Study of Ambient Air Quality at Fleetwood. Interim Report 2

9 May 2024 to 19 March 2025

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Executive Summary

This interim report presents the results from a study of ambient air quality in the vicinity of Jameson Road, Fleetwood. The Environment Agency's Ambient Air Monitoring Team (National Monitoring) conducted the study on behalf of the Cumbria and Lancashire Area, between 9 May 2024 and 19 March 2025 (315 days), with monitoring continuing after this date.

A mobile monitoring facility (MMF) containing equipment capable of measuring concentrations of hydrogen sulphide (H_2S), sulphur dioxide (SO_2), methane (CH_4) and particulate matter (TSP, PM_{10} and $PM_{2.5}$) was set up. Wind speed and wind direction measurements were also collected.

The objective of the study was to identify local sources of air pollution and to quantify the environmental impact of the emissions from sources in the surrounding area. It is assumed that the conditions during the monitoring period were representative of a typical year. These calculations do not consider changes in weather conditions or changes to local sources that might occur outside of the monitoring period.

Comparison of the H_2S data with the World Health Organisation (WHO) guidance showed that H_2S concentrations were below health limits. H_2S levels were above WHO guideline values for odour annoyance for ~0.4% of the monitoring period.

The average methane concentration over the monitoring period was 1.40 mg/m^3, which is above the Northern Hemisphere background concentration[2] of ~1.31 mg/m^3.

The UK Air Quality Strategy (AQS) provide health-based limits for $PM_{10,}$ $PM_{2.5}$ and SO_2 in ambient air. Comparison with the AQS objectives for statutory compliance can only be undertaken at specific Defra monitoring stations. However, a comparison with the AQS objectives has been made in this report. This provides a measure of air quality in the immediate vicinity of sites that we regulate, it can help evaluate compliance and quantify the sites' environmental impact. The AQS objective also has an annual standard for SO_2 for the protection of vegetation and ecosystems. This standard is only relevant if the location meets certain criteria. In this instance the monitoring location does not meet these criteria and therefore the standard does not apply. The $PM_{2.5}$ data is also compared against the new UK Environment Act target value.

Comparison of the collected data from monitoring undertaken at Copse Road, Fleetwood with the AQS objectives showed that the monitoring location was subject to concentrations of $PM_{10,}$ $PM_{2.5}$ and SO_2 that were likely to meet their respective AQS objectives. Levels of $PM_{2.5}$ at the monitoring site were likely to meet the new Environmental Target for fine PM, which is to be met by 2040.

PM and SO_2 data were retrospectively compared against the Daily Air Quality Index (DAQI). This index uses air quality forecasts to predict next day air quality levels and assign an index number (1 low-10 very high) which is then divided into a banding for that day. There are four different bands (low-very high) and each of these has an associated health message, advising people when to limit/or avoid exercise outside. Consideration of $PM_{10,}$ $PM_{2.5}$ and SO_2 concentrations against the Air Quality Index (AQI) banding showed that concentrations were mainly in the low AQI banding (no precautions required) during the monitoring period. A volcanic plume observed between 31 May and 1 June 2024 caused a haze across the United Kingdom, however air quality remained in the low banding for SO_2, PM_{10} and $PM_{2.5}$.

Analysis of the meteorological data collected at the MMF showed the dominant wind direction was between 140°-170° and 230°-310°, with wind coming from these sectors for 19.2% and 33.4% of the monitoring period respectively. The most frequent wind speeds came from sectors 140°-170° at wind speeds of 3-7 m/s and 230°-310° at wind speeds of 4-9 m/s.

Consideration of meteorological conditions suggests that the highest H_2S and CH_4 concentrations were seen from the direction of Jameson Road landfill site for a range of wind speeds, suggesting a relatively continuous source(s). At lower wind speeds, where there is less dispersion or mixing of air, there was an accumulation of H_2S and CH_4 concentrations at the monitoring location.

The highest SO_2 concentrations were measured when the wind was blowing from the north and were caused by a short-duration volcanic eruption that originated in Iceland. No other significant source of SO_2 was noted although an intermittent elevation in concentrations at higher wind speeds was seen from the direction of Jameson Road landfill site and Fleetwood Marsh WwTW.

Elevated average concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were seen from sectors 50°-150°. But when considering wind speed, the highest concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were seen from sectors 30°-60°, 200°-255° and 290°-330°at high wind speeds greater than 10 m/s.

Contents

1 Introduction

This interim report presents the results from a study of ambient air quality in the vicinity of Jameson Road, Fleetwood. The Environment Agency's Ambient Air Monitoring Team (National Monitoring) conducted the study on behalf of the Cumbria and Lancashire Area, between 9 May 2024 and 19 March 2025 (315 days), with monitoring continuing after this date.

A mobile monitoring facility (MMF-see appendix A) containing equipment capable of measuring concentrations of hydrogen sulphide (H_2S), sulphur dioxide (SO_2), methane (CH_4) and particulate matter (TSP, PM_{10} and $PM_{2.5}$) was set up. Wind speed and wind direction measurements were also collected.

The absolute values of the collected data have associated uncertainties in the monitoring process, but these are minimised by the QAQC measures described in Appendix B. These should be considered when assessing the results of any comparisons with the WHO guidelines, the AQS objectives, the Environment Act and the DAQI.

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. Within this objective, the following individual aims were identified:

- To assess the general air quality of the area relative to the Air Quality Strategy (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 Monitoring Location

The Ambient Air Monitoring team deployed a mobile monitoring facility (MMF) in an area adjacent to Copse Road, Fleetwood. The main site of interest was Jameson Road landfill site (LFS) operated by Transwaste Recycling and Aggregates Limited. Jameson Road LFS was approximately 1.25 kms from the monitoring site at a bearing of approximately 140°-185°. A landfill gas utilisation plant, operated by Jameson Road Energy, is located within the Jameson Road landfill site compound at a bearing of approximately 180°. The plant comprises 5 engines and a flare.

There are a number of other activities being undertaken in the vicinity of the landfill site. These include Preesall and Fleetwood Marsh wastewater treatment works (WwTW) operated by United Utilities Ltd and a landfill operated by Hillhouse Restoration Ltd (unrestored former ICI Hillhouse landfill and lagoons).

Figure 2.1 shows the location of the MMF and some of the industrial sites in the area and the approximate bearing of these sites from the MMF.

Figure 2.1: Map of Monitoring Location and Approximate Bearing of Sites from the MMF (Google Maps, 2024).

	Operator name	Approximate bearing from MMF
🟪	Preesall WwTW	90°-110°
🟨	Jameson Road Landfill	140°-185°
🟧	Hillhouse Landfill	160°-190°
🟦	Fleetwood Marsh WwTW	170°-200°
🟥	Fleetwood Household Waste Recycling Centre	180°-185°
■	Landfill gas utilisation plant	180°

Figure 2.2 shows the location of the MMF at Copse Road, Fleetwood.

Figure 2.2: Photograph of the Monitoring Location.

3 Monitoring Results

3.1 Meteorology

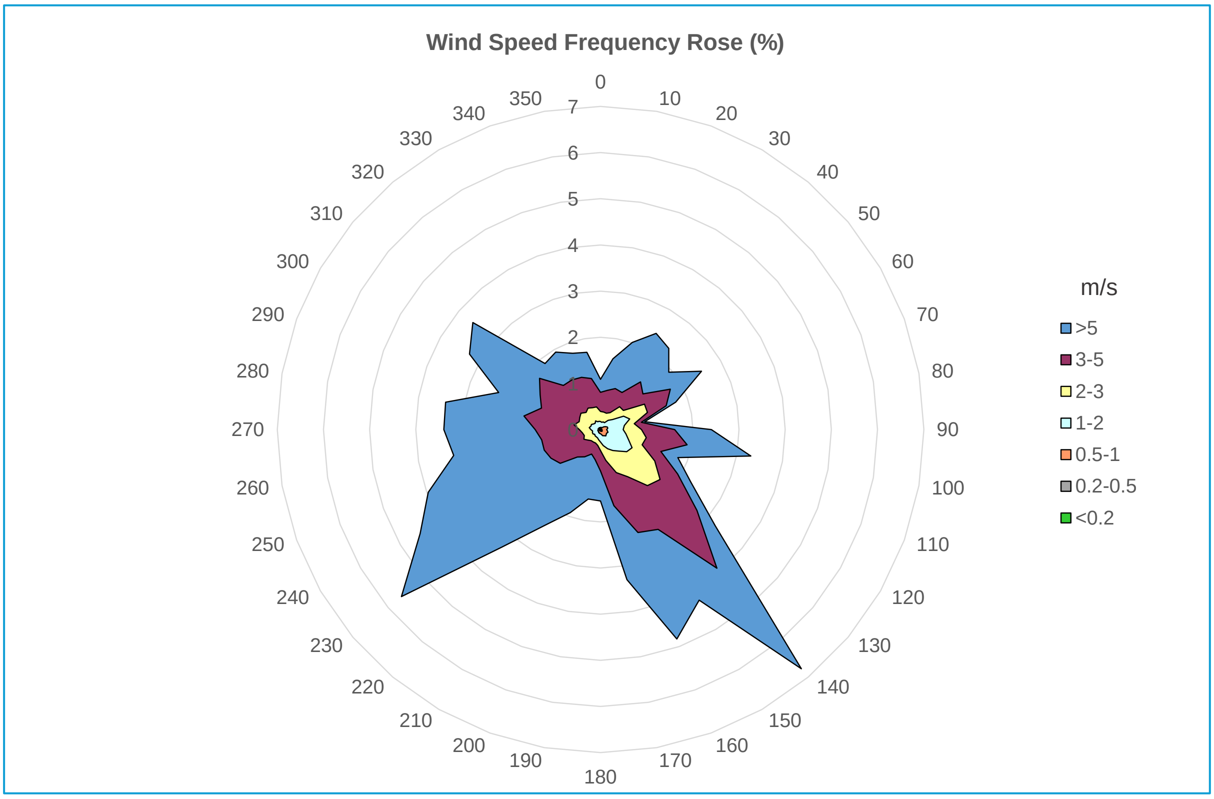
Wind speed and direction measurements were collected at the MMF site during the study. The sensor was mounted on a mast extending 6m from the top of the MMF trailer giving an overall height above ground of 8m. Where possible MMFs are located over 100m from any buildings of greater or comparable height, so as to reduce any influence that surrounding buildings may have on the wind distribution. In this instance the MMF was located close to a building of greater height to the east, which will influence the winds coming from this direction.

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°.

Directional plots have been interpreted assuming that the wind was travelling in a straight line, but it is worth noting that real-world conditions are more complex, with topography, buildings and other meteorological conditions influencing movement. This may cause wind direction to vary along a plume's trajectory so that the wind direction will not simply "point" to the source.

The wind direction frequency distribution for the monitoring location between 9 May 2024 and 19 March 2025 (315 days) is shown in Figure 3.1.1. The plot shows that over the period the dominant wind direction was between 140°-170° and 230°-310°, with wind coming from these sectors for 19.2% and 33.4% of the monitoring period respectively.

Figure 3.1.1: Wind Speed Frequency Rose (%).



The meteorological data collected as part of this study was considered representative of conditions at the monitoring location and has therefore been used for directional analysis. The frequency distribution of wind speeds against wind direction at the monitoring location is shown in Figure 3.1.2. The most frequent wind speeds were from sectors 140°-170° at wind speeds of 3-7 m/s and 230°-310° at wind speeds of 4-9 m/s.

Figure 3.1.2: Polar Frequency Plot.

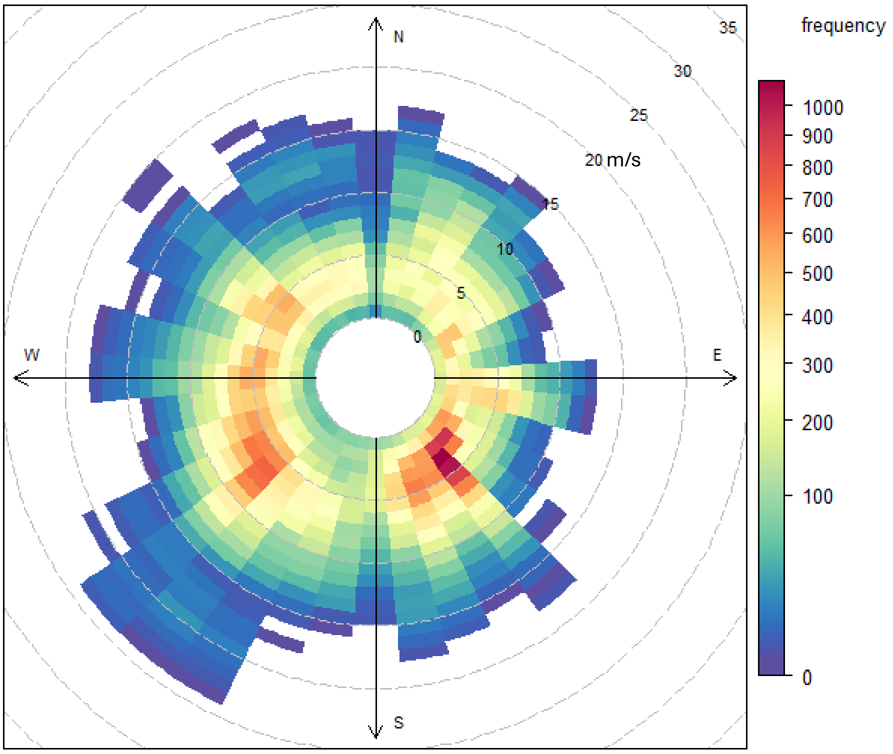


Table 3.1.1 shows a summary of wind speed frequencies at the monitoring location for all directions. The table shows that 76 % of wind speeds were greater than 3 m/s.

Table 3.1.1 Summary of Wind Speed Frequencies for the Monitoring Location.

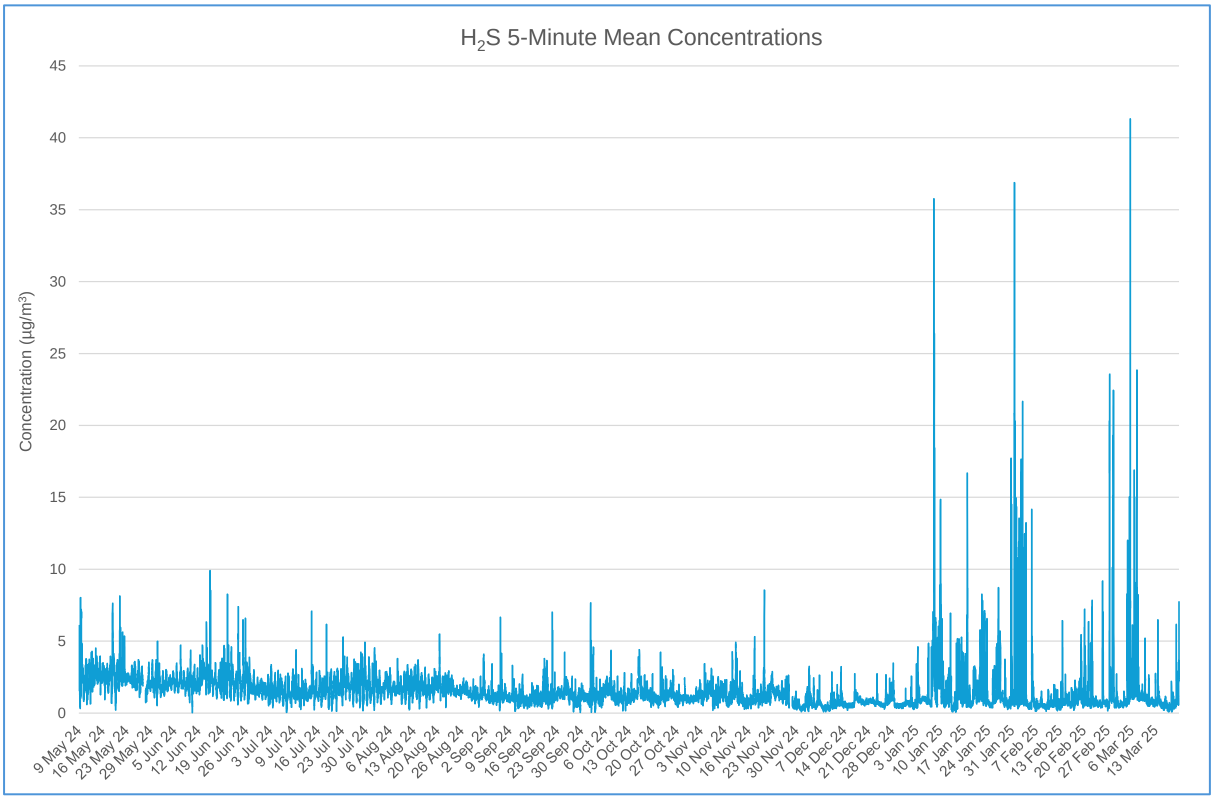
Wind Speed (m/s)	Frequency of wind speed (%)
>5	48.7
3-5	27.3
2-3	12.2
1-2	8.7
0.5-1	2.3
0.2-0.5	0.7
< 0.2	0.2
Total	**100**

3.2 Hydrogen Sulphide (H_2S)

Airborne H_2S concentrations were measured, at a height of 2m above ground, between 9 May 2024 and 19 March 2025 (315 days). Details of the instrumentation and methodology are given in Appendix C. Successful data collection for the monitoring period was 99.0%.

A time series plot of 5-minute average concentrations of H_2S between 9 May 2024 and 19 March 2025 is shown in Figure 3.2.1. The average concentration over the monitoring period was 1.5 µg/m^3. The maximum 5-minute average concentration of 41.3 µg/m^3 was recorded on 6 March 2025.

Figure 3.2.1: H_2S 5-Minute Average Concentrations.

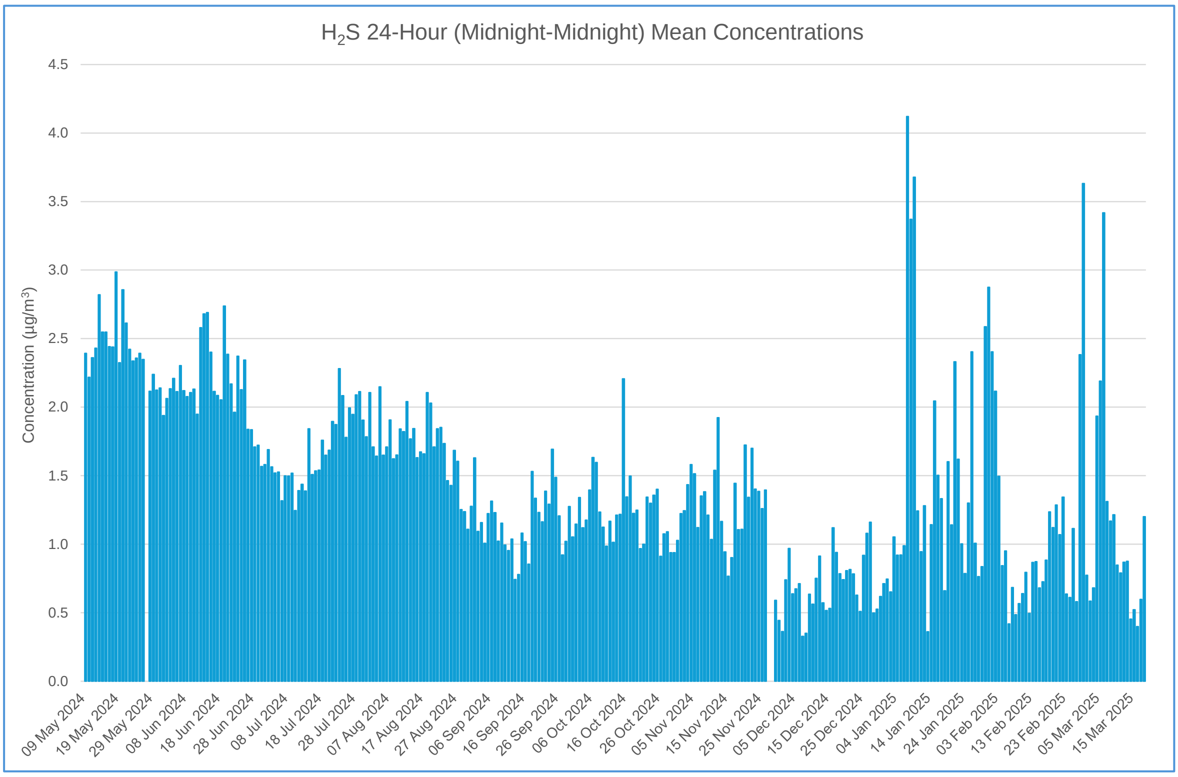


3.2.1 Comparison with WHO Guidelines

The World Health Organisation (WHO) guidelines for Europe (2000) have set a 24-hour guidance limit of 150 µg/m^3 for H_2S in the context of human health.

A time series plot of 24-hour average H_2S concentrations at the monitoring site is shown in Figure 3.2.2. The highest recorded 24-hour average was 4.1 µg/m^3, which is considerably lower than the 150 µg/m^3 guideline.

Figure 3.2.2: H_2S 24-Hour Average Concentrations.



The WHO guidelines have also set a 30-minute average H_2S guide level of 7 µg/m^3 above which substantial reports about odour annoyance can be expected. A time series plot of 30-minute average H_2S concentrations measured over the period is shown in Figure 3.2.3.

Figure 3.2.3: H_2S 30-Minute Average Concentrations.

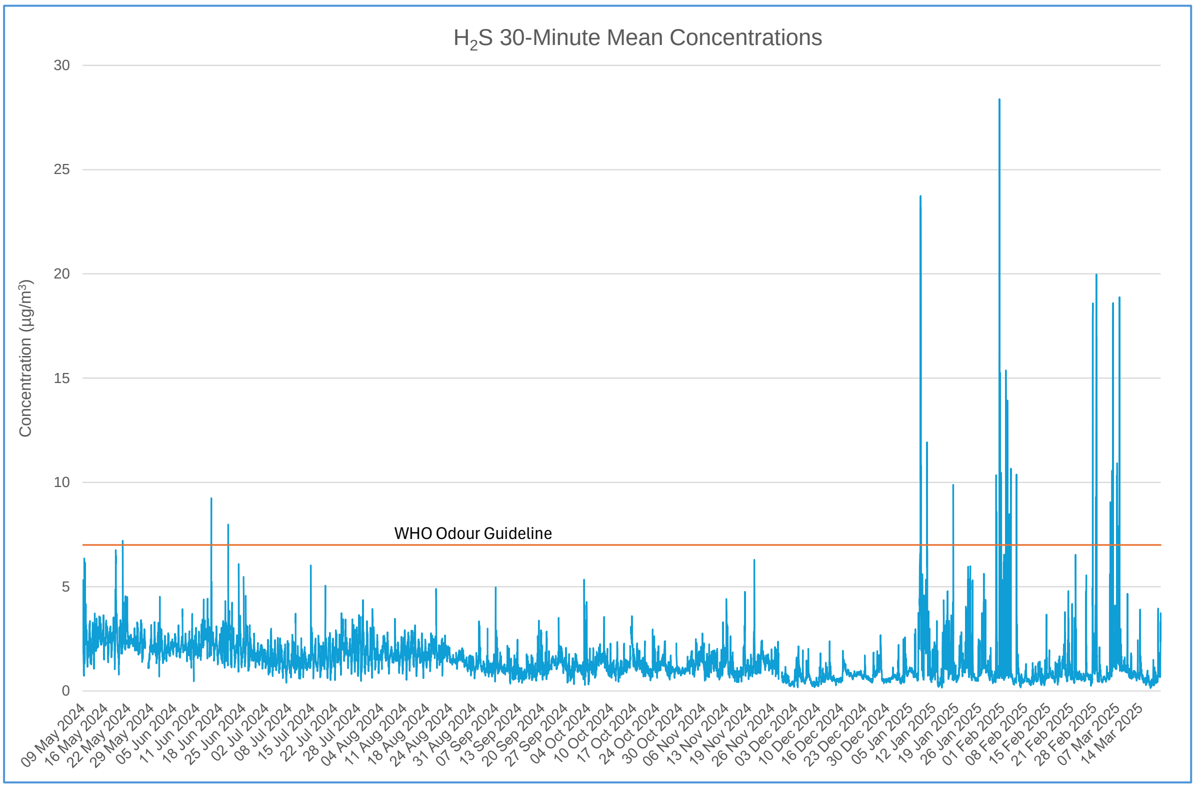


Figure 3.2.3 shows that the highest recorded 30-minute average during the monitoring period was 28.4 µg/m^3. There were 57 occasions on 19 separate days during the monitoring period where a 30-minute average value exceeded the WHO guide level of 7 µg/m^3. Substantial complaints due to odour nuisance from H_2S could be expected for 0.4% of the monitoring results reported, based on the WHO guideline alone, however this does not take in to account the subjective nature of odour complaints.

3.2.2 Directional Analysis

Figure 3.2.4 shows the number of exceedances of the WHO guide level of 7 µg/m^3 against average wind direction, for each 10° sector (based on a 30-minute average) over the monitoring period at the monitoring site.

Figure 3.2.4: H_2S Radial Exceedance Histogram (Number of 30-minute values above 7 µg/m^3).

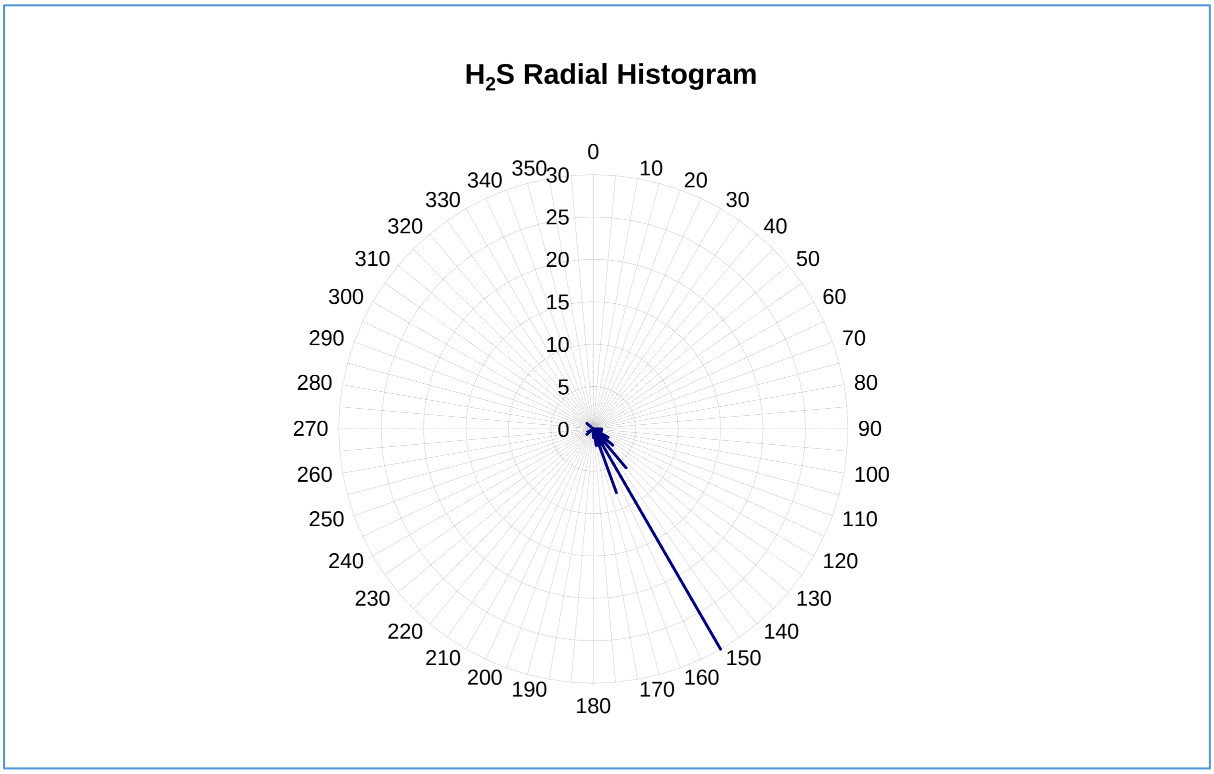


Figure 3.2.4 shows that the majority of exceedances of the 30-minute values of 7 ug/m^3 were seen when the wind was coming from sectors 120°–180° (the direction of Jameson Road landfill site) with single exceedances from 230°- 240°, 310° and 90°–100°.

A radial plot of average H_2S concentrations (µg/m^3) against wind direction is shown in Figure 3.2.5.

Figure 3.2.5 shows that the highest concentrations came from sectors 110º–180º (the direction of Jameson Road landfill site), 260º–270º and 290º–310º with average concentrations >1.5 µg/m^3.

Figure 3.2.5: H_2S Average Pollution Rose.

Plots showing the contribution to H_2S loading (µg/m^3) for different percentiles are shown in Figure 3.2.6. An explanation of percentile analysis is given in Appendix G.

Figure 3.2.6: H_2S Percentile Roses.

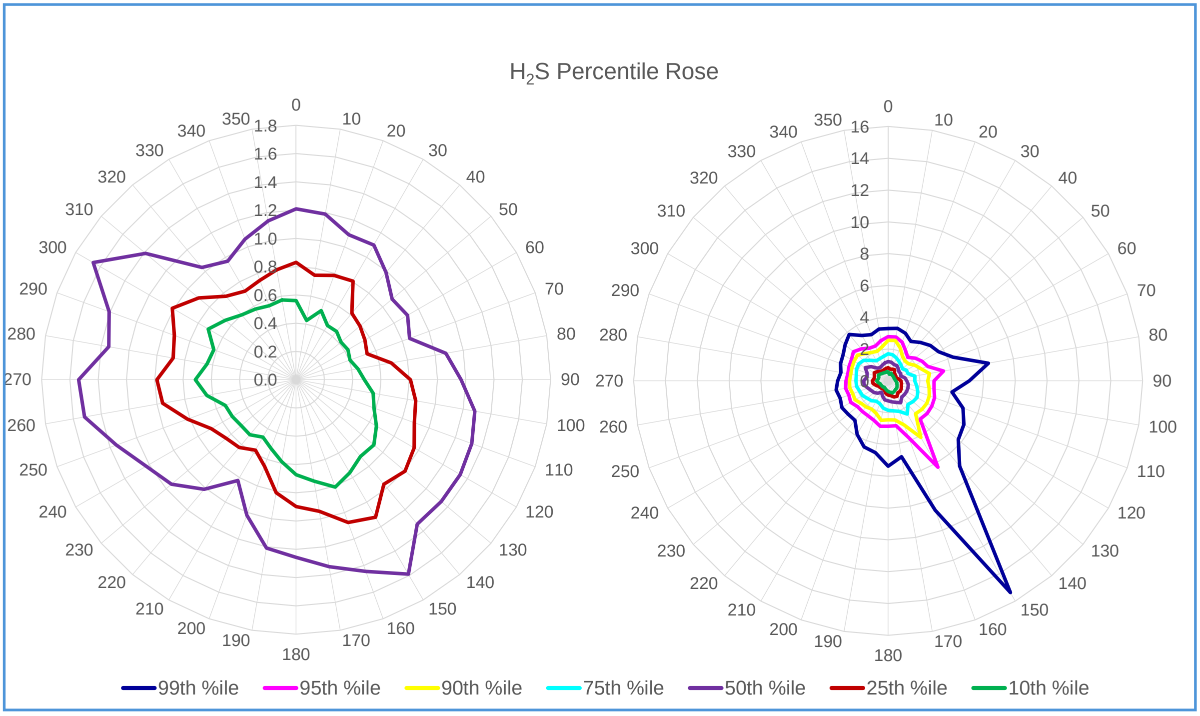
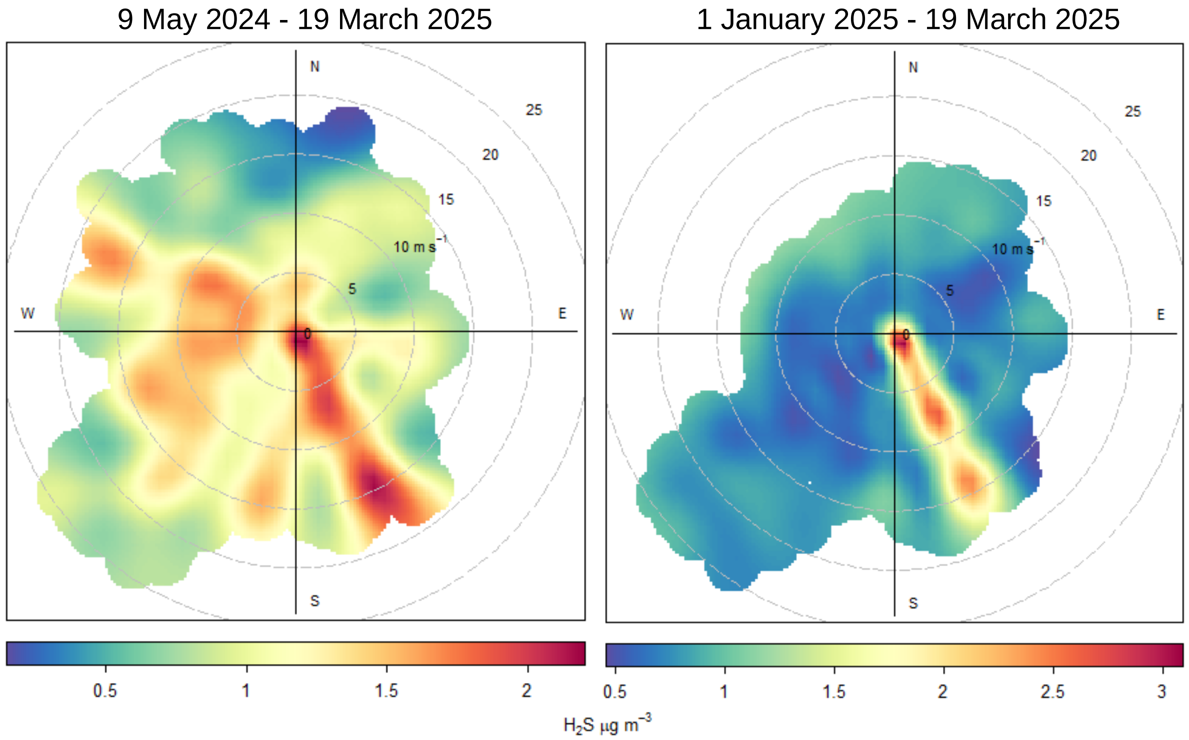


Figure 3.2.6 shows the highest concentrations of H_2S came from sectors 110°-170° (the direction of Jameson Road Landfill and gas utilisation plant) and were evident in the lower and higher percentiles. This suggests a relatively continuous source of H_2S from these directions. Elevated H_2S concentrations were more evident in the higher percentiles from sectors 70°-90° (the direction of Preesall WwTW) and 180°-210° (the direction of Fleetwood Marsh WwTW) which indicates intermittent sources from these directions which can contribute to elevated H_2S concentrations at the monitoring site.

Polar frequency plots showing the average H_2S concentrations for varying wind speeds and wind directions over the monitoring period and separately for the period 1 January 2025 – 19 March 2025 is shown in Figure 3.2.7.

Figure 3.2.7: H_2S (µg/m^3) Polar Frequency Plots.



9 May 2024 - 19 March 2025

1 January 2025 - 19 March 2025

Figure 3.2.7 shows that the highest H_2S concentrations were seen between sectors 140º-170º (the direction of Jameson Road landfill site) for a range of wind speeds, suggesting a continuous source from this direction. This is seen most clearly when considering the spikes in H_2S seen between the 1 January 2025 - 19 March 2025. The plots also suggests that elevated H_2S concentrations have been measured at lower wind speeds, where there is less dispersion or mixing of air.

3.2.3 Conclusion

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

Comparison of the H_2S data with the WHO guidelines for odour annoyance of 7 µg/m^3, as 30-minute average concentrations, indicated that the air quality at the monitoring site exceeded this guideline for approximately 0.4% of the monitoring results reported. The average H_2S concentration over the monitoring period was 1.5 µg/m^3.

Most exceedances of the 30-minute values of 7 ug/m^3 (91%) were seen when the wind was coming from sectors 120°–180° (the direction of Jameson Road landfill site)

Directional analysis indicated that the highest average H_2S concentrations were measured from the direction of Jameson Road landfill site, with average concentrations greater than 1.5 µg/m^3.

Percentile rose analysis showed there was a continuous source of H_2S from sectors 110°-170^o (the direction of Jameson Road landfill site) which can contribute to elevated H_2S concentrations at the monitoring site. There were also intermittent sources from sectors 70°-90° and 180°-210° the direction of Preesall WwTW and Fleetwood Marsh WwTW.

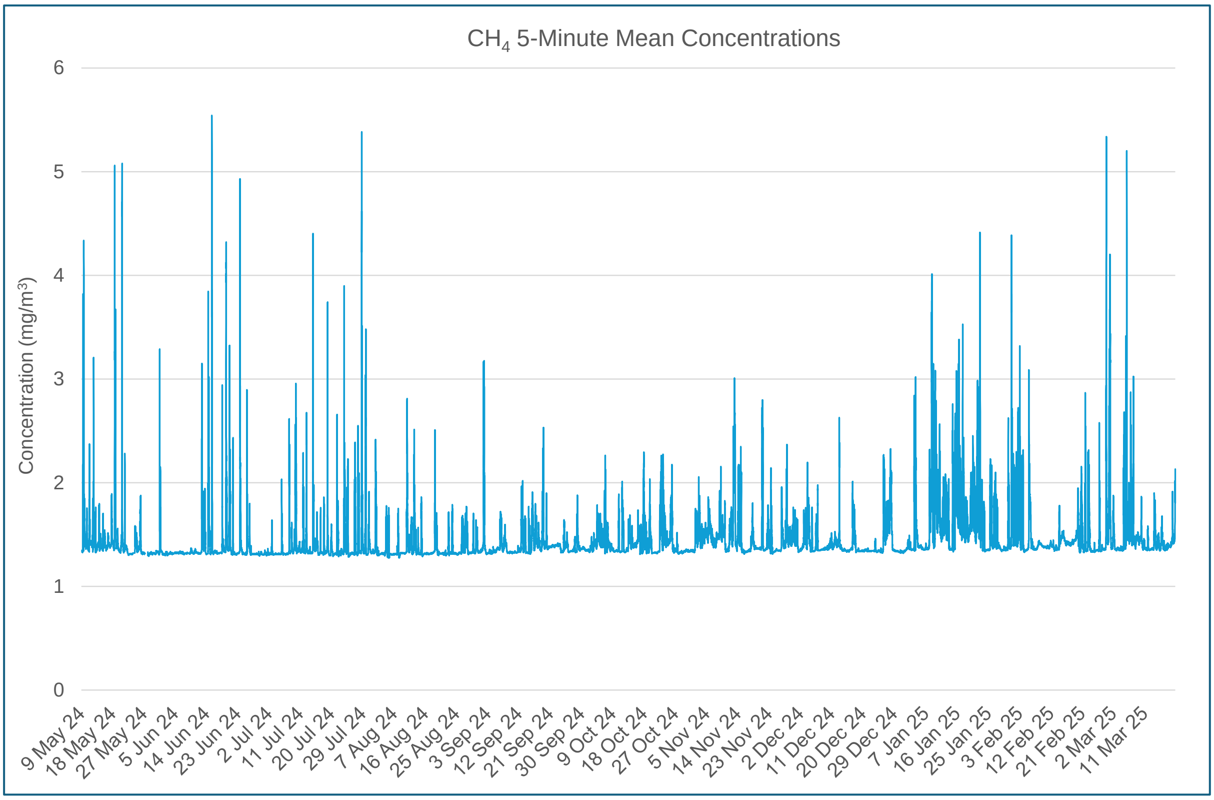
Consideration of meteorological conditions suggests that the highest H_2S concentrations were seen from the direction of Jameson Road landfill site for a range of wind speeds. The plot also suggests an elevation in H_2S concentrations at lower wind speeds, where there is less dispersion or mixing of air. It should be noted that at low wind speeds, directional analysis and the correct identification of the origin of a source is more uncertain.

3.3 Methane (CH_4)

Airborne CH_4 concentrations were measured at a height of 2m above ground between 9 May 2024 and 19 March 2025 (315 days). Successful data collection for the monitoring period was very good at 99%. Details of the instrumentation and methodology are given in Appendix D.

A time series plot of 5-minute CH_4 concentrations (mg/m^3) over the monitoring period is shown in Figure 3.3.1.

Figure 3.3.1: CH_4 5-Minute Average Concentrations.



Methane does not have any associated impacts on human health, except for the risk of explosion at very high concentrations. The primary environmental impact from methane is its impact on global warming. The average concentration over the period was 1.4 mg/m^3, which was marginally higher than the northern hemisphere background concentration of around 1.31 mg/m^3, suggesting there was a localised CH_4 source.

3.3.1 Directional Analysis

Radial plots of average CH_4 concentrations (mg/m^3) against wind direction are shown in Figure 3.3.2.

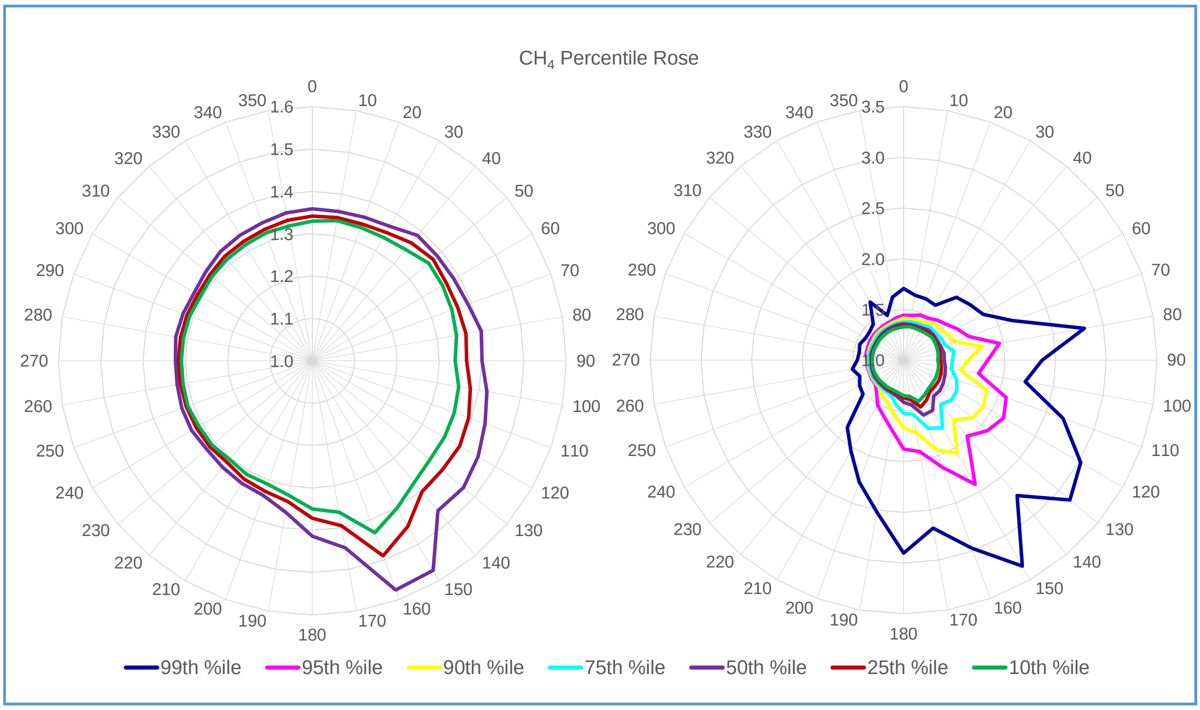
Figure 3.3.2: CH_4 Mean Pollution Rose (Scale 1:1.7 mg/m^3)

The plot of average CH_4 concentrations shows that the highest average CH_4 concentrations were seen for sector 110°-180°. (the direction of Jameson Road landfill site and Fleetwood Marsh WwTW) with concentrations >1.5 mg/m^3. A source from this direction was also seen in the H_2S data. There was also a slight elevation in CH_4 concentrations from sectors 80°

Percentile plots showing the contribution to CH_4 loading (mg/m^3) at the monitoring site for different percentiles are shown in Figure 3.3.3.

Figure 3.3.3 shows the highest concentrations of CH_4 came from sector 110°-180^o (the direction of Jameson Road landfill site) and were evident in all percentiles. This suggests a relatively continuous source of CH_4 from this direction. A continuous source from this direction was also seen in the H_2S data. The plots also show elevated concentrations in the higher percentiles at 80^o suggesting an intermittent source(s) from this direction.

Figure 3.3.3: CH_4 percentile rose



A polar frequency plot showing the average CH_4 concentrations for varying wind speeds and wind directions over the monitoring period is shown in Figure 3.3.4.

Figure 3.3.4: CH_4 Wind Speed Dependency Plot

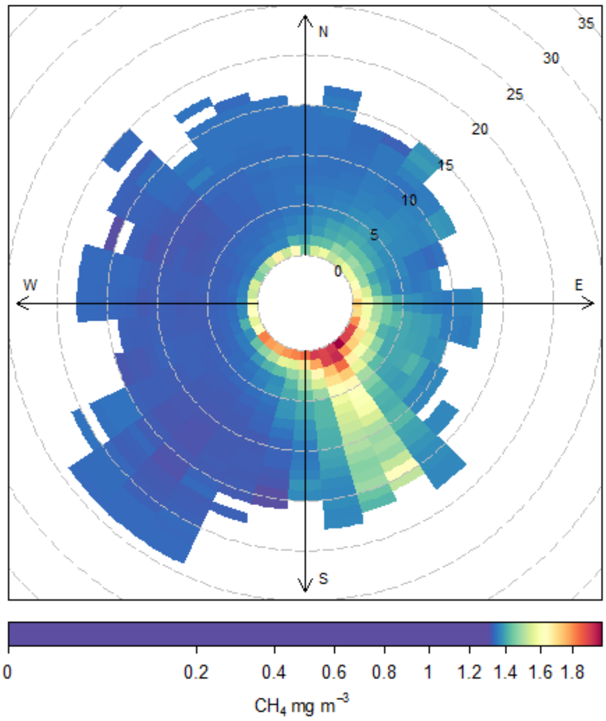


Figure 3.3.4 shows that for wind speeds up to 1 m/s, elevated CH_4 concentrations were seen for all wind directions. This suggests that at lower wind speeds, where there is less mixing of air, there was an accumulation of CH_4 concentration at the monitoring location. The highest CH_4 concentrations could be seen at lower wind speed for sector 110° – 220° and for all wind

speeds for sector 140°-170° (the direction of Jameson Road landfill site) suggesting a continuous source of CH_4.

3.3.2 Diurnal analysis

Consideration of the diurnal variation of CH_4 concentrations can provide further useful information about the conditions contributing to the ambient levels in each sector.

Plots showing the average hourly diurnal CH_4 concentrations, for each 45° wind sector, are shown in Figure 3.3.5.

Figure 3.3.5: CH_4 diurnal plots

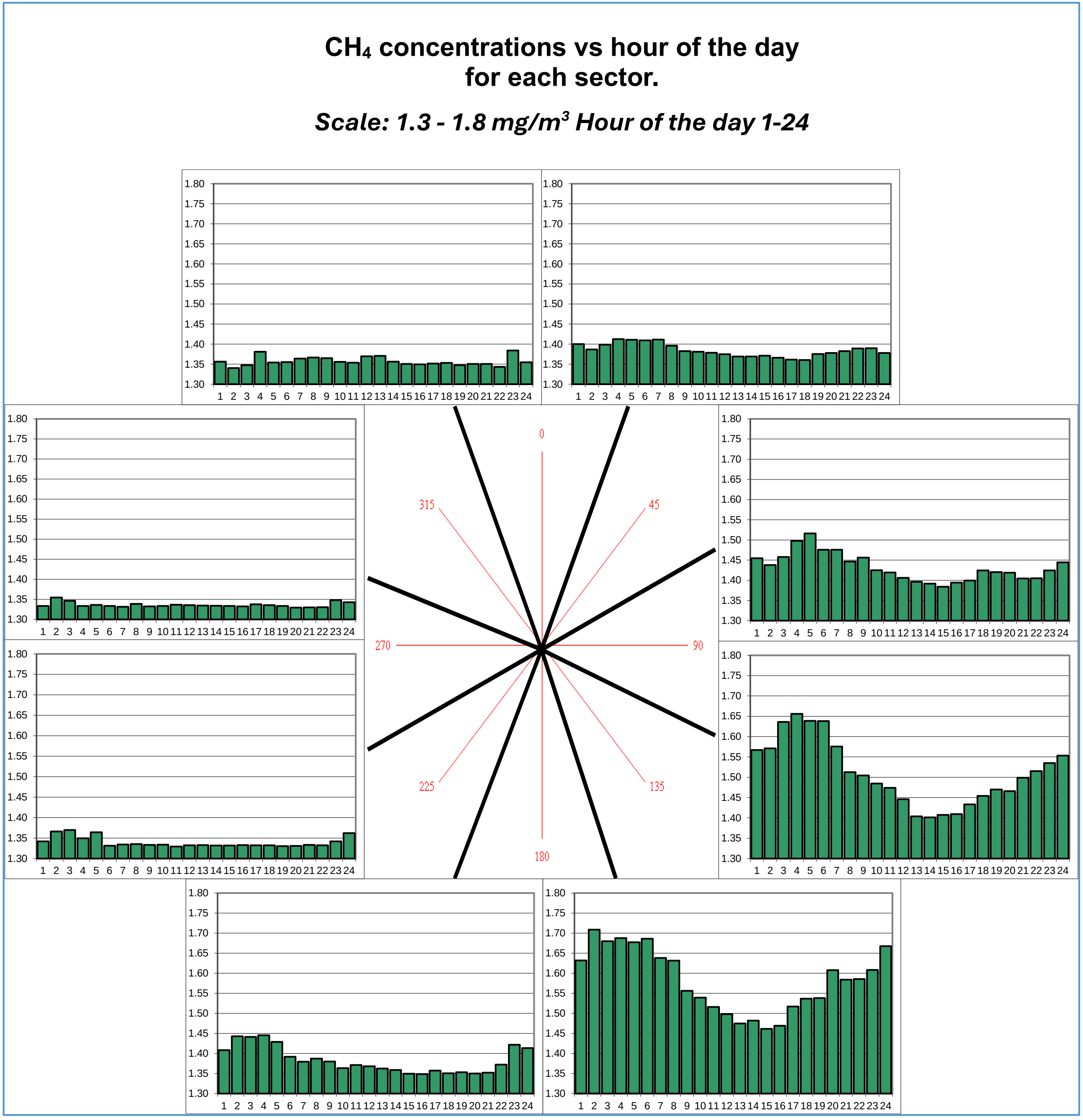


Figure 3.3.5 shows that the highest CH_4 concentrations were seen from sectors 90º-180º (the direction of Jameson Road landfill site) between 8pm and 8am. The plots also show elevated CH_4 concentrations from sectors 90º-135º (the direction of Preesall WwTW and Jameson Road Landfill) between midnight and 6am. There was also a source of CH_4 from sector 45°-90°. CH_4 concentrations are higher overnight suggesting that there was an accumulation of CH_4 concentrations at the monitoring location likely due to lower wind speeds and temperatures seen overnight resulting in less mechanical and thermal mixing.

3.3.3 Conclusion

The average CH_4 concentration over the period was 1.40 mg/m^3, which was higher than the northern hemisphere background concentration of around 1.31 mg/m^3, suggesting there was a localised source.

Directional analysis indicated that the highest average CH_4 concentrations were measured from the direction of Jameson Road landfill site, with average concentrations greater than 1.5 mg/m^3

Percentile rose analysis showed that there was a continuous source of CH_4 from sector 110°-180º (the direction of Jameson Road landfill site). A continuous source was also seen in the H_2S data. There was an intermittent source(s) of CH_4 from sector 80º.

Consideration of meteorological conditions suggests that at low wind speeds, there was poor dispersion and a build-up of CH_4 concentrations. The highest concentrations were seen from sectors 110º-220º at wind speeds <1 m/s. Elevated concentrations of CH_4 at all wind speeds also suggests a continuous source of CH_4 from sector 140°-170° (the direction of Jameson Road landfill site).

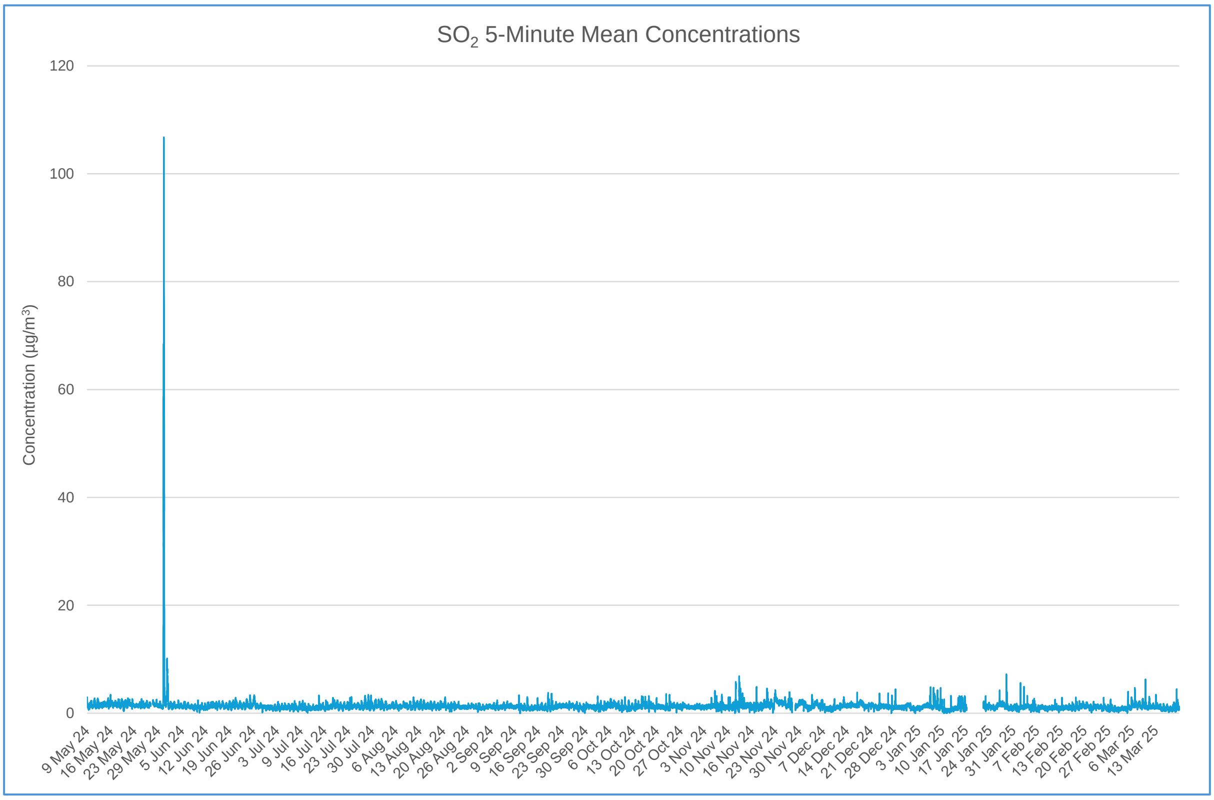
Consideration of the diurnal trends in CH_4 concentrations showed that the highest CH_4 concentrations were seen overnight and from sector 135º-180º (the direction of Jameson Road landfill site).

3.4 Sulphur Dioxide (SO_2)

Airborne SO_2 concentrations were measured, at a height of 2m above ground, between 9 May 2024 to 19 March 2025 (315 days). Details of the instrumentation and methodology are given in Appendix E. Successful data collection for the monitoring period was 97%.

A time series plot of 5-minute average concentrations of SO_2 between 9 May 2024 to 19 March 2025 is shown in Figure 3.4.1. The average concentration over the monitoring period was 1.3 µg/m^3. The maximum 5-minute average concentration was 106.7 µg/m^3 and was recorded on 31 May 2024.

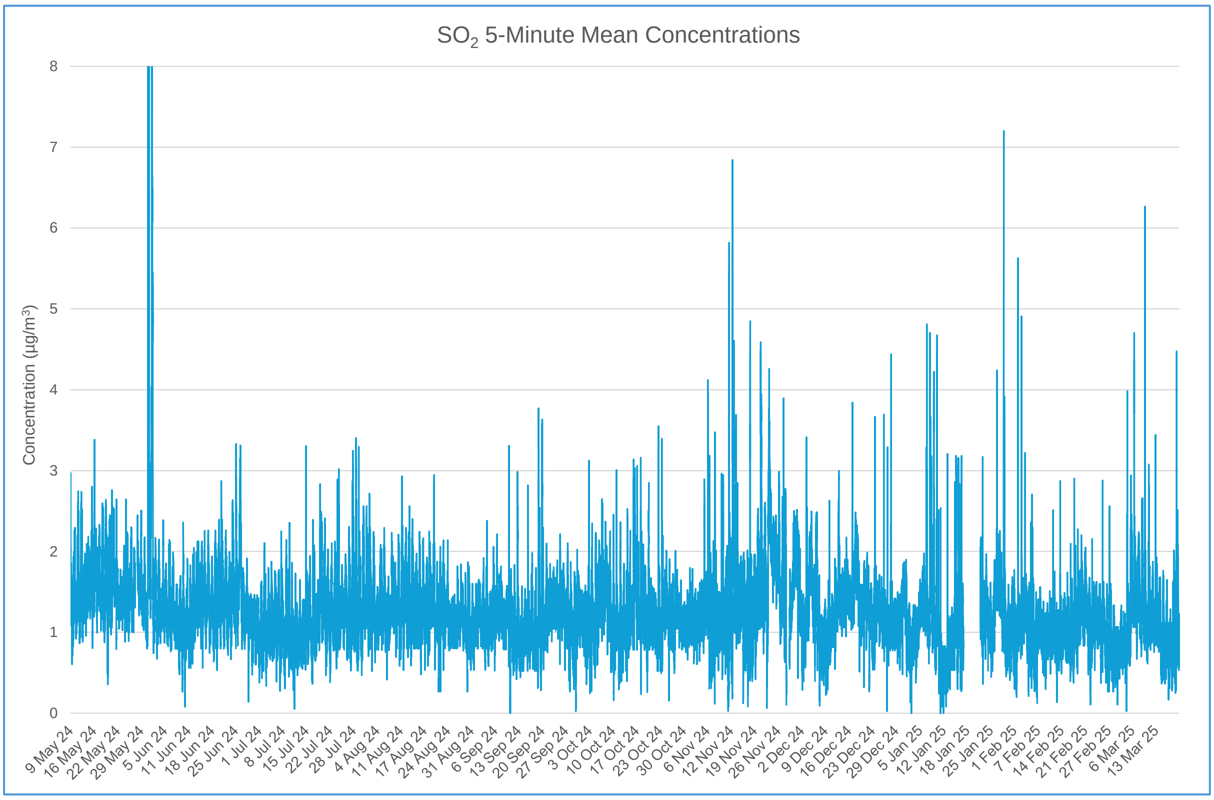
Figure 3.4.1: 5-Minute Average SO_2 Concentrations.



The very high levels of SO_2 seen between 31 May and 3 June 2024 have been attributed to a volcanic plume that transited the UK following a volcanic eruption on the Reykjanes Peninsula in Iceland.

A time series plot of 5-minute average concentrations of SO_2 between 9 May 2024 to 19 March 2025 with values on the Y-axis restricted to 5 µg/m^3 is shown in Figure 3.4.2.

Figure 3.4.2: 5-Minute Average SO_2 Concentrations (Restricted Y-Axis).

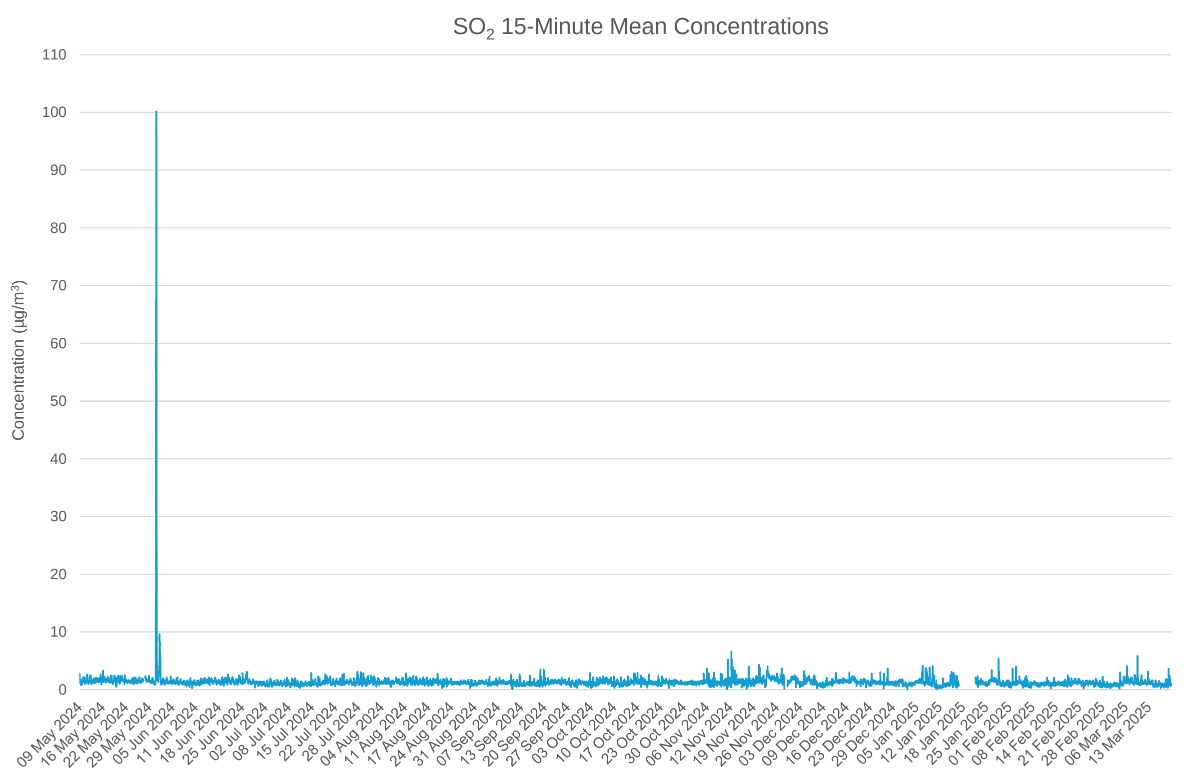


The plot shows that by excluding the data attributed to the volcanic eruption, the 5-minute average values fall below 8 µg/m^3 during the monitoring period. UK SO_2 concentrations are generally very low and close to limits of detection.

3.4.1 Comparison with Air Quality Strategy (AQS) Objectives

The AQS objective states that the limit of 266 µg/m^3 (100 ppb) as 15-minute averages must not be exceeded more than 35 times during one year. A time series plot for 15-minute average concentrations of SO_2 is shown in Figure 3.4.3.

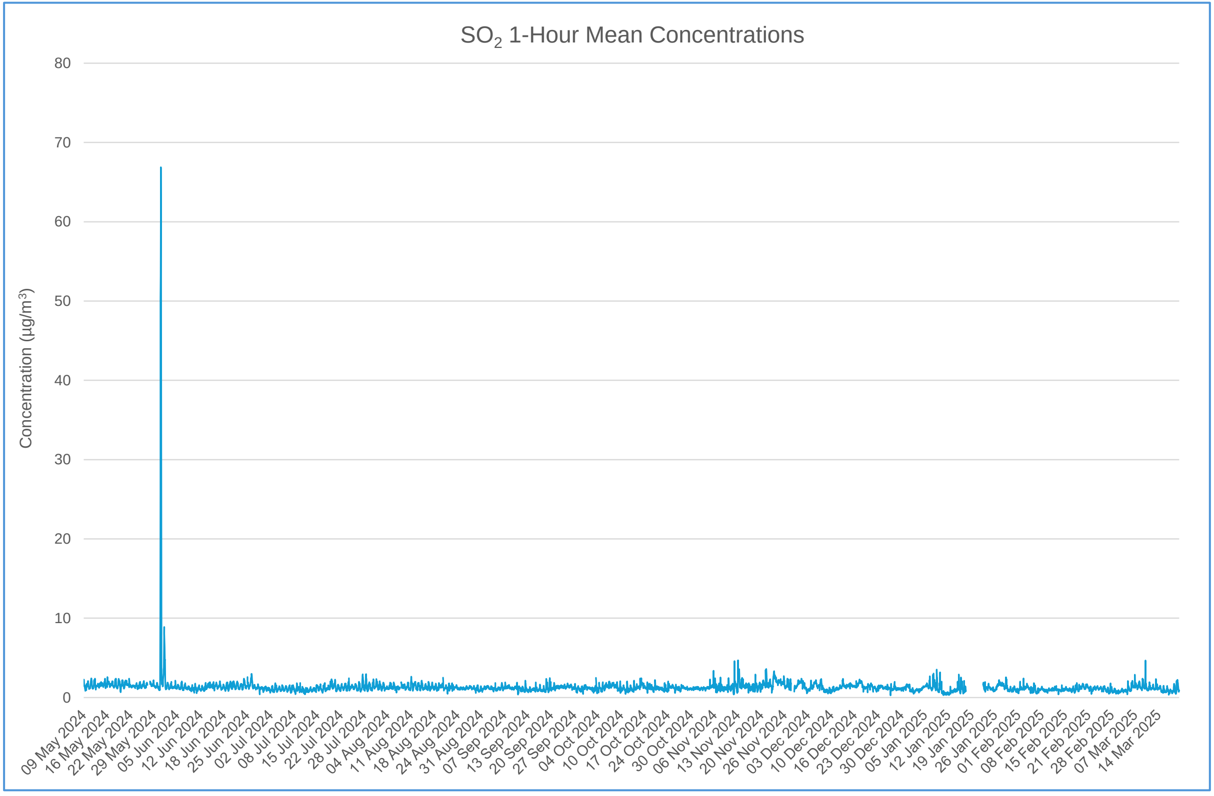
Figure 3.4.3: 15-Minute Average SO_2 Concentrations.



The plot shows that the measured 15-minute average did not exceed the AQS objective limit of 266 µg/m^3 during the monitoring period, the maximum concentration being 100 µg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the AQS for 15-minute SO_2 average concentrations would not be exceeded at the monitoring site. If the SO_2 data collected between 31 May and 1 June 2024 during the volcanic eruption is excluded the maximum 15-minute SO_2 concentration recorded would be 6.6 µg/m^3.

The AQS objective for 1-hour average concentrations of SO_2 states that a limit of 350 µg/m^3 (132 ppb) must not be exceeded more than 24 times during one year. A time series plot for 1-hour average concentrations of SO_2 is shown in Figure 3.4.4.

Figure 3.4.4: 1-Hour Average SO_2 Concentrations

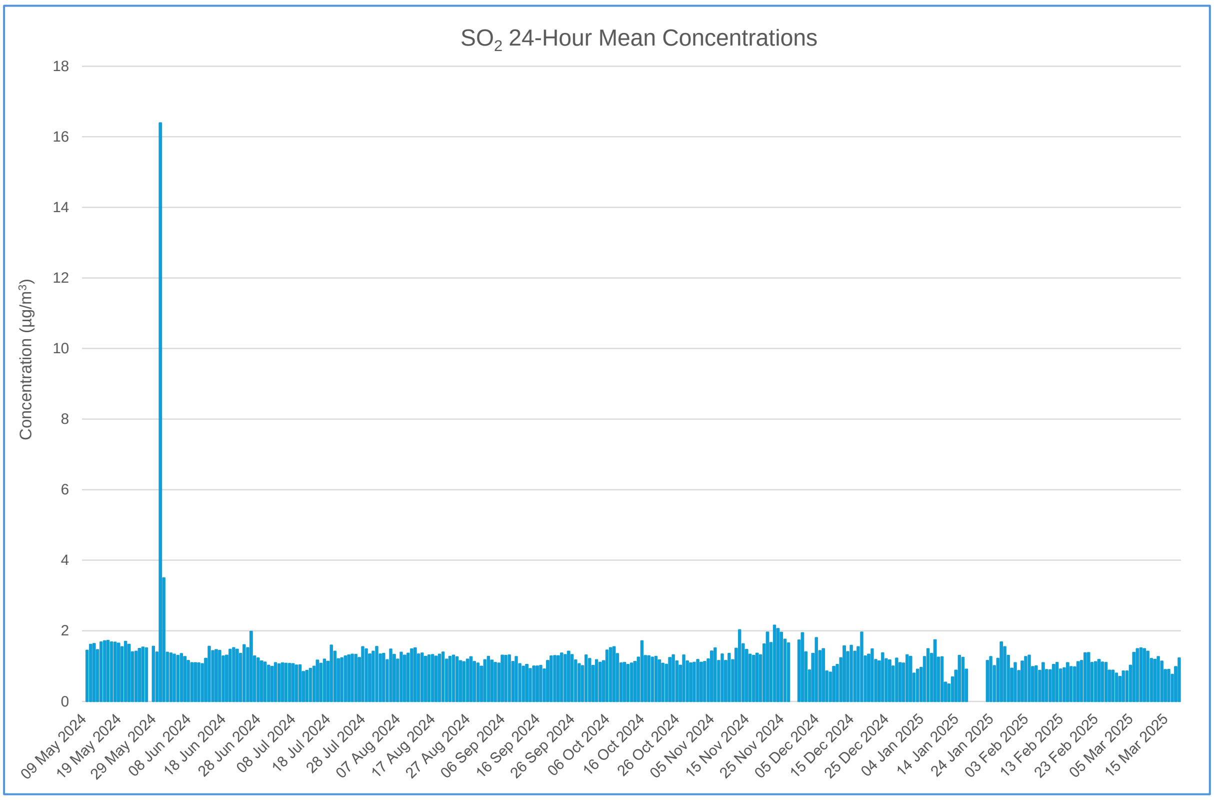


The plot shows that the measured 1-hour average did not exceed the AQS objective limit of 350 µg/m^3 during the monitoring period, the maximum concentration being 66.9 µg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the AQS objective for 1-hour SO_2 average concentrations would not be exceeded at the monitoring site. If the SO_2 data collected between 31 May and 1 June 2024 during the volcanic eruption is excluded the maximum 1-hour SO_2 concentration recorded would be 4.7 µg/m^3.

The 24-hour (midnight-midnight) AQS objective states that a value of 125 µg/m^3 (47 ppb) must not be exceeded on more than 3 occasions during one year. A time series plot for 24-hour (midnight-midnight) average concentrations of SO_2 is shown in Figure 3.4.5.

The plot indicates that over the monitoring period, no 24-hour average concentrations were recorded that exceeded the AQS objective, the maximum concentration being 16.4 µg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then it is unlikely that the AQS objective for 24-hour SO_2 average concentrations would be exceeded at the monitoring site. If the SO_2 data collected between 31 May and 1 June 2024 during the volcanic eruption is excluded the maximum 24-hour SO_2 concentration recorded would be 2.2 µg/m^3.

Figure 3.4.5: 24-Hour (Midnight-Midnight) Average SO_2 Concentrations

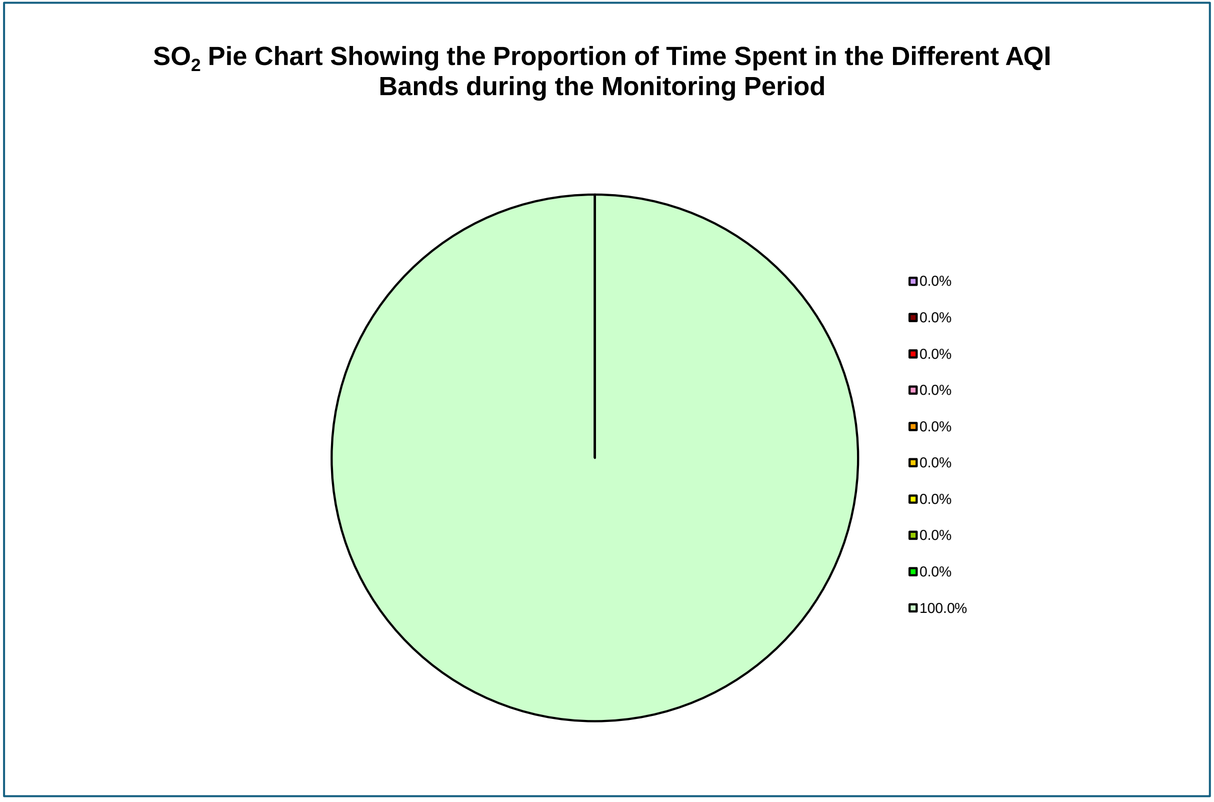


3.4.2 Comparison with Air Quality Index

In the United Kingdom, a daily Air Quality Index has been developed. The AQI can be used to summarise air pollution and assess the frequency of pollution episodes. The system uses an index numbered 1-10 (low-very high pollution), divided into four bands, to provide information about daily air pollution levels. Each of these bands has an associated health message, advising people most at risk when to limit or avoid exercise outside. The AQI is primarily designed to provide health information on short-term variations in air quality and not longer-term exposure.

Figure 3.4.6 looks retrospectively at the 15-minute SO_2 concentrations in relation to the Air Quality Index banding.

Figure 3.4.6: SO_2 AQI Pie Chart (Including Volcanic Plume Data).



The Figure shows that during the monitoring period, the SO_2 15-minute concentrations remained in the low banding of the Air Quality Index at the monitoring site for the duration of the monitoring period and therefore, according to the associated index health message, no precautions were necessary.

During the volcanic plume observed between 31 May and 1 June 2024 air quality remained in the low banding for SO_2 at the monitoring location.

3.4.3 Directional Analysis

All directional plots were generated using wind data from the MMF. To focus on localised sources, the data attributed to the volcanic eruption between 31 May and 1 June 2024 has mostly been excluded from the directional analysis.

A radial plot of average SO_2 concentrations (µg/m^3) against wind direction is shown in Figure 3.4.7 which includes the volcanic eruption data between 31 May and 1 June 2024.

Figure 3.4.7 shows that the highest concentrations came from the wind directions 0°, 20°-30° and 290° - 310° with average concentrations >1.4 µg/m^3. These sources can be attributed to the volcanic plume event.

A radial plot of average SO_2 concentrations (µg/m^3) against wind direction excluding the data attributed to the volcanic eruption is shown in Figure 3.4.8.

Figure 3.4.8 does not show a particularly strong average SO_2 signal for any wind direction.

Plots showing the contribution of SO_2 loading (µg/m^3) for different percentiles (excluding the data attributed to the volcanic eruption) are shown in Figure 3.4.9. An explanation of percentile analysis is given in Appendix G.

Figure 3.4.7: SO$_2$ Average Pollution Rose (µg/m^3).

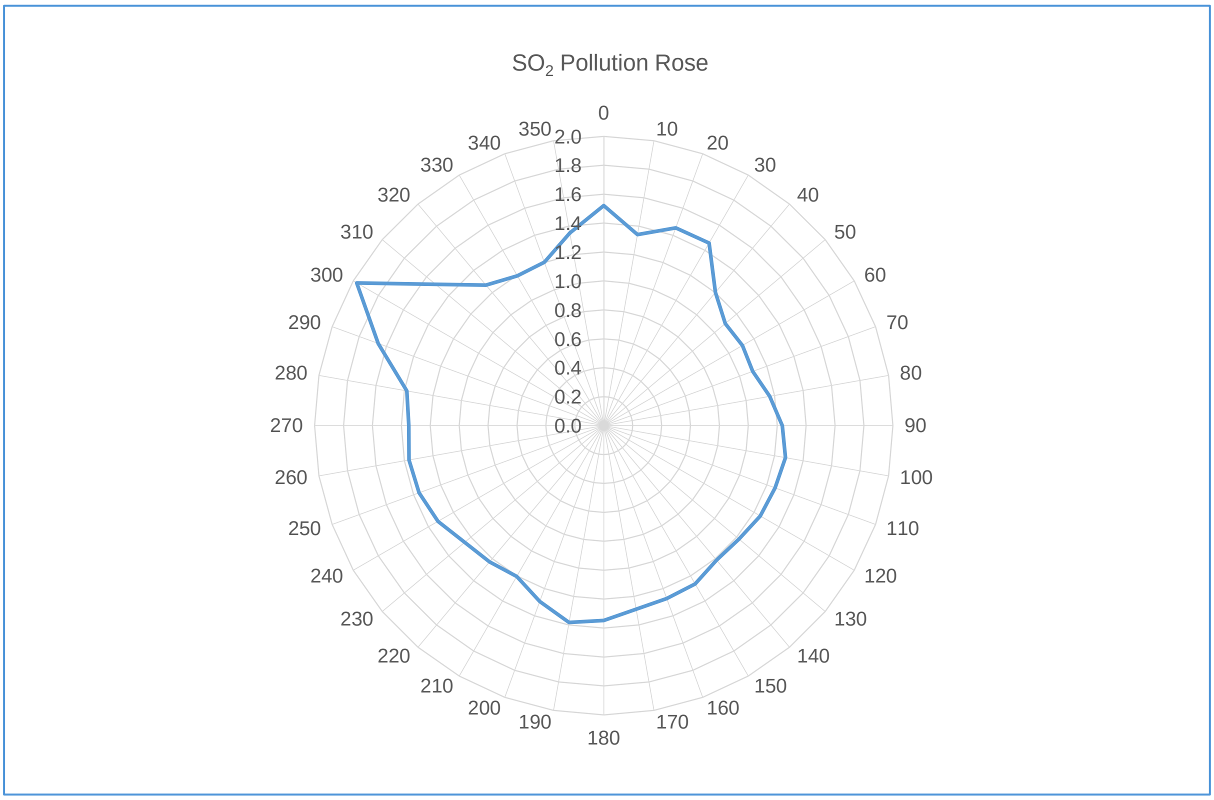


Figure 3.4.8: SO$_2$ Average Pollution Rose (µg/m^3) (Excluding Volcanic Plume Data).

Figure 3.4.9: SO_2 Percentile Roses (µg/m³) (Excluding Volcanic Plume Data).

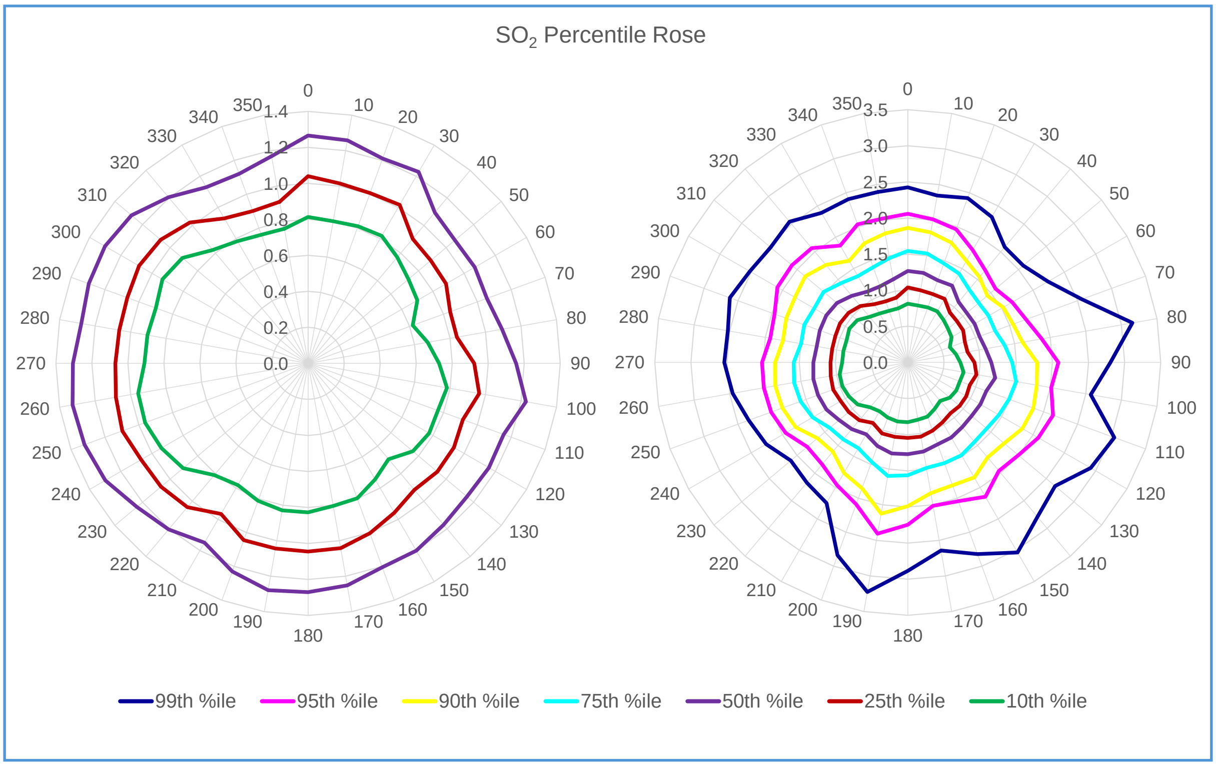
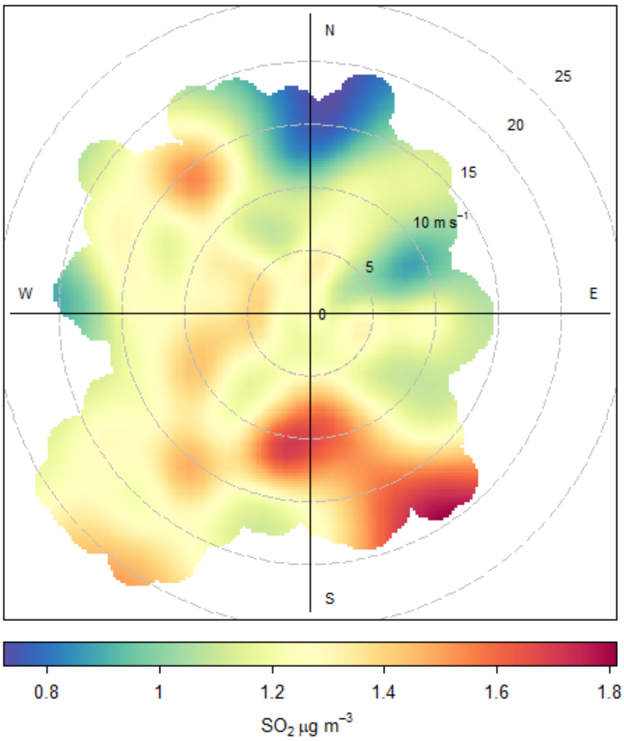


Figure 3.4.9 shows that the highest SO_2 concentrations were seen in the higher percentiles for sectors 110°-150° and 190° (the direction of Jameson Road landfill site and Fleetwood Marsh WwTW) and in the 99th percentile at 80° which indicates an intermittent source from these directions.

Polar frequency plots showing the average SO_2 concentrations for varying wind speeds and wind directions over the monitoring period, excluding the 31 May and 1 June 2024, are shown in Figure 3.4.10.

The polar frequency plot shows that the highest concentrations of SO_2 were seen from sectors 130°-170° (the direction of Jameson Road landfill site) at higher wind speeds between 13-20 m/s, and sector 160°-200° (the direction of Fleetwood Marsh WwTW) at wind speeds between 5-15 m/s, although these sources were not causing appreciably high levels of SO_2 at the monitoring location.

Figure 3.4.10: SO_2 Polar Frequency Plot for 10° Sectors (Excluding Volcanic Plume Data).



3.4.4 Conclusion

Comparison of the SO_2 data with the AQS objective for the 15-minute, 1-hour and 24-hour (midnight-midnight) average concentrations indicated that SO_2 concentrations would comply with all these objectives.

A comparison of the SO_2 concentrations against the daily Air Quality Index showed that during the monitoring period, the SO_2 15-minute concentrations remained in the low banding of the Air Quality Index.

Directional analysis demonstrated that the highest SO_2 concentrations were measured when the wind was blowing from the north and were caused by a short-duration volcanic eruption that originated in Iceland. No other significant source of SO_2 were noted.

Percentile rose analysis excluding volcanic plume data suggested intermittent sources from sectors 80°, 110°-150° and 190°. These sources were not causing appreciably high levels of SO_2 at the monitoring location and no considerable SO_2 source was detected.

Consideration of meteorological conditions suggests that the highest SO_2 concentrations were seen from the direction of Jameson Road landfill site and Fleetwood Marsh WwTW at higher wind speeds, although these sources were not causing appreciably high levels of SO_2 at the monitoring location.

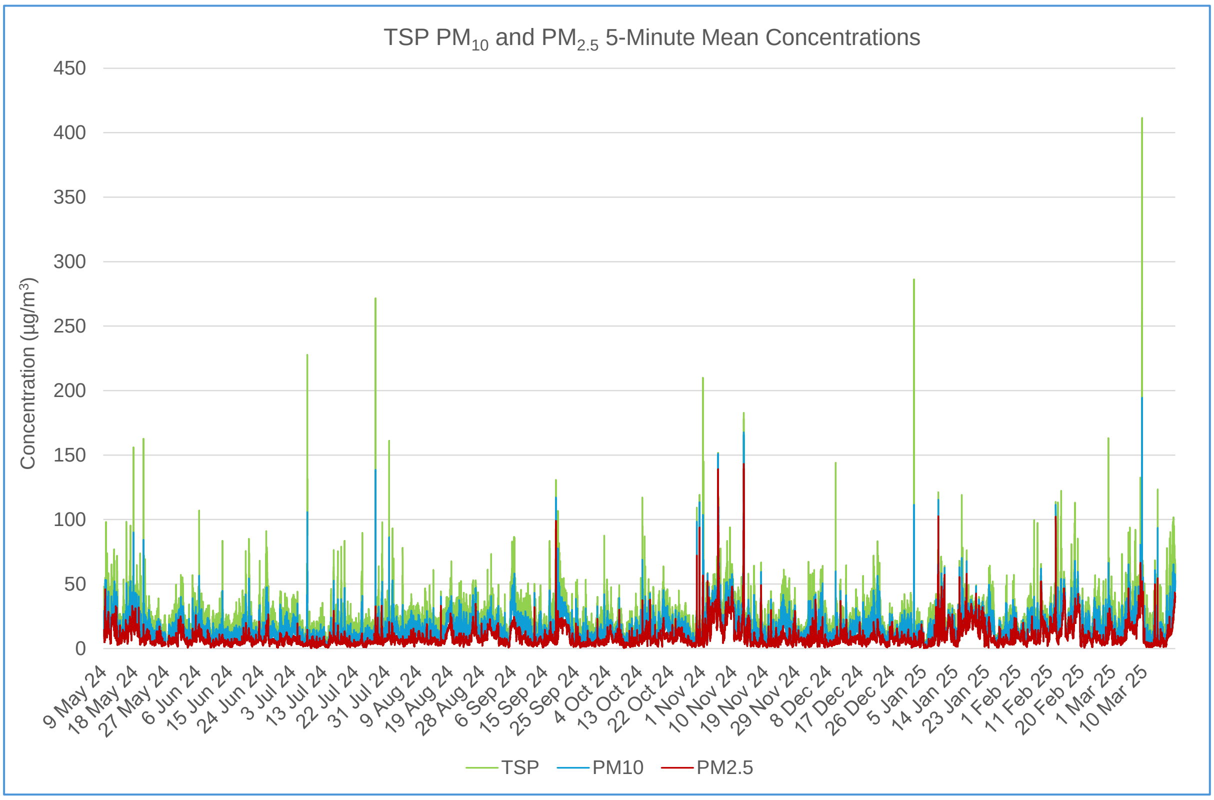
3.5 Particulate (TSP, PM_{10} and $PM_{2.5}$)

Between 9 May 2024 and 19 March 2025 (315 days) airborne concentrations of TSP (Total Suspended Particulate matter less than 18 microns in diameter), PM_{10} (particulate matter less than 10 microns in diameter) and $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter) were measured at the MMF (at a height of 2m above ground) using a FIDAS 200 instrument. Details of the instrumentation and methodology are given in Appendix F.

Successful data collection of 5-minute data for TSP, PM_{10} and $PM_{2.5}$ over the period was 99.8%.

A time series plot of 5-minute TSP, PM_{10} and $PM_{2.5}$ concentrations for the monitoring location is shown in Figure 3.5.1. The highest concentrations of TSP and PM_{10} were recorded on 10 March 2025, and the highest concentrations of $PM_{2.5}$ were recorded on 13 November 2024.

Figure 3.5.1: Particulate Matter 5-Minute Average Concentrations



3.5.1 Comparison with Standards

Comparison of PM_{10} and $PM_{2.5}$ concentrations against relevant Air Quality Strategy (AQS) objectives and the UK Environment Act target for fine particulate matter is made in this chapter.

3.5.1.1 Comparison with Air Quality Strategy (AQS) Objectives

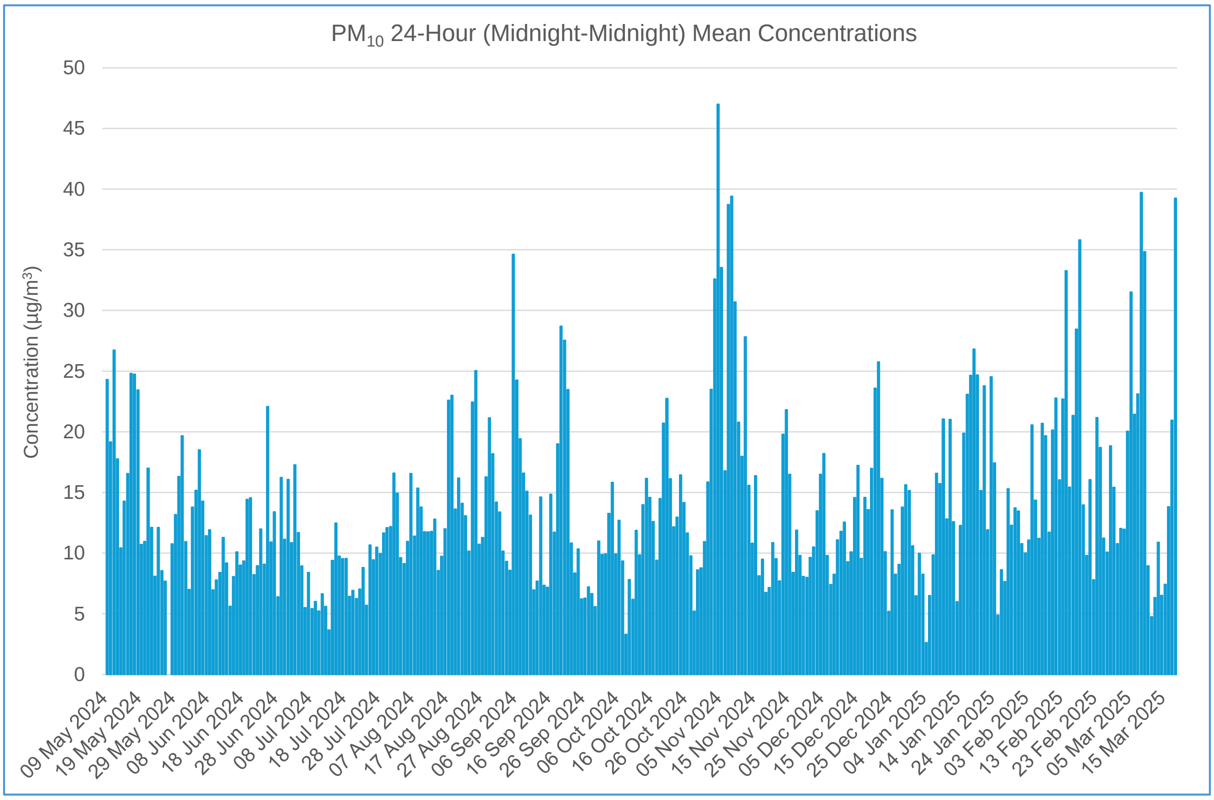
A comparison with the Air Quality Strategy (AQS) objectives has been made to provide a measure of air quality, to help evaluate compliance and quantify environmental impact in the immediate vicinity of sites that the Environment Agency regulates. The monitoring location must meet several criteria that ensure it is a suitable ‘sensitive receptor’ in regards AQS objectives. The monitoring location in this study does not meet these criteria and therefore the data should not be compared with the AQS objectives for statutory compliance purposes.

The AQS has two objectives for PM_{10}; the first is to limit the annual mean concentration to 40 μg/m^3 and the second objective states that the 24-hour mean (midnight-midnight) must not exceed 50 μg/m^3 on more than 35 occasions during one year. The AQS objective for $PM_{2.5}$ is an annual mean concentration of 25 μg/m^3.

The mean PM_{10} concentration over the monitoring period at the monitoring location was 14.1 μg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the results would indicate that the AQS annual mean objective would not be exceeded at the monitoring location.

Figure 3.5.2 shows that for PM_{10}, the 24-hour (midnight-midnight) average concentrations at the monitoring location did not exceed the 50 μg/m^3 objective during the monitoring period; the maximum concentration was 47.0 μg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the results would indicate that the AQS annual mean objective would not be exceeded at the monitoring location.

Figure 3.5.2: PM_{10} 24-Hour (Midnight-Midnight) Average Concentrations.



The mean $PM_{2.5}$ concentration over the monitoring period at the monitoring location was 8.5 μg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the results would indicate that the AQS annual mean objective would not be exceeded at the monitoring location.

3.5.1.2 Comparison with UK Environment Act

As a requirement of the Environment Act 2021, an environmental target has been set in England for the regulation of fine particulate matter (2023). An annual target for $PM_{2.5}$ of 10 μg/m^3 to be met by 2040 at relevant monitoring stations.

As it is not a requirement to meet the target value at this time, and the required monitoring period has not been reached, comparison of $PM_{2.5}$ concentrations against the target value is made here merely as a point of possible interest.

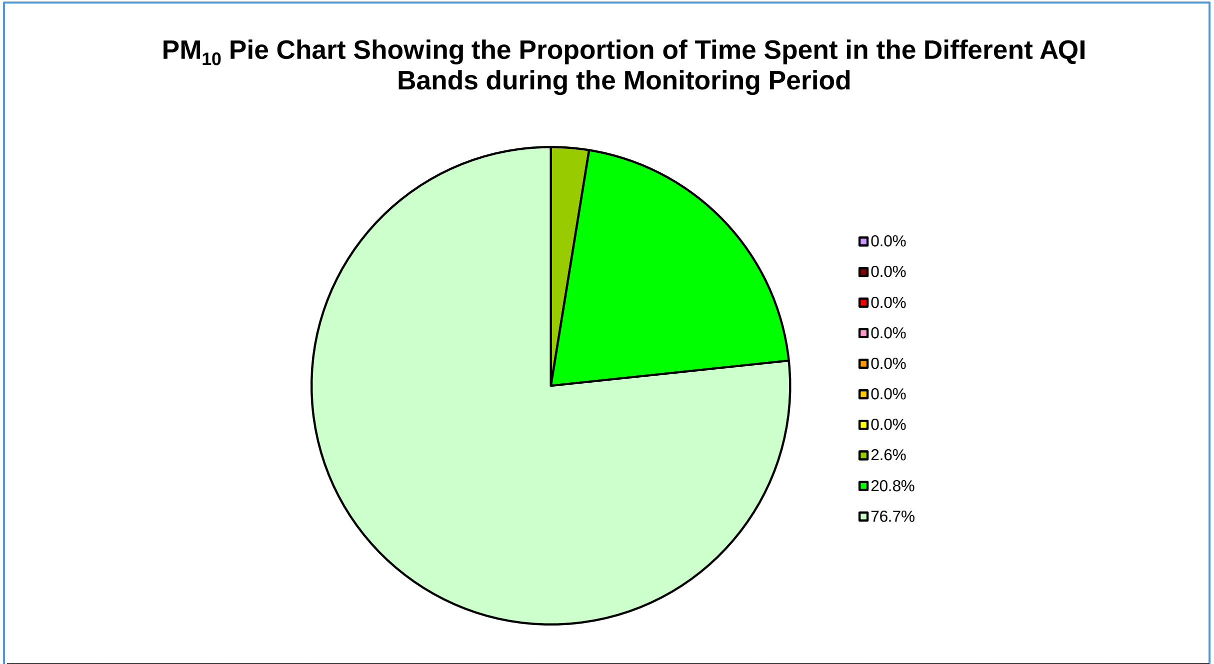
The mean $PM_{2.5}$ concentration over the monitoring period was 8.5 µg/m^3. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the results would indicate that levels of $PM_{2.5}$ at the monitoring location were likely to meet the 2040 $PM_{2.5}$ target value.

3.5.2 Comparison with the Air Quality Index

PM_{10} and $PM_{2.5}$ are two of the five pollutants used to assess the overall air quality index.

Figures 3.5.3 and 3.5.4 look retrospectively at the daily PM_{10} and $PM_{2.5}$ concentrations at the monitoring location in relation to the Air Quality Index (AQI) banding.

Figure 3.5.3: PM_{10} Air Quality Pie Chart.

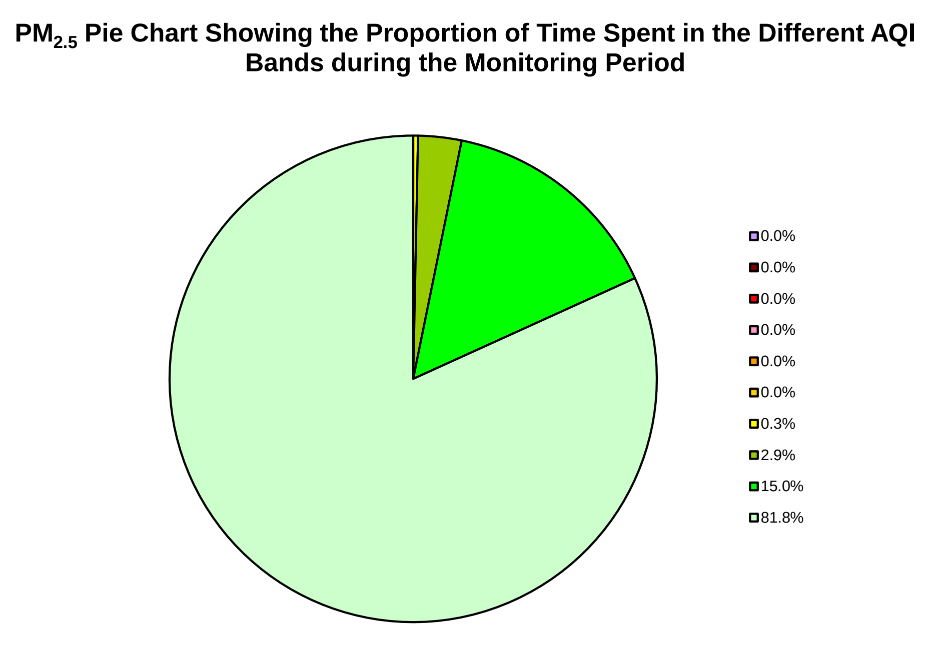


Index Band	10	9	8	7	6	5	4	3	2	1
	Very High	High	High	High	Moderate	Moderate	Moderate	Low	Low	Low
µg/m^3	101+	92 - 100	84 - 91	76 - 83	67 - 75	59 - 66	51 - 58	34 - 50	17 - 33	0 - 16
	0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.6%**	**20.8%**	**76.7%**

Figure 3.5.3 shows that the PM_{10} 24-hour average Concentrations were in the low banding (no precautions required) at the monitoring location for the duration of the monitoring period.

Figure 3.5.4 shows that the $PM_{2.5}$ 24-hour average Concentrations were mainly in the low banding (no precautions required) during the monitoring period, with just one day in the moderate banding.

Figure 3.5.4: PM_{10} Air Quality Pie Chart.



$PM_{2.5}$ Pie Chart Showing the Proportion of Time Spent in the Different AQI Bands during the Monitoring Period

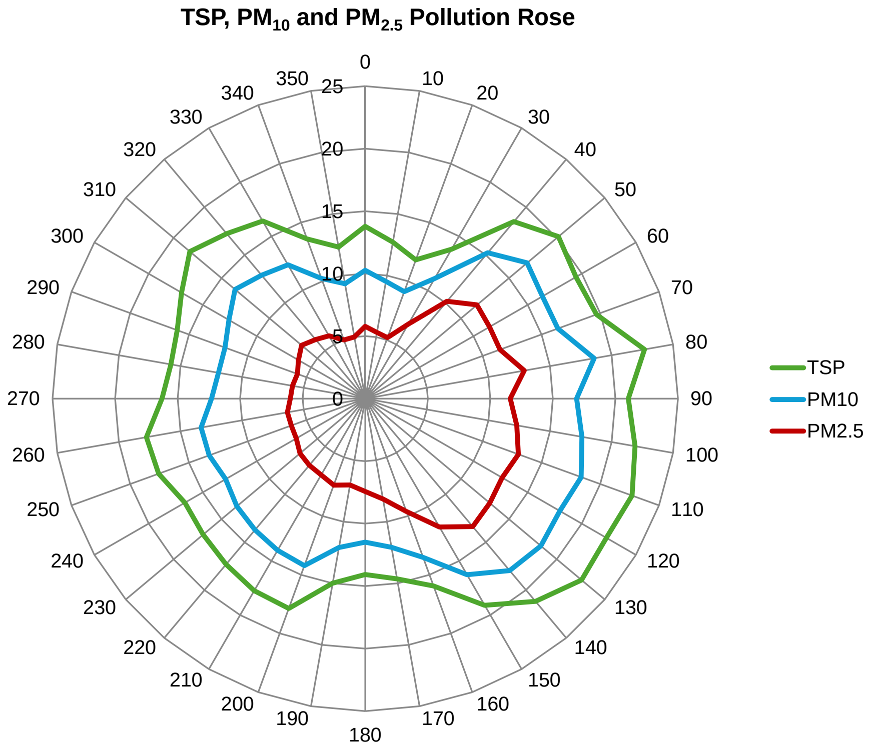
Index Band	10	9	8	7	6	5	4	3	2	1
	Very High	High	High	High	Moderate	Moderate	Moderate	Low	Low	Low
µg/m³	71+	65 - 70	59 - 64	54 - 58	48 - 53	42 - 47	36 - 41	24 - 35	12 - 23	0 - 11
	0.0%	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.3%**	**2.9%**	**15.0%**	**81.8%**

3.5.3 Directional Analysis

A radial plot of mean TSP, PM_{10} and $PM_{2.5}$ concentrations against wind direction at the MMF site is shown in Figure 3.5.5.

Figure 3.5.5 shows that the highest mean TSP and PM_{10} concentrations were seen for sector 40°- 150° with mean TSP and PM_{10} concentrations greater than 18 µg/m³ and 15 µg/m³ respectively. The highest mean $PM_{2.5}$ concentrations were seen for sectors 50°-150° with mean $PM_{2.5}$ concentrations greater than 11 µg/m³. The plot shows very similar trends in TSP, PM_{10} and $PM_{2.5}$ concentrations from the east for sector 50°-150°, suggesting that the source of PM is most likely related to background regional concentrations rather than a strong localised source from industrial emissions which would typically generate a higher amount of TSP and PM_{10} emissions.

Figure 3.5.5: PM Concentration Rose (µg/m^3 Mean Concentration)



Plots showing the contribution to TSP, PM$_{10}$ and PM$_{2.5}$ loading at the MMF monitoring location for different percentiles are shown in Figure 3.5.6. Details of how percentiles are calculated are given in Appendix G.

Figure 3.5.6: PM Percentile Roses.

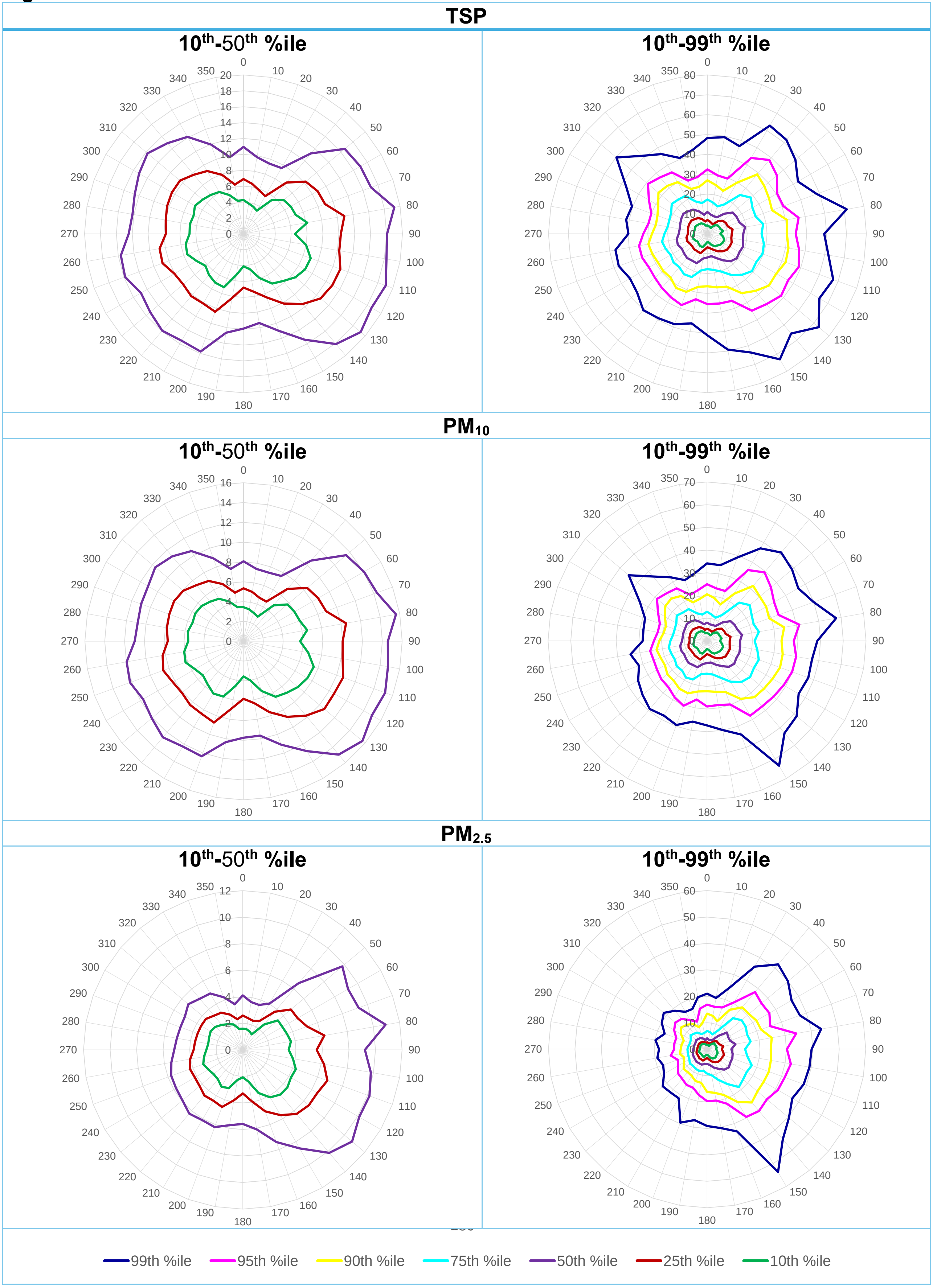


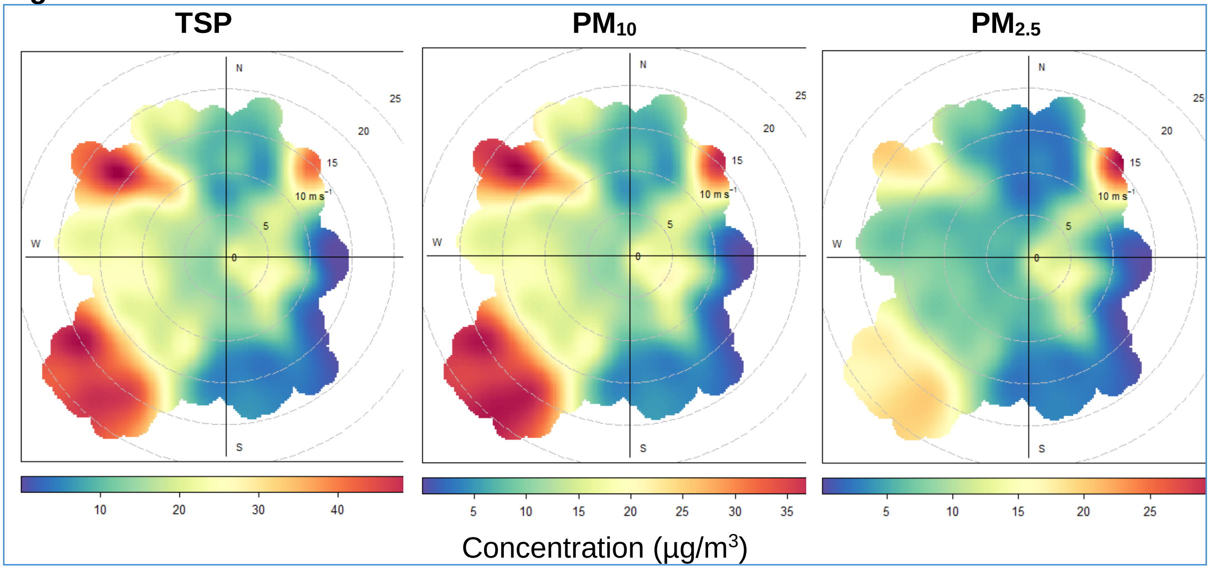
Figure 3.5.6 shows elevated concentrations of TSP and PM_{10} for all percentiles for sectors 80°, 100°-150° and 310°. This suggests a relatively continuous particulate source from these directions, although these sources were not causing appreciably high levels of TSP and PM_{10} at the monitoring location. The plots for $PM_{2.5}$ show elevated concentrations in all percentiles for sectors 40°-150° suggesting a relatively continuous combustion source, such as traffic emissions, or regional pollution from these directions.

3.5.4 Wind Speed Analysis

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 into the nature of contributing sources.

Figure 3.5.7 shows the variation in TSP, PM_{10} and $PM_{2.5}$ concentrations with wind speed seen for all wind directions at the monitoring location.

Figure 3.5.7: Polar Plots.



Splitting the data by wind speed has highlighted that the highest concentrations of particulate matter over the monitoring period were seen under conditions of high wind speed (greater than 10 m/s) for wind sectors 30°-60°, 200°-255° and 290°-330°

3.5.5 Diurnal Analysis

Consideration of the diurnal distribution of concentrations 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 an industrial site, meanwhile, are usually characterised by a single peak spanning the hours of the working day or operations on site.

Figure 3.5.8 shows the diurnal variation of mean TSP, PM_{10} and $PM_{2.5}$ concentrations for different wind directions.

Figure 3.5.8: TSP, PM_{10} and $PM_{2.5}$ Diurnal Polar Plots.

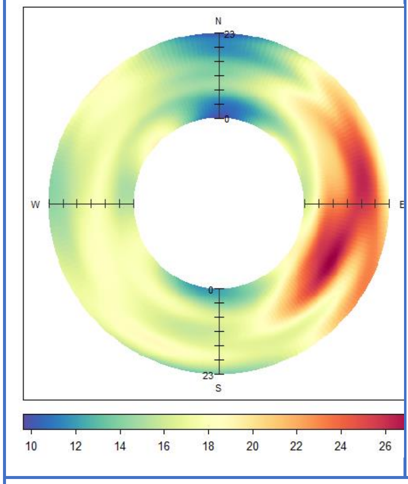
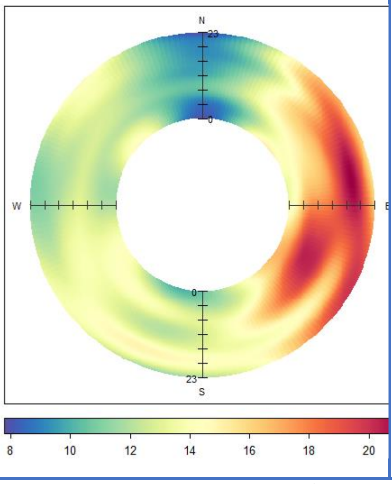
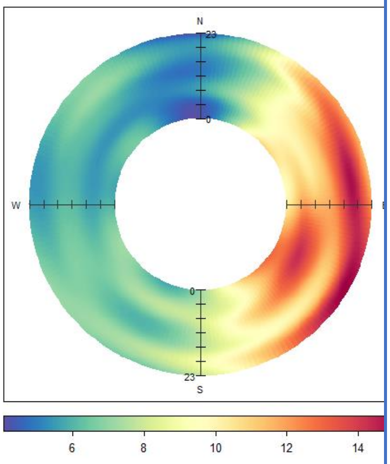
TSP	**PM_{10}**	**$PM_{2.5}$**
		
Concentration ($\mu g/m^3$)		

Figure 3.5.8 shows stronger diurnal concentrations for particulate matter (TSP, PM_{10} and $PM_{2.5}$) from sectors 40°-150°, with peak concentrations between 2 pm and 9pm for sector 60°-90° and peak concentrations between 4 am and 2 pm for sector 90°- 150°. The source also appears more elevated in these directions for PM_{10} and $PM_{2.5}$ around mid-day and midnight.

3.5.6 Conclusions

Comparison of the PM_{10} data with the AQS objective for the 24-hour (midnight-midnight) mean indicated that the standard would not be exceeded at the monitoring location.

The mean PM_{10} concentration over the monitoring period at the monitoring location was 14.1 $\mu g/m^3$. If the assumption is made that the conditions during the monitoring period were representative of a typical year, then the results would indicate that the AQS annual mean objective of 40 $\mu g/m^3$ would not be exceeded at the monitoring location.

The mean $PM_{2.5}$ concentration over the monitoring period was 8.5 $\mu g/m^3$. If the assumption is made that the conditions during the monitoring periods were representative of a typical year, then the results would indicate that the AQS annual mean objective for $PM_{2.5}$ of 25 $\mu g/m^3$ would not be exceeded at the monitoring location. Comparison of $PM_{2.5}$ concentrations with the new annual UK Environment Act target showed that the target would not be exceeded at the monitoring location.

The PM_{10} and $PM_{2.5}$ 24-hour concentrations were mainly in the low banding of the air quality index at the monitoring location during the study.

Pollution rose analysis indicates that the highest mean TSP and PM_{10} concentrations measured at the monitoring location when the wind was coming from sectors 40°-150°. The highest mean $PM_{2.5}$ concentrations were seen for sectors 50°-150°.

Percentile rose analysis suggested that the monitoring location was affected by continuous source of TSP and PM_{10} from sectors 80°, 100°-150° and 310°. There was a continuous source of $PM_{2.5}$ from sectors 40°-150° suggesting a combustion source, such as traffic emissions, or regional pollution from these directions.

Wind speed analysis shows that elevated concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were seen from sectors 30°-60°, 200°-255° and 290°-330°at high wind speeds greater than 10 m/s.

Diurnal analysis suggests that the elevated PM concentrations occurred between 2 pm and 9pm for sector 60°- 90° and 4 am and 2 pm for sector 90°- 150°. The source also appears more elevated in these directions for PM_{10} and $PM_{2.5}$ around mid-day and midnight.

4 Conclusion

The average methane concentration over the monitoring period was 1.40 mg/m^3, which is above the Northern Hemisphere background concentration[2] of ~1.31 mg/m^3.

In the absence of an Air Quality Standard (AQS) objective, the hydrogen sulphide (H_2S) data was compared with the World Health Organisation (WHO) guidelines[3] for both human health and odour annoyance (Table 4.1).

Table 4.1 Impact summary of H_2S compliance with the WHO guidelines for Europe 2000$^{(1)}$.

Pollutant	Averaging Time	Guidance Limit	Percentage of Time Exceeding the Guidance Limit
H_2S	24-hr (midnight-midnight)	150 µg/m^3	0
	30-min	7 µg/m^3	0.4%

Comparing the collected data with the World Health Organisation (WHO) guidelines showed that H_2S concentrations were below the guideline value, with a maximum 24-hour average H_2S concentration of 4.1 µg/m^3 over the monitoring period. Comparison of the H_2S data with the WHO guideline for odour annoyance of 7 µg/m^3 (as 30-minute average concentrations) indicated that the air quality at the monitoring site exceeded this guideline for 0.4% of the monitoring period.

Tables 4.2 and 4.3 summarise the extent of likely compliance/exceedance for each of the AQS objectives and the environmental target[4] for $PM_{2.5}$ at the MMF monitoring site. Table 4.4 summarises the extent of likely compliance, where appropriate, with other standards. A projected compliance ratio of <1 indicates compliance, whilst a value of >1 indicates non-compliance.

Table 4.2 Impact summary for short-term air quality objectives.

Pollutant	Averaging Time	AQS	Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Permitted Exceedance (A)	Measured Exceedance	Extrapolated Exceedance* (B)	Projected Compliance Ratio (B/A)
PM_{10}	24-hr (midnight-midnight)	2000	50	47.0	35/year	0.0	0.0	0.0
SO_2	15-min	2000	266	100.2	35/year	0.0	0.0	0.0
	1-hr	2000	350	66.9	24/year	0.0	0.0	0.0
	24-hr (midnight-midnight)	2000	125	16.4	3/year	0.0	0.0	0.0

Table 4.3 Impact summary for long-term air quality objectives.

Pollutant	Averaging Time	AQS	UK Environment Act*	Standard (A) (µg/m^3)	Measurement (B) (µg/m^3)	Projected Compliance Ratio (B/A)
PM_{10}	Year	2000	-	40	14.1	0.35
$PM_{2.5}$	Year	2007	-	25	8.5	0.34
$PM_{2.5}$	Year	-	2023	10	8.5	0.85

* **Environmental Targets (Fine Particulate Matter) (England) Regulations 2023, as required by UK Environment Act 2021. To be met by 2040.**

Table 4.4 Impact summary for other relevant$^{\Delta}$, long-term standards.

Pollutant	Averaging Time	AQS	Standard (A) (µg/m^3)	Measurement* (A) (µg/m^3)	Projected Compliance Ratio (B/A)
SO_2	Year	2000	20	1.3	0.07

∆ Provisional AQS objectives, proposed AQS objectives and 2000 NAQS objectives for the protection of vegetation and ecosystems.

◊The areas where the UK vegetation and ecosystem air quality objectives apply are based on the monitoring criteria for the vegetation and ecosystems limit values set under the 1st Air Quality Directive

1. More than 20km from an agglomeration (i.e. an area with a population of more than 250,000);
2. More than 5km away from industrial sources regulated under Part A of the Environment Act 1990 (and/or Part A1 sites under PPC regulations);
3. More than 5km away from motorways
4. More than 5km away from built up areas of more than 5000 people.

*Extrapolated from effective monitoring period

Comparing the collected data with the AQS objectives showed that the monitoring location was subject to concentrations of PM_{10}, $PM_{2.5}$ and SO_2 that were likely to meet their respective AQS objectives. Levels of $PM_{2.5}$ at the monitoring site were below the new Environmental Target for fine PM which is to be met by 2040.

The AQS objective has an annual standard for SO_2 for the protection of vegetation and ecosystems. This standard is only relevant if the location meets certain criteria$^{\lozenge}$. In this instance the monitoring location does not meet these criteria and therefore the standard does not apply. It is mentioned merely as a point of possible interest, that the levels measured were below the standard.

It is worth noting that the assumption has been made that the conditions during the monitoring period were representative of a typical year. These calculations do not consider changes in weather conditions or changes to local sources that might occur outside of the monitoring period.

Comparison against the Air Quality Index (AQI) banding showed that SO_2, PM_{10} and $PM_{2.5}$ concentrations were mainly in the low AQI banding during the monitoring period. Although the volcanic plume observed between 31 May and 1 June 2024 caused a haze across the United Kingdom, air quality remained in the low banding for SO_2, PM_{10} and $PM_{2.5}$.

Analysis of the meteorological data collected at the MMF showed the dominant wind direction was between 140°-170° and 230°-310°, with wind coming from these sectors for 19.2% and 33.4% of the monitoring period respectively. The most frequent wind speeds came from sectors 140°-170° at wind speeds of 3-7 m/s and 230°-310° at wind speeds of 4-9 m/s.

Consideration of meteorological conditions suggests that the highest H_2S and CH_4 concentrations were seen from the direction of Jameson Road landfill site for a range of wind speeds, suggesting a relatively continuous source(s). At lower wind speeds, where there is less dispersion or mixing of air, there was an accumulation of H_2S and CH_4 concentrations at the monitoring location.

The highest SO_2 concentrations were measured when the wind was blowing from the north and were caused by a short-duration volcanic eruption that originated in Iceland. No other significant source of SO_2 was noted although an intermittent elevation in concentrations at higher wind speeds was seen from the direction of Jameson Road landfill site and Fleetwood Marsh WwTW.

Elevated average concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were seen from sectors 50º-150º. But when considering wind speed, the highest concentrations of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were seen from sectors 30°-60°, 200°-255° and 290°-330°at high wind speeds greater than 10 m/s.

5 References

1. Department for Business, Energy and Industrial Strategy *(2022). Long-Term Atmospheric Measurement and Interpretation of Radiatively Active Trace Gases, Annual Report (October 2020-September 2021).*
2. World Health Organisation (2000), *WHO Air Quality Guidelines for Europe*
3. Department of the Environment (January 2000), *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland,* (HMSO)
4. *The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023*
5. Carslaw, D. C., and K. Ropkins. 2012. "openair — An R package for air quality data analysis." *Environmental Modelling and Software* 27–28 (0): 52–61. https://doi.org/10.1016/j.envsoft.2011.09.008.
6. Google Maps (2024) *Fleetwood, 1:1,000*. Available from: www.www.google.com/maps [Accessed 5 August 2024].
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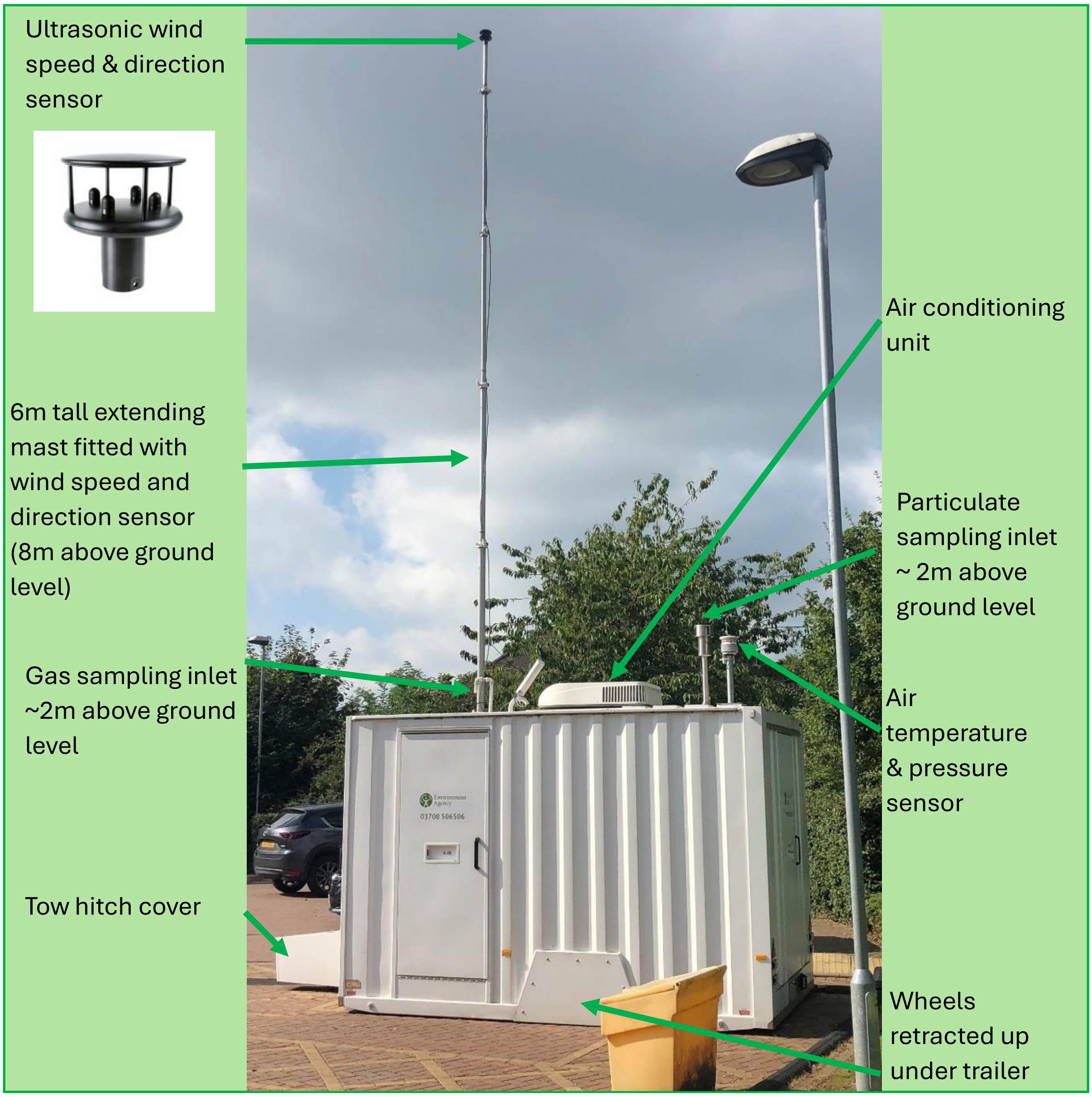
Appendix A Mobile Monitoring Facility

National Monitoring Services carries out ambient air monitoring on behalf of Environment Agency operational areas using Mobile Monitoring Facilities (MMFs). These facilities allow the Agency to carry out flexible, short-term studies examining the potential impact of Industrial sites regulated by the Environment Agency on local communities. The facilities contain 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. Air is sampled at a height of 2m, slightly above adult head hight and in a location away from the ground, where it is unlikely to be damaged. Figure A1 shows the typical configuration of the MMF's exterior.

Figure A1: Annotated diagram of MMF exterior



The pollutants being measured during this study were:

- particles (Total Suspended Particulate (TSP), PM_{10} & $PM_{2.5}$)
- hydrogen sulphide (H_2S)
- methane (CH_4)
- sulphur dioxide (SO_2)

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 being measured are:

- wind direction
- wind speed
- temperature
- pressure

Wind direction and wind speed measurements are taken at an elevation of 8m above the ground (6m mast on top of 2m MMF). The data is recorded as 5-minute averages. Temperature and pressure are measured by the particulate monitor at an elevation of 2m above the ground. The data is recorded as 5-minute averages.

Wind direction is an important consideration as it provides direct information about the orientation of any source relative to the monitoring site. In general, the measured wind direction is considered a reasonable indication of where a pollutant's trajectory has come from locally. However, it is sometimes possible for wind direction to vary along a plume's trajectory so that the wind direction will not simply "point" to the source. Wind speed and temperature both have a strong influence on the amount of mixing within the atmosphere, having profound effects on the vertical distribution of pollutants through the atmospheric boundary layer.

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.

To ensure that data from the MMF and standalone cabinets 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.

Uncertainty - The final data set will be subject to uncertainties that are generated during the monitoring process. However, the QAQC measures help to keep these uncertainties to a minimum. For uncertainty budgets please refer to the pollutant appendices.

Quality assurance included:

Training - All personnel involved with the running of the facility have received training in the execution of the tasks they are expected to undertake.

Analyser selection - Careful consideration has been given to the choice of analysers, ensuring that they can demonstrate their levels 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 at suitable intervals, using traceable gas standards and any adjustments made to the analysers documented. Regular checks using traceable gas standards are also performed in between routine calibrations.

Routine maintenance - Undertaking and documenting a range of checks on operational equipment derived from best established practice and manufacturer recommendation.

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. The data is checked 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 identified through regular checks on the instruments using traceable gas standards.

Appendix C Hydrogen Sulphide (H_2S)

Hydrogen sulphide (H_2S) is a colourless, toxic and flammable gas, with a characteristic odour of 'rotten eggs'.

Sources

Hydrogen sulphide is produced naturally in the environment by emissions from volcanoes and geothermal activity, microbial decomposition of organic material in the absence of oxygen (anaerobic digestion) in swamps and saltmarshes and is an important participant in the natural sulphur cycle. Natural sources account for 90% of the global H_2S emissions, whilst the other 10% is emitted from anthropogenic sources such as oil refineries, coke ovens, tanneries, paper mills (using the Kraft process (sulphate process)), wastewater treatment plants, viscose rayon textile production, landfills and farm manure storage facilities, to name but a few.

Human Health and Standards

'Although it is unlikely that the general population will be exposed to a level of H_2S high enough to cause adverse health effects' (1), levels around some industrial sources can cause a nuisance due to the unpleasant odour associated with the hydrogen sulphide. The odour threshold (point above which an odour can be perceived by 50% of a human panel) for H_2S is between 0.2 – 2ug/m^3 depending on the purity. However, at these levels the human nose can only detect that an odour is present, the characteristic 'rotten egg' odour is not perceptible until 3-4 times this threshold level.

The World Health Organisation (WHO) has set two guidelines for H_2S, a health standard and an odour threshold above which substantial complaints with regard to odour nuisance should be expected.

Health guideline: 150ug/m^3 as a 24-hour average

Odour guideline: 7µg/m^3 as a 30-minute average

The health guideline is based on the lowest level of H_2S to cause an adverse effect, which is 15mg/m^3 (15,000µg/m^3), where it has been shown to cause eye irritation. A high protection (safety) factor of 100 is then applied and the guideline of 0.15mg/m^3 (150µg/m^3) over a 24-hour averaging time is the result.

The high protection factor applied to create the guideline for health is a result of the marked toxicity of H_2S with increasing concentration above the first observable adverse effect.

H_2S analyser

The analyser used to measure hydrogen sulphide is an API T101 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.

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. These excited SO_2 molecules quickly return to their ground state by emitting a photon at a longer wavelength (330nm) and this fluorescence can then be measured by a PMT with a secondary UV filter. The equations describing the reactions are:

$$\textbf{Irradiation}\quad \mathbf{SO_2 + h\nu_{214nm} \longrightarrow SO_2^*}$$

$$\textbf{Fluorescence}\quad \mathbf{SO_2^* \longrightarrow SO_2 + h\nu_{330nm}}$$

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, $\mathbf{a}$ the absorption coefficient of SO_2, $\mathbf{x}$ 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.

As the T101 has not been formally certified, the sources of likely uncertainty in the adjusted data were derived from the factory specification and known uncertainties relating to the T100 Sulphur Dioxide (SO_2) instrument, which has been formally certified and with which the T101 shares significant componentry and principles of operation. These are defined under standard EN14212.

There are some aspects of uncertainty that cannot be derived from the certification. These are associated with calibration gas traceability and degradation of the thermal oxidiser. For the uncertainty budget, gas traceability was taken from manufacturer certification. A converter efficiency of 90% has been assumed, although we would expect for efficiency to be higher than this in most cases.

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor (k = 2), providing a level of confidence of approximately 95%. The reported uncertainty covers the data collected from 1 January 2025.

Data for the uncertainty analysis was taken from the specifications reported by both the instrument and calibration gas manufacturer's and from the TUV and MCERTS product conformity certificates.

Assessment of compliance for H_2S/SO_2 UV Fluorescent analyser		
Teledyne API T101		1 hour limit value 132ppb
Measurement performance related to laboratory and field conditions		
Performance Characteristic	**Value**	**Square of Standard Uncertainty**
Repeatability at zero	0.5ppb	0.0222ppb
Lack of fit	0.2%	0.0232ppb
Sample gas pressure	0.06ppb/kPa	2.5613ppb
Sample gas temperature	0.013ppb/K	0.0105ppb
Surrounding temperature	0.03ppb/K	0.0559ppb
Electrical voltage	0.02ppb/V	0.0467ppb
Water interference	-1.5ppb	1.4668ppb
Other interference	7.6ppb	12.6928ppb
Averaging effect	1.1%	0.7028ppb
Reproducibility under field conditions	4.8%	40.1449ppb
zero drift	1.35ppb	0.6075ppb
span drift	1.56%	1.4134ppb
Converter efficiency (in the field)	90%	174.2ppb
Uncertainty of gas (used in the field)	5%	10.89ppb
Combined standard uncertainty (Uc)		15.6ppb
Total expanded uncertainty for H_2S 95% confidence)		**23.7%**

References

1. ‘Hydrogen Sulphide: General Information’, Public Health England, Toxicology Department, CRCE, PHE 2009 (version 1)
2. World Health Organisation (2000), *WHO Air Quality Guidelines for Europe*
3. ‘Model T101 UV Fluorescence H_2S Analyser’, User Manual, Teledyne Advanced Pollution Instrumentation, August 2016
4. Sira Certification Service. December 2020. Certificate No: Sira MC050067/08
5. TÜV Rheinland Energy GmbH. March 2023. Certificate No: 0000038501_03

Appendix D 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 and lakes. 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. The major emitting sources in 2020 were from agriculture (48%), the waste sector (31%), and the UK energy sector (11%) (2).

The Northern Hemisphere background concentration is currently around 1.96 ppm (1.31 mg/m^3) (3). There has been a small increase in methane background concentrations over the last 30 years, this 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.

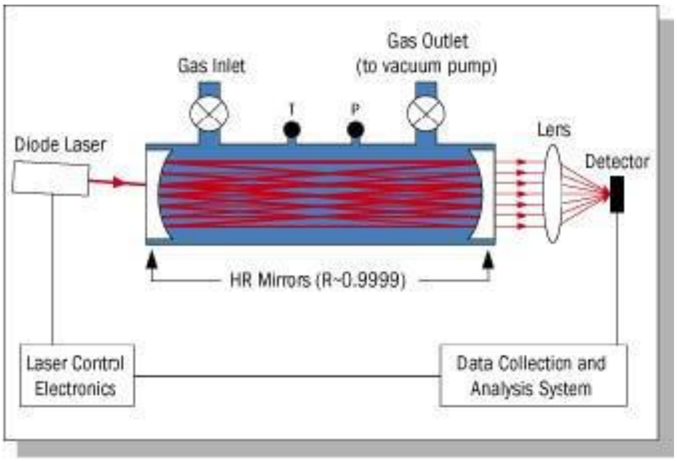
CH_4 Analysers

The analyser used for the study 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. Los Gatos Research’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.'

As the Los Gatos CH_4 analyser has not been formally certified, the sources of likely uncertainty in the adjusted data were derived from the factory specification and calibration gas traceability.

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor (k = 2), providing a level of confidence of approximately 95%. The reported uncertainty covers the data collected from 1 January 2025.

Performance Characteristic	**Uncertainty**
Total uncertainty without calibration	1%
Uncertainty of gas	5.0%
Total expanded uncertainty (95% confidence)	12.0 %

References

1. ABB. 2014. Ultra-Portable Greenhouse Gas Analyzer User Manual.
2. Department for Business, Energy & Industrial Strategy. 2024. United Kingdom methane memorandum. [online] Available from: United Kingdom methane memorandum - GOV.UK (www.gov.uk) [Accessed 23 September 2024].
3. Department for Business, Energy and Industrial Strategy. 2021. *Long-Term Atmospheric Measurement and Interpretation of Radiatively Active Trace Gases, Annual Report (Oct 2020 – Sept 2021)*. Retrieved from Long-Term Atmospheric Measurement and Interpretation of Radiatively Active Trace Gases: annual report 2021 (publishing.service.gov.uk) [Accessed 11 December 2023]

Appendix E Sulphur Dioxide (SO_2)

Sulphur dioxide is formed by the oxidation of sulphur. At normal temperature and pressure, it is a gas. It dissolves in water to give an acidic solution which oxidises to sulphuric acid.

Sources

Traditionally sulphur dioxide pollution has been associated with the burning of coal in the domestic, commercial and industrial sectors. However, following the smogs of the 1950s and the Clean Air Act of 1956 the pattern of sulphur dioxide emissions changed considerably. Cleaner fuels have replaced coal in the domestic sectors and in many industrial applications. Power generation in urban areas has predominantly moved to large and efficient plants situated at rural sites.

The consequence of this changing pattern has been an overall decrease in sulphur dioxide emissions in the UK by some 98% since 1970. The decrease in SO_2 emissions in recent years, with UK emissions falling by 70 per cent between 2012 and 2020, was largely due to the closure or conversion to biomass fuel of many coal-fired power stations. The restrictions on the sulphur content of fuels has contributed further reductions.

The main source of emissions of SO_2 in 2022 was from domestic combustion (31%), followed by industrial combustion (26%) and combustion in energy production and transformation (23%).

SO_2 Analyser

The analyser used to measure sulphur dioxide is an API Model T101. The operation of this analyser 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 Photo multiplier tube (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:

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

where 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.

This instrument has been certified by the Environment Agency's Monitoring Certification Scheme (MCERTS), meeting the required performance standards which are based on International and European standards.

A calculation of the total uncertainty of the data has been made based on known uncertainties relating to the T100 Sulphur Dioxide (SO_2) analyser manufactured by Teledyne API. These known uncertainties are defined under standard EN14212.

Data for the uncertainty analysis was taken from the specifications reported by both the instrument and calibration gas manufacturer's and from the TUV and MCERTS product conformity certificates.

Calibration gas traceability cannot be derived from the certification. For the uncertainty budget, gas traceability was taken from manufacturer certification.

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor (k = 2), providing a level of confidence of approximately 95%. The reported uncertainty covers the data collected from 1 January 2025.

Assessment of compliance for SO_2 UV Fluorescent analyser according to ISO 14956		
Teledyne API T100/T100E		
2013 TUV for SO_2 concentrations	1 hour limit value 132ppb	
Measurement performance related to laboratory and field conditions		
Performance Characteristic	**Value**	**Square of Standard Uncertainty**
Repeatability at zero	0.5ppb	0.0222ppb
Lack of fit	0.2%	0.0232ppb
Sample gas pressure	0.06ppb/kPa	2.5613ppb
Sample gas temperature	0.013ppb/K	0.0105ppb
Surrounding temperature	0.03ppb/K	0.0559ppb
Electrical voltage	0.02ppb/V	0.0467ppb
Water interference	-1.5ppb	1.4668ppb
Other interference	7.6ppb	12.6928ppb
Averaging effect	1.1%	0.7028ppb
Reproducibility under field conditions	4.8%	40.1449ppb
zero drift	1.35ppb	0.6075ppb
span drift	1.56%	1.4134ppb
Uncertainty of gas (used in the field)	3%	3.9204ppb
Combined standard uncertainty (Uc)		8.0ppb
Total expanded uncertainty for SO_2 (95% confidence)		**12.1%**

References

1. Department for Environment, Food and Rural Affairs. 2024. National Statistics. [online] Available from: Emissions of air pollutants in the UK – Sulphur dioxide (SO2) - GOV.UK (www.gov.uk) [Accessed 24 September 2024]

2. Sira Certification Service. December 2020. Certificate No: Sira MC050067/08

3. TÜV Rheinland Energy GmbH. March 2023. Certificate No: 0000038501_03

Appendix F Particulate Matter (TSP, PM_{10}, $PM_{2.5}$)

Airborne particulate matter can be found in a wide range of particle sizes (nm-µm) and chemical constituents. PM_{10} and $PM_{2.5}$ levels have been reported in this study. PM_{10} is defined as particulate matter with an aerodynamic diameter less than 10µm. $PM_{2.5}$ is defined as particulate matter with an aerodynamic diameter less than 2.5 µm. The description of PM_{10} and $PM_{2.5}$ is restricted to its physical characteristic and no particular chemical composition is implied. The size is of importance because it is this that determines where in the human respiratory tract a particle deposits when inhaled. Most concern is given to particles small enough to penetrate into the lungs reaching the alveoli where the delicate tissues involved in the exchange of oxygen and carbon dioxide are to be found. When inhaled almost all particles larger than 7µm are deposited in the nose and throat, and only 20-30% of particles between 1 and 7µm are deposited in the alveoli. However, up to 60% of particles below 0.1µm are deposited in the alveoli. The size of the particles also determines how long they spend in the atmosphere with smaller particles remaining in suspension for longer and can be transported over long distances. The measurement of PM_{10} and $PM_{2.5}$ relies on the use of a size-selective instrument, which collects small particles preferentially.

Sources
There are a number of important natural sources of particulate in the air with forest fires and volcanic eruptions being two sources which, can cause extreme pollution episodes and can be very adverse to human health. Sea spray and the erosion of soil and rocks by wind are important sources in many localities. There are also many biological sources with considerable numbers of pollen grains, fungal spores and their fragments contributing to the total loading of airborne particles. Man-made airborne particles result mainly from combustion processes, from the working of soil and rock, from industrial processes and from the attrition of road surfaces by motor vehicles.

The major PM components are sulphate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. Particles can be classified as being either primary or secondary: the former are released directly into the air, while the latter are formed in the atmosphere by the chemical reaction of gases, first combining to form less volatile compounds which in turn condense into particles. Primary particles have an immediate effect on the particulate loading in the vicinity of the source. The main sources of primary PM_{10} and $PM_{2.5}$ in the UK in 2022 were :

- Domestic combustion; has once more become a major source of airborne particles, accounting for 15% and 29% of primary PM_{10} and $PM_{2.5}$ emissions. Most emissions from this source come from household burning wood stoves and open fires with coal contributing 12% of $PM_{2.5}$ emissions.
- Road transport; nationally, road transport contributed around 16% and 18% of primary PM_{10} and $PM_{2.5}$ emissions, with reductions due to a decrease in exhaust emissions thanks to stricter standards but this has been partially offset by an increase in traffic and non-exhaust emissions (brake, tyre and road wear) since 1996.
- Industrial combustion and processes; nationally, it is estimated that these processes accounted for around 48% of primary PM_{10} emissions and 21% of primary $PM_{2.5}$ emissions. Emissions from this source have decreased in the long term but have remained fairly stable in recent years.

Secondary particles are less easy to ascribe to their original sources. They comprise mainly ammonium sulphate and nitrate, originating from the oxidation of gaseous sulphur and nitrogen oxides to acids, which are then neutralised by atmospheric ammonia, derived from agricultural sources. The chemical processes involved in the formation of these secondary particles are relatively slow (in the order of days) and their persistence in the atmosphere is similarly prolonged. Thus, while road traffic may be the main source of the original oxides of nitrogen, and coal and oil burning the main sources of sulphur oxides, the secondary particles are distributed more evenly throughout the air with less difference between urban and rural areas. They may also drift for considerable distances. This can result in the transport of pollution across national boundaries.

Particulate Analyser
The analyser used to measure PM concentration is a Palas Fidas 200 optical measuring system. It provides measurements of TSP, PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in real time and stores them as 15-minute averages.

The Fidas measures PM using an optical light scattering technique and uses an algorithm to calculate concentrations based upon the number and size distribution of particles.

The Fidas has a flow volume of 0.3 m^3/h (flow rate of 4.8 l/m). The inlet is fitted with a Sigma-2 (TSP) sampling head which allows the full range of particle sizes to reach the Intelligent Aerosol Drying System (IADS). The IADS conditions the sampled air, which helps prevent possible measurement inaccuracies due to condensation during periods of high ambient air humidity.

Once the sample has been conditioned the particle size is determined using the Lorenz-Mie scattered light analysis of single particles by an optical aerosol spectrometer. The spectrometer measures the scattered light impulse generated by each particle as it is illuminated by a white LED light at an angle of 90°. The number of scattered light impulses allows the determination of the particle number and the height of the impulse is related to particle size. The scattered light signal is then allocated to a particle size diameter bin using a calibration curve and measurement of the signal number. The bins are then used to form a histogram of the measured particle sizes.

A number of computational steps are required to convert the measured particle sizes into a mass concentration. The measured size distribution is altered to a distribution based on a representative index for environmental aerosol. To account for the variability in the shape of each particle the distribution is altered from optical diameter (spherical shape) to reflect the aerodynamic diameter (variable shape) of the particles. Once the distribution has been altered to account for the refractive index and diameter the EU particle distribution line is used to apply the cut curves for each of the PM fractions.

The data is then converted from particle size to particle mass using a size dependent density algorithm. This system allows for a lower detection limit of 180nm with a sampling range of 0.18 - 18µm.

A calculation of the total expanded uncertainty of the data has been made for the Fidas 200 analyser manufactured by PALAS GmbH. Because performance tests using certified calibration standards are not possible, demonstration of equivalence was conducted based on a series of comparison tests against a reference sampling device as defined under standard EN 16450.

Data for the uncertainty analysis was taken from the specifications reported from the MCERTS product conformity certificate.

For PM_{10} the method 11 algorithm fulfils the relevant Data Quality Objective of EU Directive 2008/50/EC without the need for slope and/or intercept correction. For $PM_{2.5}$ the method does not fulfil the relevant Data Quality Objective of EU Directive 2008/50/EC when used without correction. Slope correction of dividing by 1.06 is required to make the $PM_{2.5}$ Palas Fidas 200 Method 11 equivalent.

PM_{10} Palas Fidas 200	**Calculated slope of all paired data**	**Calculated intercept of all paired data (µg/m^3)**	**Range of individual expanded uncertainties**	**Expanded uncertainty of all paired data**
Uncorrected data	1.035	-1.36	5.7% to 19.1 %	7.5%

$PM_{2.5}$ Palas Fidas 200	**Calculated slope of all paired data**	**Calculated intercept of all paired data (µg/m^3)**	**Range of individual expanded uncertainties**	**Expanded uncertainty of all paired data**
Data corrected for slope by dividing by 1.060	0.999	-0.19	8.5% to 22.4%	9.3%

The expanded uncertainty has been calculated as 7.5% for PM_{10} and 9.3% for $PM_{2.5}$. The reported uncertainty covers the data collected from 1 January 2025.

References

1. Department for Environment, Food and Rural Affairs. 2022. National Statistics. [online] Available from:
   Emissions of air pollutants in the UK – Particulate matter (PM10 and PM2.5) - GOV.UK (www.gov.uk) [Accessed 23 September 2024]

2. DETR – May 2000 - Pollutant Specific Guidance

3. Sira Certification Service. April 2021. Certificate No: Sira MC160290/03

Appendix G 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 formula's:

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

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.

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 can 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 'average 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 several different percentiles, it can be seen whether biases are present in all 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 percentiles (Figure 1) suggests that the source from that 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 100° – 140° that is evident in all the percentiles.

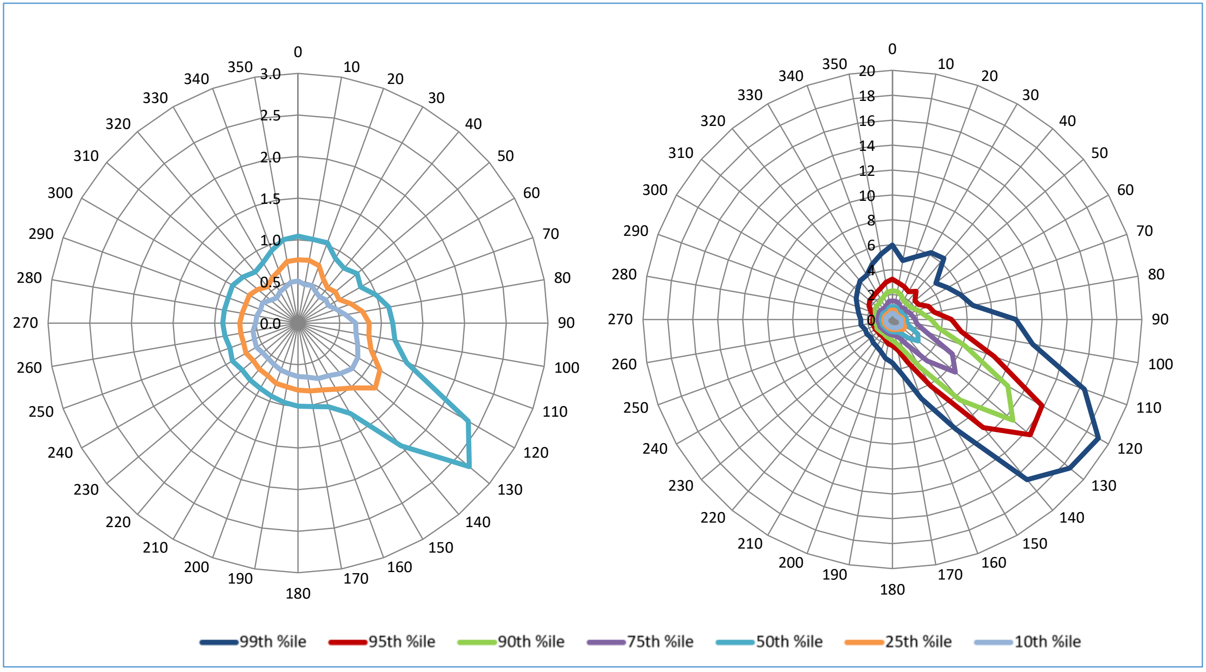


Figure 2: Shows a bias at 260° - 160º that is only evident in the higher percentiles.

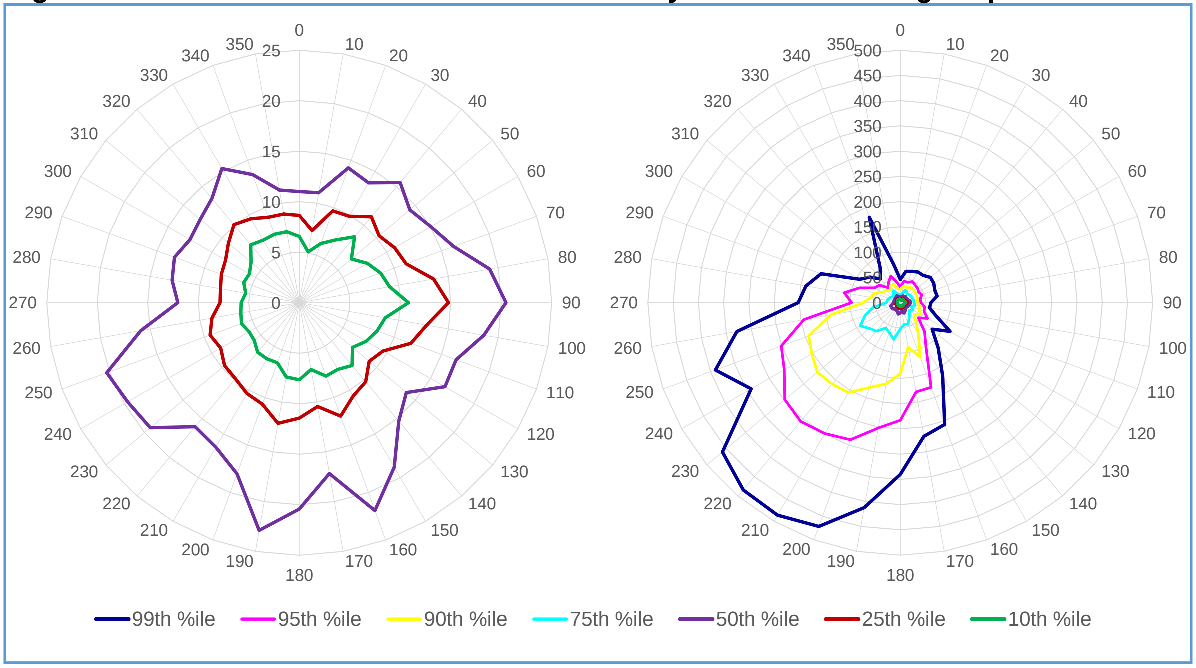
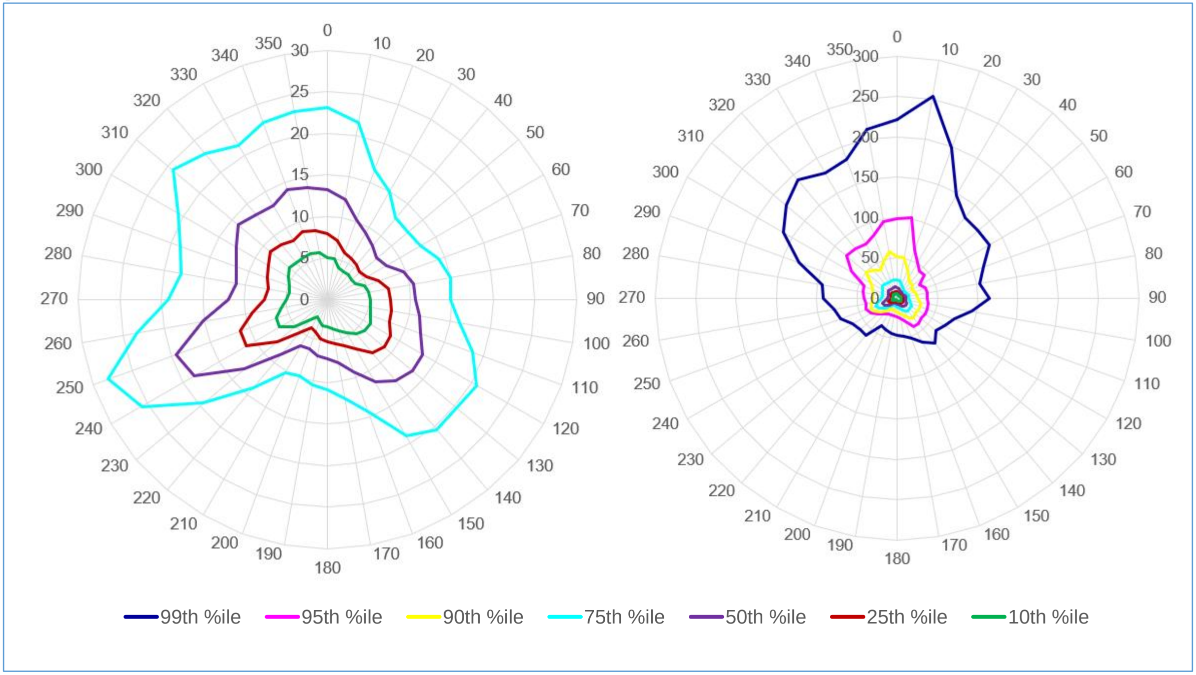


Figure 3: Shows a bias between 230° – 270° that is only evident in the lower percentiles.



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