Study of Ambient Air Quality at Stella

8 July 2016 – 9 December 2016

Report – AAM/TR/2017/01

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Executive summary

This report provides the results from the study of ambient air quality in the vicinity of Path Head landfill site, in Newcastle. The Environment Agency's Ambient Air Monitoring Team (in National Permitting Services) carried out the study on behalf of the North East Area.

This report presents the measured levels of hydrogen sulphide (H_2S) and methane (CH_4), and compares these levels with the objectives of the World Health Organisation (WHO) Guidelines where applicable.

The H_2S data was compared with its respective WHO guidelines and was found to be within the specified health limits. However, comparison of the H_2S data with the WHO guideline for odour annoyance of 7µg/m^3 (as 30-minute mean concentrations) indicated that the air quality at the monitoring site exceeded this guideline ~4% of the monitoring time. Likely sources of the H_2S are Path Head and Blaydon Quarry Landfill sites.

The direction of the landfill sites could be identified as a relatively continuous source of CH_4 and H_2S in the data.

Contents

Appendices

1 Introduction

The Environment Agency's Ambient Air Monitoring Team (AAM Team), on behalf of the North East Area, carried out a study to investigate ambient air quality in the vicinity of Path Head Landfill Site, near Gateshead.

Path Head Landfill site was operational between February 2007 – January 2017. Suez UK Environment Ltd were permitted to accept 600,000 tonnes a year of non-hazardous waste, although typically it only accepted between 250,000 – 300,000 tonnes per year. The landfill was primarily set up to accept local authority domestic waste and it has never accepted gypsum containing material (such as plasterboard). Prior to opening as a landfill, the site had been a working sand and gravel quarry. The monitoring was carried out due to the number of complaints received from local residents with regard to odour and health concerns.

The study involves a programme of monitoring carried out between 8 July 2016 and 9 December 2016 (155 days).

The Ambient Air Monitoring Team's Mobile Monitoring Facility (MMF 3) was used to measure the ambient concentrations of pollutants. The reported pollutants are H_2S and CH_4.

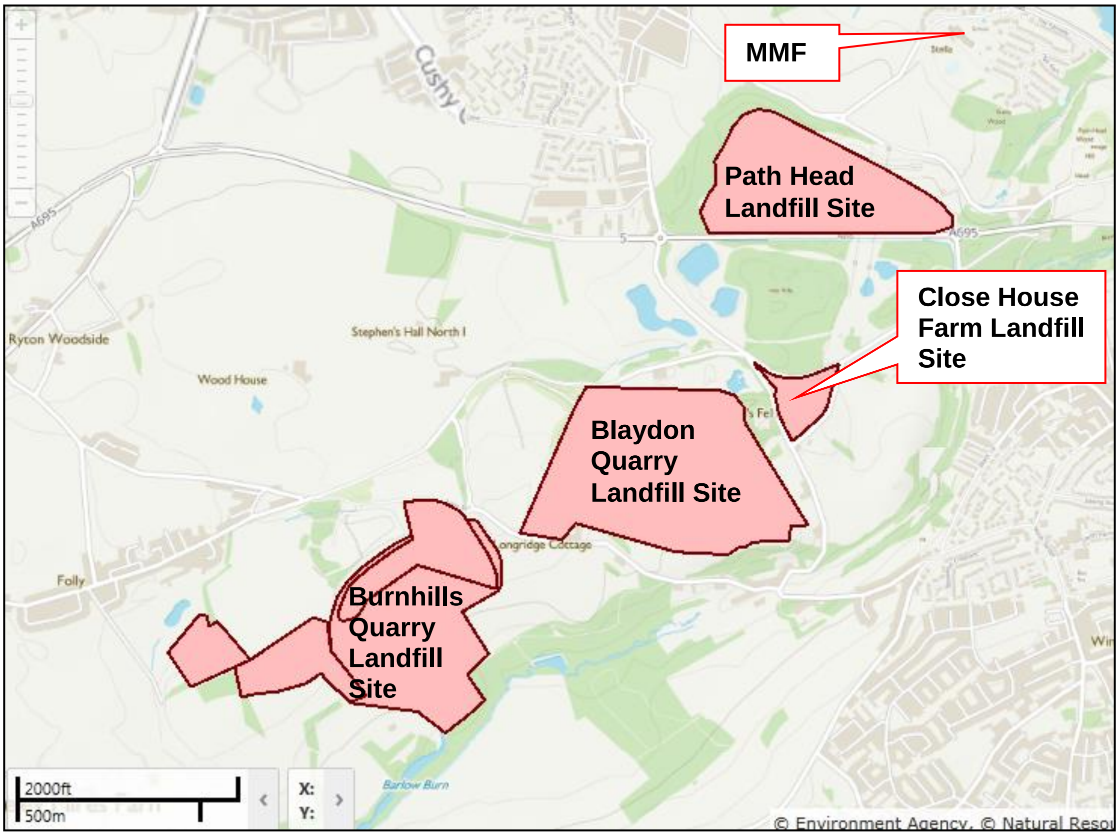
The overall objective of the study was to identify the local sources of air pollution and to quantify the environmental impact of the emissions from these sources on the surrounding area and the local community. Within this objective, the following individual aims were identified:

- To assess the general air quality of the area relative to the AQS objectives
- To quantify the impact of surrounding pollution sources on local air quality
- To identify specific sources causing an appreciable impact on air quality
- To identify and understand the conditions that give rise to episodes of poor air quality

2 Location

The Ambient Air Monitoring team deployed its mobile monitoring facility (MMF 3) on the grounds of the St. Mary and St. Thomas Aquinas Catholic Primary School in Blaydon-on-Tyne (Figure 2.1). Unfortunately, deploying the MMF at this location meant that all the local landfill sites were lined up at a bearing of approximately 185° - 255° from the MMF, meaning that emissions from one landfill could not be distinguished from another. However, Close House Farm and Burnhills Quarry landfill sites were not active during the study (they are both capped) and therefore are unlikely to be sources of odour. However, both Path Head and Blaydon Quarry landfill sites were active during the monitoring study.

Figure 2.1: Ordnance Survey map showing MMF monitoring location



3 Monitoring Results

3.1 Meteorology

Wind speed and direction measurements were collected at the MMF site during the study. The sensor was mounted on a mast extending 6m from the top of the MMF trailer giving an overall height above ground of 8m. Where possible MMFs are located over 100m from any buildings of greater or comparable height, so as to reduce any influence that surrounding buildings may have on the wind distribution. Unfortunately, this was not possible at this site and there are buildings within 100m of the MMF, but not in the direction of interest.

When setting up the instrument measuring wind direction at the beginning of the study, the mast was rotated such that the vane pointed in a known direction and this was used as datum from which other directions were determined by the sensor. An uncertainty of ±5° on the wind direction is introduced which affects all readings by the same amount. For the production of rose plots the wind direction data are resolved into 10° sectors for analysis and interpretation, therefore the uncertainty of each sector is ±5°.

The frequency distribution of wind direction between 21 May 2014 and 18 August 2015 (455 days) is shown in Figure 3.1.1. The plot shows that over the period the dominant wind direction was from between 220° - 280°, with wind coming from this sector 45% of the time.

Figure 3.1.1: Wind rose for Blaydon-on-Tyne

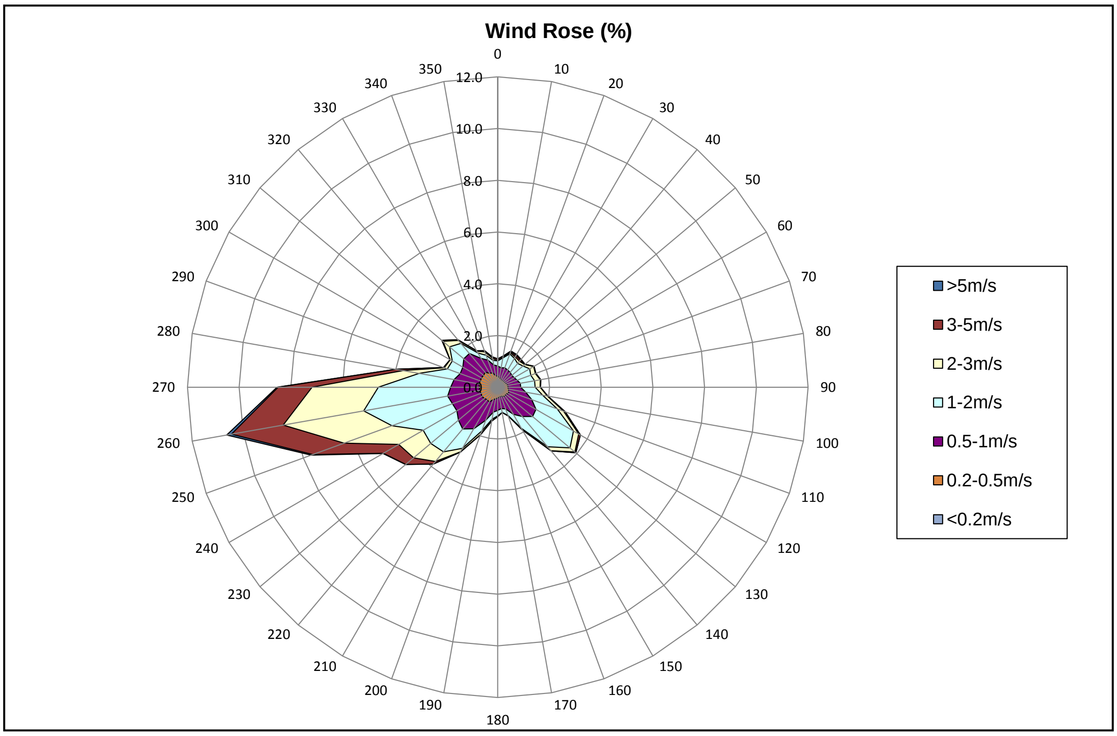
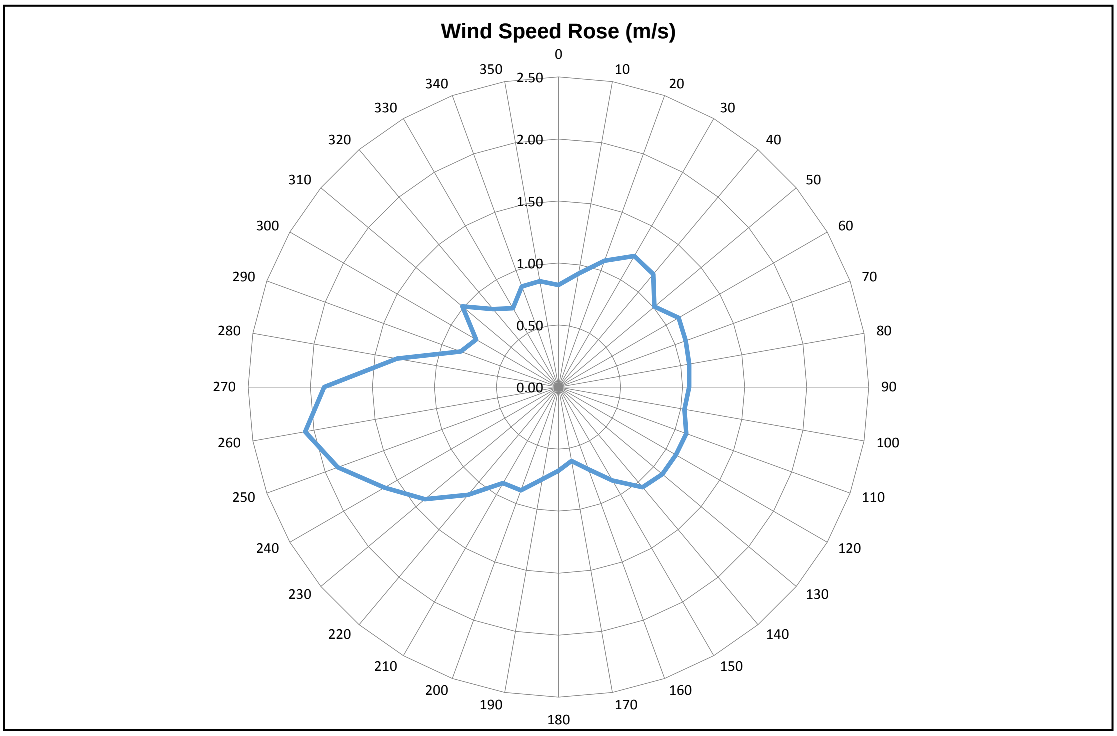


Table 3.1.1 Summary of wind speed frequencies.

Wind Speed (m/s)	Frequency of wind speed (%)
<0.2	2.27
0.2 - 0.5	16.2
0.5 - 1	28.0
1 - 2	31.6
2 - 3	14.5
3 - 5	7.02
>5	0.44
Total	**100.00**

A plot of mean wind speed against wind direction is shown in Figure 3.1.2. It can be seen that the highest average wind speed was greater than 1.5m/s and came from the wind direction between 240º - 270º.

Figure 3.1.2: Wind speed rose at Blaydon-on-Tyne

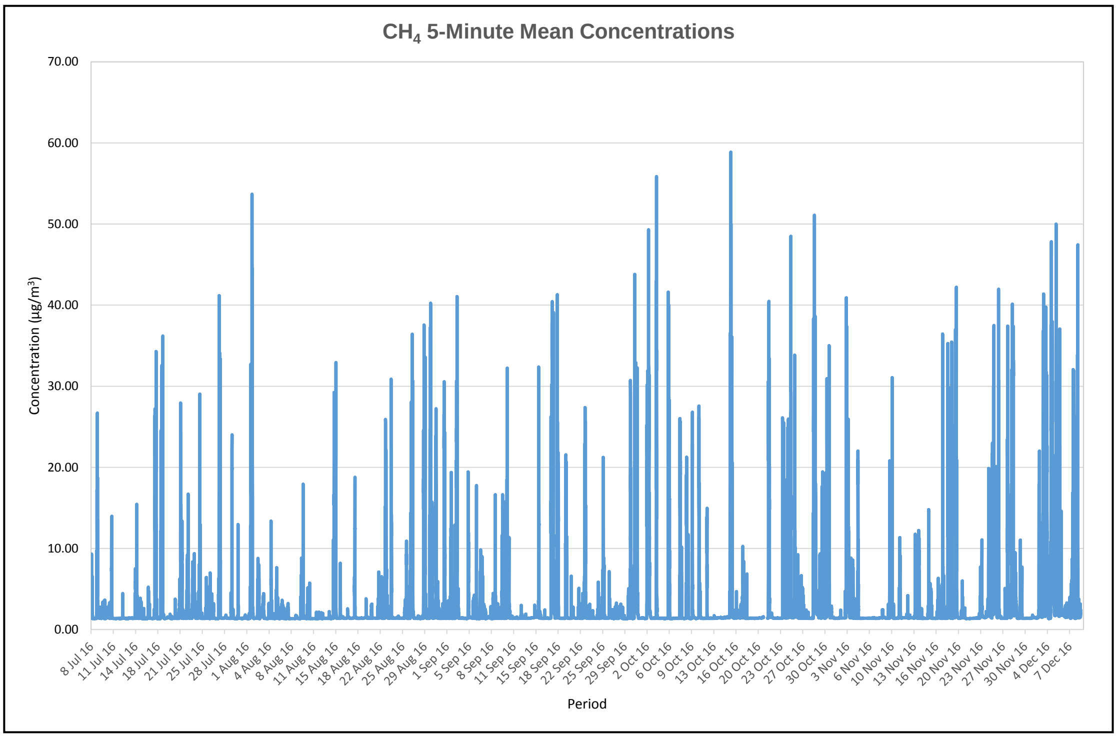


3.2 Methane (CH_4)

Between 8 July 2016 and 9 December 2016 (155 days) airborne CH_4 concentrations were measured at a height of 2m above ground. Details of the instrumentation and methodology are given in Appendix C. Successful data collection over the monitoring period was 99%.

The time series plot of 5-minute mean CH_4 concentrations (mg/m^3) over the period is shown in Figure 3.2.1.

Figure 3.2.1: CH_4 5-minute mean concentrations at the monitoring site



The average concentration over the period was 2.71mg/m^3, which is higher than the Northern Hemisphere background concentration of around 1.21mg/m^3.

3.2.1 Detailed consideration of CH_4 pollution events

Periods where CH_4 concentrations increased above the average level have been considered as separate ‘pollution events’. The five highest levels of CH_4 have been identified from the 5-minute mean concentrations. These ‘pollution events’, have been further examined and compared with wind direction and wind speed in an effort to understand the conditions leading to elevated levels of CH_4 at the monitoring site.

The results of the pollution event analysis are summarised in Table 3.2.1.

3.2.1 Table Summary of CH_4 pollution events

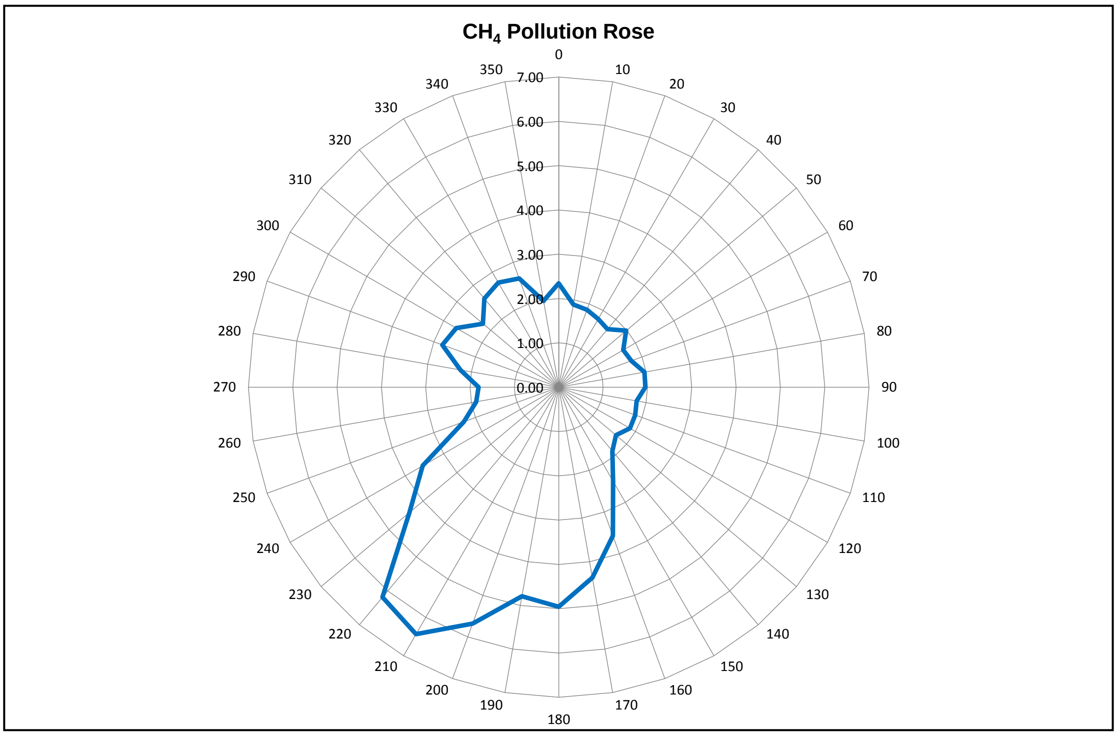
Pollution Event	Date	Time	Maximum 5-Minute Concentration (mg/m^3)	Wind Direction (degrees)	Wind Speed (m/s)
1	2 Aug 2016	03:00	53.7	237	0.4
2	4 Oct 2016	06:45	55.8	213	0.5
3	15 Oct 2016	21:15	58.9	195	1.0
4	28 Oct 2016	22:20	51.1	68	0.3
5	5 Dec 2016	16:25	50.0	316	0.4

Table 3.2.1 shows that elevated concentrations of CH_4 were seen for wind directions between 68° - 316°. All of the events were recorded at very low wind speeds, i.e. poor dispersion conditions, ranging from 0.4 – 1.0 m/s and occurred between the hours of 16:25 - 06:45.

3.2.2 Directional Analysis

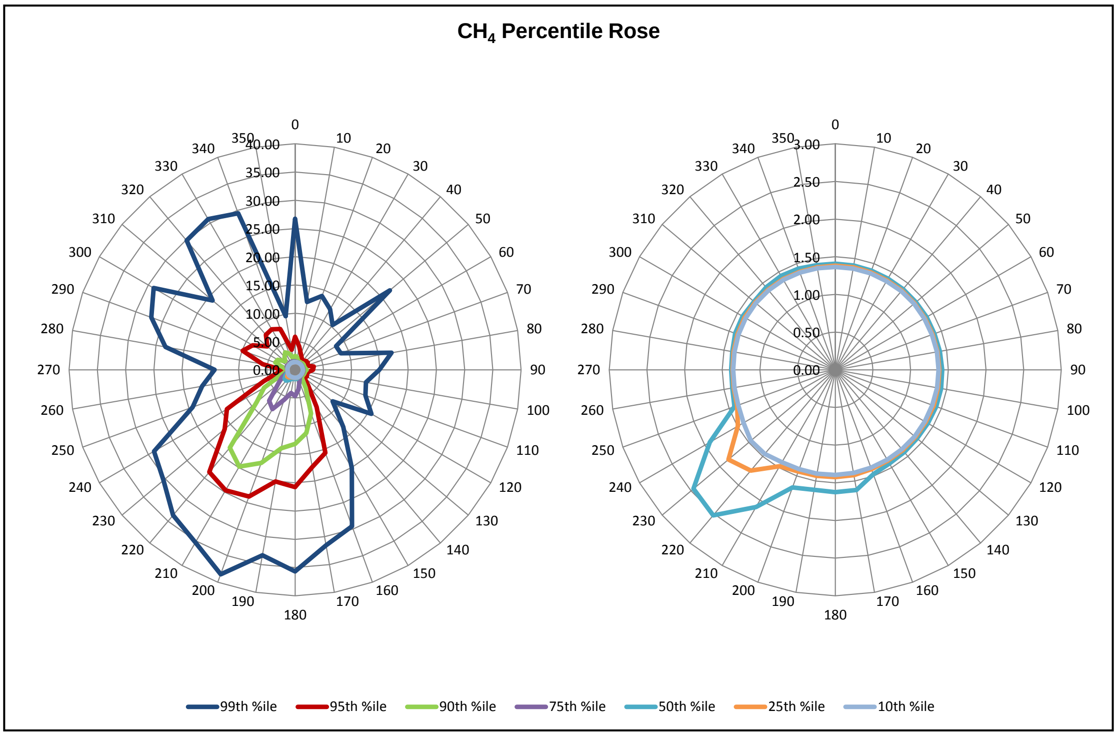
A radial plot of mean CH_4 concentrations against wind direction is shown in Figure 3.2.2. The highest average CH_4 concentration are seen for wind sectors 200° - 220°, with average concentrations >5mg/m^3.

Figure 3.2.2: CH_4 Pollution Rose



An array of plots showing the contribution to CH_4 loading at the monitoring site for different percentiles are shown in Figure 3.2.3. An explanation of percentile analysis is given in appendix E. The plots show that the contribution from the source(s) between 210° - 240° (the direction of the landfill site) affect all the percentiles, which indicates that the source(s) is relatively continuous and commonly affects CH_4 concentrations at the monitoring site. Contribution from the sources at 0° – 120°, 150° - 200° and 280° - 340° are more evident in the higher percentiles, suggesting that there are intermittent sources of CH_4 in these wind sectors that give rise to occasional elevated CH_4 concentrations.

Figure 3.2.3: CH_4 Percentile Rose



3.2.3 Wind Speed Variation

Wind speed plays an important role in the dispersion of air pollutants. Higher wind speeds generate more mechanical turbulence, which has the effect of distributing emissions more rapidly through the mixed boundary layer of the atmosphere. The relative concentrations measured at different wind speeds can provide insight to the nature of contributing sources.

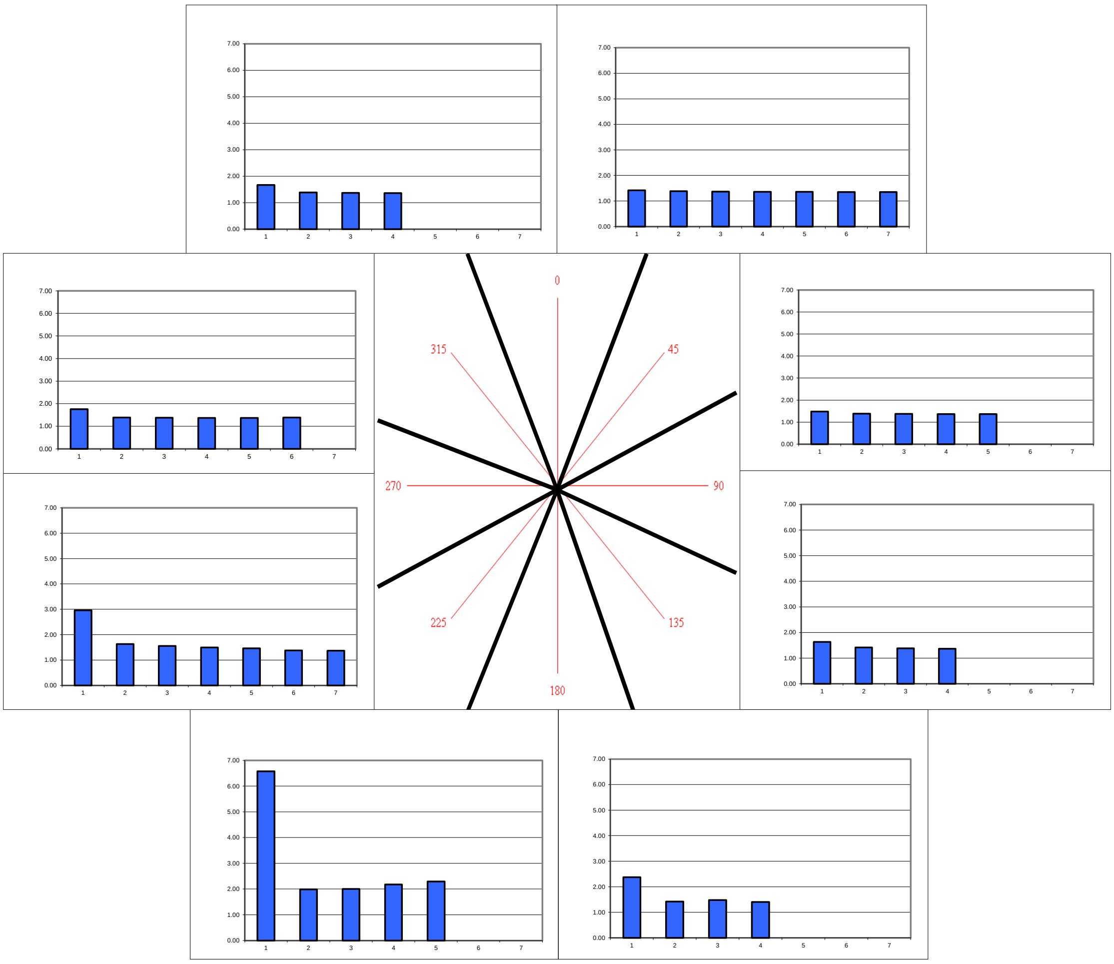
Figure 3.2.4 shows the variation in CH_4 concentrations ($\mu g/m^3$) with wind speed, for each 45° wind direction sector at the monitoring location.

The plot for the wind sector 180° – 225° shows that the highest levels of CH_4 are seen at low wind speed, during poor dispersion conditions.

Figure 3.2.4: CH_4 Wind Speed Dependency Plots

CH_4 concentration against wind speed for each of the wind direction segments

Scale: 0-7 mg/m^3 WS 1-7 m/s

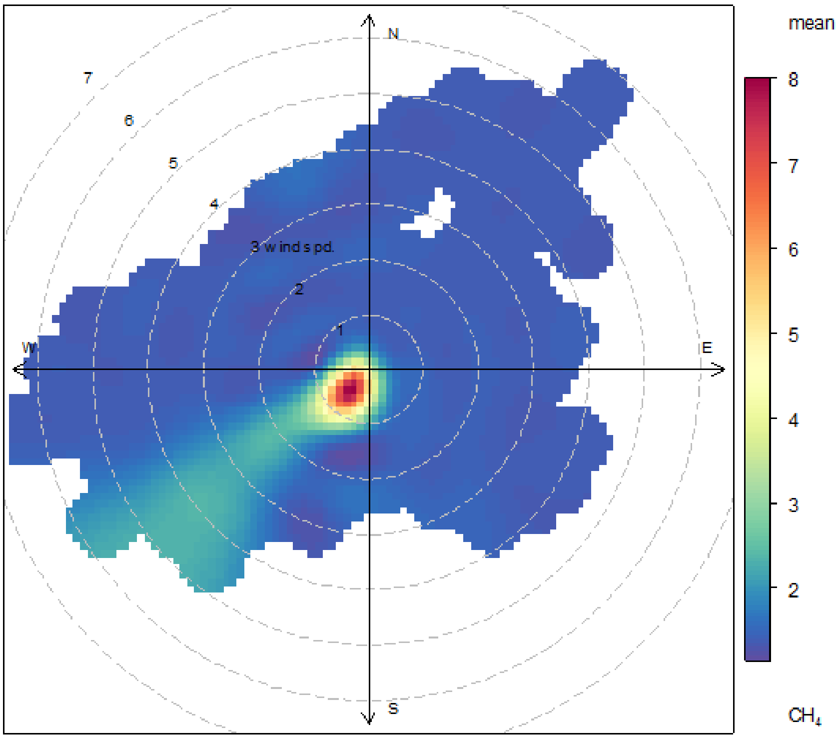


Further information can sometimes be seen by plotting the data using Openair polar plots (Figure 3.2.5).

The plot shows a hot spot of CH_4 concentrations at the monitoring site between 205° - 237° at wind speeds ~0.5m/s, suggesting that the highest levels are seen at very low wind speeds from the direction of the landfill sites.

This is also seen in the polar plot for H_2S, suggesting that the two pollutants have a common source.

Figure 3.2.5: CH_4 Openair Wind Speed Dependency Plot



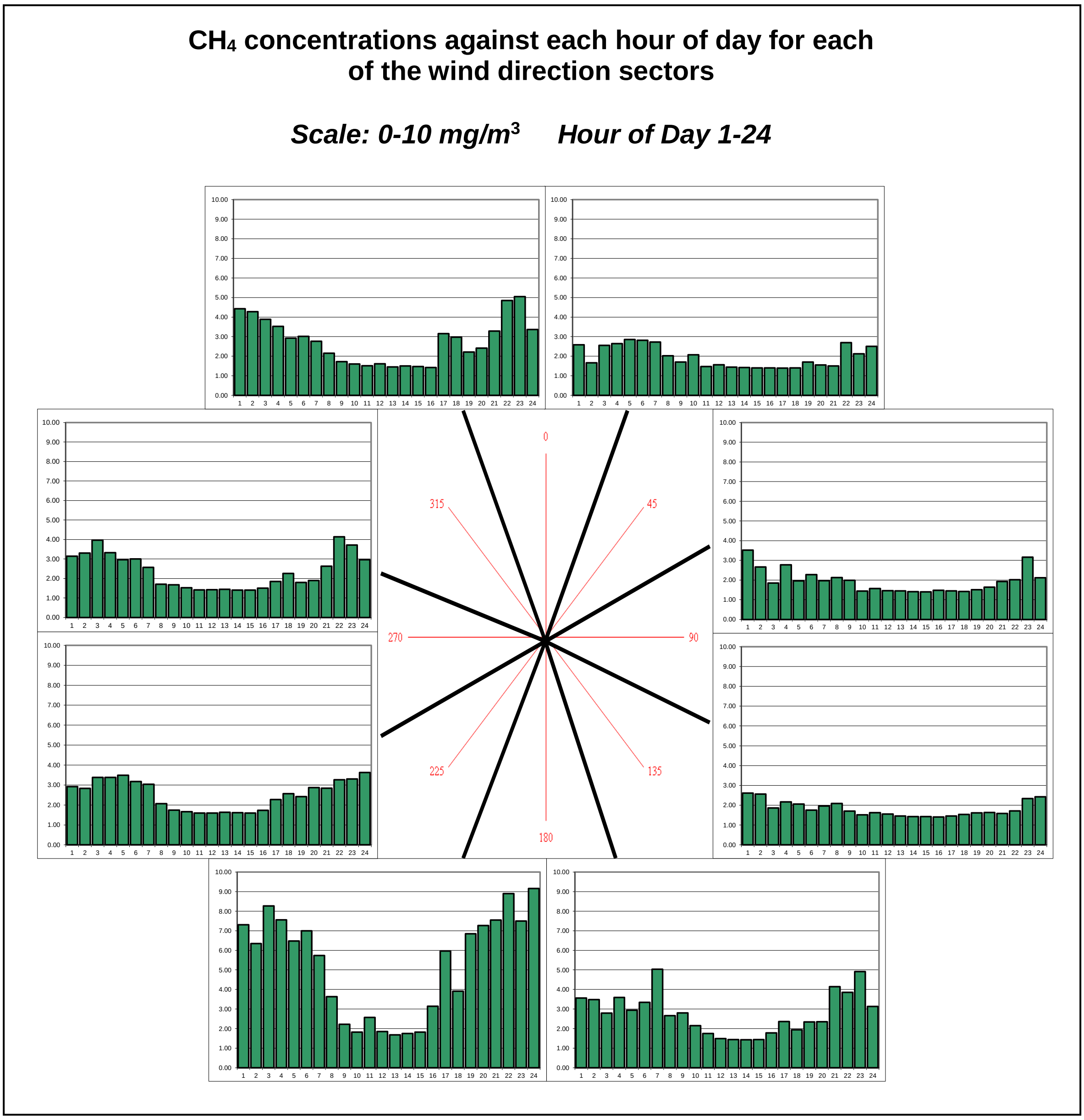
3.2.4 Diurnal and Weekday Analysis

Consideration of the diurnal distribution of concentration levels can provide further useful information about the sources contributing to the ambient levels in each sector.

Figure 3.2.6 shows diurnal variation of average CH_4 concentrations for each 45° wind direction sector.

All of the plots to a greater or lesser extent show a rise in the early hours of the morning and variable rise at night. This is likely to be the result of poor dispersion resulting from stable conditions caused by nocturnal inversion layers trapping fugitive emissions close to the ground. However, the highest levels are seen in the plot for the wind sector 180° – 225°, the direction of the landfill sites.

Figure 3.2.6 CH_4 diurnal plot

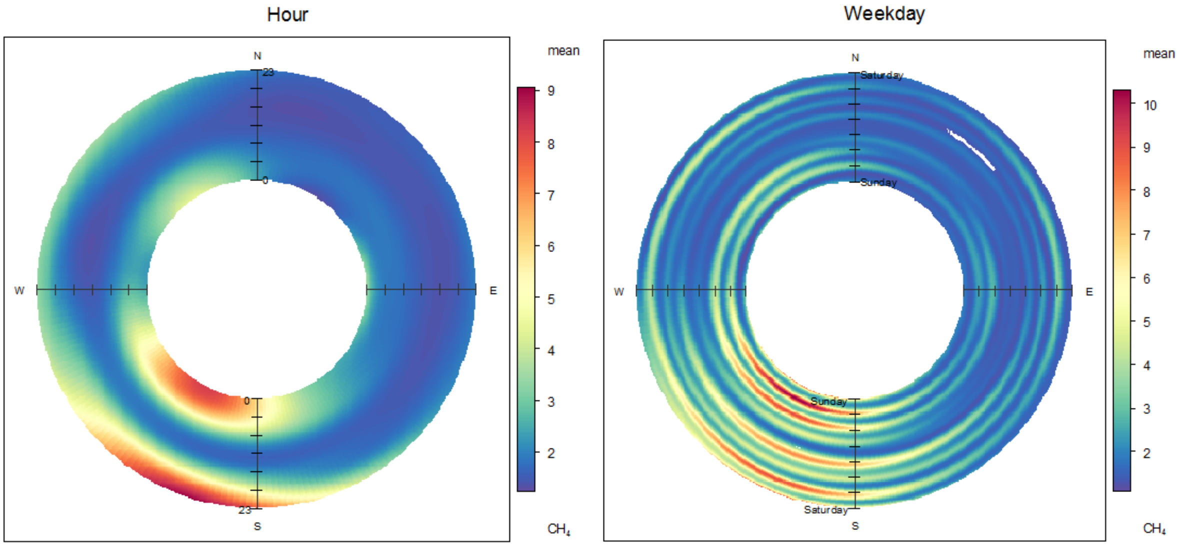


Diurnal and weekday Openair plots for CH_4 at the monitoring site are shown in Figure 3.2.7.

The CH_4 diurnal plot shows that the highest levels are observed during the evening and early morning between 165° – 245°.

The CH_4 weekday plot shows that the highest levels were seen in the wind sector 170° - 250° were high both during the week and at weekends.

Figure 3.2.7 CH_4 Openair Diurnal and Weekday Annulus Plots



3.2.5 Conclusions

The mean CH_4 concentration over the monitoring period was 2.71mg/m^3.

The event analysis suggests that peaks in CH_4 concentration were recorded at the monitoring site during times of poor dispersion.

The directional analysis indicated that the highest average CH_4 concentrations were recorded at the monitoring site when the wind direction was from between 200° - 220° (the direction of the landfill sites).

Percentile analysis suggested that the source(s) of CH_4 in the direction of the landfill sites is relatively continuous, whilst there is evidence of intermittent sources in other directions.

Wind speed analysis suggests that the monitoring site is affected by low level source emissions, such as fugitive emissions.

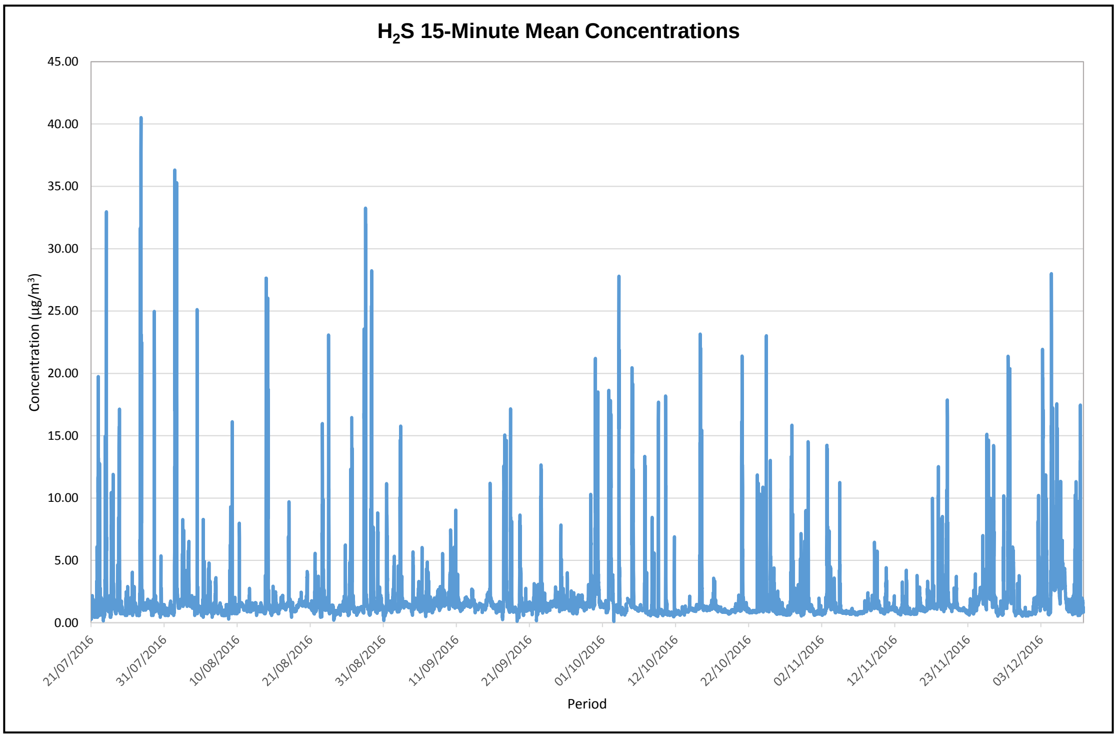
Diurnal and weekday analysis suggest that the monitoring site is being influenced by CH_4 levels arising from fugitive emissions that are trapped close to the ground during times of poor dispersion, such as nocturnal temperature inversions. This is most evident in the direction of the Landfill sites.

3.3 Hydrogen Sulphide (H_2S)

Between 21 July 2016 and 9 December 2016 (142 days) airborne H_2S concentrations were measured at a height of 2m above ground. Details of the instrumentation and methodology are given in Appendix D. Successful data collection for the monitoring period was 99%.

A time series plot of 15-Minute concentrations of H_2S over the monitoring period is shown in Figure 3.3.1. The plot shows that H_2S concentrations remained below 25µg/m^3 for the majority of the data recorded with occasional peaks above this value. The average concentration over the period was 1.88µg/m^3.

Figure 3.3.1: H_2S 15-Minute mean concentrations at the monitoring site.



3.3.1 Comparison with WHO Guidelines

A time series plot of 24-hour mean H_2S concentrations at the monitoring site is shown in Figure 3.3.2. This data can be compared directly with the relevant WHO Guideline for Europe 2000. The highest recorded 24-hour mean was 6.35µg/m^3 which is comfortably less than the 150µg/m^3 limit set as a guideline by WHO, in the context of human health.

A time series plot of 30-minute average H_2S concentrations measured over the period is shown in Figure 3.3.3. This data allows direct comparison with the WHO Guidelines for Europe 1987, which have set a guide level of 7µg/m^3 above which substantial complaints about odour annoyance can be expected. The highest recorded 30-minute mean was 39.1µg/m^3 and levels were above 7µg/m^3 for 4% of the monitoring period, therefore complaints due to odour nuisance from H_2S could be expected at the monitoring site.

Figure 3.3.2: H_2S 24-hour (midnight – midnight) mean concentrations at the monitoring site.

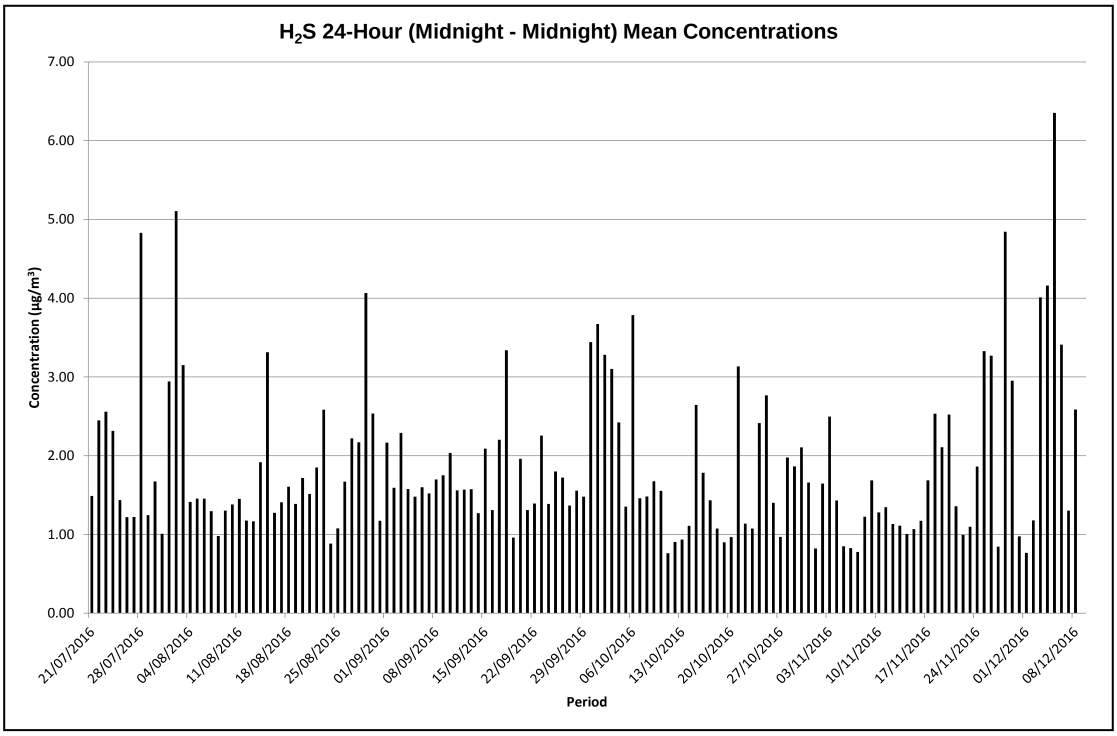
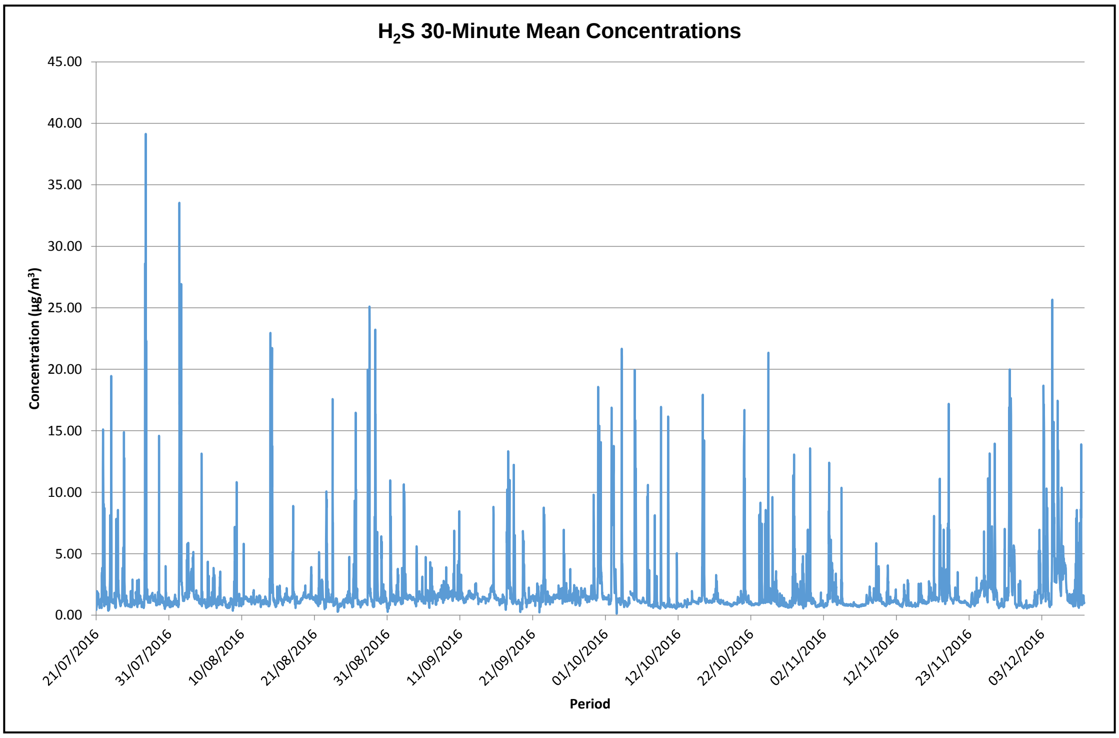


Figure 3.3.3: H_2S 30-minute mean concentrations at the monitoring site.



3.3.2 Directional Analysis

A radial plot of mean H_2S concentrations (µg/m^3) and CH_4 concentrations (mg/m^3) against wind direction at the MMF site is shown in Figure 3.3.4. The plot shows that the highest concentrations for both H_2S and CH_4 came from the same wind directions, between 190º - 230º, which suggests that they have come from the same source. Further evidence of this can be seen by plotting a scatter plot of CH_4/H_2S (Figure 3.3.5). The plot shows that there is good correlation between CH_4 and H_2S, especially at lower concentrations, apart from an event at very low CH_4 concentration, where higher than expected H_2S was observed.

Figure 3.3.4: H_2S and CH_4 Pollution Rose

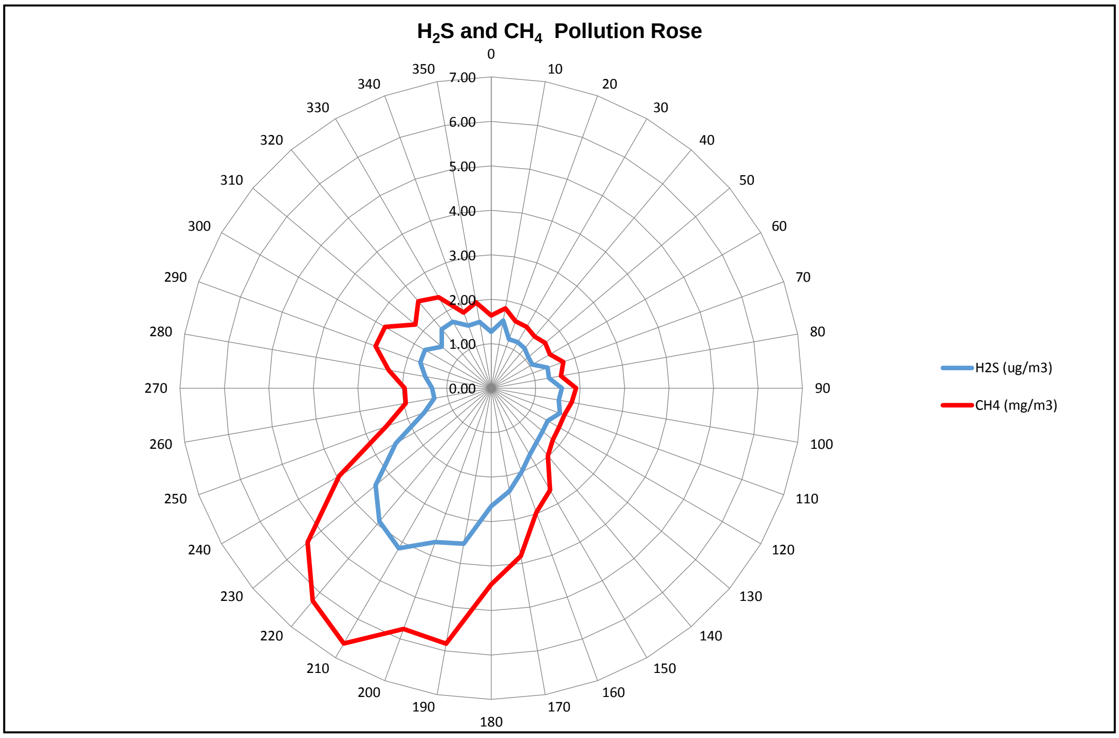
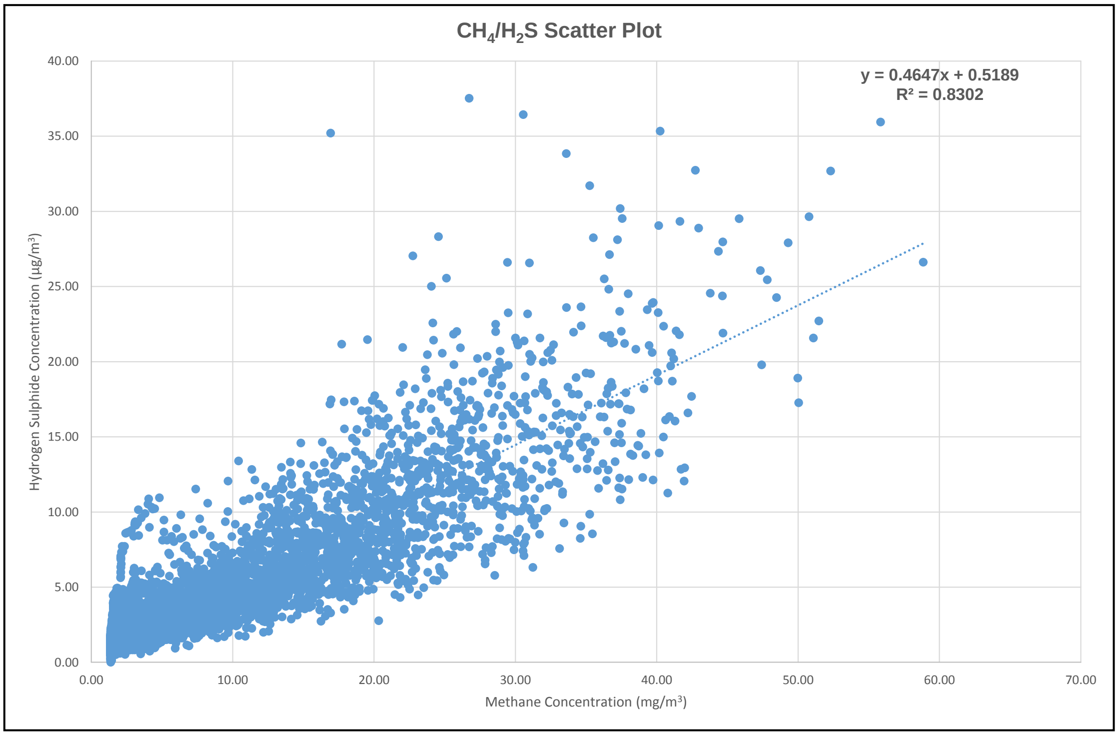


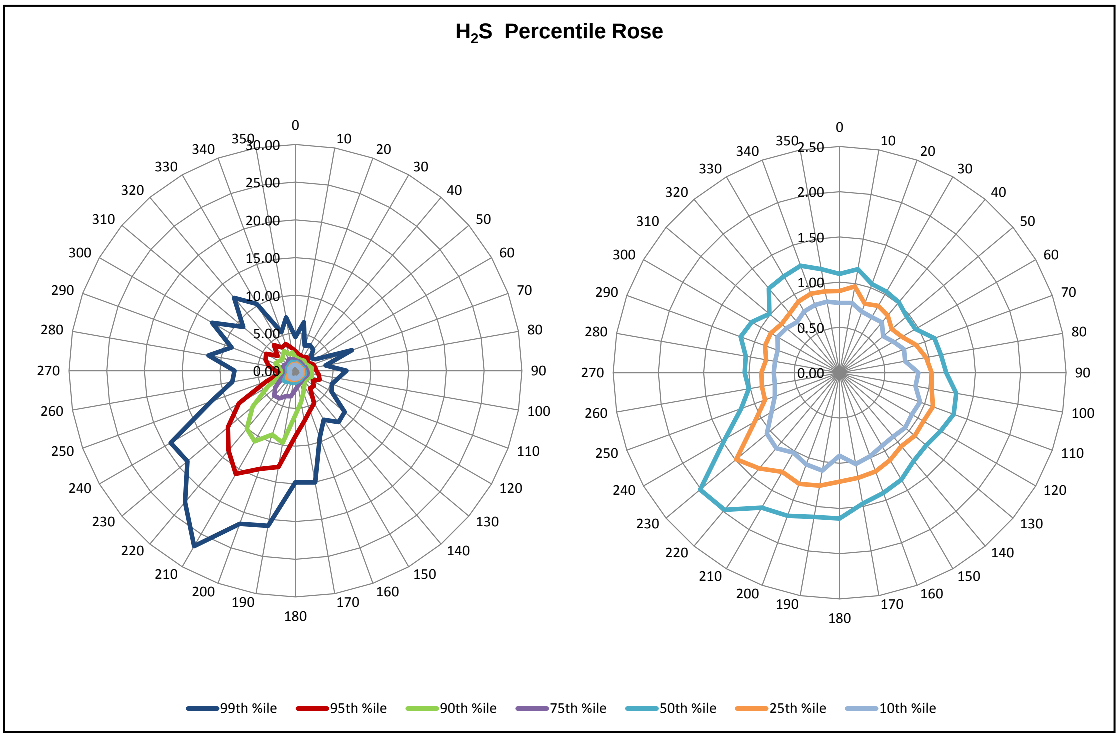
Figure 3.3.5: CH_4/H_2S Scatter Plot



An array of plots showing the contribution to H_2S loading at the monitoring site for different percentiles is shown in Figures 3.3.6.

Figure 3.3.6 shows that the contribution from the source(s) between 190° - 230° (the direction of the landfill sites) affect all the percentiles, which indicates that the source(s) is relatively continuous and commonly affects H_2S concentrations at the monitoring site.

Figure 3.3.6: H_2S Percentile Rose



3.3.3 Wind Speed Variation

Wind speed plays an important role in the dispersion of air pollutants. Higher wind speeds generate more mechanical turbulence, which has the effect of distributing emissions more rapidly through the mixed boundary layer of the atmosphere. The relative concentrations measured at different wind speeds can provide insight to the nature of contributing sources.

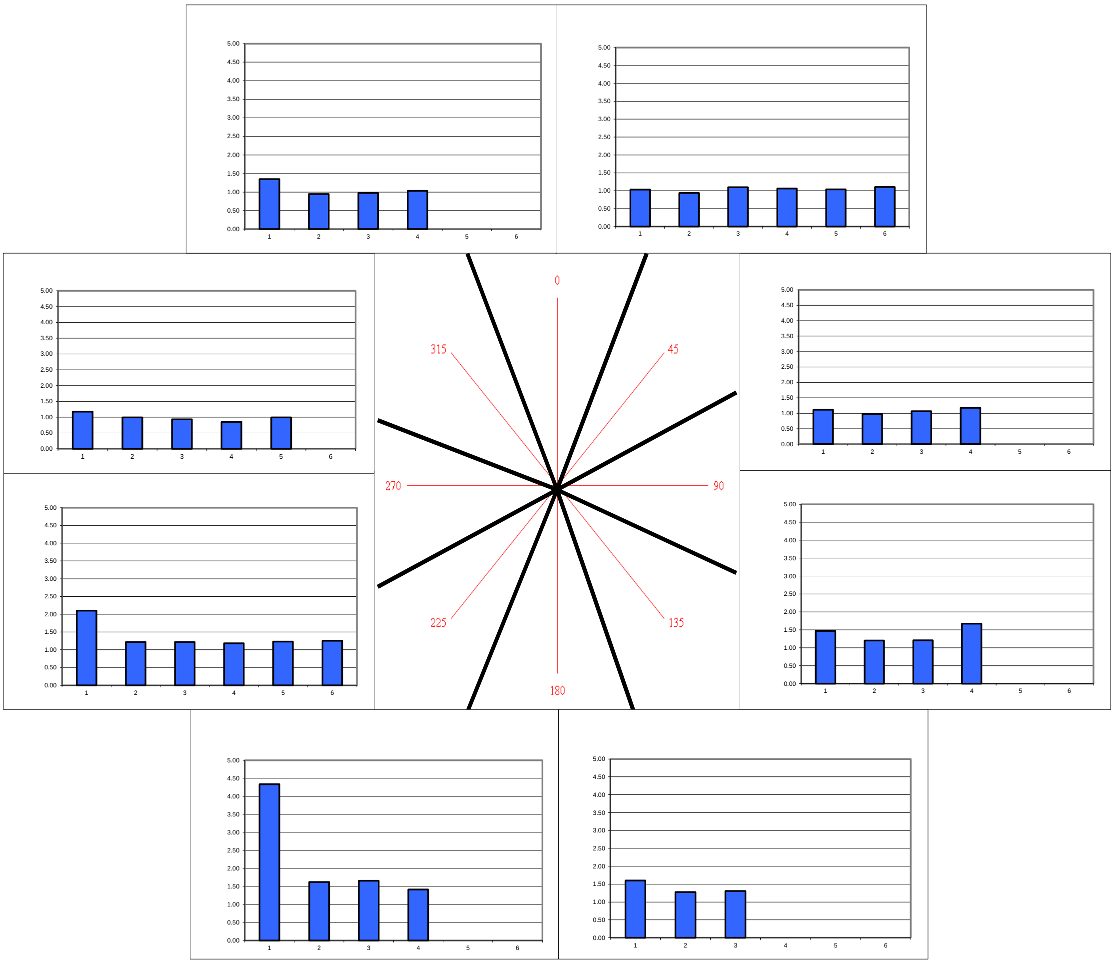
Figure 3.3.7 shows the variation in H_2S concentrations (µg/m^3) with wind speed, for each 45° wind direction sector at the monitoring location.

The majority of the plots show relatively flat profiles with levels remaining unchanged by wind speed. This suggests that there are no significant sources of H_2S in these sectors and levels remain around background levels. However, the plots for the wind sector 180° – 270° show that H_2S concentrations are highest at very low wind speed, i.e. poor dispersion conditions, suggesting a low level source such as fugitive emissions. Possible sources in this wind sector are the landfill sites.

Figure 3.3.7: H_2S Wind Speed Dependency Plots

H_2S concentration against wind speed
for each of the wind direction segments

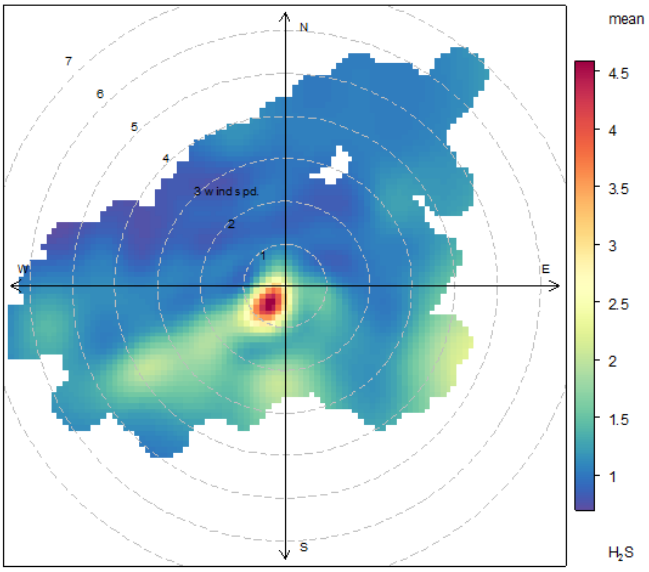
Scale: 0-5µg/m^3 WS 1-6 m/s



Further information can sometimes be seen by plotting the data using Openair polar plots (Figure 3.3.8).

The plot shows a hot spot of H_2S concentrations at the monitoring site between 205° - 237° at wind speeds ~0.5m/s, suggesting that the highest levels are seen at very low wind speeds from the direction of the landfill sites.

Figure 3.3.8: H_2S Openair Wind Speed Dependency Plot



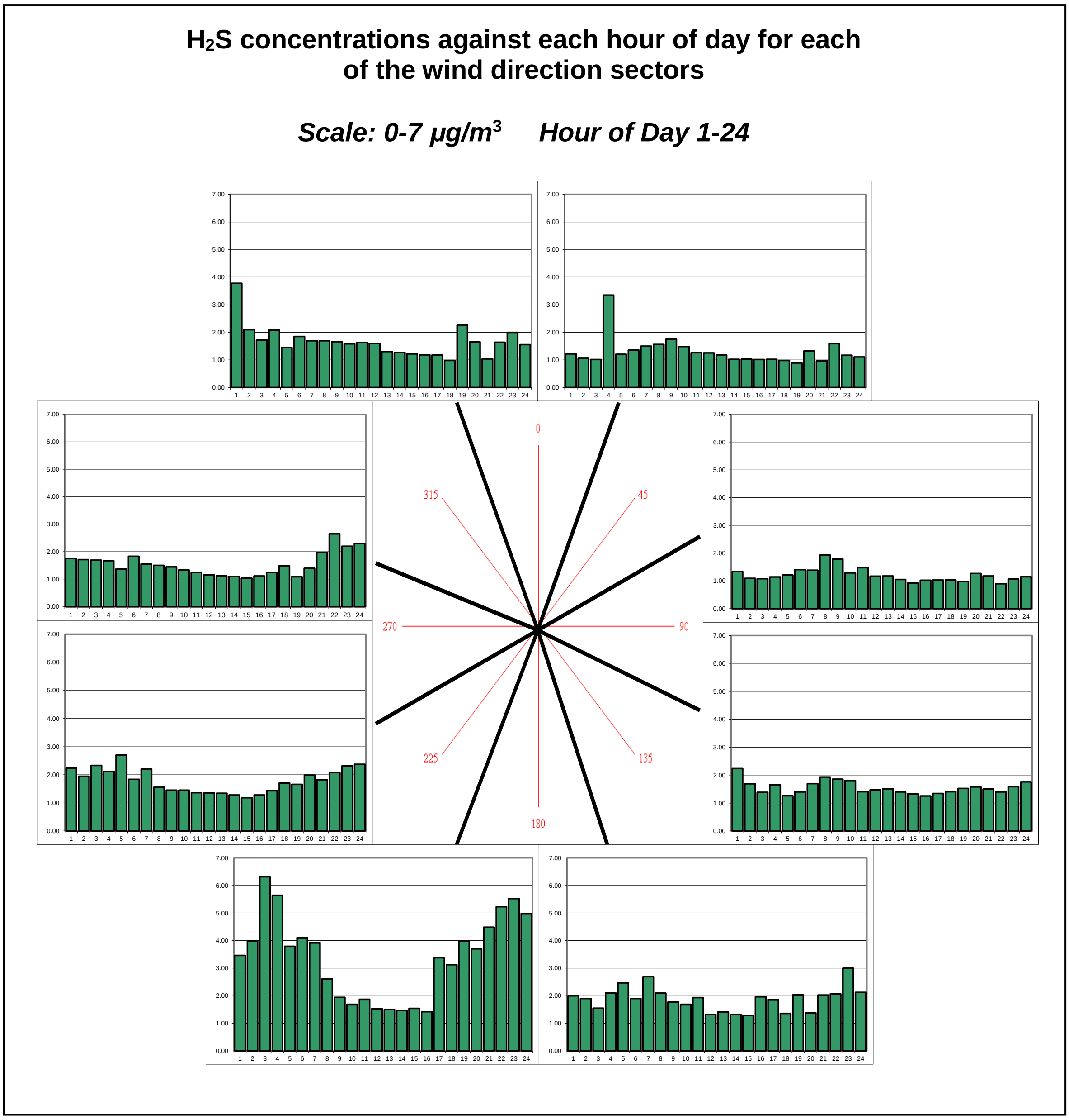
3.3.4 Diurnal and Weekday Analysis

Consideration of the diurnal distribution of concentration levels can provide further useful information about the sources contributing to the ambient levels in each sector. Pollutants generated from everyday traffic on the roads typically take the form of a double peak pattern, where the peaks correspond to the morning and afternoon/evening rush hours. Emissions from activities on site, meanwhile, are usually characterised by a single peak spanning the hours of the working day or operations on site.

Figure 3.3.9 shows diurnal variation of average H_2S concentrations for each 45° wind direction sector at the MMF site.

The Figure shows that the highest levels are seen in the plot for the wind sector 180^o - 225^o, with levels rising around 17:00 and remaining elevated throughout the night before dropping back down around 09:00. This is likely to be the result of poor dispersion conditions arising from stable conditions caused by nocturnal inversion layers trapping fugitive emissions close to the ground.

Figure 3.3.9 H_2S diurnal plot

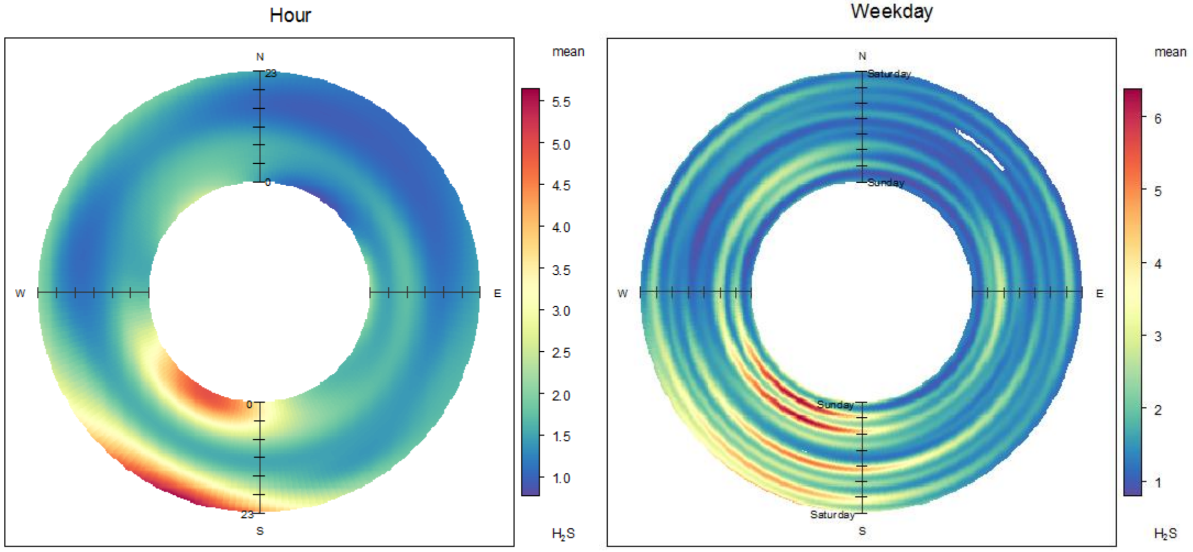


Diurnal and weekday Openair plots for H_2S at the monitoring site are shown in Figure 3.3.10.

The H_2S diurnal plot shows that the highest levels are observed during the evening and early morning between 175° – 240°.

The H_2S weekday plot shows that the highest levels were seen in the wind sector 170° - 250° were high both during the week and at weekends.

Figure 3.3.10 H_2S Openair Diurnal and Weekday Annulus Plots



3.3.5 Conclusions

Comparison of the H_2S data with the WHO guidelines for human health of 150µg/m^3, as 24-hour mean concentrations, indicated that the air quality at the monitoring site was well within these guidelines.

However, comparison of the H_2S data with the WHO guideline for odour annoyance of 7µg/m^3 (as 30-minute mean concentrations) indicated that the air quality at the monitoring site exceeded this guideline ~4% of the monitoring time.

Pollution rose analysis indicates that the highest average H_2S concentrations were measured at the monitoring site when the wind was coming from between 190^o - 230^o, the direction of the landfill sites.

Percentile rose analysis suggested that the monitoring site was affected by relatively continuous H_2S emissions.

Wind speed and diurnal analysis suggests that the monitoring site is affected by low level source emissions that build up under poor dispersion conditions.

Directional and scatter plot analysis suggest that the H_2S and CH_4 came from the same source, i.e. fugitive emissions from the landfill sites.

4 Complaint Analysis

During the monitoring period there were ~392 complaints received with regard to odour. Many of these complaints described the smell as a 'rotten egg smell', which is characteristic of hydrogen sulphide gas. As discussed earlier, although health standards for H_2S levels were not exceeded at the monitoring site, levels did rise above nuisance odour thresholds and therefore odour complaints due to H_2S are not unexpected.

Many of the complaints occurred during periods of low wind speeds, where stable, anti-cyclonic conditions led to poor dispersion of the fugitive emissions. The diurnal plots for methane and hydrogen sulphide both show that levels were highest overnight, with levels starting to rise in the evening and remaining high until morning. This is likely to be the result of nocturnal inversion layers. Formed on clear nights, when cold air close to the ground is trapped by a layer of warmer air above, effectively preventing the dispersion of air pollutants that build up under the inversion.

The three days during the monitoring study that received the highest number of complaints have been analysed in an attempt to establish the cause of the odour nuisance.

Table 4.1 looks at the bearing of each individual complaint from four local landfill sites (Close house Farm and Burnhills were not active during the study and are capped and therefore not likely to be sources of odour) to see whether the complainant had been down-wind of a landfill site when the odour had occurred. By looking at the direction of the wind in the 5-minute data for the hour prior to the complaint time stamp, we were able to establish how often within that hour the wind direction had come across a given landfill site and therefore the likelihood of that landfill site being the cause of the odour. The table also reports the number of 5-minute wind speeds within that hour that were ≤ 1 m/s, i.e. indicating times of poor dispersion.

The table shows that on the 17 August 2016, 17 odour complaints were received, the highest amount on a single day during our monitoring study. The wind speed shows that there was poor dispersion at the beginning and the end of the day, although complaints were received throughout the day (between 01:52 to 23:36). Wind direction during periods of low wind speed is more erratic and therefore the correlation between wind direction and the bearing of the landfill sites from the complainant is sometimes not as evident. The table shows that the wind direction, prior to many of the complaints during the 17 August, had come across Path Head, with wind directions coming across the other landfill sites less frequently.

On the 28 November 2016, 12 odour complaints were received, between 10:25 and 21:30. The wind speed shows that once again there was poor dispersion at the beginning and the end of the day, but this time the dispersion does not improve that much during the day. There were a cluster of complaints between 18:00 – 18:40 at properties that were downwind of both the Path Head and Blaydon Quarry landfill sites.

Table 4.1 Comparison of complaint time and wind direction (OS = on site)

Number of 5-minute WD data that blew across a landfill in the hour prior to complaint time stamp						
🟫	🟥	🟧	🟨	🟩	🟦	⬜
11-12	9-10	7-8	5-6	3-4	1-2	0

Date	Time (GMT)	Number of 5-min WS in hour ≤ 1m/s	Path Head	Close House Farm	Blaydon Quarry	Burnshill
17/08/2016	01:52	12	⬜	🟩	🟩	⬜
	05:12	12	⬜	🟨	🟩	⬜
	06:03	12	🟧	⬜	⬜	⬜
	06:39	10	🟫	🟦	⬜	⬜
	06:50		OS	⬜	⬜	⬜
	06:59	8	🟨	⬜	⬜	⬜
	07:37	9	🟩	⬜	⬜	⬜
	07:47	8	🟦	⬜	⬜	⬜
	10:07	4	🟦	🟧	🟦	🟦
	11:46	1	🟩	🟩	🟩	🟦
	13:56	1	🟨	⬜	⬜	⬜
	16:52	0	🟧	⬜	⬜	⬜
	19:42	10	🟧	🟦	⬜	⬜
	20:18	9	🟫	⬜	⬜	⬜
	21:32	12	🟥	🟦	🟦	⬜
	23:19	12	🟦	🟦	🟧	⬜
	23:36	12	🟨	🟦	⬜	⬜
28/11/2016	10:25	12	⬜	⬜	⬜	⬜
	10:54	12	⬜	⬜	⬜	⬜
	16:50	12	🟨	🟩	🟩	⬜
	17:22	11	🟦	⬜	🟦	🟦
	18:00	8	🟫	🟩	🟧	🟩
	18:04	8	🟥	🟦	🟧	🟩
	18:05	8	🟫	🟩	🟧	🟩
	18:08	9	🟥	🟩	🟧	🟩
	18:30	8	🟥	🟦	🟥	🟨
	18:40	8	🟥	🟨	🟥	🟩
	19:44	12	🟩	⬜	🟦	🟩
	21:30	12	🟦	🟦	🟦	🟦
05/12/2016	08:26	12	⬜	⬜	⬜	⬜
	10:14	12	⬜	⬜	⬜	⬜
	11:09	12	⬜	⬜	⬜	⬜
	14:49	12	🟦	⬜	🟩	🟦
	14:51	12	🟦	⬜	🟩	🟦
	14:51	12	🟦	⬜	🟦	⬜
	15:24	12	🟦	🟦	🟩	🟦
	15:24	12	⬜	🟦	🟩	🟦
	15:37	12	🟦	🟨	🟦	⬜
	15:59	12	⬜	⬜	🟩	🟩
	16:10	12	🟦	⬜	🟦	⬜
	17:21	10	⬜	⬜	🟨	⬜
	18:06	11	🟦	⬜	🟩	🟩

On the 5 December 2016, 13 odour complaints were received between 8:26 and 18:06. The wind speed shows that there was poor dispersion conditions throughout the day. As expected the correlation between wind direction and the bearing of the landfill sites from the complainant is not as clear, with a lower number matching up with having come across a specific landfill site. However, the data does suggest that fugitive emissions from Blaydon Quarry landfill site may have been the most dominant source on this particular day.

5 Conclusions

The average CH_4 concentration over the period was 2.71mg/m^3, which is higher than the Northern Hemisphere background concentration of around 1.21mg/m^3.

Comparing the collected data from the monitoring at Blaydon-on-Tyne with the World Health Organisation (WHO) guidelines showed that H_2S was within health limits. However, comparison of the H_2S data with the WHO guideline for odour annoyance of 7µg/m^3 (as 30-minute mean concentrations) indicated that the air quality at the monitoring site exceeded this guideline ~4% of the monitoring time. Likely sources of the H_2S are Path Head and Blaydon Quarry Landfill sites, as the two capped landfills are unlikely to contribute to odour issues.

Tables 4.1 summarises the extent of likely compliance with the WHO guidelines. A projected compliance ratio ≤ 1 indicates compliance, whilst a value >1 indicates non-compliance.

Table 4.2 summarises the results from the mean pollution roses, where wind directions showing a significant bias for a particular pollutant are shaded in red.

A time series plot for the pollutants monitored is shown in Figure 4.1.

Table 4.1 Impact summary of H_2S compliance with the WHO guidelines for Europe 2000.

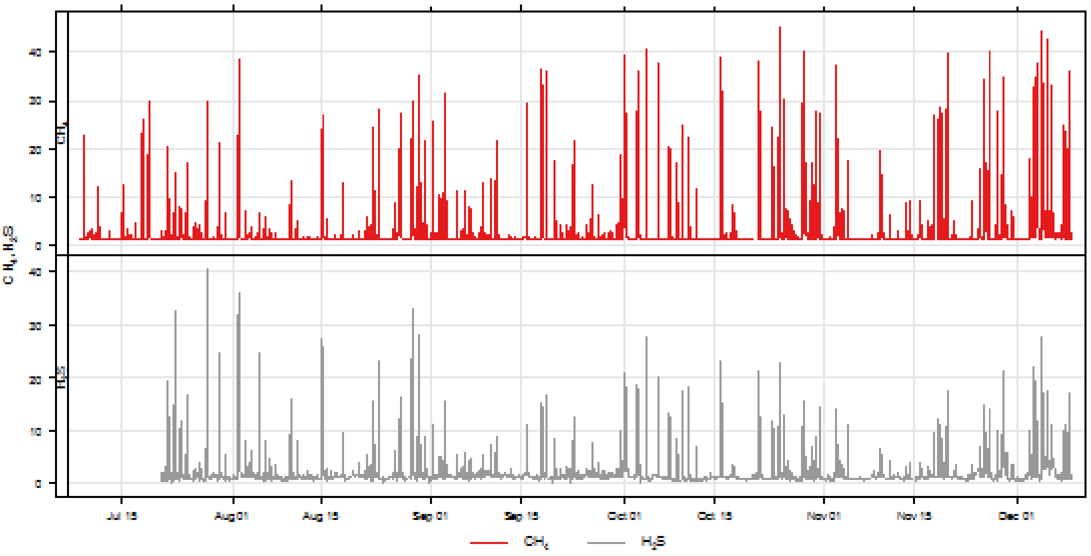
Pollutant	Averaging Time	Guidance Limit	Time Exceeding the Guidance Limit (%)
H_2S	24hr (midnight- midnight)	150µg/m^3	0
	30-Minute	7µg/m^3	4

Table 4.2 Summary of mean pollution roses. The bearing of Path Head landfill site from the monitoring site is shaded in yellow.

	Wind Direction (Degrees)																	
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**
H_2S																		
CH_4																		

	Wind Direction (Degrees)																	
	190	**200**	**210**	**220**	**230**	**240**	**250**	**260**	**270**	**280**	**290**	**300**	**310**	**320**	**330**	**340**	**350**	**360**
H_2S	🟥	🟥	🟥	🟥														
CH_4		🟥	🟥	🟥														

Figure 4.1 Time Series for the monitoring site in Blaydon-on-Tyne (15-Minute mean concentrations)



The landfill sites could be identified as a relatively continuous source of both CH_4 and H_2S in the data.

6 References

1. World Health Organisation (2000), *WHO Air Quality Guidelines for Europe*

Appendix A Mobile Monitoring Facility

National Monitoring Services carries out ambient air monitoring on behalf of Environment Agency regions using Mobile Monitoring Facilities (MMFs). These facilities allow us to carry out flexible, short-term studies examining the impact of specific EPR permitted installations on local communities. The facilities contain a number of analysers designed to sample the atmosphere for a selection of pollutants commonly associated with industrial emissions. The equipment is contained within a trailer that can conveniently be towed. This allows it to be strategically sited at temporary locations with the intention of quantifying pollution loadings and determining sources. The MMF used in the Newcastle study was MMF3. The pollutants that can be measured using MMF3 are:

- hydrogen sulphide
- methane

Meteorological Instruments

In addition to analysers measuring the concentration of pollutants in the air the facility contains equipment that can measure meteorological conditions. This provides the opportunity to consider measured pollutant levels relative to the prevailing meteorological situation. This can supply important information allowing a more detailed understanding of the pollutants' dispersion in the atmosphere and consequently a more accurate assessment of their origins. The meteorological parameters that can be measured are:

- wind direction,
- wind speed,
- ambient air temperature
- relative humidity.

All meteorological measurements are taken at an elevation of 8m above the ground and from positions where the wind approach was unobstructed. The temporal resolution of all logged meteorological data is 5 minutes.

Wind direction is an important consideration as it provides direct information about the orientation of any source relative to the monitoring site. It must be noted, however, that pollutants will be carried along a wind's trajectory that may, over distances of several kilometres, be curved so that in these cases the wind direction will not simply 'point' to the source's direction. Wind speed and temperature both have a significant influence on the amount of mixing within the atmosphere, having profound effects on the vertical distribution of pollutants through the atmospheric boundary layer. Relative humidity is important because the level of moisture within the air affects the rates of reaction and removal of some air pollutants.

Appendix B Quality Assurance and Quality Control

Quality assurance covers practices that are undertaken prior to data collection in order to ensure that the sampling arrangements and analysers are capable of providing reliable measurements. Quality Control covers practices applied after data collection in order to ensure that the measurements obtained are repeatable and traceable.

In order to ensure that data from the MMF are representative of pollutant concentrations and meet appropriate standards of quality, a number of QA and QC procedures are routinely implemented in the monitoring facility's execution.

Quality assurance included:

Training - all personnel involved with the running of the facility have received appropriate training in the execution of the tasks they are expected to undertake. This training has been recorded in the personal training log of the individuals concerned.

Procedures - all routine activities undertaken in the operation of the facility are clearly and unambiguously laid out in a documented set of procedures.

Analyser selection - careful consideration has been given to the choice of analysers, ensuring that they meet the required standards of accuracy and precision. Also that they can be relied on to be robust and flexible enough to present the data in a suitable format.

Trailer Location - attention is given to how representative the location of the facility is when compared against the objectives of the study.

Quality control included:

Routine calibration - calibrations are performed every two weeks, using traceable gas standards and any adjustments made to the analysers documented.

Routine maintenance - undertaking of stipulated checks and changes of filters.

Periodic maintenance - employment of a qualified engineer to service the analysers twice a year.

Instrument history - all invasive work carried out on analysers is documented and recorded.

Data review - all data is checked to ensure correct scaling, rejecting negative or out-of-range readings, questioning rapid excursions, generally considering the integrity of recorded levels.

Data handling - following recognised procedures to ensure that data capture is maximised. The data is analysed frequently so that measurements affected by instrument fault are recognised quickly.

Data comparison - comparing the collected data sets with data sets from other monitoring studies that are carried out in close enough proximity to be relevant. Consideration of the relationship between different pollutants i.e. some pollutant levels will be expected to rise and fall together.

Data rectification - the adjustment of data to minimise the effects of analyser drift.

Independent assessment- the analysers are regularly assessed by independent specialists to provide documented evidence that the analysers are performing to nationally accepted criteria.

Appendix C Methane (CH_4)

Methane, commonly known as marsh gas, is a colourless, odourless gas with a melting point of -184°C and boiling point -164°C. Its main environmental impact is from its relatively high potential for global warming. It affects the radiation balance of the Earth by absorbing infrared radiation and converting it to heat, therefore increased methane concentrations lead to increased surface temperatures.

Sources

Methane is produced by anaerobic bacterial fermentation processes in water that contains substantial organic matter, such as swamps, marshes, rice fields, lakes and landfills. This microbial degradation of organic matter may be written:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Methane is also produced by enteric fermentation in mammals and other species.

Until the late 1970s, it was accepted that the background concentration of methane was in the range of 1.4 – 1.6 ppm, since then ambient levels have risen to a background norm of approximately 1.8ppm. The increase in methane background concentrations is mainly due to an increase in the emissions from primary sources. However the reduction in environmental levels of the hydroxide radical [OH] brought about by the increased levels of carbon monoxide (CO) also plays a part.

CH_4 Analysers

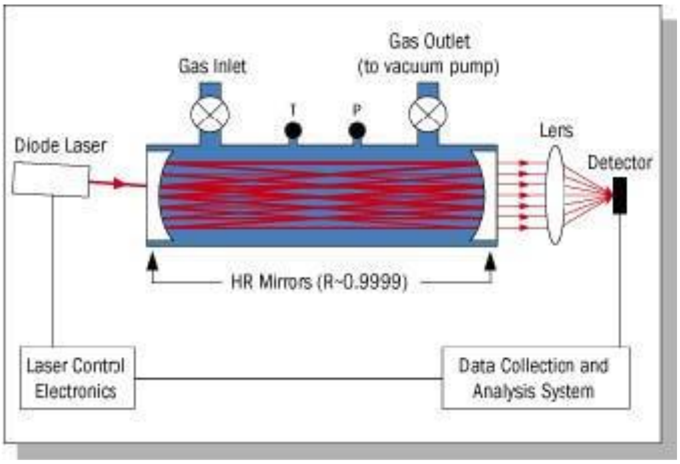
The first CH_4 analyser employed in the study was a Synspec GC855, which also measured total non-methane hydrocarbons (tNMHC). The instrument is a gas chromatograph with a flame ionisation detector (FID). It contains a compact oven with a column that separates methane from total non-methane hydrocarbons. The gas sample passes through a column with a special layered packing. The methane (CH4) passes through and is first injected into the detector. A second after this, the column is BACKFLUSHED and all other hydrocarbons pass to the detector. This results in two peaks generated by the FID: a methane and a TNMHC-peak.

The second analyser was a Los Gatos CH_4 analyser, which uses Off Axis Integrated Cavity Output Spectroscopy (OA-ICOS).

‘Until recently, high-sensitivity trace-gas measurements have been possible only by using expensive lasers (e.g., lead-salt or quantum-cascade) or broadband lamps that operate in the mid-infrared region where absorption features are strong. LGR’s advances in cavity-enhanced absorption-spectroscopy techniques provide dramatic increases in the optical path length and as a result, enable ultrasensitive trace-gas measurements using robust, reliable, room-temperature diode lasers that operate in the near infrared.

Off-Axis ICOS utilizes a high-finesse optical cavity as an absorption cell as shown in Figure 8. Unlike conventional multi-pass arrangements, which are typically limited to path lengths less than two-hundred meters, an Off-Axis ICOS absorption cell effectively traps the laser photon so that, on average, they make thousands of passes before leaving the cell. As a result, the effective optical path length may be several thousands of meters using high-reflectivity mirrors and thus the measured absorption of light after it passes through the optical cavity is significantly enhanced. For example, for a cell composed of two 99.99% reflectivity mirrors spaced by 25 cm, the effective optical path length is 2500 meters.

Figure 1: Schematic diagram of an Off-Axis ICOS Instrument



Because the path length depends only on optical losses in the cavity and not on a unique beam trajectory (like conventional multipass cells or cavity-ring-down systems), the optical alignment is very robust allowing for reliable operation in the field. The effective optical path length is determined routinely by simply switching the laser off and measuring the necessary time for light to leave the cavity (typically tens of microseconds).

As with conventional tunable-laser absorption-spectroscopy methods, the wavelength of the laser is turned over a selected absorption feature of the target species. The measured absorption spectra is recorded and combined with measured gas temperature and pressure in the cell, effective path length, and known line strength, used to determine a quantitative measurement of mixing ratio directly and without external calibration.’

References

1. Los Gatos Economical Ammonia Analyser User Manual.

Appendix D Hydrogen Sulphide (H_2S)

Hydrogen sulphide is formed by the direct combination of the two elements, or by the action of dilute hydrochloric or sulphuric acid on iron sulphide. At normal temperature and pressure it is a gas. It is readily decomposed and highly reactive and will combine rapidly with other elements to form a range of compounds, notably sulphur dioxide.

Sources

Following the introduction of catalytic converters into the manufacture of modern cars, a greater incidence of the characteristic "bad eggs" smell of H_2S has been observed. This is due to the chemical reduction of sulphur dioxide, from a poorly tuned engine, within the catalytic converter. Sulphur compounds are temporarily "stored" in the converter and then released "en masse" during abrupt acceleration or following prolonged periods of high speed driving (e.g. on motorways).

Hydrogen sulphide is not simply a by-product of chemical processes, but can also arise from other sources e.g. decomposition of organic matter such as sewage which in some instances has generated highly toxic, even fatal concentrations.

Health Effects

Hydrogen sulphide is a potent chemical asphyxiant, combining with haemoglobin and with cytochromes and thus rapidly stopping oxygen from access to cellular metabolism (just like gases such as carbon monoxide and hydrogen cyanide). Indeed H_2S is arguably as toxic as hydrogen cyanide HCN.

Hydrogen sulphide is very foul smelling but very quickly paralyses the sense of smell, and can at high levels go on to overcome the victim and eventually cause death. Therefore smell cannot be relied upon to provide warnings of this treacherous gas.

Hydrogen sulphide is also an irritant of mucous membranes including the eyes and respiratory tract.

H_2S analyser

The analyser used to measure hydrogen sulphide is an adapted sulphur dioxide analyser. Gas entering the analyser first passes through a selective scrubber to remove sulphur dioxide, then enters a catalytic converter, where hydrogen sulphide is oxidised to form sulphur dioxide. This secondary gas stream of sulphur dioxide is then sampled and analysed using a standard sulphur dioxide analyser.

The operation of the sulphur dioxide analysers is based on the measurement of fluorescence from SO_2 due to absorption of UV energy. An ultraviolet (UV) lamp emits radiation that passes through a filter admitting only light with a wavelength of 214nm. This radiation excites SO_2 molecules in the sampling air, which produce fluorescence that can be measured by a PMT with a secondary UV filter. The equations describing the reactions are:

$$\textbf{Irradiation} \quad SO_2 + h\nu_1 \longrightarrow SO_2^*$$
$$\textbf{Fluorescence} \quad SO_2^* \longrightarrow SO_2 + h\nu_2$$

The UV light at any point in the system is given by:

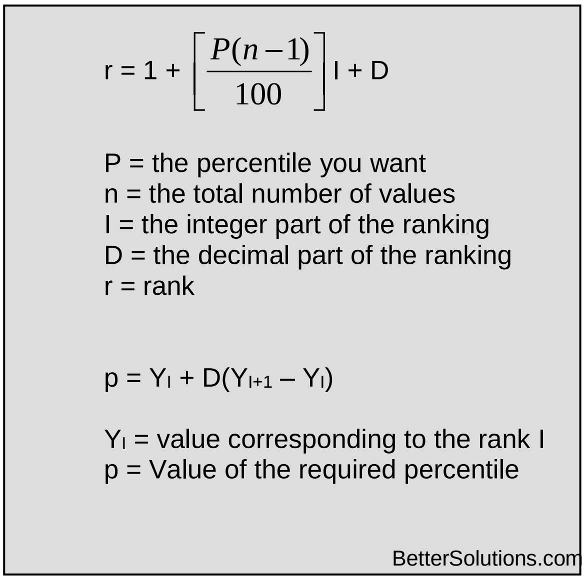
$$\mathbf{I_a = I_o[1 - \exp(-ax(SO_2))]}$$

where $\mathbf{I_O}$ is the UV light intensity, **a** the absorption coefficient of SO_2, **x** the path length, and (SO_2) the concentration of SO_2. When the SO_2 concentration is relatively low and the path length of excited light short, the fluorescence radiation impinging upon the PMT can be considered directly proportional to the concentration of SO_2. The PMT transfers the light energy into an electrical signal, which is directly proportional to the light energy in the sample stream being analysed.

An UV detector measures the UV light. Software calculates the ratio of the PMT output and the UV detector in order to compensate for variations in the UV light energy. Stray light from background is determined by passing gas with zero SO_2 concentration through the analyser. Once the effect of background light is accounted for, the Central Processing Unit will convert the electrical signal into a concentration value that is directly proportional to the number of SO_2 molecules and by inference hydrogen sulphide molecules.

Appendix E Percentile Analysis

Percentile analysis provides a method of looking at the distribution of concentrations within a data set.
Excel calculates percentiles by first sorting the concentrations into ascending order and then ranking each concentration. It then uses the following formulas,



$$r = 1 + \left[\frac{P(n-1)}{100}\right] I + D$$

P = the percentile you want
n = the total number of values
I = the integer part of the ranking
D = the decimal part of the ranking
r = rank

$$p = Y_I + D(Y_{I+1} - Y_I)$$

Y_I = value corresponding to the rank I
p = Value of the required percentile

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to interpolate the value of a particular percentile from the calculated ranking. i.e. it calculates the concentration below which a certain percentage of concentrations fall. For example, at the 95th percentile, 95% of the data will lie below this value and 5% of the data will lie above it.

In order to produce radial percentile roses, the data is first divided into the required wind sectors and then the data in each sector undergoes separate percentile analysis. By calculating the concentration of a pollutant at different percentiles for different wind sectors, you are able to visually examine the distribution of pollutant concentrations at a particular monitoring site. This in turn will provide information on the source that may be influencing levels at the monitoring site.

By separating the data into various wind sectors, it allows you to assess which wind directions are having the greatest influence on pollutant concentrations at the monitoring site. By calculating the average concentration for every wind sector you can produce a ‘mean pollution rose’, where the influence on pollutant concentrations from a particular wind sector is seen as a bias on a radial plot. This type of analysis is very effective at visually highlighting the wind sectors where there are significant sources of a given pollutant. By breaking each wind sector down into a number of different percentiles it can be seen whether biases are present in all of the percentiles or just certain ones, which can tell you whether a source is affecting the monitoring site relatively continuously or just intermittently. For example, a bias that is observed in all of the percentiles (Figure 1) suggests that the source in that particular wind sector is emitting relatively continuously as it is influencing a large percentage of the data. Whilst a bias that is only observed in the higher percentiles (Figure 2) suggests that the source is intermittent as it only affects a small percentage of the data, i.e. it doesn’t affect concentrations at the monitoring site every time the wind is coming from this direction. Occasionally, a bias is observed in the lower percentiles that is not evident in the higher percentiles (Figure 3). This suggests that the source is relatively continuous, as it is affecting a large percentage of the data, but it also tells you that the source is not causing appreciably high concentrations at the monitoring site.

Figure 1 - shows a bias between 280° – 300° that is evident in all of the percentiles.

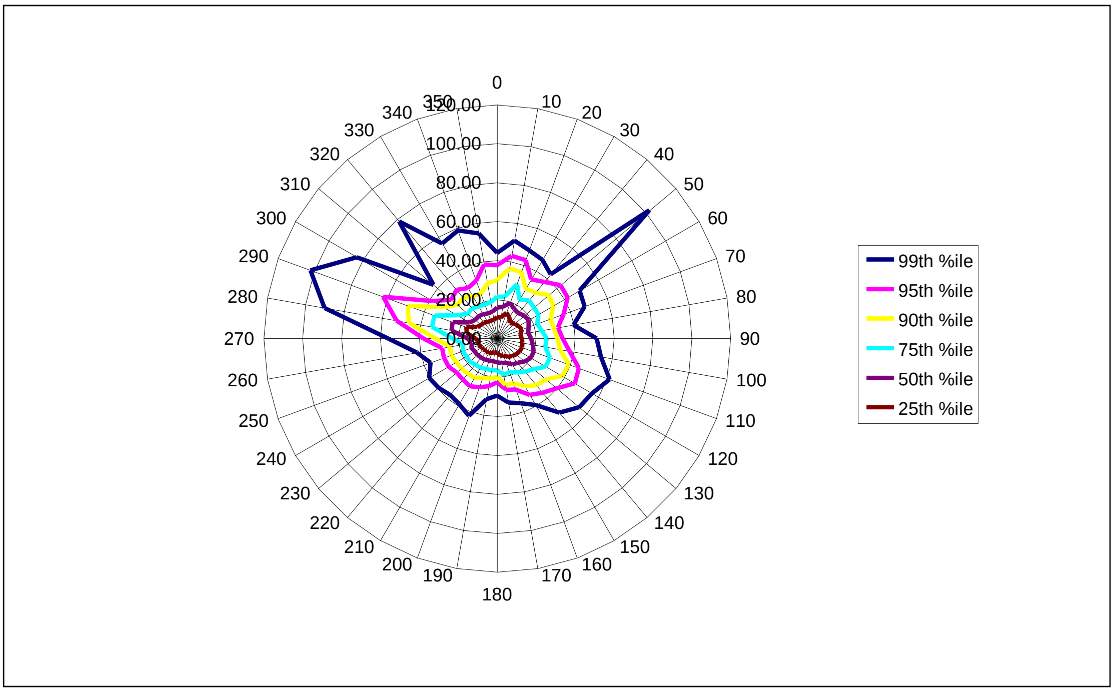


Figure 2 - shows a bias at 260° that is only evident in the 99th percentile.

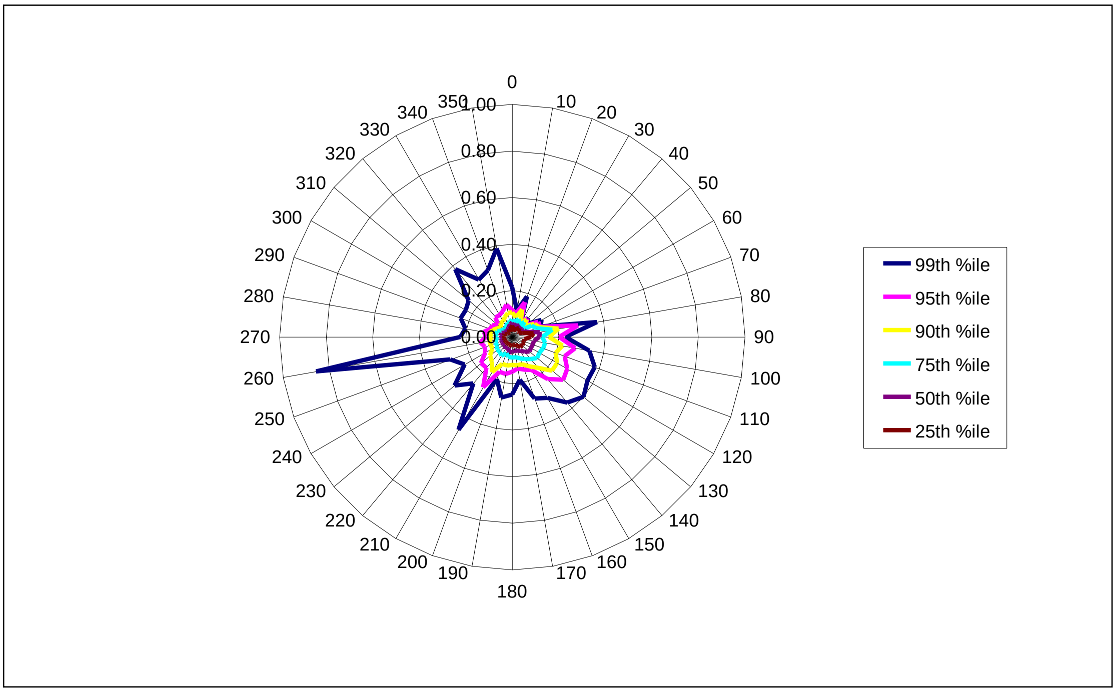
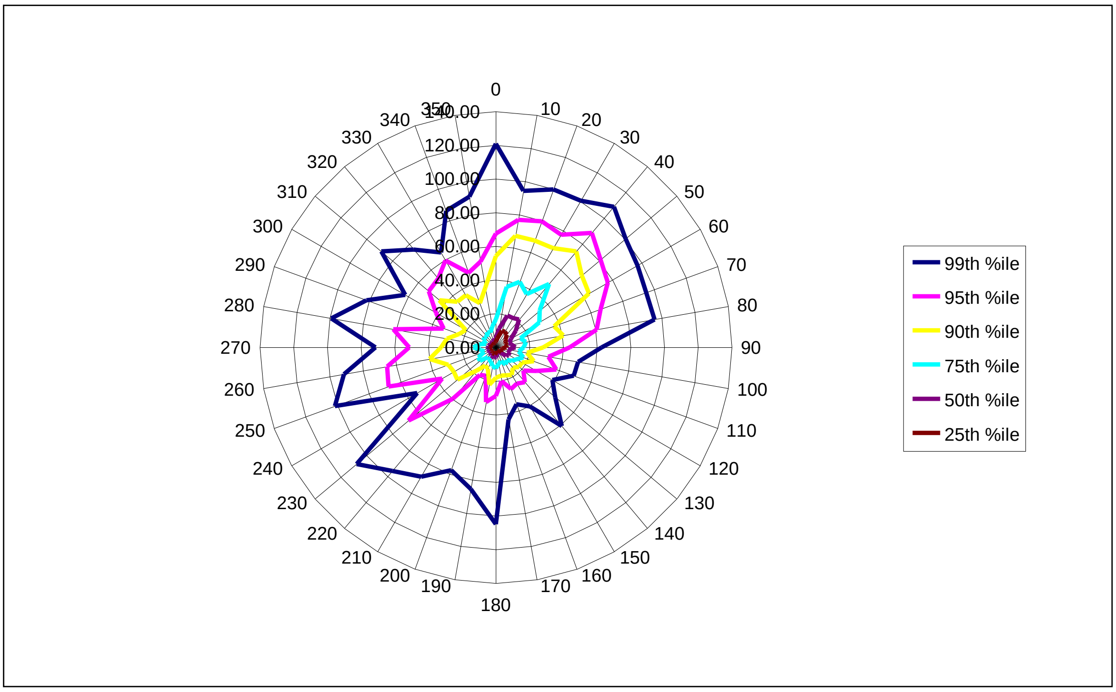


Figure 3 - shows a bias between 20° – 50° that is only evident in the lower percentiles.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