plus** Addnls
	5	**3 plus** Addnls	Naphthalene 0.016	**5 plus** Addnls	Addnl	m&p Cresol 0.00098 Phenol 0.00098 Addnl
	6	Addnl	nd	Addnl	Phenol 0.0025 Addnl	**4 plus** Addnls
Bremnar Road	**1**	nd	nd	None	nd	nd
	2	nd	nd	nd	None	nd
	3	None	nd			
	4					
	5					
	6					
Hamel Training Centre	**1**					
	2					
	3				nd	nd
	4	None	nd	nd (Addnl)	nd (Addnl)	nd (Addnl)
	5	Naph 0.0031	2-MNaph 0.0053 1-Mnaph 0.0026	nd	nd (Addnls)	nd
	6	m&p Cresol 0.015 Addnls	nd	m&p Cresol 0.0050	m&p Cresol 0.0051	nd (Addnls)

** See Appendix 2B for more detailed information at this locality.
Shading indicates no samples were collected.

Appendix 10 B: PAHs concentration at Yarloop Lawn Bowls as determined by active sampling method USEPA TO-13A.

Week #	1	2	3 **DAYS**	4	5
1	***No samples Collected.***				
2		Lost	Naphthalene 0.025 Phenanthrene 0.0031 Dibenzofuran 0.0031 1-MNaph 0.0062 2-MNaph 0.012 m&p Cresol 0.018 o-Cresol 0.0092 Phenol 0.0062 2,4-Dimethylphenol 0.0092 1,4-Dichlorobenzene 0.0031	Fluorene 0.0033 Naphthalene 0.030 Phenanthrene 0.0066 Dibenzofuran 0.0033 1-Mnaph 0.0099 2-Mnaph 0.020 m&p Cresol 0.0039 o-Cresol 0.0020 Phenol 0.0099 2,4-Dimethylphenol 0.013 1,4-Dichlorobenzene 0.0099	Naphthalene 0.0032 1-MNaph 0.0099 2-MNaph 0.020 m&p Cresol 0.0050 o-Cresol 0.0050 Phenol 0.0011 1,4-Dichlorobenzene 0.0011
3	1-Mnaph 0.0033 2-Mnaph 0.0033 m&p Cresol 0.0065 o-Cresol 0.0033 2,4-Dimethylphenol 0.0033 1,4-Dichlorobenzene 0.0033 Addnls	1-Mnaph 0.0037 2-Mnaph 0.0074 m&p Cresol 0.011 o-Cresol 0.0037 2,4-Dimethylphenol 0.0037 Benzyl Alcohol 0.015 1,4-Dichlorobenzene 0.0037 Addnls	Naphthalene 0.0098 1-MNaph 0.0033 2-Mnaph 0.0033 m&p Cresol 0.016 o-Cresol 0.0033 1,4-Dichlorobenzene 0.0033	Naphthalene 0.0090 2-Mnaph 0.0030 1,4-Dichlorobenzene 0.0030	Fluoranthene 0.0011 Fluorene 0.0022 Naphthalene 0.018 Phenanthrene 0.0056 Pyrene 0.0011 1-MNaph 0.0056 2-MNaph 0.010 m&p Cresol 0.0011 1,4-Dichlorobenzene 0.0022 Addnls
4	Naphthalene 0.0034	nd	Naphthalene 0.0036 Addnl	Naphthalene 0.016 1-Mnaph 0.0040 2-Mnaph 0.0080 m&p Cresol 0.0080 o-Cresol 0.0040 Addnl	Naphthalene 0.0061 Phenanthrene 0.0020 1-MNaph 0.0020 2-MNaph 0.0031 m&p Cresol 0.0080 o-Cresol 0.0040 1,4-Dichlorobenzene 0.0022 Addnls
5	Naphthalene 0.0032 m&p Cresol 0.0096 o-Cresol 0.0064 Addnls	Naphthalene 0.016	Naphthalene 0.0095 1-Mnaph 0.0040 2-Mnaph 0.0032 m&p Cresol 0.0032 1,4-Dichlorobenzene 0.0032 Addnls	Addnl	m&p Cresol 0.00098 Phenol 0.00098 Addnl
6	Addnl	nd	Addnl	Phenol 0.0025 Addnl	1-Mnaph 0.0040 2-Mnaph 0.0032 m&p Cresol 0.014 o-Cresol 0.0016 Addnls

Appendix 11: Metals concentrations at the 5 key sampling points around Wagerup as determined by AS-2800.

		Hoffman Road (Weeks)						Bremnar Road (Weeks)					
(ug/m3)	Ave MDL	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
TSP		9	12	12	16	13	16	8.0	9.4	9.6	**NO samples collected**		
Lead	*0.0000042*	0.00017	0.00031	0.000051	0.00017	0.00025	0.00066	0.00018	0.00080	nd			
Aluminium	*0.0000167*	nd	0.26	nd	0.67	0.53	0.78	nd	2.1	nd			
Arsenic	*0.0000042*	0.000019	0.000051	nd	nd	0.0000071	0.000075	0.000040	0.00014	nd			
Boron	*0.0000836*	nd	nd	nd	0.017	nd	0.11	nd	0.44	nd			
Barium	*0.0000084*	nd	nd	nd	nd	nd	nd	nd	0.012	nd			
Beryllium	*0.0000004*	nd	0.000010	nd	nd	nd	0.0000063	0.000012	0.000026	nd			
Cadmium	*0.0000004*	0.000015	0.0000038	nd	nd	nd	nd	0.000006	0.0000047	nd			
Cobalt	*0.0000167*	nd	nd	nd	0.000051	nd	0.000016	nd	0.00016	nd			
Chromium	*0.0000084*	nd	0.00077	nd	0.0010	0.00071	0.0013	0.0018	0.0023	nd			
Copper	*0.0000167*	0.00010	0.00067	0.000051	0.00037	0.00014	0.00036	0.00018	0.0011	0.00049			
Galium	*0.0000004*	nd	nd	nd	0.00034	nd	nd	nd	0.00094	nd			
Mercury	*0.0000143*	nd	nd	nd	nd	nd	nd	nd	nd	nd			
Lithium	*0.0000167*	nd	nd	nd	0.00017	0.00018	0.00063	nd	0.0016	nd			
Molybdenum	*0.0000836*	nd	nd	0.000034	nd	nd	nd	nd	0.00012	nd			
Nickel	*0.0000418*	nd	0.00028	0.00014	0.00049	0.00025	0.00094	0.00060	0.00068	nd			
Selenium	*0.0000418*	0.00017	0.000077	0.000068	0.000098	0.000053	0.000094	nd	0.00012	nd			
Thallium	*0.0000004*	0.000019	0.0000036	0.0000038	0.0000051	nd	0.0000047	0.0000074	0.0000044	nd			
Vanadium	*0.0000167*	nd	0.00077	nd	0.0015	0.0012	0.0016	0.00020	0.0023	nd			
Zinc	*0.0000167*	0.00038	nd	nd	0.0017	nd	nd	nd	0.0094	nd			

		Hamel Training Centre (Weeks)						Boundary Rd 2 (Weeks)					
	Ave MDL	1	2	3	4	5	6	1	2	3	4	5	6
TSP				12	17	16	19	10					
Lead	*0.0000041*			0.00039	0.00028	0.00045	0.00064	nd					
Aluminium	*0.0000165*			nd	0.35	1.3	0.60	nd					
Arsenic	*0.0000041*			nd	0.000035	0.000050	0.000072	nd					
Boron	*0.0000823*			nd	nd	0.25	0.10	nd					
Barium	*0.0000082*			nd	nd	nd	nd	nd					
Beryllium	*0.0000004*			nd	nd	nd	0.0000045	nd					
Cadmium	*0.0000004*			nd	nd	nd	0.0000075	nd					
Cobalt	*0.0000165*			nd	0.000053	0.00010	0.000045	0.000056					
Chromium	*0.0000082*	**N0 samples collected**		nd	0.0021	0.0025	0.0034	0.0014	**NO samples collected**				
Copper	*0.0000165*			0.00086	0.00049	0.00065	0.00075	nd					
Galium	*0.0000004*			nd	nd	nd	0.000030	nd					
Mercury	*0.0000150*			nd	nd	0.00000050	nd	nd					
Lithium	*0.0000165*			nd	nd	0.0012	0.00045	nd					
Molybdenum	*0.0000823*			nd	nd	0.00012	0.00010	nd					
Nickel	*0.0000411*			nd	0.0010	0.00094	0.0017	0.00056					
Selenium	*0.0000411*			nd	0.000071	0.000050	0.000090	nd					
Thallium	*0.0000004*			0.0000043	0.0000053	nd	0.0000030	0.0000061					
Vanadium	*0.0000165*			nd	0.00088	0.0022	0.00075	0.00028					
Zinc	*0.0000165*			nd	nd	nd	nd	nd					

** No samples were collected for TSP and metals analysis at Yarloop Lawn Bowals.

Appendix 12: Inorganic acids concentration at the 5 key sampling points around Wagerup as determined by NIOSH 7903.

		Boundary Rd 2 (Days)					Hoffman Road (Days)					Yarloop Lawn Bowls (Days)				
	Week #	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Sulphuric Acid	1					nd (95)										
	2	nd (93)					nd (110)						nd (90)			
	3		None				Invalid					Invalid				
	4	nd (100)					D (110)					nd (100)				
	5	nd (110)						nd (110)				D (100)				
	6	nd (110)						130 (110)				nd (90)				
Nitric Acid	1					nd (95)										
	2	nd (93)					nd (110)						nd (90)			
	3		None				Invalid					Invalid				
	4	nd (100)					nd (110)					nd (100)				
	5	nd (110)					nd (110)					nd (100)				
	6	nd (110)					nd (110)					nd (90)				
Phosphoric Acid	1					nd (95)										
	2	nd (93)					nd (110)						nd (90)			
	3		None				Invalid					Invalid				
	4	nd (100)					nd (110)					nd (100)				
	5	nd (110)					nd (110)					nd (100)				
	6	nd (110)					nd (110)					nd (90)				
Hydrogen Bromide	1					nd (95)										
	2	nd (93)					nd (110)						nd (90)			
	3		None				Invalid					Invalid				
	4	nd (100)					nd (110)					nd (100)				
	5	nd (110)					nd (110)					nd (100)				
	6	nd (110)					nd (110)					nd (90)				
Hydrogen Chloride	1					nd (95)										
	2	nd (93)					nd (110)						nd (90)			
	3		None				Invalid					Invalid				
	4	nd (100)					nd (110)					nd (100)				
	5	nd (110)					nd (110)					nd (100)				
	6	nd (110)					nd (110)					nd (90)				
Hydrogen Fluoride	1					nd (47)										
	2	nd (46)					nd (57)						nd (45)			
	3		None				Invalid					Invalid				
	4	nd (51)					nd (54)					nd (51)				
	5	nd (56)					nd (56)					nd (50)				
	6	nd (57)					nd (57)					nd (45)				

No sample collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 12 (cont.)

		Bremnar Road (Days)					Hamel Training Centre (Days)				
	Week #	1	2	3	4	5	1	2	3	4	5
Sulphuric Acid	1					nd (90)					D (93)
	2	**360 (91)**					D (93)				
	3	D (97)							Invalid		
	4	D (100)							nd (120)		
	5	nd (110)							nd (110)		
	6	nd (130)							**260 (110)**		
Nitric Acid	1					nd (90)					nd (93)
	2	nd (91)					nd (93)				
	3	nd (97)							Invalid		
	4	nd (100)							nd (120)		
	5	nd (110)							nd (110)		
	6	nd (130)							nd (110)		
Phosphoric Acid	1					nd (90)					nd (93)
	2	nd (91)					nd (93)				
	3	nd (97)							Invalid		
	4	nd (100)							nd (120)		
	5	nd (110)							nd (110)		
	6	nd (130)							nd (110)		
Hydrogen Bromide	1					nd (90)					nd (93)
	2	nd (91)					nd (93)				
	3	nd (97)							Invalid		
	4	nd (100)							nd (120)		
	5	nd (110)							nd (110)		
	6	nd (130)							nd (110)		
Hydrogen Chloride	1					nd (90)					nd (93)
	2	nd (91)					nd (93)				
	3	nd (97)							Invalid		
	4	nd (100)							nd (120)		
	5	nd (110)							nd (110)		
	6	nd (130)							nd (110)		
Hydrogen Fluoride	1					nd (45)					nd (47)
	2	nd (45)					nd (46)				
	3	nd (48)							Invalid		
	4	nd (53)							nd (61)		
	5	nd (56)							nd (54)		
	6	nd (64)							nd (56)		

No sample collected.
Bold typeface indicates measured value is "reportable" as > 2 times MDL.

Appendix 13: Bromine and chlorine concentrations at the 5 key sampling points around Wagerup as determined by NIOSH 6011.

		Bromine (Days)					Chlorine (Days)				
	Week #	1	2	3	4	5	1	2	3	4	5
Boundary Rd 2 Property	1										
	2										
	3				nd (140)					nd (140)	
	4				nd (140)					nd (140)	
	5	nd (140)					nd (140)				
	6	nd (140)					nd (140)				
Hoffman Road	1										
	2										
	3				nd (140)					nd (140)	
	4	nd (150)					150 (150)				
	5			nd (140)					170 (140)		
	6			nd (140)					nd (140)		
Yarloop Lawn Bowls	1										
	2										
	3										
	4										
	5										
	6										
Bremnar Road	1										
	2										
	3					nd (130)					nd (130)
	4		nd (140)					nd (140)			
	5	nd (140)					nd (140)				
	6	nd (170)					nd (170)				
Hamel Training Centre	1										
	2										
	3				nd (140)					nd (140)	
	4			nd (170)					nd (170)		
	5			nd (160)					nd (160)		
	6			nd (140)					nd (140)		

Shaded cells show days when no samples were collected