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REPORT

2011–12 Midland Background Air Quality Study

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Executive Summary

The Department of Environment Regulation (DER) (formerly the Department of Environment Conservation) conducted a study of acid gases at Midland and surrounding suburbs from June 2011 to June 2012. This Midland Background Air Quality Study (Phase II) was a 12-month targeted study to measure the acid gases hydrogen fluoride (HF) and hydrogen chloride (HCl) in ambient air using an open-path fourier transform infrared spectrometer (OP-FTIR). Opportunistic sampling for sulfur dioxide (SO_2) was also undertaken from 30 January 2012 until the completion of the study.

The data gathered indicate that levels of acid gasses measured in the Midland area are low and are below the Department of Health (DoH)'s recommended guideline. The DoH guideline for combined acid gases defined as the total of HCl, HF, SO_2 and SO_3 (sulfur trioxide) concentrations is 500 µg/m^3 for averaging periods of 10 minutes to one-hour.

Although HCl was detected on at least one occasion at all of the monitoring sites, the median concentrations (10-minute and one hour averaged) indicate that on the vast majority of monitoring days HCl and HF concentrations were low, or below the limit of detection (LOD). Low level SO_2 was detected at a number of sites during the study.

Odours were recorded at 9 of the 11 monitoring sites. Odour observations were generally transient in nature and although strong brickworks odours were observed by DER staff at a number of sites, these odours usually only lasted for a few seconds to minutes.

The days in which the strongest odours were observed did not necessarily correlate with the days in which the highest levels of acid gases were recorded; however, strong brickworks odours were observed on 23 February 2012, the day during which the maximum combined acid gas level of 87 ppb (137 µg/m^3) (10-minute average) was recorded.

Addendum

This October 2014 version of the report has the following addendum applied on page 11:

"The 10-minute maximum combined acid gas concentration measured during the study of 82 ppb (133 µg/m^3) was recorded at 9:00 am on this day."

Now reads:

***"**The 10-minute maximum combined acid gas concentration measured during the study of 87 ppb (137 µg/m^3) was recorded at 9:00 am on this day."*

Contents

Purpose

The 2011–12 Midland Background Air Quality study was undertaken in order to measure levels of the acid gases hydrogen chloride (HCl) and hydrogen fluoride (HF) in the ambient air in the Midland area. An open path fourier transform infrared spectrometer (OP-FTIR) was used as it allows the measurement of low levels of HF and HCl in ambient air over time periods that allow short term events to be captured.

Introduction

The Midland Background Air Quality Study (Phase II) was a 12-month targeted study to measure the acid gases, hydrogen fluoride (HF) and hydrogen chloride (HCl), which was undertaken in the Midland area from June 2011 to June 2012 using an OP-FTIR.

The aims of this study were to:

- sample the acid gases HF and HCl in the Midland area over a 12-month period using an OP-FTIR;
- provide targeted short-term averaged HCl and HF data for a number of locations within the Midland area;
- measure background acid gases in the Midland area;
- capture real-time worst-case acid gas levels by sampling down-wind from sources; and
- compare the measured levels of acid gases against established air quality guidelines.

Potential sources of acid gases in the Midland area included four brickworks located in Caversham (Austral Caversham), Hazelmere (BGC Brickmakers), Middle Swan (Boral Bricks) and Bellevue (Austral Bellevue). Of these potential sources, Austral Bellevue and Boral Bricks were the closest to sensitive receptors, including residential areas and schools.

1 Previous studies

The Midland Background Air Quality Study (MBAQS) (Phase I), was a 15-month screening study of air pollutants in Midland and surrounding suburbs undertaken by the then Department of Environment and Conservation (DEC) from August 2007 to November 2008. This screening-level study was undertaken as part of an ongoing and broader investigation of air quality throughout Perth and regional Western Australia.

Both passive and active monitoring methods were employed at a total of 10 sites within Midland and the surrounding suburbs to characterise ambient air quality. Known air emission source types within the area included brickworks, rendering and asphalt plants, abattoirs, saleyards and motor vehicles. As part of the Phase 1 study, seven-day averaged concentrations of the acid gases HF and HCl were measured using Radiello passive samplers.

DoH advised that the concentrations measured in this study are similar in magnitude to those previously reported for Perth and are unlikely to be associated with adverse health effects. Some elevated concentrations of hydrogen chloride were detected in six samples taken at Midvale Primary School. While these concentrations did not present a health concern, DER elected to undertake further monitoring of HCl and HF over shorter time periods to allow better comparison to health guidelines and ensure that these guidelines were not being exceeded. Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations measured during the Phase I study were found to be well below National Environmental Protection Measure (NEPM) annual average standards at all monitoring sites.

2 Methods

In mid-2009, the then DEC purchased an OP-FTIR, an instrument capable of real-time measurement of the acid gases hydrogen chloride (HCl) and hydrogen fluoride (HF) with high temporal resolution.

The OP-FTIR spectrometer passes a beam of infrared radiation through a specified portion of air and measures the path-integrated pollutant concentration along the entire length of the infrared path. After passing through the ambient air, the IR beam is subjected to spectral analysis to determine the infrared absorbance of the individual compounds passing through the beam. Electronics within the OP-FTIR calculate the path integrated concentration of the compounds by comparing the collected spectra against standard reference spectra.

During this study, the path-integrated concentration in the pollutant plume was measured by the OP-FTIR at 1.5-metres above ground level, and along a path which was approximately perpendicular to the prevailing wind direction. Concurrent wind speed and wind direction measurements were undertaken.

2.1 Pilot study (2009–10)

The OP-FTIR was deployed at the Police Operations Branch in Midland from mid November 2009 to April 2010 for testing purposes. The location of the OP-FTIR was determined by assessing various criteria including central location, availability of power and high security. The instrument and its IR source were housed in separate sheds at a separation distance of 75 metres. Due to the open-path nature of the OP-FTIR, the source and detector require a direct line of sight and so the shed doors

remained open throughout the duration of the study. Storm damage on 22 March 2010 forced the removal of the OP-FTIR from Midland to DEC's air quality laboratory where it underwent repairs and further testing.

The pilot study provided confidence in the OP-FTIR for the measurement of acid gases in ambient conditions and allowed data analysis methods to be refined.

2.2 Site selection (2011–12)

Sampling was undertaken at 11 sites in the Midland area. The sites were selected to provide a range of locations where there was likely to be impact from potential sources of HCl and HF in the Midland area and where elevated HCl concentrations were reported during the MBAQS Phase I study. Further considerations included a range of physical requirements relating to set-up and operation of the OP-FTIR: such factors as access to a 240V power outlet; a clear path length of at least 60 metres; ability to direct the light source away from housing and roads; and vehicular access to the site. The locations and names of the 11 sampling locations are presented in Figure 2.2.1.

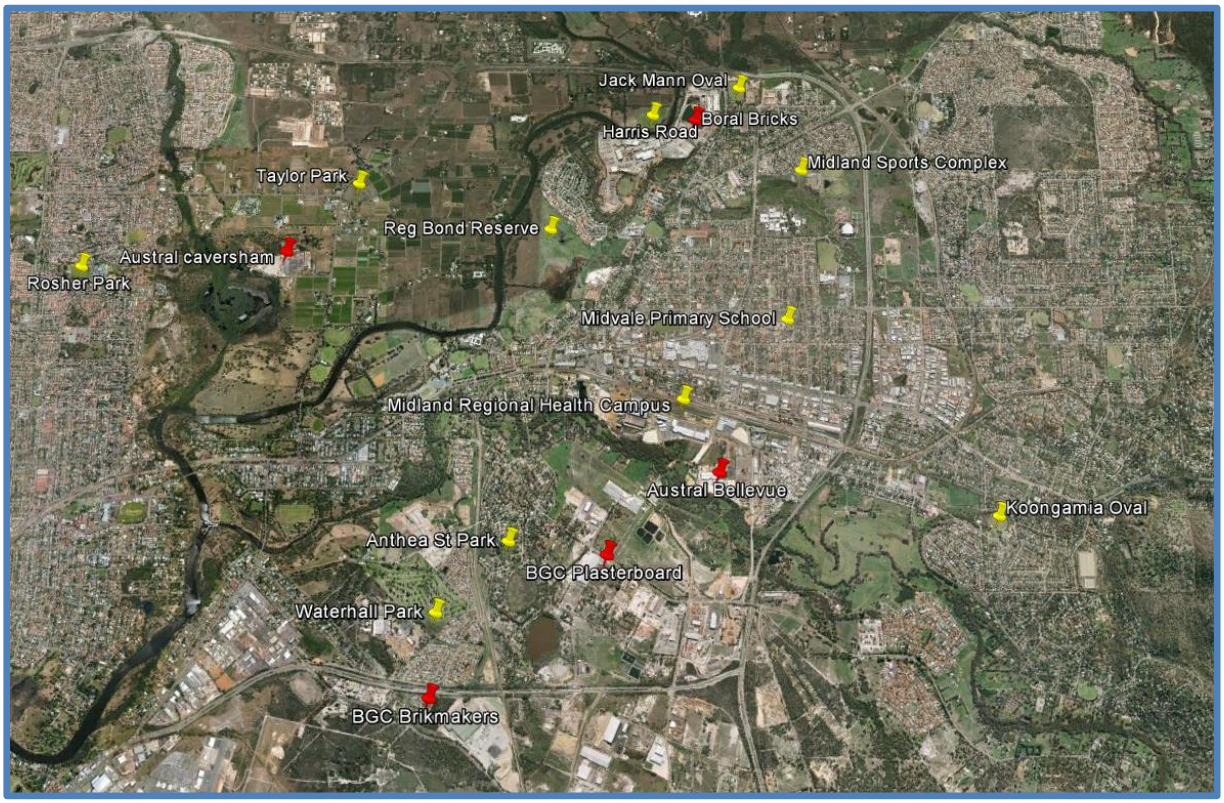


Figure 2.2.1: Locations of sampling sites (yellow) and potential sources of acid gases (red) within the Midland area.

2.3 Sampling design

Days and locations for specific monitoring events were selected throughout the period of the study based on the suitability of forecast weather conditions. Sampling events at the various sites were selected with the aim of collecting data at each site under wind conditions deemed likely to provide a clear pathway from potential sources of acid gases (i.e. targeting worst case scenario conditions). A number of periods were also

included to provide sufficient upwind sampling to assess background levels.

For the measurement of the acid gases HCl and HF, the OP-FTIR (Midac model M4416-F) was deployed at each site on an axis approximately perpendicular to the prevailing wind direction, with a precisely-measured path length of 60 metres. General observations relating to the site conditions, weather conditions and any odour events were recorded by the operators on an hourly basis during sampling.

The OP-FTIR was operated using an indium antimonide (InSb) detector with stirling-cycle engine cooling system. This detector has a spectral wavenumber range of 2100 to 7000 cm^{-1} and was configured to 0.5 cm^{-1} resolution and scan rate of 1 scan per second, providing 32-second averaged concentrations of HF and HCl.

In parallel with the OP-FTIR measurements, five minute averaged wind speed, wind direction, air temperature and relative humidity were logged. A wind sensor (Gill windsonic) was used to measure wind speed and wind direction. Air temperature and relative humidity were measured using a Rotronics MP 100 sensor. These sensors were mounted on a four-metre mast within 10 metres of the OP-FTIR sample path.

Figure 2.3.1 Typical OP-FTIR monitoring set-up. Images displayed clockwise from left are OP-FTIR detector, OP-FTIR light source, OP-FTIR detector and source separated by a 60-metre sample path with meteorological sensors on mast (circled in red) and computer logging measurements.

Although not proposed in the original monitoring plan, concurrent SO_2 monitoring was carried out on an opportunistic basis during OP-FTIR sampling events.

The SO_2 monitor was first deployed onsite with the OP-FTIR and meteorological measurements on 30 January 2012 and measurements were taken until the end of the study.

SO_2 was measured continuously using a Thermo 43C SO_2 analyser housed in an air-conditioned mobile cabinet mounted on a trailer. The trailer was typically placed within 10 metres downwind of the OP-FTIR sample path. The instrument required a warm-up and stabilisation period of approximately one–two hours before meaningful data could be recorded, and, consequently, the available sampling period for SO_2 analysis was generally shorter than that covered by OP-FTIR. A zero/span calibration was carried out on the SO_2 analyser at the completion of each sampling day in order to ensure the validity of SO_2 data and to confirm optimum operation of the instrument. The detection limit of the SO_2 analyser was 0.4 ppb.

Table 2.3.1 : Sampling sites and dates of sampling events.

Site Name	Sampling Dates	Number of sampling days	Total OP-FTIR sampling time (hours)
Anthea Street Park, *Anthea Street, Hazelmere*	29/09/11; 10/08/11; 23/03/12; 17/06/12	4	24
Harris Road *Foreshore Reserve, Caversham*	01/11/11; 12/01/12; 30/01/12; 07/02/12; 27/05/12	5	30
Jack Mann Oval *Bishop Road, Middle Swan*	23/02/12; 25/02/12; 04/03/12; 29/03/12; 20/05/12	5	30
Koongamia Oval *Clayton Street, Koongamia*	14/02/12; 29/02/12; 18/03/12; 11/05/12	4	24
Midland Health Campus Site, *Yelverton Drive, Midland*	21/06/11; 05/07/11; 04/08/11; 06/09/11; 07/09/11; 23/09/11; 11/11/11; 16/12/11; 18/05/12; 21/06/12	10	60
Midland Sports Complex *Patterson Drive, Middle Swan*	28/09/11; 05/10/11; 10/11/11; 21/12/11; 12/05/12	5	30
Midvale Primary School *Wellaton Street, Midvale*	13/07/11; 14/07/11; 19/07/11; 04/10/11; 14/10/11; 15/10/11	6	36
Reg Bond Reserve *Avon Crescent, Middle Swan*	06/08/11; 11/08/11; 25/08/11; 24/09/11; 23/11/11	5	30
Rosher Park *Rosher Road, Lockridge*	20/10/11; 08/03/12; 28/03/12	3	18
Taylor Park *DeBurgh Road, Caversham*	30/08/11; 14/09/11; 16/11/11; 21/04/12	4	24
Waterhall Park *Waterhall Road, South Guilford*	06/07/11; 05/08/11; 24/03/12; 02/05/12	4	24

3 Results

The OP-FTIR provides ambient concentrations for both HCl and HF at 32-second time intervals. Each data point is an average of 32 one-second scans and also contains the

standard error calculation (SEC) for that datum. This SEC represents a 1σ standard deviation. The HCl results reported are those values that are greater than 3 × σ (better than 99 per cent confidence interval). Due to the very low measured concentrations of HF, the results reported are those values that are greater than 2 × σ (better than 95 per cent confidence interval).

The detection limit (LOD) is defined as being the minimum concentration of a target gas that can be determined in the presence of confounding spectral interferences. The HF detection limit was calculated to be 12 ppb (11 µg/m^3) and the HCl detection 16 ppb (26 µg/m^3) for the particular detector used. In the calculation of 10-minute and hourly averaged concentrations, concentrations below the detection limit have been allocated a scaled concentration of half the LOD or below, depending on the standard error of the measurement.

3.1 Background sampling

Ambient background conditions were typically characterised using the data obtained from measurements taken at Koongamia Oval on 29 February and 11 May 2012. On these days the OP-FTIR remained upwind of the brickworks during the sample period.

DoH provided a guideline for combined acid gases (HF, HCl, SO_3 and SO_2) of 100 ug/m^3 for a 24-hour average and 500 ug/m^3 for a 10-minute or one-hour average.

DoH has advised that 'DEC air monitoring for the Perth region indicates that sulfur oxides are unlikely to constitute a major component of ambient air pollution in the vicinity of existing brickworks' and that 'hydrogen fluoride and hydrogen chloride are likely to be more critical brickwork emission components'. Consequently, the focus of this study was on HF and HCl; however, opportunistic monitoring of SO_2 was also undertaken during the second half of the monitoring period to allow better comparison to the DoH combined acid gas guideline. All SO_2 concentrations measured in this study were found to be low.

Sulfur trioxide (SO_3) is difficult to monitor in ambient air and was not measured during this study; however, stack concentrations of SO_3, are reported by the brickworks as part of their licence conditions

Table 3.1.1 displays the maximum and average one-hour and 10-minute averaged background concentrations for HF and HCl measured during this study. HCl and HF concentrations remained below the limit of detection on 29 February and 11 May 2012, indicating that the background levels of HF and HCl in Midland were low.

Table 3.1.1 Background levels of HCl and HF measured at Koongamia Oval on 29 February and 11 May 2012.

	HCl ppb (ug/m^3)	LOD HCl ppb (ug/m^3)	HF ppb (ug/m^3)	LOD HF ppb (ug/m^3)
10-minute average	<LOD	16 (26)	<LOD	12(11)
10-minute maximum	<LOD	16 (26)	<LOD	12(11)
one-hour average	<LOD	16 (26)	<LOD	12(11)
one-hour maximum	<LOD	16 (26)	<LOD	12(11)

3.2 Acid gases

All of the brick and tile manufacturers in the Swan Valley use gas-fired tunnel kilns to fire their products (DoE 2003). As the clay is heated, elements naturally present in the clay including fluoride, chloride and sulfur are emitted into the air in the kiln. These elements combine with water vapour or oxygen to produce HF, HCl, SO_2 and SO_3. The amount of each depends on the elemental composition of the clay, temperature in the kiln, type of fuel used and pollutant controls such as scrubbers. Sulfur oxides (SO_2 and SO_3) may also be produced by the burning of fuel and additives; however, as the brickworks in the Swan Valley all use gas fired kilns, sulfur oxides emissions from these sources are low.

The emissions may be discharged to air via controlled discharge points, such as dryer exhausts or kiln stacks, or from a range of unintended discharge points (fugitive emissions). Fugitive emissions could include, for example, dust blown from roads or stockpiles, kiln gases released when the kiln doors are opened, and leaks from inadequately sealed flanges or valves (DoE 2003). Gases generated in the dryers and kilns are vented to the atmosphere via separate stacks. Most of the emissions associated with clay product manufacture arise in the kiln, where temperatures are much higher than in the dryers.

3.2.1 Hydrogen chloride

At room temperature, hydrogen chloride is a colourless to slightly yellow gas with a pungent odour. On exposure to air, the gas forms dense white vapours due to condensation with atmospheric moisture (ATSDR 2011). Hydrogen chloride has a number of uses including cleaning, pickling and electroplating metals. It is used in the refining of mineral ores, soaps and oils.

Chloride is naturally present in the clay used for brick manufacture and is emitted into the kiln atmosphere when the clay is heated. This combines with water vapour to form HCl.

The results of ambient hydrogen chloride sampling are provided in table 3.2.1.1 below, which show the maximum 10-minute and one-hour averaged HCl concentration measured at each site during the study.

Table 3.2.1.1 Maximum 10-minute and one-hour averaged HCl concentrations measured at each site.

Site	Max 10-min[1] ppb (µg/m^3)	Median 10-min[1] ppb (µg/m^3)	Max 1-Hour[1] ppb (µg/m^3)	Median 1-Hour[1] ppb (µg/m^3)
Health Campus	57 (93)	<LOD	49 (79)	<LOD
Anthea Park	21 (34)	<LOD	13 (21)	<LOD
Harris Road	72 (118)	21 (34)	64 (104)	21 (34)
Jack Mann Oval	81 (131)	<LOD	50 (81)	<LOD
Koongamia Oval	34 (56)	<LOD	23 (38)	<LOD
Midland Sport Complex	73 (119)	14 (23)	41 (67)	13 (21)
Midvale Primary School	34 (55)	<LOD	27 (44)	<LOD
Reg Bond Reserve	36 (59)	<LOD	24 (39)	<LOD
Rosher Park	58 (94)	<LOD	47 (77)	<LOD
Taylor Park	35 (57)	<LOD	25 (41)	<LOD
Waterhall Park	25 (40)	<LOD	18 (29)	<LOD

1. These values have been calculated using a 10-minute or one-hour clock average from the 32 second HCl data.

The maximum 10-minute averaged HCl concentration of 81 ppb (131 µg/m^3) was measured at Jack Mann Oval on 23 February 2012. The maximum one-hour averaged HCl concentration of 64 ppb (104 µg/m^3) was measured at Harris road on 12 January 2012. Although HCl was detected on at least one occasion at all of the monitoring sites, the median concentrations (10-minute and one-hour averaged) indicate that on the vast majority of monitoring days HCl concentrations were low, or below the LOD.

3.2.2 Hydrogen fluoride

Hydrogen fluoride (HF) is a colourless pungent liquid or gas which is soluble in water (WHO 2002). It is released into the environment from a variety of sources including the manufacture of glass, brick and ceramic products.

All the brick and tile making operations in the Swan Valley use gas-fired tunnel kilns to fire their products. Fluoride is naturally present in the clay used for brick manufacture in the Swan Valley and is emitted into the kiln atmosphere when the clay is heated. This combines with water vapour to form HF.

The results of hydrogen fluoride sampling are provided in table 3.2.2.1 below, which show the maximum 10-minute and one-hour averaged HCl concentration measured at each site during the study.

Table 3.2.2.1: Maximum 10-minute and one-hour averaged HF concentration measured at each site.

Site	Max 10-min[1] ppb (µg/m^3)	Median 10-min[1] ppb (µg/m^3)	Max 1-Hour[1] ppb (µg/m^3)	Median 1-Hour[1] ppb (µg/m^3)
Health Campus	14 (12)	<LOD	<LOD	<LOD
Anthea Park	<LOD	<LOD	<LOD	<LOD
Harris Road	17 (15)	<LOD	13 (12)	<LOD
Jack Mann Oval	<LOD	<LOD	<LOD	<LOD
Koongamia Oval	<LOD	<LOD	<LOD	<LOD
Midland Sport Complex	<LOD	<LOD	<LOD	<LOD
Midvale Primary School	14 (12)	<LOD	<LOD	<LOD
Reg Bond Reserve	<LOD	<LOD	<LOD	<LOD
Rosher Park	<LOD	<LOD	<LOD	<LOD
Taylor Park	<LOD	<LOD	<LOD	<LOD
Waterhall Park	15 (13)	<LOD	<LOD	<LOD

1-These values have been calculated using a 10-minute or one-hour clock average from the 32 second HF data

The maximum 10-minute averaged HF concentration of 17 ppb (15 µg/m^3) and the maximum one-hour averaged HF concentration of 13 ppb (12 µg/m^3) were recorded at Harris Road on 7/02/12. HF was detected at four of the 11 monitoring sites. For the sites in which HF was detected, concentrations were close to the LOD. HF concentrations measured during the study period were low. At all monitoring sites, all median HF concentrations were below the LOD, indicating that on the vast majority of monitoring days, HF levels were low.

3.2.3 Sulfur dioxide

Sulfur dioxide (SO_2) is a colourless gas with a pungent odour. The sources of air emissions include natural sources such as volcanoes and anthropogenic sources such as fossil fuel burning, power plants or copper smelting (ATSDR 1998).

All the brick and tile making operations in the Swan Valley use gas-fired tunnel kilns to fire their products. Sulfur is naturally present in the clay used for brick manufacture in the Swan Valley and is emitted into the kiln atmosphere when the clay is heated. This combines with oxygen to form SO_2 and SO_3. Other sources of SO_2 emitted during brick manufacture include the type of fuel used and additives used during the manufacturing process.

The results of SO_2 sampling undertaken during the study period are provided in Table 3.2.3.1 below, which show the maximum 10-minute and one-hour averaged SO_2 concentration measured at each site during the study. SO_2 measurements commenced on 19 January 2012 at a limited number of sites.

Table 3.2.3.1: Maximum 10-minute and one-hour averaged average SO_2 concentration measured at each site.

Site	Max 10-min[1] ppb (µg/m^3)	Median 10-min[1] ppb (µg/m^3)	Max 1-Hour[1] ppb (µg/m^3)	Median 1-Hour[1] ppb (µg/m^3)
Health Campus	5 (13)	<LOD	4 (11)	<LOD
Anthea Park	<LOD	<LOD	<LOD	<LOD
Harris Road	17 (48)	2 (6)	9 (25)	3 (9)
Jack Mann Oval	10 (29)	<LOD	6 (18)	1 (2)
Koongamia Oval	6 (17)	<LOD	4 (11)	<LOD
Midland Sport Complex	1 (3)	<LOD	1 (2)	<LOD
Rosher Park	1 (1)	<LOD	<LOD	<LOD
Taylor Park	5 (15)	<LOD	3 (9)	<LOD
Waterhall Park	1 (3)	<LOD	1 (3)	1 (2)

1-These values have been calculated using a 10-minute or one-hour clock average from the 5 minute SO2 measurements

The maximum measured 10-minute averaged SO_2 concentration of 17 ppb (48 µg/m^3) during the study was recorded at Harris Road on 27 May 2012. The maximum one-hour averaged SO_2 concentration of 9 ppb (25 µg/m3) was recorded at Harris Road on 7 February 2012 and at Harris Road on 27 May 2012. Although SO_2 was detected at a number of sites during the study, SO_2 levels were low. On the vast majority of days in which SO_2 measurements were undertaken, SO_2 concentrations were below the LOD.

A more detailed analysis of the days in which the maximum 10-minute averaged acid gas concentrations were recorded follows. Ten minute averaged concentrations were chosen as these values are the most conservative and provide the worst-case-scenario acid gas concentrations recorded during the study to compare against the DoH guideline.

3.2.4 Jack Mann Oval Site 23 February 2012

The 10-minute maximum HCl concentration measured during the study of 81 ppb (131ug/m3) was recorded at Jack Mann Oval on 23 February 2012. Figure 3.2.4.1 displays a polar chart in which HCl and SO_2 concentrations are plotted against vector averaged wind direction. The bars lengths are proportional to the 10-minute averaged concentrations, and also indicate the wind direction at the time of the measurement. HF was not detected on this day.

Figure 3.2.4.1 10-minute averaged HCl concentration (grey bars 20 ppb increments) (left) and SO_2 concentration (green bars, 3 ppb increments) (right) versus wind direction measured at Jack Mann Oval on 23 February 2012.

On 23 February 2012, wind directions remained between 235 (SW) and 335 (NNW) during the monitoring period. Wind speeds were between 1.3 and 3.0 m/s. Wind direction remained from the sector of the brickworks for the majority of the sampling period. The highest 10-minute averaged HCl concentration was recorded under west north-westerly winds. The majority of 10-minute averaged HCl readings were recorded under westerly to north-westerly wind directions (figure 3.2.4.1) which correspond with the direction of the brickworks. These HCl readings are likely to have been influenced by the presence of kiln 9 and kiln 10 stacks in the northern end of the Boral brickworks. It is possible also that there may also be fugitive emissions from the northern end of the brickworks. Winds were light and highly variable throughout the day. HF remained below the limit of detection for the entire monitoring period.

The majority of SO_2 readings on 23 February 2012 were recorded under north-westerly winds; however, the maximum 10-minute SO_2 concentration was recorded under west south-westerly winds. These winds would have passed over the length of the brickworks before reaching the monitoring site and the SO_2 concentrations measured are likely to have been influenced by a number of stack and fugitive sources in the plant, including kiln stacks 9, 10 and 11.

The 10-minute maximum combined acid gas concentration measured during the study of 87 ppb (137 µg/m^3) was recorded at 9:00 am on this day. This value was calculated by summing the HCl concentration with half LOD for HF, as HF was not detected on this day. As the SO_2 analyser did not stabilise until 9:50 am, no SO_2 measurements were obtained at the time of the maximum combined acid gas concentration.

DEC staff observed strong brickworks odours on this day (Appendix 1). Charts comparing odour observations with HCl and SO_2 measurements are displayed in figure 3.2.4.2 below. The yellow shaded areas represent times when brickwork odours were detected. The odour observations have not been assigned a numerical value for the purposes of this chart (i.e. do not relate to numerical values on the X axes) but have been included to compare the time in which a brickworks odour was noted with HCl or SO_2 measurements. Brickworks odours were observed at 9:20 am and 9:40 am, followed by a period in which no odours were observed. At 11:35 am brickworks

odours were observed again and the odour was present until sampling stopped at 1:35 pm. There did not appear to be a strong relationship between HCl and SO_2 measurements and odour observations on this day.

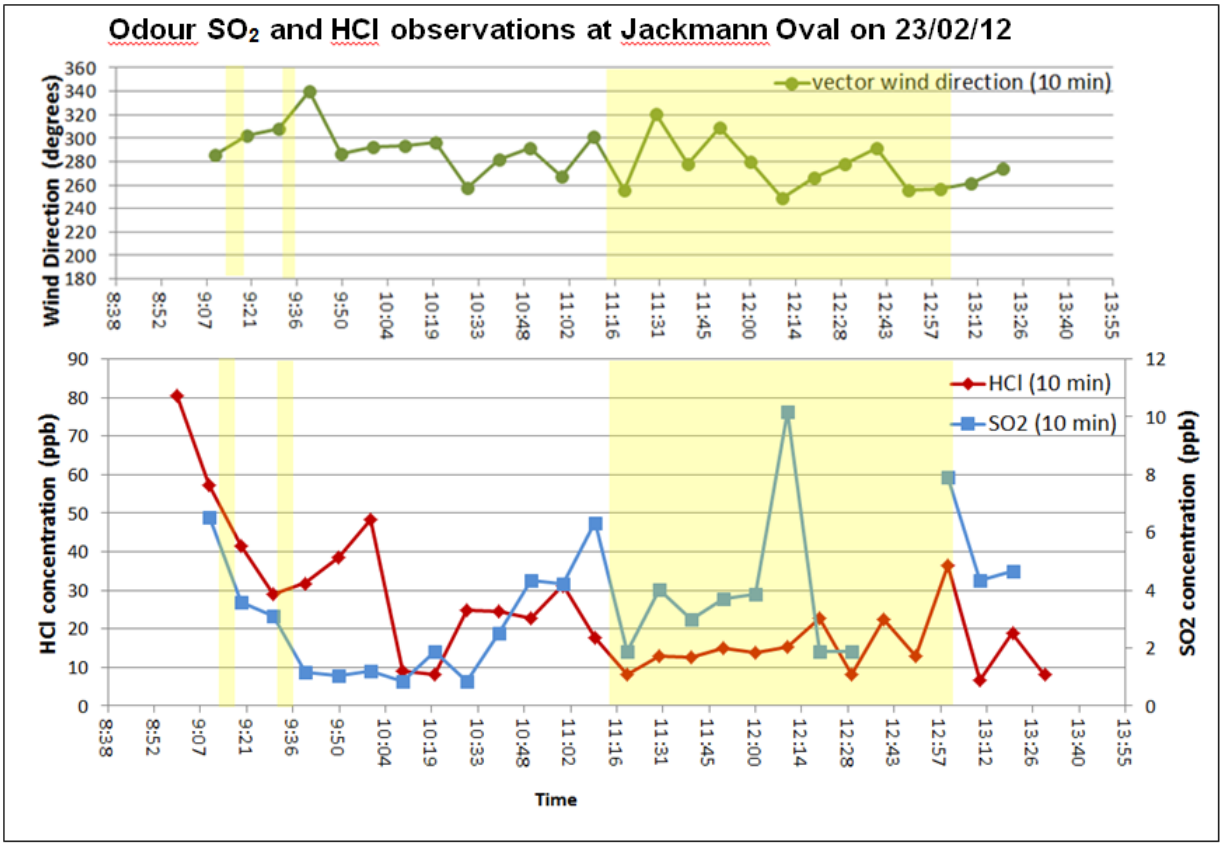


Figure 3.2.4.2 Odour, SO_2 and HCl observations at Jackmann Oval on 23 February 2012

There were a number of spikes in the 10-minute averaged HCl concentrations; however, these spikes occurred both when a brickworks odour was present and when there was no odour observed.

SO_2 concentrations measured on 23 February 2012 were low; however, there do appear to be some spikes that correspond with odour observations in the early afternoon. The maximum 10-minute averaged SO_2 concentration was observed when a strong brickworks odour was present; however, other measurements did not correlate well with the odour observations.

3.2.5 Harris Road Site 7 February 2012

The maximum 10-minute averaged HF concentration of 17 ppb (15 µg/m^3) and hourly averaged HF concentration of 13 ppb (12 µg/m^3) measured during the study period were recorded at Harris road on 7 Februaruy 2012. Figure 3.2.5.1 shows a polar chart in which HF, HCl and SO_2 concentrations are plotted against vector averaged wind direction. The bars lengths are proportional to the 10-minute averaged concentrations as well as indicate the wind direction at the time of the measurement. (Please note that the scale used varies for the different gases.)

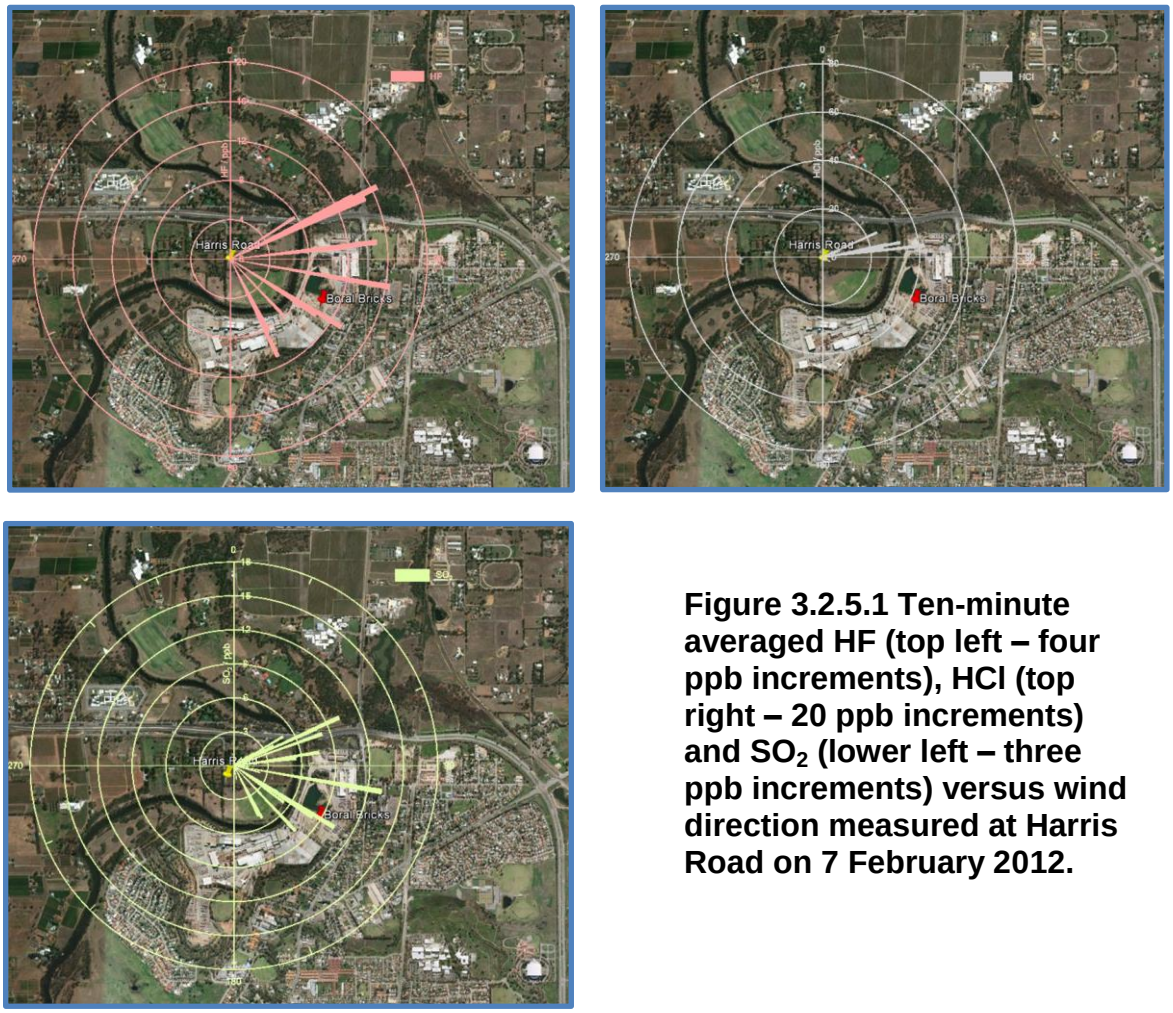


Figure 3.2.5.1 Ten-minute averaged HF (top left – four ppb increments), HCl (top right – 20 ppb increments) and SO_2 (lower left – three ppb increments) versus wind direction measured at Harris Road on 7 February 2012.

There were only four hours of validated HF and HCl data collected on this day. Measurements were collected from 9:10 am to 12:50 pm. SO_2 measurements were collected for six hours (9:10 am to 3:10 pm).

On 7 February 2012 wind direction ranged from 53 to 159 degrees and wind speeds ranged from 1.2 to 2.7 m/s during the monitoring period. Wind direction remained from the direction of the Boral brickworks (75 to 159 degrees) for the majority of the sampling period.

The maximum 10-minute averaged HF concentration was recorded under east north-easterly winds and the maximum one-hour averaged HF concentration was recorded under easterly winds. There are two kiln stacks (kilns 9 and 10) in the northern end of the plant that correspond with an easterly wind direction from the brickworks to the monitoring site and are likely to be the source of the HF recorded under easterly and east north-easterly winds. There are also a number of HF readings corresponding to a south-easterly wind direction. The HF concentrations recorded under east south-easterly to south south-easterly winds are likely to be influenced by emissions from the kiln 11 stack which is located in the southern third of the plant. These winds would pass close to the kiln 11 stack before reaching the monitoring site.

The maximum 10-minute averaged HCl concentrations on 7 February 2012 were measured under easterly winds and maximum one-hour averaged HCl concentrations were recorded under east north-easterly winds.

On this day, the majority of the HCl readings were recorded under an east north-easterly to easterly wind direction, indicating a shared source with SO_2 and HF in the northern end of the plant.
There appears to be no source of HCl to the south-east of the monitoring site on this day (as there is for SO_2 and HF); however, it is possible that the HCl concentrations were below the limit of detection rather than being completely absent. SO_2, HF and HCl are all emitted from the kiln stacks simultaneously and in varying proportions which are heavily influenced by the composition of the clay and raw materials used, the temperature in the kiln and the efficiency of the stack scrubbers for each compound.

The maximum 10-minute SO_2 reading on this day was observed under easterly winds and the maximum one-hour SO_2 reading under east south-easterly winds. The SO_2 data in figure 3.2.5.1 appears to have two nodes, one from the east north-east and one from the south-east suggesting different sources within the plant.

As there are a number of potential sources of SO_2, HF and HCl emissions from the brickworks, including stack and fugitive sources, it is likely that the brickworks are the source of the SO_2, HF and HCl readings recorded on 7 February 2012. Levels of acid gases measured on this day were low.

3.2.6 Harris Road Site 27 May 2012

The maximum 10-minute averaged SO_2 concentration of 17 ppb (48 µg/m^3) and one-hour averaged SO_2 concentration of 9ppb (25 µg/m^3) were measured at Harris Road on 27 May 2012. Figure 3.2.6.1 shows a polar chart in which SO_2 and HCl concentrations are plotted against vector-averaged wind direction, overlayed on an aerial photograph of the Harris Road site. The bars lengths are proportional to the 10-minute averaged concentrations as well as indicate the wind direction at the time of the measurement. HF was not detected on this day.

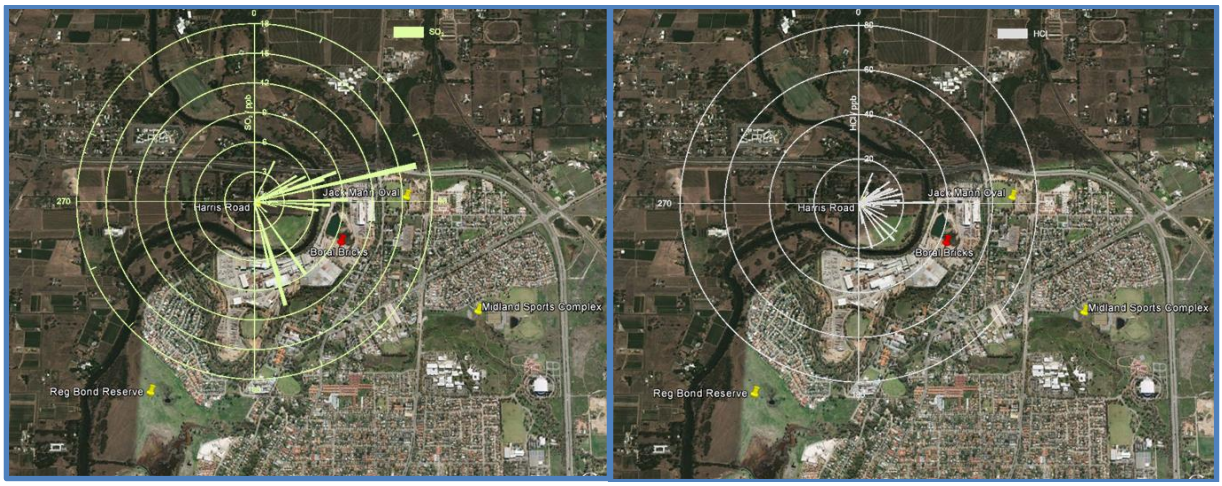


Figure 3.2.6.1 Ten-minute averaged SO_2 concentration (green bars, 3 ppb increments) (left) and HCl concentration (grey bars, 20 ppb increments) (right) versus wind direction measured at Harris Road on 27 May 2012.

On 27 May 2012 wind direction ranged from 25 (north north-easterly) to 170 (southerly) degrees and wind speeds ranged from 0.9 to 2.2 m/s during the monitoring period. The 10-minute maximum SO_2 concentration was recorded under east north-

easterly winds. The second highest 10-minute averaged SO_2 concentration was recorded under south south-easterly winds. There appears to be a bimodal distribution of SO_2 readings in figure 3.2.6.1, indicating that these measurements were possibly influenced by two different sources.

There are two kiln stacks (kilns 9 and 10) in the northern end of the plant that correspond with an easterly wind direction from the brickworks to the monitoring site and are likely to be the source of the SO_2 recorded under easterly and east north-easterly winds.

The SO_2 concentrations recorded under south-easterly to south south-easterly winds are likely to be influenced by emissions from the kiln 11 stack which is located in the southern third of the plant. South south-easterly winds would need to pass over the kiln 11 stack before reaching the monitoring site.

HCl measurements on this day were recorded under north north-easterly to south south-easterly winds. The maximum HCl reading was recorded under easterly winds. There are no apparent nodes in the HCl measurements; however, HCl was recorded under the same range of wind directions as the SO_2 measurements. The reason for the lack of two apparent nodes in the HCl data may be due to the open path nature of the HCl measurements. The HCl measurements recorded by the OP-FTIR are an average concentration measured over a 60-metre path length whereas SO_2 measurements are measured at a single point (the SO_2 analyser was located mid-way between the OP-FTIR path). As the HCl readings were an average concentration measured over a 60-metre area, small fluctuations in wind direction would be less apparent. The HCl measurements (FTIR) show a similar pattern to the SO_2 measurements (SO_2 analyser) demonstrating confirmation of results by two different measurement types and methodologies.

There were some SO_2 and HCl readings recorded under a north north-easterly wind direction. As there are no known SO_2 sources directly to the north of the brickworks these readings may have been influenced by low level fugitive emissions in the northern side of the plant. The wind variability was high on this day which may have also influenced the movement of emissions. HF concentrations were below the limit of detection.

As there are a number of potential sources of SO_2, HF and HCl emissions from the brickworks, including stack and fugitive sources, it is likely that the brickworks are the source of the SO_2 and HCl readings recorded on 27 May 2012. Levels of acid gases measured on this day were low.

3.3 Analysis of acid gas levels detected at Midvale Primary School on 14 July 2011

As part of the previous 2007–08 Midland Background Air Quality study, seven-day averaged hydrogen chloride (HCl) and hydrogen fluoride (HF) acid gas concentrations were collected at a number of sites in the Midland area using Radiello® passive samplers. A number of duplicate and background samples were taken in parallel with the Radiello samples, the results of which indicate laboratory (or field) contamination (Appendix 3) was highly likely.

One elevated HCl reading of 99 $\mu g/m^3$ averaged over a period of seven-days was recorded at Midvale Primary School (MPS) on 27 March 2008. It is notable that a high field blank of 36 $\mu g/m^3$ was recorded on the same day as the MPS recording of

99 µg/m^3. The large differences evident between the sampled and duplicate tubes and the high concentration of the field blank on 22 May 2008 indicate possible field and/or laboratory contamination which may compromise this Phase I screening study results.

In order to verify the assumption that laboratory or field contamination contributed to levels of HCl recorded during the 2007–08 Phase I Midland Background Air Quality Study, acid gases were measured at MPS as part of this study using OP-FTIR.

Acid gases were measured during this study using OP-FTIR at MPS on 13 July 2011, 14 July 2011, 19 July 2011, 15 October 2011, 14 October 2011 and 15 October 2011. The maximum (10-minute average) acid gas measurement at MPS of 35ppb (55 µg/m^3) was recorded on 14 July 2011. The maximum one-hour averaged acid gas level at this site of 25 ppb (46 µg/m^3) was also recorded on this day. A more detailed analysis of acid gases detected on this day follows.

Figure 3.3.1 shows a polar chart in which HCl concentration is plotted against vector-averaged wind direction. The grey bars display the 10-minute averaged HCl measurements as well as the wind direction at the time of the measurement. Each gradation away from the centre of the plot increases in 20 ppb increments. The polar chart is overlayed on an aerial photograph of the MPS site.

Figure 3.3.1 Polar chart displaying HCl concentration versus wind direction measured at Midvale Primary School on 14 July 2011.

The maximum 10-minute averaged HCl concentration recorded on this day was 34 ppb (55 µg/m^3) under north-easterly winds. The second highest 10-minute averaged HCl concentration of 33 ppb (54 µg/m^3) was recorded under northerly winds. The winds were highly variable on this day as indicated by relatively high sigma-theta (σθ) values.

The HCl measurements recorded under northerly winds may have been influenced by emissions from Boral Bricks; however, HCl was also recorded under north-easterly winds, possibly indicating another source in the area. The highest one-hour averaged HCl concentration was 27 ppb (44 µg/m^3).

HF remained below the LOD for the entire sampling period on this day. Acid gas measurements taken during this study indicate that levels of acid gases measured at MPS were low.

3.4 Analysis of acid gases levels detected at Midland Health Campus on 16 December 2011

The future Midland Regional Health Campus (MRHC) is to be constructed on land bordering Lloyd Street, Centennial Place and Clayton Street in Midland. The south east corner of the site lies within the Midland Redevelopment Authority air quality buffer for the Austral Brick site. This location was included as one of the sites for the current study in order to sample the levels of HF and HCl that may be experienced in the area. It is important to note that the purpose of this study was to determine background levels of acid gases in the Midland area. Acid gas monitoring was undertaken at the MRHC site on the following dates: 21 June 2011, 05 July 2011, 04 August 2011, 06 September 2011, 07 September 2011, 23 September 2011, 11 November 2011, 16 December 2011, 18 May 2012 and 21 June 2012. These days were chosen for monitoring because the wind direction was forecast to be coming from the direction of one of the brickworks sites. On 16 December 2011, the maximum HCl and the maximum combined acid gas level measured at this site were recorded.

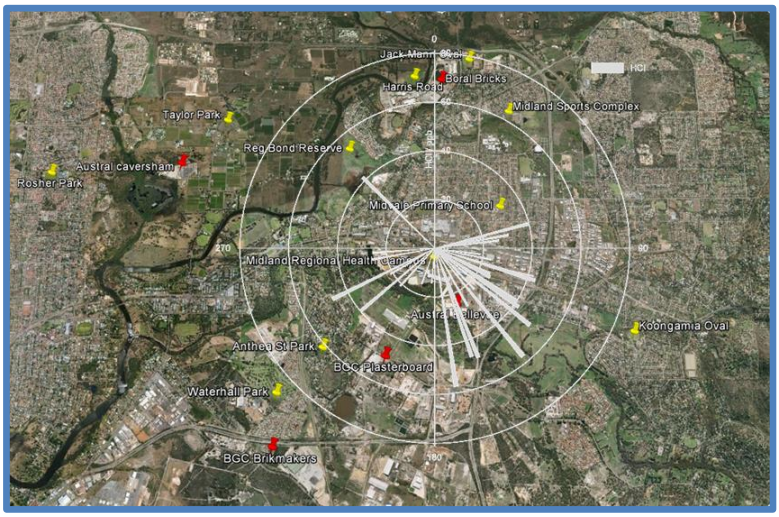


Figure 3.4.1 Polar chart displaying HCl concentration versus wind direction measured at the MRHC site on 16 December 2011.

Figure 3.4.1 shows a polar chart in which HCl concentration is plotted against vector averaged wind direction and overlayed on the MRHC site. The grey bars display the 10-minute averaged HCl concentrations as well as the vector wind direction at the time of the measurement. Each gradation away from the centre of the plot increases in 20 ppb increments.

The highest 10-minute averaged HCl concentration of 57 ppb (93 µg/m^3) was recorded at 12:10 pm under south-easterly winds and again at 12:20 pm under southerly winds. The second highest 10-minute averaged HCl concentration of 50 ppb (80 µg/m^3) was recorded at 11:20 am under south-easterly winds. HF remained below the LOD for the entire monitoring period on this day.

There appears to be a node in the HCl measurements from the south-east, with the majority of HCl readings detected under east south-easterly to south south-easterly winds. Possible sources of the HCl readings recorded under south-easterly and south south-easterly winds include Austral Bricks to the south-east of the site. There is also

a smaller node in the HCl measurements from the south-west. Possible sources to the south-west of the site include the BGC brickworks. There was one elevated HCl measurement recorded under north-westerly winds.

The 10-minute maximum acid gas level recorded on this day was 59 ppb (95 µg/m^3) . This level was calculated as the sum of the HF and HCl measurements as no SO_2 measurements were undertaken on this day. As HF was not present above the detection limit, a scaled level below half LOD was used for the calculation.

A number of odours described as being of a brickworks nature were recorded by DER officers during this study and further details are provided in section 3.5 and Appendix 1. Although DER officers noted strong odours at this site, they were often transient, generally only lasting for a few seconds or minutes and there was no apparent relationship between odour observations and HCl and HF concentrations at this site. Levels of acid gases recorded at MRHC were low.

3.5 Odour observations

Odour observations recorded during the study were described as being 'cement like, strong paint, brickworks, strong odour, odour, bush smoke, smoke smell, sweet brickworks, sheep urine, slight brick odour, tar like smell, burnt organic, bitumen, fried food odour, wet cement, mown grass and greenwaste odour'.

Odours were recorded at 9 of the 11 monitoring sites. These sites were; MRHC, Jackmann Oval, Harris Road, Taylor Park, MPS, Reg Bond Reserve, Waterhall Park, Anthea St Park and Koongamia Oval. Brickworks odours were observed at MRHC, Harris Rd, Jack Mann Oval, Reg Bond Reserve and Anthea St Park. A 'slight brickworks odour' was recorded on one occasion at MPS.

Odour observations were generally transient in nature and although strong brickworks odours were observed by DER staff at a number of sites, these odours usually only lasted for a few seconds to minutes. The exception to this was Jack Mann Oval, where brickworks odours lasting longer time periods were noted on 23 February 2012, 25 February 2012 and 29 March 2012. Although strong brickworks odours were observed at Jack Mann Oval on these occasions, the level of acid gases detected was low. An analysis of odour observations and acid gas concentrations recorded at Jack Mann Oval on 29 March 2012 is provided in section 3.5.1. An analysis of odour observations and acid gas levels on 23 February 2012 is provided in section 3.2.1. A relationship between odour and acid gas concentrations on 25 February 2012 was not evident.

A detailed summary of all odour observations recorded by DER staff during the study is provided in Appendix 1. The days in which the strongest odours were observed did not necessarily correlate with the days in which the highest levels of acid gases were recorded, however strong brickworks odours were observed on 23/02/12, the day during which the maximum combined acid gas level of 87 ppb (137 µg/m^3) (10-minute average) was recorded. There was no apparent relationship between HCl and HF concentrations on this day, however there were some spikes in SO_2 that correspond with odour observations in the early afternoon. The maximum 10-minute averaged SO_2 concentration recorded on this day was observed when a strong brickworks odour was present; however, there does not appear to be a strong relationship between SO_2 measurements and odour observations on this day. The levels of acid gases detected on the days that odour observations were recorded were low.

3.5.1 Relationship between odour observations and acid gas measurements on 29 March 2012

A number of odour observations were made by DEC officers on 29 March 2012. DEC officers noted odours described as 'green waste' or 'brickworks' odour. These odour observations are displayed in figure 3.5.1 along with HCl, HF, SO_2 and wind direction measurements taken at Jack Mann Oval on 29/03/12.

HCl measurements are displayed by the red triangles, HF by purple crosses and SO_2 by orange circles, with the concentrations displayed on the primary axis. Wind direction (blue diamonds) is displayed on the secondary axis. Odour observations are displayed by the yellow shaded areas. The odour observations have not been assigned a numerical value for the purposes of this chart (i.e. do not relate to numerical values on the x axes) but have been included to compare the time in which an odour was noted with HCl, HF and SO_2 measurements.

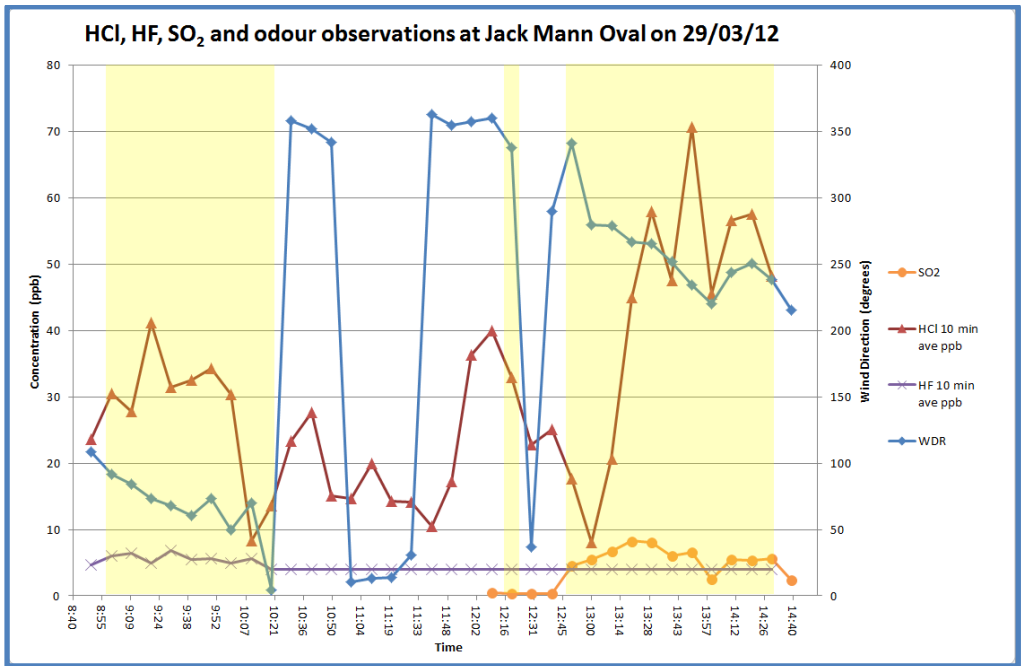


Figure 3.5.1 Odour observations and acid gas measurements at Jack Mann Oval on 29 March 2012.

On 29 March 2012 wind direction was highly variable. Wind speeds ranged from 1.7 to 3.5 m/s. Green waste odours were observed in the morning from 9:30 am to 10:40 am under easterly to north-easterly winds after which, green waste odours diminished corresponding with a change in wind direction to northerly winds. There was a period between 10:40 am and 12:20 am in which no odours were observed followed by one observation of a 'brickworks odour' at 12:21 pm and then another period in which no odours were observed until 12:49 pm. Brickworks odours were observed for the rest of the monitoring period, from 12:49 pm to 2:40 pm which corresponded with a change in wind direction from northerly to westerly and south-westerly winds during this period. As indicated in figure 3.5.1, there is an increase in HCl and SO_2 concentrations that corresponds with the change in wind direction (to winds coming from the brickworks direction) and brickworks odours during this period. Given that these increased

concentration measurements correspond with a change in wind direction so that the monitoring site was located downwind of the brickworks and that DEC staff noticed a brickworks odour at this time, it is likely that emissions from the brickworks contributed to the observed increase in SO_2 and HCl. Possible sources from within the brickworks include kiln stack and fugitive emissions.

HF was detected at low levels in the morning from 8:50 am to 10:20 am under easterly and north-easterly winds. This corresponds with the time that green waste odours were observed. There was a large stockpile of mulched plants in the area bordering the park to the east and north-east of the monitoring site. Given that the increase in HF concentration corresponds with the green waste odours observed in the morning, the source of HF detected in the morning could be from the mulched vegetation stockpiles. HF concentrations were below the limit of detection for the remainder of the sampling period and HF was below the limit of detection at the time the brickworks odours were noted.

The maximum 10-minute and one-hour averaged combined acid (sum of HCl, HF and SO_2) gas concentrations recorded on this day were 80 ppb and 54 ppb respectively. Levels of acid gases measured on this day were low.

4 Summary and conclusions

Measurements of hydrogen fluoride (HF) and hydrogen chloride (HCl), were undertaken at eleven sites in the Midland area from June 2011 to June 2012 using an OP-FTIR. This technique was chosen as it allows the measurement of low levels of HCl and HF in ambient air, over time periods that allow short term events to be captured. Measurements of SO_2 were also undertaken from January to June 2012 using an SO_2 analyser.

Figure 4.1 displays the maximum, 10-minute and one-hour averaged concentration of acid gases along with the maximum 10-minute and one-hour combined acid gas concentration recorded during the study.

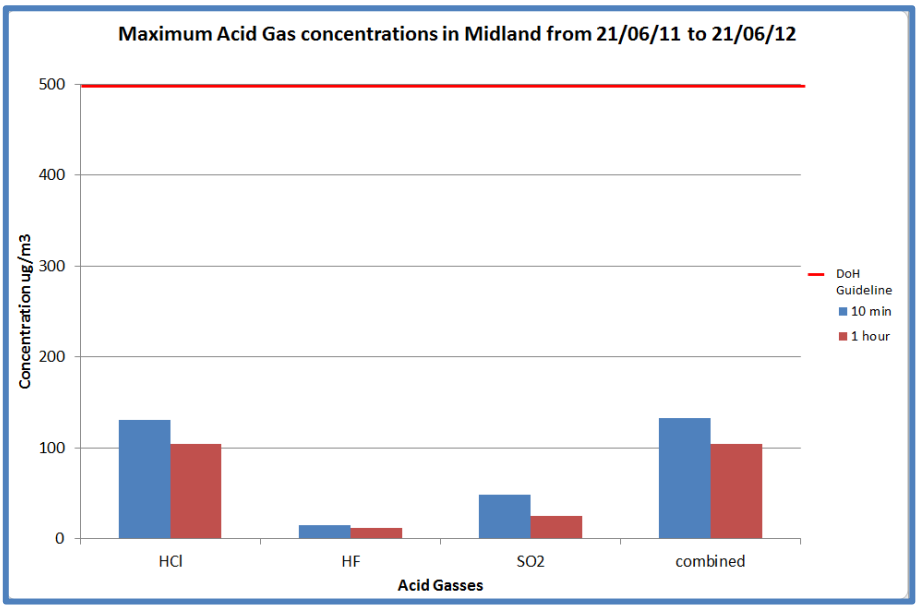


Figure 4.1 Maximum acid gas concentrations in Midland (21 June 2011 to 21 June 2012).

The 10-minute maximum concentrations of each gas were slightly higher than the corresponding one-hour maximum concentrations, although the 10-minute and hourly averaged maximum concentrations for each pollutant did not necessarily occur on the same day. The maximum 10-minute and one-hourly concentrations recorded during the study were 81ppb (131µg/m^3) and 64 ppb (104 µg/m^3) for HCl, 17 ppb (15 µg/m^3) and 13 ppb (12 µg/m^3) for HF and 17 ppb (48 µg/m^3) and 9 ppb (25 µg/m^3) for SO_2. The maximum 10-minute and one-hour combined acid gas concentrations were 87ppb (137µg/m^3) and 70ppb (108µg/m^3) respectively. The combined concentration illustrated in figure 4.1 meets the DOH guidelines for acid gases. Levels of acid gases recorded during the study were low.

Odours were recorded at 9 of the 11 monitoring sites. Odour observations were generally transient in nature and although strong brickworks odours were observed by DER staff at a number of sites, these odours usually only lasted for a few seconds to minutes. The days in which the strongest odours were observed did not necessarily correlate with the days in which the highest levels of acid gases were recorded; however, strong brickworks odours were observed on 23 February 2012, the day during which the maximum combined acid gas level of 87 ppb (137 µg/m^3) (10-minute average) was recorded.

5 Appendices

Appendix 1 Odour observations

Table A.1.0 Numerical odour intensity levels used by trained DER odour assessors. The levels used are described in VDI Part 3 2010.

Odour strength	Intensity level
Extremely strong	6
Very strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

Table A.1.1 Odour observations and odour intensity observed by trained DER odour assessors during OP-FTIR monitoring.

Date	Site	Time	Description	Intensity
21/06/2011	**Midland Regional Health Campus site**	11:40	strong paint odours	3-4
		13:06	cement like odour	2-3
		14:13	brickworks odour	3-4
6/07/2011	**Waterhall Park**	14:12	strong odour	3
4/08/2011	**Midland Regional Health Campus site**	11:53	strong odour noticed lasted about 1 min	4
		12:01	strong odour noticed lasted about 1 min	
		12:16	odour	
		12:26	odour	
		12:59	odour	
		13:36	odour	
		14:23	odour	
		14:38	odour	
		14:45	odour	
11/08/2011	**Reg Bond Reserve**	11:22	odour (brickworks)	

Date	Site	Time	Description	Intensity
		11:31	odour	
		11:44	odour	
		11:54	odour	
		12:05 to 13:05	periodically odour wafting through path length	
		13:29	odour	
		14:00	odour	
		14:05	odour	
		14:08	strong odour	
38/08/2011	**Taylor Park**	9:43	strong plume of bush smoke came through path length	
14/09/2011	**Taylor Park**	10:37	smoke smell, burning close	
23/09/2011	**Midland Regional Health Campus site**	9:49	sweet brickworks odour	3
		9:52	sweet brickworks odour	3-4
		9:55	sweet brickworks odour	3-4
		9:57	sweet brickworks odour	3
		10:07	sweet brickworks odour	3
		10:15	sweet brickworks odour	3
		10:24	sweet brickworks odour	3
		10:48	sweet brickworks odour	3
		11:35	sweet brickworks odour	3
		12:27	sweet brickworks odour lasted until 12:31	4
		12:40	sweet brickworks odour	3-4
		12:46	strong sheep urine odour	4
		13:08	strong sheep urine odour	4-5
		13:21	sweet brickworks odour	4
		13:33	sheep urine odour	3
		14:29	sweet brickworks odour	4
29/09/2011	**Anthea Street Park**	10:27	sweet brickworks odour	2
4/10/2011	**Midvale Primary School**	11:42	slight brick odour (like dryer)	2

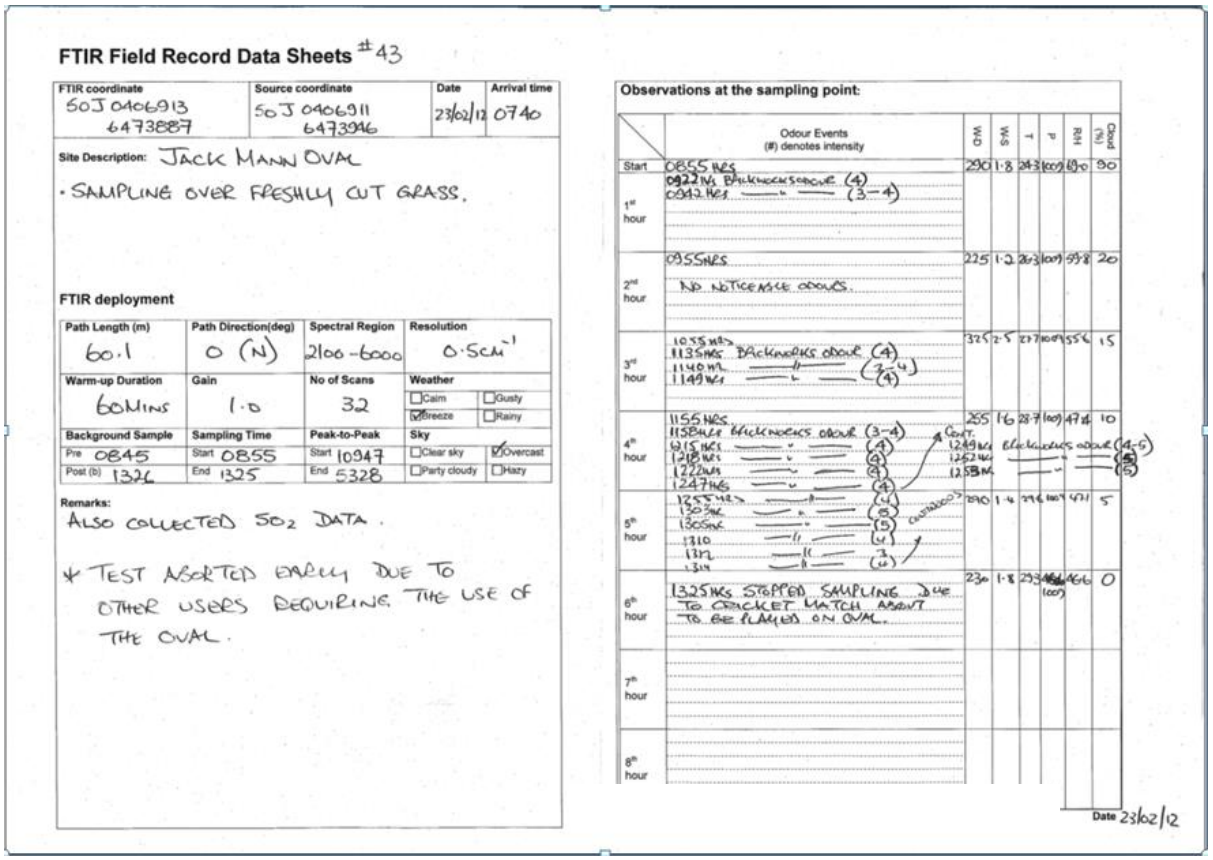
Date	Site	Time	Description	Intensity
		13:24 to 1:25	tar like smell, burnt organic	
		1:27	bitumen smell	
14/10/2011	**Midvale Primary School**	13:03	fried food odour	3
			fried food odour	3
			fried food odour	2
1/11/2011	**Harris Road**	9:35	odour, wet cement	3
		13:29	brickworks odour	4
		13:43	mown grass odour	4
1/11/2011	**Midland Regional Health Campus site**	10:00	brickworks, wet cement	3
		10:25	odour, wet cement	3
			odour, wet cement	4
		10:50	odour, wet cement	4
		10:55	odour, wet cement	4
		11:05	odour, wet cement	4
		11:10	odour, wet cement	4
16/12/2011	**Midland Regional Health Campus site**	14:03	brickworks odour	3
		14:12	brickworks odour	3
30/01/2012	**Harris Road**	12:37	brickworks odour	2
		13:00	brickworks odour	2
7/02/2012	**Harris Road**	9:34	brickworks odour	2
23/02/2012	**Jack Mann Oval**	9:22	brickworks odour	4
		9:42	brickworks odour	3-4
		11:35	brickworks odour	4
		11:40	brickworks odour	3-4

Date	Site	Time	Description	Intensity
		11:49	brickworks odour	4
		11:58	brickworks odour	3-4
		12:18	brickworks odour	4
		12:22	brickworks odour	4
		12:57 to 13:14	continuous brickworks odour. Stopped sampling due to other users using the oval	4-5
25/02/2012	**Jack Mann Oval**	9:54	brickworks odour	4
		10:55	brickworks odour	4
		11:10	brickworks odour	4
		11:35 to 11:44	brickworks odour	4-5
		11:53	brickworks odour	5
		12:02	brickworks odour	5
			odours 3-5 kept passing through at various times too numerous to keep track of	3-5
		12:50 to 14:50	constant odour events ranging in intensity from 2-5 only dropping below for 1-2 min periods	2-5
			until end of sampling	
4/03/2012	**Jack Mann Oval**	8:51	green waste odour	4
		8:51 to 10:40	continuous green waste odours until 10:40	2-4
		11:50	occasional green waste odours when wind swings to NE	
		13:50	green waste odours intermittent	
		14:35	brickworks odour	3
		14:47	brickworks odour	3
		14:48	brickworks odour	4
29/03/2012	**Jack Mann Oval**	9:03	green waste odour	4
		9:09	green waste odour	4
		9:13	green waste odour	4
		9:20	green waste odour	4
		9:24	green waste odour	4
		9:32	green waste odour	4
		9:46	green waste odour	4
		9:50	green waste odour	4
		9:54	green waste odour	4-5

Date	Site	Time	Description	Intensity
			continuous GW odour events too numerous to document	
		10:40	GW odour events diminished with wind direction change	
		12:21	GW odour events diminished with wind direction change	4
		12:49	brickworks odour	3
		12:53	brickworks odour	3-4
		12:58	brickworks odour	3
		13:03	brickworks odour	3
		13:07	brickworks odour	3
		13:09	brickworks odour	4
		13:12	brickworks odour	4-5
		13:14	brickworks odour	5
		13:22	brickworks odour	4
		13:25	brickworks odour	4
		13:28	brickworks odour	4
		13:31	brickworks odour	4
		13:35	brickworks odour	4
		14:12	brickworks odour	4-5
		14:16	brickworks odour	4
		14:26	brickworks odour	4-5
		14:37	brickworks odour	4
11/05/2012	**Koongamia Oval**	11:10	wood fire/smoke smell. Smoke plume in distance	
18/05/2012	**Midland regional Health Campus site**	14:09	brickworks odour	4
		14:24	brickworks odour	3-4
20/05/2012	**Jack Mann Oval**	10:35	green waste	4
		10:45	green waste	3
		10:46	green waste	3
		10:48	green waste	3
		10:50	green waste	4
		10:51	green waste	3
		10:59	green waste	4
		11:03	green waste	3
		11:07 to	continuous green waste	4

Date	Site	Time	Description	Intensity
		11:14		
27/05/2012	**Harris Road**	8:40	brickworks odour	2-3
		8:56	brickworks odour	2
		10:56	brickworks odour	2
		13:22	brickworks odour	2-3

Appendix 2 Example field observation log sheet



FTIR Field Record Data Sheets #43

FTIR coordinate	Source coordinate	Date	Arrival time
50J 0406913 6473887	50J 0406911 6473946	23/02/12	0740

Site Description: JACK MANN OVAL

- SAMPLING OVER FRESHLY CUT GRASS.

FTIR deployment

Path Length (m)	Path Direction(deg)	Spectral Region	Resolution
60.1	0 (N)	2100-6000	0.5cm⁻¹
Warm-up Duration	**Gain**	**No of Scans**	**Weather**
60MINS	1.0	32	☐Calm ☐Gusty ☑Breeze ☐Rainy
Background Sample	**Sampling Time**	**Peak-to-Peak**	**Sky**
Pre 0845	Start 0855	Start 10947	☐Clear sky ☑Overcast
Post (b) 1326	End 1325	End 5328	☐Party cloudy ☐Hazy

Remarks:

ALSO COLLECTED SO_2 DATA.

* TEST ABORTED EARLY DUE TO OTHER USERS REQUIRING THE USE OF THE OVAL.

Observations at the sampling point:

	Odour Events (#) denotes intensity	WD	WS	T	P	RH	Cloud (%)
Start	0855 HRS	290	1.8	24.3	1009	60	90
1st hour	0922 HRS BLACKWOODS ODOUR (4) 0942 HRS " " (3-4)						
2nd hour	0955 HRS NO NOTICEABLE ODOURS.	225	1.2	26.3	1009	59.8	20
3rd hour	1035 HRS 1135 HRS BLACKWOODS ODOUR (4) 1140 HRS " " (3-4) 1149 HRS " " (4)	325	2.5	27.7	1009	55.6	15
4th hour	1155 HRS 1158 HRS BLACKWOODS ODOUR (3-4) 1215 HRS " " (4) 1218 HRS " " (4) 1222 HRS " " (4) 1247 HRS " " (4)	255	1.6	28.7	1009	47.8	10
5th hour	1255 HRS " " (4) 1305 HRS " " (5) 1308 HRS " " (5) 1310 " " (4) 1312 " " (3) 1314 " " (4)	290	1.4	29.6	1009	47.1	5
6th hour	1325 HRS STOPPED SAMPLING DUE TO CRICKET MATCH ABOUT TO BE PLAYED ON OVAL.	230	1.8	29.3	1009	46.6	0
7th hour							
8th hour							

Date 23/02/12

Figure A.2.0 FTIR and field observation log sheet.

Appendix 3 Results of seven day averaged passive sampling during the 2007-2008 Midland Background Air Quality Study (Phase I)

Table A.3.0 is a list of all HCl concentrations collected during the Phase I MBAQS that were greater than 10 ug/m^3. If a duplicate sample was taken at the same site during the same seven-day period, then this concentration is also shown in the table.

Table A.3.0 Seven-day averaged Radiello concentrations greater than 10 ug/m^3.

		Concentration (ug/m^3)		
Location	7-day period ending	Primary Sample	Duplicate	Field Blank
Midvale Primary School	22/05/2008	99		36‡
Swan Health Service DUP	3/04/2008	<1	76	<1*
Caversham AQMS	25/09/2008	75		<1‡
Midvale Primary School	29/05/2008	51		<1‡
Harford Avenue, Viveash DUP	24/04/2008	2.1	50	<1*
Midvale Primary School	8/05/2008	44		<1‡
Jack Mann Oval	11/09/2008	42		<1‡
Caversham AQMS	11/09/2008	40		<1‡
Kalamunda Road, South Guildford FBL	22/05/2008	<1	<1	36*
Midvale Primary School	27/03/2008	33	<1	<1*
Midvale Primary School	31/07/2008	26		<1‡
Elgee Road, Bellevue DUP	31/01/2008	1.9	25	<1*
Midvale Primary School	17/07/2008	19	<1	8‡
Caversham AQMS	10/07/2008	15		<1‡
Elgee Road, Bellevue	29/11/2007	11		<1‡
Harford Avenue, Viveash	3/07/2008	11	<1	<1*

* Field blank procedure was conducted at the noted sample site. ‡ Field blank procedure was conducted at sites other than the noted sample site.

Three of the elevated samples were duplicates and are marked as **DUP** in the above table. The actual sample for each of the three duplicate samples were 0.5 ug/m^3 at the Swan Health Service, 2.1 ug/m^3 at Harford Avenue, Viveash and 1.9 ug/m^3 at Elgee Road, Bellevue.

Other duplicate samples taken during the above events that did not correlate well with the primary sample were at Midvale Primary School on 27/03/2008 (<1 ug/m^3), 17/07/2008 (<1 ug/m^3) and Hartford Avenue, Viveash on 3/7/2008 (<1 ug/m^3).

Forty-six field blanks were analysed over the course of the study. All bar two, Kalamunda Road, South Guilford (36 ug/m^3) and Stirling Crescent, Hazelmere (8 ug/m^3) were below the laboratory reporting limit (i.e. < 1 ug/m^3).

It is notable that the high field blank of 36 ug/m^3 was recorded on the same day as the Midvale Primary School's recording of 99 ug/m^3. The large differences evident between the sampled and duplicate tubes and the high concentration of the field blank on 22/05/2008 indicate possible field and/or laboratory contamination which may compromise the study results.

Appendix 4 Brief description of the OP-FTIR used in the Midland Background Air Quality Study (Phase II)

Open-path Fourier transform infrared (OP-FTIR) spectroscopy is being used increasingly as a method for ambient monitoring of air pollutants. OP-FTIR can be used to detect and quantify a wide range of air pollutants simultaneously, in situ and continuously. This monitoring system is used over long path lengths, providing path-integrated gas concentrations less prone to artefacts induced by point-based sampling.

In the Midland Background Air Quality Study (Phase II), The OP-FTIR was fitted with an indium antimonide (InSb) detector. The fitted InSb detector had a spectral range of 2000–7000 cm^{-1} and was cooled by a stirling cycle cooling system. The cooling system, detector, instrument electronics and spectrometer mechanical parts were enclosed in a light metal case. The device and IR light source were powered by a 12v DC power supply and controlled by a computer. Raw interferograms were recorded at the highest possible spectral resolution of 0.5 cm^{-1} with 32 consecutive scans and were converted to single beam spectra via Fourier Transform. A variety of analysis techniques are available to retrieve gas concentrations from measured single-beam spectra acquired by FTIR instrumentation. These generally involve comparing the measured spectra with reference spectra of the gas of interest collected under known conditions of temperature, pressure and concentration. The classical least squares (CLS) technique was used as the retrieval method in this study. Reference spectra were obtained from infrared absorption databases produced by US EPA and MIDAC. Atmospheric parameters were measured in the field to account for any uncertainties that might arise when studying plumes in more difficult field situations (e.g. at uncertain atmospheric pressure and temperature).

Concentrations were calculated based upon the spectral area(s) chosen from each reference spectra. Any noise due to interfering compounds may influence reported concentrations, including leading to a false positive being recorded. A false positive concentration is a concentration that is reported for a compound that is not really present in the ambient air. To prevent any false positive results for a compound, the standard error calculation (SEC) is also reported with the concentration, which indicates how well the target compound fits the reference spectra. One SEC represents one standard deviation and if the SEC value is higher than the reported concentration, the result is a false positive.

Depending on the level of certainty required (e.g. the target measurement uncertainty and acceptance criteria), various conventions can be applied to estimating the LOD. The US EPA (TO-16) recommendation is to quote the LOD as the minimum concentration of acid gases that can be detected by the OP-FTIR within a given statistical probability. The recommended detection limit is given as three times the standard deviation of the noise in the system.

Table A.1.0: Specifications of the OP-FTIR deployed in the Midland Background Air Quality Study (Phase II).

	Specifications
Instrument type	Bi-Static Open-Path Fourier Transform Infrared
IR Source	20" IR Source, Gold Plated, Collimating Mirror
Spectral range (cm^{-1})	Mid IR: 6,000–2000
Co-added scans	2-256
Spectral resolution (cm^{-1})	0.5-8
Detector type	Indium Antimonide (InSb) with 10" Telescope
Detection Limits	Vary by compound (10-20 ppb for acid gases)
Typical Pathlength	Approximately 60m
Power	12v DC for both IR source and Detector

Glossary of terms and abbreviations

Acid Gas	An acid gas is a gas which forms an acidic compound when mixed with water
AQMS	Air Quality Monitoring Station
BAQS	Background Air Quality Study
Clock average	Clock hour averages are calculated by averaging data that finished at the end of each clock hour. Ten minute clock averages are calculated by averaging data that finishes at the end of each 10-minute period
cm^{-1}	Wavenumber
DoH	Western Australian Department of Health
HCl	Hydrogen chloride
HF	Hydrogen fluoride
LOD	Limit of detection – lowest concentration that can be detected but not necessarily quantified.
MPS	Midvale Primary School
MRHC	Midland Regional Health Campus
OP-FTIR	Open-path Fourier transform infrared spectrometer
ppb	Parts per billion
σ	Standard deviation
σθ	Sigma theta – measurement of variability in measured wind direction
SO_2	Sulfur dioxide
SO_3	Sulfur trioxide
ug/m^3	micrograms per cubic metre at 0°C and 101325 Pa
US EPA (TO-16)	US EPA Compendium Method TO-16 Long-Path Open-Path Fourier Transform Infrared Monitoring Of Atmospheric Gases

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